frontiers | Research Topics

Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age, 2nd Edition

Edited by
Maha Hoteit, Reema Fayez Tayyem, Radwan Qasrawi and Haleama Al Sabbah

Published in
Frontiers in Nutrition
Frontiers in Sustainable Food Systems

ISSN 1664-8714
ISBN 978-2-8325-3179-2
DOI 10.3389/978-2-8325-3179-2

About Frontiers

Frontiers is more than just an open access publisher of scholarly articles: it is a pioneering approach to the world of academia, radically improving the way scholarly research is managed. The grand vision of Frontiers is a world where all people have an equal opportunity to seek, share and generate knowledge. Frontiers provides immediate and permanent online open access to all its publications, but this alone is not enough to realize our grand goals.

Frontiers journal series

The Frontiers journal series is a multi-tier and interdisciplinary set of open-access, online journals, promising a paradigm shift from the current review, selection and dissemination processes in academic publishing. All Frontiers journals are driven by researchers for researchers; therefore, they constitute a service to the scholarly community. At the same time, the *Frontiers journal series* operates on a revolutionary invention, the tiered publishing system, initially addressing specific communities of scholars, and gradually climbing up to broader public understanding, thus serving the interests of the lay society, too.

Dedication to quality

Each Frontiers article is a landmark of the highest quality, thanks to genuinely collaborative interactions between authors and review editors, who include some of the world's best academicians. Research must be certified by peers before entering a stream of knowledge that may eventually reach the public - and shape society; therefore, Frontiers only applies the most rigorous and unbiased reviews. Frontiers revolutionizes research publishing by freely delivering the most outstanding research, evaluated with no bias from both the academic and social point of view. By applying the most advanced information technologies, Frontiers is catapulting scholarly publishing into a new generation.

What are Frontiers Research Topics?

Frontiers Research Topics are very popular trademarks of the *Frontiers journals series*: they are collections of at least ten articles, all centered on a particular subject. With their unique mix of varied contributions from Original Research to Review Articles, Frontiers Research Topics unify the most influential researchers, the latest key findings and historical advances in a hot research area.

Find out more on how to host your own Frontiers Research Topic or contribute to one as an author by contacting the Frontiers editorial office: frontiersin.org/about/contact

Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age, 2nd Edition

Topic editors

Maha Hoteit — Lebanese University, Lebanon
Reema Fayez Tayyem — Qatar University, Qatar
Radwan Qasrawi — Al-Quds University, Palestine
Haleama Al Sabbah — Zayed University, United Arab Emirates

Citation

Hoteit, M., Tayyem, R. F., Qasrawi, R., Al Sabbah, H., eds. (2023). *Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age, 2nd Edition*. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-8325-3179-2

Publisher's note: In this 2nd edition, the following article has been updated:

Hoteit M, Qasrawi R, Al Sabbah H and Tayyem R (2023) Editorial: Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age. Front. Nutr. 10:1211186. doi: 10.3389/fnut.2023.1211186

Table of contents

frontiers | Frontiers in Nutrition

TYPE Editorial
PUBLISHED 24 July 2023
DOI 10.3389/fnut.2023.1211186

OPEN ACCESS

EDITED AND REVIEWED BY
Reza Rastmanesh,
American Physical Society, United States

*CORRESPONDENCE
Maha Hoteit
✉ maha.hoteit@cnrs.edu.lb

RECEIVED 24 April 2023
ACCEPTED 14 July 2023
PUBLISHED 24 July 2023

CITATION
Hoteit M, Qasrawi R, Al Sabbah H and Tayyem R (2023) Editorial: Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age. *Front. Nutr.* 10:1211186.
doi: 10.3389/fnut.2023.1211186

Editorial: Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age

Maha Hoteit[1]*, Radwan Qasrawi[2,3], Haleama Al Sabbah[4] and Reema Tayyem[5]

[1]Food Sciences Unit, National Council for Scientific Research Lebanon (CNRS-L), Beirut, Lebanon, [2]Department of Computer Science, Al-Quds University, Jerusalem, Palestine, [3]Department of Computer Engineering, Istinye University, Istanbul, Türkiye, [4]Department of Public Health, College of Health Sciences, Abu Dhabi University, Abu Dhabi, United Arab Emirates, [5]Department of Human Nutrition, College of Health Sciences, Qatar University, Doha, Qatar

KEYWORDS

editorial, innovation, food system, dietary patterns, sustainability

Editorial on the Research Topic
Innovation and trends in the global food systems, dietary patterns and healthy sustainable lifestyle in the digital age

The transformation of food systems to address healthy nutrition, food insecurity, and public health issues is a global concern. In today's world, where there is a growing dependence on processed foods, fast food, edible oils, sugar-sweetened beverages, and sedentary lifestyles, the importance of food security and nutrition systems cannot be overstated. These factors have a direct impact on human wellbeing and global stability.

The increasing prevalence of non-communicable diseases such as obesity, diabetes, hypertension, and cardiovascular diseases is a clear indication of the impact of lifestyle changes which are being observed worldwide (1). Although food security has improved in developed countries, many countries, particularly low-to middle-income countries (LMIC), suffer from significant food insecurity challenges (2). In addition, food production, accessibility, and availability have been further impacted due to the COVID-19 outbreak, causing growing global concerns regarding food security, especially within the most vulnerable communities (3). Due to this situation and in this dynamic context, both technology actors and the consumers they cater to occupy a crucial position in the food system. They have the potential to make choices that can address the challenges and opportunities for enhancing sustainable outcomes in the food system. According to the literature, the integration of artificial intelligence, the deployment of data science techniques, and information and communication technology (ICT) applications have introduced innovative methods in understanding the trends in food systems, dietary patterns, and healthy sustainable lifestyles at the global level (4).

The main objective of this Research Topic is to gather papers that enhance our understanding of the intersections between food security, nutrition, and technological innovation through the utilization of artificial intelligence, data science, and ICT.

These papers aim to provide comprehensive insights into their impact on human health and to analyze global trends before and after the COVID-19 pandemic. The special e-collection comprises 15 papers that cover the aforementioned areas. The most extensively examined aspect in the Eastern Mediterranean Region (EMR), both before and during the COVID-19 pandemic, has been the nutrition-related factors and dietary intake of its populations.

Data from Al-Jawaldeh and Abbass show that the prominent nutrition-related non-communicable diseases (NCDs) risk factors in EMR include obesity, hypertension, high fasting plasma glucose, and upregulated unhealthy diet consumption, which can lead to nutrition inadequacies, including anemia. According to the authors, these risk factors, even if treated, are often poorly controlled. Therefore, it is imperative to adopt healthy dietary habits and ensure adequate physical activity to counter their presence and prevent their onset. To tackle and manage obesity, Jabbour et al. published a meta-analysis (NMA) on the current Research Topic, which compared the effects of different diets [moderate macronutrients (MMs), low fat/high carbohydrate (LFHC), high fat/low carbohydrate (HFLC), and usual diet (UD)] on weight, body mass index (BMI), and waist circumference (WC) changes at $\geq$12 months. The authors show that dietary interventions extending over $\geq$12 months are superior to UD in inducing weight, BMI, and WC loss. HFLC might be associated with a slightly higher weight loss compared with MM diets. In contrast, this Research Topic also addresses nutritional inadequacy, specifically anemia, by using a novel analytical method that was implemented to classify nutritional anemia using the cluster analysis approach. In this study, Qasrawi and Al-Halawa conducted the Classification and Regression Tree (CRT) model to study the association between hemoglobin clusters and vitamin B12, folate, and iron intakes, sociodemographic variables, and health-related risk factors, accounting for grade and age. The study findings indicated that vitamin B12, iron, and folate intakes are important factors related to anemia. In girls, anemia was associated with age, locality, food consumption patterns, and physical activity levels, whereas, iron and folate intakes were significant factors related to anemia in boys associated with the place of residence and the educational level of their mothers. According to the authors, the deployment of clustering and classification techniques for identifying the association between anemia and nutritional factors might facilitate the development of nutritional anemia prevention and intervention programs that will improve the health and wellbeing of schoolchildren. Outside the EMR, in Chile, a study conducted by Schnettler et al., showed that there were positive associations between mothers' modeling and adolescents' satisfaction with food-related life (SWFoL) between mothers' diet quality and fathers'; and between mothers' modeling and fathers' SWFoL via the fathers' diet quality. Parents' modeling can improve the three family members' diet quality, while mothers' modeling and diet quality has been shown to improve fathers' and adolescents' SWFoL. Knowing that good dietary patterns start from the prenatal period, Abi Khalil et al. investigate the feeding patterns of women and their off-springs in Lebanon. Data from Abi Khalil et al. demonstrate low rates of exclusive breastfeeding (EBF) and continuous breastfeeding (CBF), high prevalence of exclusive bottle feeding (EBOT), and early introduction of complementary foods among children ages 0–59 months. Furthermore, for children ages 6–59 months, there was poor mother-child dietary diversity and a high prevalence of overweight and stunted children in the main two Lebanese provinces.

The Mediterranean Diet (MedDiet) represents a healthy dietary pattern in the context of healthy lifestyle habits. Epidemiological studies have shown that a higher degree of adherence to the MedDiet pattern is associated with reduced mortality concerning deaths due to non-communicable diseases. This is favored by the adoption of this dietary pattern. To investigate the current situation concerning adherence to the Mediterranean diet in Lebanon and Syria, Karam et al. showed that the Lebanese participants, especially men and those who are aged between 64 and 67, had higher adherence than their counterparts. It is essential to invest in the education and behavior of healthcare professionals as it can significantly impact the dietary habits of their patients, ultimately aiding in the promotion of a healthy Mediterranean diet and the prevention of unhealthy eating patterns.

This was identified by Hoteit, Mohsen et al., who show that the risk of eating disorders was prevalent in 22.5% of healthcare practitioners in Lebanon. The highest proportion of high-risk participants were participants studying and practicing nutrition (40.9%), outracing their counterparts in nursing (18.7%), medicine (17.8%), pharmacy (17.7%), and midwifery (4.9%), sciences ($p = 0.02$).

The impact of the COVID-19 pandemic on dietary diversity and intake has also been widely discussed. According to Hoteit, Mortada et al.'s data, the fragility of the EMR food system is presenting significant obstacles to maintaining a healthy and sustainable lifestyle. While the aggressive containment strategy from the COVID-19 pandemic was essential for most countries in the EMR to help prevent the spread, it came at a high nutritional cost, driving poor dietary diversity. This situation affects maternal diets as well. This was identified in a survey that was carried out among a convenient sample of 1,939 pregnant women from five Arab countries by Hoteit, Hoteit et al., who found an increment in the consumption of cereals, fruit, vegetables, dairy products, meats, and nuts that occurred during the COVID-19 pandemic. In this survey, the daily consumption of almost all food groups was lower than the USDA's daily recommendations, except for fruits intake, which was higher than the daily standard. Demonstrated poor adherence to prenatal USDA dietary guidelines by Arab pregnant women can lead to numerous deficiencies and health risks among their offspring. According to the authors, the findings emphasize the need for nutritional education and intervention during prenatal visits. Similarly, Papazian et al. also found that dietary patterns among pregnant women should be monitored regularly. In Lebanon, pregnant women with the lowest pre-gestational body mass index and higher gestational age tended to follow a diet called "Neo-Mediterranean," which is mainly composed of protein-rich foods such as poultry, fish, eggs, and dairy products.

Tayyem et al.'s survey showed that postpartum women exhibit poor adherence to the USDA's recommended amounts for dietary intake and the five food groups, with their dietary intake falling below the recommended levels.

During the COVID-19 pandemic, while many people were forced to stay home, scholars began investigating the impact of online food delivery services on health and wellbeing. These services may affect the achievement of the United Nations 2030 Sustainable Development Goals (SDGs). According to Jia et al.'s research, online food delivery services may pose a threat to several SDGs, including those addressing good health and wellbeing, responsible consumption and production, climate action, and decent work and economic growth.

The scholars in this study proposed a research and policy agenda that is aligned with entry points within a systems approach identified by the World Health Organization, which are the food industry reforms, synergized public health messaging, and the continuous monitoring of the growing impact of online food delivery.

In summary, the results of the above-mentioned studies and reviews represent an enormous amount of new relevant data on obesity management, food insecurity, dietary patterns among all age categories, novel cluster models, and the impact of the COVID-19 pandemic on all the listed topics. Despite all the existing literature and evidence related to these extremely important topics, the papers published in this e-book clearly show that there are still many aspects to be clarified and understood in the fascinating world of dietary diversity, food insecurity, dietary intake, and the management of non-communicable diseases. Upon reading this book, readers will gain clarity on various topics and develop a stronger conviction regarding the significance of studying nutrition systems, food security, and the roles of technological advances, especially in LMIC. Understanding these factors is crucial for comprehending the food transition and population health. Such understanding is imperative to prioritize equity, sustainability, and health as priorities in food provision and consumption in LMIC (5).

Author contributions

MH, RQ, HA, and RT: conceptualization, validation, supervision and editorial administration, methodology, and resources. MH and RT: formal analysis, data curation, and writing—original draft preparation. All authors contributed to the editorial and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

1. Cecchini M, Warin, L. Impact of food labelling systems on food choices and eating behaviours: a systematic review and meta-analysis of randomized studies. *J Int Assoc Study Obes*. (2016) 17:201–10. doi: 10.1111/obr.12364

2. Horizon A. *2030: Prospects for Enhancing Food Security in the Arab Region*. Near East and North Africa: FAO (2017).

3. Abu Hatab A, Krautscheid L, Boqvist S. COVID-19, Livestock systems and food security in developing countries: a systematic review of an emerging literature. *Pathogens*. (2021) 10:586. doi: 10.3390/pathogens10050586

4. Camaréna S. Artificial Intelligence (AI) for sustainable institutional food systems: implementation of AI tools for school nutrition program management in the United States of America. *Front Sustain Food Syst*. (2022) 6:743810. doi: 10.3389/fsufs.2022.743810

5. FAO, IFAD, UNICEF, WFP, and WHO. The State of Food Security and Nutrition in the World 2022. *Repurposing Food and Agricultural Policies to Make Healthy Diets More Affordable*. Rome: FAO (2022).

frontiers in Nutrition

ORIGINAL RESEARCH
published: 15 February 2022
doi: 10.3389/fnut.2022.813154

Dietary Diversity in the Eastern Mediterranean Region Before and During the COVID-19 Pandemic: Disparities, Challenges, and Mitigation Measures

Maha Hoteit[1,2,3†], Hussein Mortada[2,4†], Ayoub Al-Jawaldeh[5], Rania Mansour[1], Batoul Yazbeck[1], Majid AlKhalaf[6], Khlood Bookari[6,7], Reema Tayyem[8], Narmeen J. Al-Awwad[9], Haleama Al Sabbah[10], Leila Cheikh Ismail[11,12], Radwan Qasrawi[13,14], Rania Abu Seir[15], Iman Kamel[16], Somaia Dashti[17], Sabika Allehdan[18], Mariam Al-Mannai[19], Hiba Bawadi[20], Mostafa Waly[21] and The Regional CORONA COOKING Survey Group*

[1] Faculty of Public Health, Lebanese University, Beirut, Lebanon, [2] PHENOL Research Group (Public HEalth Nutrition prOgram Lebanon), Faculty of Public Health, Lebanese University, Beirut, Lebanon, [3] Lebanese University Nutrition Surveillance Center (LUNSC), Lebanese Food Drugs and Chemical Administrations, Lebanese University, Beirut, Lebanon, [4] Faculty of Science IV, Lebanese University, Beirut, Lebanon, [5] World Health Organization Regional Office for the Eastern Mediterranean, Cairo, Egypt, [6] National Nutrition Committee, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [7] Department of Clinical Nutrition, Faculty of Applied Medical Sciences, Taibah University, Madinah, Saudi Arabia, [8] Department of Human Nutrition, College of Health Sciences, Qatar University, Doha, Qatar, [9] Department of Clinical Nutrition and Dietetics, Faculty of Applied Health Sciences, The Hashemite University, Zarqa, Jordan, [10] Department of Health Sciences, College of Natural and Health Sciences, Zayed University, Dubai, United Arab Emirates, [11] Department of Clinical Nutrition and Dietetics, College of Health Sciences, University of Sharjah, Sharjah, United Arab Emirates, [12] Nuffield Department of Women's & Reproductive Health, University of Oxford, Oxford, United Kingdom, [13] Department of Computer Science, Al-Quds University, Jerusalem, Palestine, [14] Department of Computer Engineering, Istinye University, Istanbul, Turkey, [15] Faculty of Health Professions, Abu Dis, Palestine, [16] National Research Centre, Cairo, Egypt, [17] Public Authority for Applied Education and Training, Kuwait City, Kuwait, [18] Department of Biology, College of Science, University of Bahrain, Zallaq, Bahrain, [19] Department of Mathematics, College of Science, University of Bahrain, Zallaq, Bahrain, [20] Human Nutrition Department, College of Health Sciences, QU-Health, Qatar University, Doha, Qatar, [21] Food Science and Nutrition Department, College of Agricultural and Marine Sciences, Sultan Qaboos University, Muscat, Oman

The COVID-19 pandemic has revealed the Eastern Mediterranean Region's food system's fragility posing severe challenges to maintaining healthy sustainable lifestyle. The aim of this cross-sectional study (N = 13,527 household's family members, mean age: 30.3 ±11.6, 80% women) is to examine the impact of the COVID-19 pandemic on food consumption patterns and household's dietary diversity in 10 Eastern Mediterranean countries. A food frequency questionnaire was used to investigate the consumption patterns along with the calculation of the Food Consumption Score (FCS), a proxy indicator of dietary diversity. Data collected on cooking attitudes, shopping and food stock explore the community mitigation measures. In the overall population, before and during the pandemic, most food groups were consumed less or equal to 4 times per week. As evident from our findings and considering that the pandemic may be better, but it's not over, small to moderate changes in food consumption patterns in relatively short time periods can become permanent and lead to substantial poor dietary diversity over time. While it is a priority to mitigate the immediate impact, one area of great concern is the long-term

OPEN ACCESS

Edited by:
Rakesh Bhardwaj, National Bureau of Plant Genetic Resources (ICAR), India

Reviewed by:
Cecile Obeid, Notre Dame University - Lebanon, Lebanon
Lara Hanna-Wakim, Holy Spirit University of Kaslik, Lebanon
Yonna Sacre, Holy Spirit University of Kaslik, Lebanon

***Correspondence:**
Maha Hoteit
m.hoteit@ul.edu.lb

†These authors have contributed equally to this work and share first authorship

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *11 November 2021*
Accepted: *04 January 2022*
Published: *15 February 2022*

Citation:
Hoteit M, Mortada H, Al-Jawaldeh A, Mansour R, Yazbeck B, AlKhalaf M, Bookari K, Tayyem R, Al-Awwad NJ, Al Sabbah H, Cheikh Ismail L, Qasrawi R, Abu Seir R, Kamel I, Dashti S, Allehdan S, Al-Mannai M, Bawadi H, Waly M and The Regional CORONA COOKING Survey Group (2022) Dietary Diversity in the Eastern Mediterranean Region Before and During the COVID-19 Pandemic: Disparities, Challenges, and Mitigation Measures. Front. Nutr. 9:813154. doi: 10.3389/fnut.2022.813154

effects of this pandemic on dietary patterns and dietary diversity in Eastern Mediterranean households. To conclude, the COVID-19 crisis revealed the region's unpreparedness to deal with a pandemic. While the aggressive containment strategy was essential for most countries to help prevent the spread, it came at a high nutritional cost, driving poor dietary diversity.

Keywords: COVID-19 pandemic, dietary diversity, Eastern Mediterranean region, food consumption score, mitigation measures

INTRODUCTION

Prior to the unprecedented COVID-19 epidemic, nearly 690 million individuals worldwide consumed fewer calories than required (1). Beyond food deprivation, due to many reasons, a growing number of people have been forced to cut back the quantity and quality of the food they ingest (1). The physical and mental health repercussions of such deficit illustrate the indisputable public health importance of food consumption patterns, dietary diversity, and related food insecurity (1). During the COVID-19 pandemic, an estimation exceeding 280 million people were at risk of becoming food insecure (2). The loss of livelihoods due to COVID-19, caused food supply disruptions and income loss, limiting the access to nutritious food, and making households across the globe facing difficulties to have access to healthy diets (1). Consequently, more than 1.5 billion people couldn't afford a nutri-dense diet that meets the required essential nutrients and around 3 billion people faced difficulties in affording the cheapest healthy diet (1–3). At regional level, embedded with many challenges, the Eastern Mediterranean (EM) countries are faced with scarce and dwindling natural resources amidst high urbanization rates, populations increase, wars, climate changes, sociopolitical crises (4) and recently, the COVID-19 pandemic (5). Today, amid the COVID-19 pandemic, almost 54.5 million people are witnessing severe food insecurity in the region, along with an increase of four times in the percentage of hungry people in the Middle Eastern countries (6). Currently, in 12 countries including Algeria, Libya, Tunisia, Lebanon, Palestine, and Sudan, more than 10 million people were assisted by short-term assistances and cash-based transfers. In addition, the situation is extremely worsening and worrying in many countries affected by conflicts, violence and socioeconomic crises including Iraq, Libya, Somalia, Syria, Sudan, Yemen, and Lebanon (7, 8). Upon the exponential increase in COVID-19 consequences on the financial status of consumers, food insecurity started to aggravate in most EM countries. Households tend to change their food consumption patterns involuntarily, rely on savings, sell household durable assets and livestock, buy foods with high shelf-life, eat less, buy cheaper food, and limit food types they cannot afford such as meat and fish, and start consuming higher quantities of starchy food due to their wide availability and cheap prices (9). Households were forced to change their food consumption patterns as a mean of mitigation measures. The lack of studies concerning the changes in food consumption, dietary diversity, and mitigation measures had made this issue of a high priority. Thus, the aim of this study is to examine the impact of the COVID-19 pandemic on the food consumption patterns, the dietary diversity, and the mitigations measures among EM households residing in 10 Eastern Mediterranean countries.

MATERIALS AND METHODS

The online survey consisted of a cross-sectional study that was launched originally in 38 different countries. The Eastern Mediterranean regional data related to Lebanon and 9 other Arabic countries (Bahrain, Egypt, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates, and Palestine) that have participated to this survey has been selected for the sake of analysis in this study. Questions of the survey were available in native Arabic language as well as other languages extending choices for the respondents. The survey was kept open between April 17th and June 25th, 2020 and consisted of multiple blocks of information. Participants included in this study were of age exceeding 18 years old, of both genders, residing in any of these Arabic countries. Convenience sampling was used to recruit respondents and advertisement of the survey was done using different social network platforms as well as academic networks of the research team. The questionnaire consisted of a validated online survey, that took around 20 min to be completed. A full overview of the study protocol, the questionnaire validation and the survey is accessible via https://osf.io/nz9xf/files/. It was used to collect information related to different topics including: sociodemographic and economic information, lockdown measures, mental health, cooking attitudes, shopping, food stock, and food frequency consumption in term of food portions per week (The question asked was: "how often did you eat the following (portions of) foods? Please indicate how often you consumed at least one portion of the following foods and drinks"). Regarding questions related to cooking attitudes, shopping, and food frequency consumption, respondents were asked to answer each question twice, reporting thus their behavior before the COVID-19 pandemic and during the COVID-19 lockdown. Food Consumption Score (FCS), which is a proxy indicator used for investigating the dietary diversity, was calculated using the frequency of consumption of different food groups consumed by a household during the 7 days before the survey. The calculation formula of the score FCS is: (starches $\times$ 2) + (pulses $\times$ 3) + vegetables+ fruit+ (meat $\times$ 4) + (dairy products $\times$ 4) + (fats $\times$ 0.5) + (sugar $\times$ 0.5). Prior to calculating the FCS score, response options were merged forming the following two categories: "lower than or equal to 4 times a week" and "equals five times a week or more" (10). The FCS was

calculated for each of the respondents based on his answers to the food frequency questionnaire. We then multiplied the frequency by the weight of the food (as listed in the formula of FCS). Two different FCS were calculated, the first one was based on the answers of respondents about food frequency consumption before the lockdown and the second one was based on their answers during the lockdown. Everyone was then classified as having a high FCS (if it is >42) or low FCS (<42) (10). When interpreting these results, people who tend to have higher FCS (>42) were consuming a diversified diet, this achieving a diversified balanced diet (10).

Statistical Analysis

Respondents' characteristics were presented as frequencies (percentages) for categorical variables while means ± standard deviation (SD) were used for continuous variables. Results were assessed for all participants as well as for countries separately in order to detect any potential behavior difference between them. Different statistical tests were used: Chi-square test was used to investigate differences for categorical variables between groups while independent *t*-test was applied for continuous variables and Marginal Homogeneity test was used to differentiate between paired data (comparison before and during COVID-19). To look for factors that may impact the FCS, a binary logistic regression was calculated. In this regression, the FCS (high vs. low) was the dependent variable. A backward approach was used and factors having a *p*-value <0.05 were considered as significant. Odds Ratio (OR) and its confidence interval were also calculated for each of the factors. A *p*-value lower than 0.05 was considered significant. Statistical analysis was conducted on IBM SPSS Statistics for Mac, Version 24.

Ethical Consideration

A consent form was attached at the beginning of the online survey that protects participants, let them know their rights and responsibilities and keep their information confidential. The study was conducted 126 according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Committee for the Social Sciences and Humanities of the University of Antwerp (file number 20_46) as well as in all other concerned countries. The patients/participants provided their written informed consent to participate in this study.

RESULTS

Socio-Demographic and Economic Characteristics

The total number of respondents who filled completely the survey in the 10 Arab countries was 13,527 households' family members. They were thus used for the subsequent analysis. Among them, 80% were females. Most participants were either adults (24 to 64 years old, 56.7%) or youth (19 to 24 years old, 37.6%). However, a very low percentage of adolescents (18 years) (4.7%) and elder people (1%) had registered (**Table 1**). The mean age of the respondents was 30.3 years with a SD of 11.69. Males who responded to this survey were significantly older than females (*p*-value = 0) (**Table 1**). Regarding the

TABLE 1 | sociodemographic and socioeconomic characteristics of the studied population.

Variables	Overall *N* (%)	Male *N* (%)	Female *N* (%)	*p*-value
Age (mean ± SD)	30.30 ±11.69	33.13 ± 13.15	29.61 ±11.20	
Adolescents (18 years)	18	18	18	
Youth	21.02 ± 1.31	20.94 ± 1.32	21.03 ± 1.31	0
Adult	36.81 ± 10.09	37.97 ± 10.74	36.47 ± 9.86	0
Elderly	68.58 ± 5.09	68.19 ± 4.90	68.92 ± 5.26	
Age categories (%)				
Adolescents (18 years)	638 (4.7)	135 (5.1)	503 (4.6)	
Youth	5,087 (37.6)	709 (26.7)	4,378 (40.3)	0
Adult	7,667(56.7)	1,749 (65.9)	5,918 (54.4)	
Elderly	135 (1)	63 (2.3)	72 (0.7)	
Gender (%)				
Male	2,656 (19.6)	NA	NA	
Female	10,871 (80.4)			
Countries (%)				
Bahrain	693 (5.1)	126 (4.7)	567 (5.2)	0.001
Egypt	734 (5.4)	170 (6.4)	564 (5.2)	
Jordan	2,675 (19.8)	581 (21.9)	2,094 (19.3)	
Kuwait	728 (5.4)	156 (5.9)	572 (5.2)	
Lebanon	2,282 (16.9)	436 (16.4)	1846 (17.0)	
Oman	186 (1.4)	32 (1.2)	154 (1.4)	
Qatar	653 (4.8)	135 (5.1)	518 (4.8)	
Saudi Arabia	2,999 (22.2)	530 (19.9)	2,469 (22.7)	
United Arab Emirates	1,718 (12.7)	313 (11.8)	1,405 (12.9)	
Palestine	859 (6.3)	177 (6.7)	682 (6.3)	
Education (%)				
Under a high school diploma	698 (5.1)	166 (6.2)	532 (4.9)	0
High school diploma or equivalent	2,763 (20.4)	553 (20.8)	2,210 (20.3)	
Bachelor's degree	7,991 (59.1)	1,378 (51.9)	6,613 (60.8)	
Master's degree	1,537 (11.4)	358 (13.5)	1,179 (10.9)	
Doctorate	538 (4.0)	201 (7.6)	337 (3.1)	
Number of adults living in the same household before the lockdown (%)				
<3	1,649 (38.0)	340 (39.7)	1,309 (37.6)	0.393
3–5	1,860 (42.9)	364 (42.5)	1,496 (43.0)	
More than 5	829 (19.1)	152 (17.8)	677 (19.4)	
Number of adults living in the same household during the lockdown (%)				
<3	4,851 (36.5)	1,114 (42.6)	3,737 (35.0)	0
3–5	5,993 (45.0)	1,096 (41.9)	4,897 (45.8)	
More than 5	2,459 (18.5)	405 (15.5)	2,054 (19.2)	
Employment before the lockdown (%)				Overall: 0
Student	5,296 (39.2)	775 (29.2)	4,521 (41.6)	Students: 0
Working	5,375 (39.7)	1,673 (63.0)	3,702 (34.0)	Working: 0
Didn't working	2,856 (21.1)	208 (7.8)	2,648 (24.4)	Not working: 0
Employment during the lockdown (%)				Overall: 0

(Continued)

TABLE 1 | Continued

Variables	Overall *N* (%)	Male *N* (%)	Female *N* (%)	*p*-value
Student	4,805 (35.5)	676 (25.4)	4,129 (38.0)	Students: 0
Working	4,210 (31.1)	1,425 (53.7)	2,785 (25.6)	Working: 0
Didn't working	4,512 (33.4)	555 (20.9)	3,957 (36.4)	Not working: 0
Loss of income since lockdown (%)				
Yes	5,336 (39.4)	1,256 (47.3)	4,080 (37.5)	0
No	8,191 (60.6)	1,400 (52.7)	6,791 (62.5)	
Struggle to make money last until the end of month (%)				
No	5,621 (41.6)	1,119 (42.1)	4,502 (41.4)	0.501
Yes	7,906 (58.4)	1,537 (57.9)	6,369 (58.6)	
Struggle to have enough money to shopping (%)				
No	6,420 (47.5)	1,340 (50.5)	5,080 (46.7)	0.001
Yes	7,107 (52.5)	1,316 (49.5)	5,791 (53.3)	

distribution of the respondents among the different countries, the higher percentage was recorded in Saudi Arabia (22.8%) while the lowest percentage was for Oman (1.4%). However, it is to be noted that a similar percentage of respondents has been recorded for the MENA region (Middle East and North Africa countries including Lebanon, Jordan, Egypt, and Palestine; 48.4%) and for the Gulf Cooperation Council (GCC) countries (the remaining 6 countries; 51.6%). As regards to the educational level, around 59% of the respondents had a bachelor's degree when analyzing both genders together. In addition, a significant higher percentage (60.8%) of females had bachelor's degree compared with males (51.9%) (p-value = 0) (**Table 1**). The household composition was also analyzed before and during the lockdown in which most households were composed of three to five adults (more than 40%). This trend has been also observed when considering males and females each separately (**Table 1**). When looking to economic characteristics, a similar percentage of respondents were students (39.2%) and active workers (39.7%) while the minority were unemployed (21.1%) before the COVID-19 lockdown. The percentage of unemployed individuals had increased to 33.4% during the lockdown. This increase has been also observed for males (7.8% before lockdown to 20.9% during lockdown) and females (24.4% before lockdown to 36.4% during lockdown). Moreover, the COVID-19 lockdown has also induced a loss of income among 39.4% of respondents. This loss was significantly higher (p-value = 0) for men (47.3%) compared to women (37.5%). In addition, most respondents, when taken either all together (58.4%) or categorized as males (57.9%) or females (58.6%) each alone, struggle to make money last until the end of the month or to earn enough money for shopping (52.4, 49.5, and 53.3% for all respondents, men and women respectively) (**Table 1**).

Consumption of Food Groups and Food Consumption Score

Tables 2–5 show the food groups consumption and the FCS in the overall population, by region and by country.

Fruits Group

In the overall population, fruits consumption (fresh or frozen), did not differ during the lockdown compared to the period before (p-value = 0.09). Despite that more than 60% of the EMR population consume fruits lower than or equal to 4 times a week, it was observed that the percentage of people consuming fruits equals five times a week or more was relatively higher in the MENA region (41.8% before the lockdown and 39.2% during the lockdown) compared to the GCC countries (32.8% before the pandemic and 36.5% during the lockdown) before and during the lockdown (p-value = 0.000 and p-value = 0.001, respectively). In addition, the percentage of people consuming fruits equals five times a week or more increased during the lockdown of 4% in the GCC countries (p-value = 0.000) and decreased of 2.6% in the MENA region (p-value = 0.000) compared to the period preceding the pandemic (**Table 2**).

When analyzed by country, it appeared that before and during the lockdown, the lowest consumption of fruits was observed in Kuwait, Saudi Arabia, UAE, and Jordan (**Tables 3**, **4**). In another word, the percentage of people consuming fruits equals five times a week or more was low in these countries compared to Bahrain (41.8% before the lockdown and 45.2% during the lockdown), Oman (56.5% before the lockdown and 60.8% during the lockdown), Qatar (40.6% before and 44% during the lockdown), Egypt (52.9% before and 55.9% during the lockdown), Lebanon (48.4% before and 43% during the lockdown), and Palestine (45.9% before and 39.3% during the lockdown) (p-value = 0.000) (**Tables 3**, **4**).

Vegetables Group

According to **Table 2**, it appears that half the population consumed vegetables equals five times a week or more before and during the pandemic. Like the fruits group consumption, it was observed that the percentage of people consuming vegetables frequently (equals five times a week or more), was higher in the MENA region before and during the lockdown (59 and 52.2%) compared to the GCC countries (50.2 and 48.8%) (p-value = 0.000). Furthermore, a decrease in vegetable's consumption of 4, 2, and 7% was observed during the pandemic in the overall population, the GCC, and the MENA countries, respectively (p-value = 0.000, p-value = 0.017, and p-value = 0.000, respectively). The analysis of data per country showed that the lowest intake was observed in Saudi Arabia (44.6% before the lockdown and 43.2% during the lockdown) and the highest intake was in Oman (71% before the lockdown and 69.4% during the lockdown) (p-value = 0.000). Furthermore, during the pandemic, there was a decrease of vegetables intake of 6% in Kuwait (p-value = 0.000), of 9% in Jordan (p-value = 0.000), of 7% in Lebanon (p-value = 0.000), and of 10% in Palestine (p-value = 0.000). However, it remained unchanged in other countries (**Tables 3**, **4**).

Legumes and Pulses Group

More than 80% of people living in the EM countries, in the current study, where consuming legumes and pulses lower than or equal to 4 times a week. Nevertheless, the percentage of people consuming frequently legumes and pulses increased during the pandemic of 3% in the overall population, the GCC and the

TABLE 2 | Food groups consumption among countries in the GCC and MENA regions, before and during COVID-19 pandemic.

Food groups consumed	Frequency per week	Overall *N* (%)			GCC *N* (%)			MENA *N* (%)			Comparison MENA vs. GCC	
		Before	During	*p*-value	Before	During	*p*-value	Before	During	*p*-value	*p*-value	
											Before COVID-19	During-COVID-19
Fruit (fresh or frozen)	4 or less	8,499 (62.8)	8,410 (62.2)	0.093	4,689 (67.2)	4,429 (63.5)	0	3,810 (58.2)	3,981 (60.8)	0	0	0.001
	5 or more	5,028 (37.2)	5,117 (37.8)		2,288 (32.8)	2,548 (36.5)		2,740 (41.8)	2,569 (39.2)			
Vegetables (fresh or frozen)	4 or less	6,162 (45.6)	6,704 (49.6)	0	3,475 (49.8)	3,570 (51.2)	0.017	2,687 (41)	3,134 (47.8)	0	0	0
	5 or more	7,365 (54.4)	6,823 (50.4)		3,502 (50.2)	3,407 (48.8)		3,863 (59)	3,416 (52.2)			
Legumes/pulses (e.g., beans, lentils, chickpeas)	4 or less	11,248 (83.2)	10,863 (80.3)	0	5,807 (83.2)	5,615 (80.5)	0	5,441 (83.1)	5,248 (80.1)	0	0.801	0.602
	5 or more	2,279 (16.8)	2,664 (19.7)		1,170 (16.8)	1,362 (19.5)		1,109 (16.9)	1,302 (19.9)			
Nuts	4 or less	10,829 (80.1)	10,704 (79.1)	0.009	5,441 (78)	5,338 (76.5)	0.003	5,388 (82.3)	5,366 (81.9)	0.51	0	0
	5 or more	2,698 (19.9)	2,823 (20.9)		1,536 (22)	1,639 (23.5)		1,162 (17.7)	1,184 (18.1)			
Processed meat/poultry/fish/ vegetarian alternatives	4 or less	10,358 (76.6)	11,226 (83)	0	5,146 (73.8)	5,599 (80.2)	0	5,212 (79.6)	5,627 (85.9)	0	0	0
	5 or more	3,169 (23.4)	2,301 (17)		1,831 (26.2)	1,378 (19.8)		1338 (20.4)	923 (14.1)			
Unprocessed fish	4 or less	12,319 (91.1)	12,003 (88.7)	0	6,230 (89.3)	6,030 (86.4)	0	6,089 (93)	5,973 (91.2)	0	0	0
	5 or more	1208 (8.9)	1524 (11.3)		747 (10.7)	947 (13.6)		461 (7)	577 (8.8)			
Unprocessed poultry	4 or less	10,292 (76.1)	10,165 (75.1)	0.009	4,974 (71.3)	4,893 (70.1)	0.027	5,318 (81.2)	5,272 (80.5)	0.163	0	0
	5 or more	3,235 (23.9)	3,362 (24.9)		2,003 (28.7)	2,084 (29.9)		1,232 (18.8)	1,278 (19.5)			
Unprocessed red meat*	4 or less	11,663 (86.2)	11,339 (83.8)	0	5,907 (84.7)	5,671 (81.3)	0	5,756 (87.9)	5,668 (86.5)	0	0	0
	5 or more	1,864 (13.8)	2,188 (16.2)		1,070 (15.3)	1,306 (18.7)		794 (12.1)	882 (13.5)			
Whole wheat bread, pasta, grains	4 or less	9,878 (73)	9,486 (70.1)	0	4,848 (69.5)	4,699 (67.3)	0	5,030 (76.8)	4,787 (73.1)	0	0	0
	5 or more	3,649 (27)	4,041 (29.9)		2,129 (30.5)	2,278 (32.7)		1,520 (23.2)	1,763 (26.9)			
White bread, pasta, grains	4 or less	8,837 (65.3)	8,535 (63.1)	0	4,541 (65.1)	4,361 (62.5)	0	4,296 (65.6)	4,174 (63.7)	0.001	0.539	0.142
	5 or more	4,690 (34.7)	4,992 (36.9)		2,436 (34.9)	2,616 (37.5)		2,254 (34.4)	2,376 (36.3)			
Milk	4 or less	8,402 (62.1)	8,304 (61.4)	0.039	3,891 (55.8)	3,884 (55.7)	0.865	4,511 (68.9)	4,420 (67.5)	0.004	0	0
	5 or more	5,125 (37.9)	5,223 (38.6)		3,086 (44.2)	3,093 (44.3)		2,039 (31.1)	2,130 (32.5)			
Other dairy products	4 or less	6,421 (47.5)	6,550 (48.4)	0.014	3,292 (47.2)	3,286 (47.1)	0.893	3,129 (47.8)	3,264 (49.8)	0	0.494	0.001
	5 or more	7,106 (52.5)	6,977 (51.6)		3,685 (52.8)	3,691 (52.9)		3,421 (52.2)	3,286 (50.2)			
Sweet snacks	4 or less	9,440 (69.8)	9,176 (67.8)	0	4,616 (66.2)	4,466 (64)	0	4,824 (73.6)	4,710 (71.9)	0.002	0	0
	5 or more	4,087 (30.2)	4,351 (32.2)		2,361 (33.8)	2,511 (36)		1,726 (26.4)	1,840 (28.1)			
Sugared beverages	4 or less	7,962 (58.9)	8,062 (59.6)	0.051	4,343 (62.2)	4,321 (61.9)	0.564	3,619 (55.3)	3,741 (57.1)	0.001	0	0
	5 or more	5,565 (41.1)	5,465 (40.4)		2,634 (37.8)	2,656 (38.1)		2,931 (44.7)	2,809 (42.9)			
Fats and oils	4 or less	10,499 (77.6)	10,190 (75.3)	0	5,299 (75.9)	5,073 (72.7)	0	5,200 (79.4)	5,117 (78.1)	0.014	0	0
	5 or more	3,028 (22.4)	3,337 (24.7)		1,678 (24.1)	1,904 (27.3)		1,350 (20.6)	1,433 (21.9)			

**Unprocessed meats: (refers to all mammalian muscle meat including beef, veal, pork, lamb, mutton, horse, and goat).*

TABLE 3 | Food groups consumption among countries in the GCC region, before and during COVID-19 pandemic.

		Bahrain N (%)			Kuwait N (%)			Oman N (%)			Qatar N (%)			Saudi Arabia N (%)			United Arab Emirates N (%)		
		Before	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**
Fruit (fresh or frozen)	4 or less	403 (58.2)	380 (54.8)	0.071	454 (62.4)	470 (64.6)	0.211	81 (43.5)	73 (39.2)	0.216	388 (59.4)	366 (56)	0.086	2,240 (74.7)	2,140 (71.4)	0	1,123 (65.4)	1,000 (58.2)	0
	5 or more	290 (41.8)	313 (45.2)		274 (37.6%)	258 (35.4)		105 (56.5)	113 (60.8)		265 (40.6)	287 (44)		759 (25.3)	859 (28.6)		595 (34.6)	718 (41.8)	
Vegetables (fresh or frozen)	4 or less	308 (44.4)	312 (45)	0.8	316 (43.4)	364 (50)	0	54 (29)	57 (30.6)	0.735	274 (42)	295 (45.2)	0.085	1,660 (55.4)	1,703 (56.8)	0.102	863 (50.2)	839 (48.8)	0.265
	5 or more	385 (55.6)	381 (55)		412 (56.6)	364 (50)		132 (71)	129 (69.4)		379 (58)	358 (54.8)		1,339 (44.6)	1,296 (43.2)		855 (49.8)	879 (51.2)	
Legumes/ pulses	4 or less	595 (85.9)	583 (84.1)	0.281	603 (82.8)	573 (78.7)	0.012	152 (81.7)	151 (81.2)	1	526 (80.6)	524 (80.2)	0.92	2,554 (85.2)	2,483 (82.8)	0.001	1,377 (80.2)	1,301 (75.7)	0
	5 or more	98 (14.1)	110 (15.9)		125 (17.2)	155 (21.3)		34 (18.3)	35 (18.8)		127 (19.4)	129 (19.8)		445 (14.8)	516 (17.2)		341 (19.8)	417 (24.3)	
Nuts	4 or less	493 (71.1)	475 (68.5)	0.142	520 (71.4)	535 (73.5)	0.238	130 (69.9)	141 (75.8)	0.054	509 (77.9)	492 (75.3)	0.149	2,460 (82)	2,410 (80.4)	0.025	1,329 (77.4)	1,285 (74.8)	0.014
	5 or more	200 (28.9)	218 (31.5)		208 (28.6)	193 (26.5)		56 (30.1)	45 (24.2)		144 (22.1)	161 (24.7)		539 (18)	589 (19.6)		389 (22.6)	433 (25.2)	
Processed meat/poultry/ fish/ vegetarian alternatives	4 or less	523 (75.5)	559 (80.7)	0.005	528 (72.5)	560 (76.9)	0.015	139 (74.7)	162 (87.1)	0.001	490 (75)	529 (81)	0.001	2,206 (73.6)	2,440 (81.4)	0	1,260 (73.3)	1,349 (78.5)	0
	5 or more	170 (24.5)	134 (19.3)		200 (27.5)	168 (23.1)		47 (25.3)	24 (12.9)		163 (25)	124 (19)		793 (26.4)	559 (18.6)		458 (26.7)	369 (21.5)	
Unprocessed fish	4 or less	598 (86.3)	570 (82.3)	0.006	659 (90.5)	646 (88.7)	0.171	152 (81.7)	153 (82.3)	1	598 (91.6)	569 (87.1)	0	2,737 (91.3)	2,655 (88.5)	0	1,486 (86.5)	1,437 (83.6)	0.002
	5 or more	95 (13.7)	123 (17.7)		69 (9.5)	82 (11.3)		34 (18.3)	33 (17.7)		55 (8.4)	84 (12.9)		262 (8.7)	344 (11.5)		232 (13.5)	281 (16.4)	
Unprocessed poultry	4 or less	502 (72.4)	477 (68.8)	0.03	565 (77.6)	551 (75.7)	0.239	146 (78.5)	138 (74.2)	0.23	484 (74.1)	479 (73.4)	0.707	1,960 (65.4)	1,961 (65.4)	1	1,317 (76.7)	1,287 (74.9)	0.111
	5 or more	191 (27.6)	216 (31.2)		163 (22.4)	177 (24.3)		40 (21.5)	48 (25.8)		169 (25.9)	174 (26.6)		1,039 (34.6)	1,038 (34.6)		401 (23.3)	431 (25.1)	
Unprocessed red meat	4 or less	605 (87.3)	597 (86.1)	0.396	622 (85.4)	606 (83.2)	0.089	163 (87.6)	159 (85.5)	0.556	555 (85)	535 (81.9)	0.027	2,500 (83.4)	2,367 (78.9)	0	1,462 (85.1)	1,407 (81.9)	0.001
	5 or more	88 (12.7)	96 (13.9)		106 (14.6)	122 (16.8)		23 (12.4)	27 (14.5)		98 (15)	118 (18.1)		499 (16.6)	632 (21.1)		256 (14.9)	311 (18.1)	
Wholewheat bread, pasta, grains	4 or less	499 (72)	476 (68.7)	0.087	519 (71.3)	497 (68.3)	0.105	123 (66.1)	127 (68.3)	0.671	468 (71.7)	452 (69.2)	0.205	2,082 (69.4)	2,046 (68.2)	0.18	1,157 (67.3)	1,101 (64.1)	0.008

(Continued)

TABLE 3 | Continued

		Bahrain N (%)			Kuwait N (%)			Oman N (%)			Qatar N (%)			Saudi Arabia N (%)			United Arab Emirates N (%)		
		Before	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**
	5 or more	194 (28)	217 (31.3)		209 (28.7)	231 (31.7)		63 (33.9)	59 (31.7)		185 (28.3)	201 (30.8)		917 (30.6)	953 (31.8)		561 (32.7)	617 (35.9)	
White bread, pasta, grains	4 or less	475 (68.5)	436 (62.9)	0.002	508 (69.8)	476 (65.4)	0.015	114 (61.3)	115 (61.8)	1	424 (64.9)	419 (64.2)	0.736	1,899 (63.3)	1,850 (61.7)	0.06	1,121 (65.3)	1,065 (62)	0.006
	5 or more	218 (31.5)	257 (37.1)		220 (30.2)	252 (34.6)		72 (38.7)	71 (38.2)		229 (35.1)	234 (35.8)		1,100 (36.7)	1,149 (38.3)		597 (34.7)	653 (38)	
Milk	4 or less	364 (52.5)	354 (51.1)	0.403	432 (59.3)	415 (57)	0.146	90 (48.4)	95 (51.1)	0.441	339 (51.9)	341 (52.2)	0.928	1,720 (57.4)	1,724 (57.5)	0.897	946 (55.1)	955 (55.6)	0.654
	5 or more	329 (47.5)	339 (48.9)		296 (40.7)	313 (43)		96 (51.6)	91 (48.9)		314 (48.1)	312 (47.8)		1,279 (42.6)	1,275 (42.5)		772 (44.9)	763 (44.4)	
Other dairy products	4 or less	326 (47)	323 (46.6)	0.867	318 (43.7)	326 (44.8)	0.565	77 (41.4)	73 (39.2)	0.607	295 (45.2)	303 (46.4)	0.536	1,413 (47.1)	1,427 (47.6)	0.587	863 (50.2)	834 (48.5)	0.145
	5 or more	367 (53)	370 (53.4)		410 (56.3)	402 (55.2)		109 (58.6)	113 (60.8)		358 (54.8)	350 (53.6)		1,586 (52.9)	1,572 (52.4)		855 (49.8)	884 (51.5)	
Sweet snacks	4 or less	496 (71.6)	487 (70.3)	0.481	430 (59.1)	413 (56.7)	0.184	145 (78)	136 (73.1)	0.2	433 (66.3)	443 (67.8)	0.444	1,978 (66)	1,886 (62.9)	0	1,134 (66)	1,101 (64.1)	0.112
	5 or more	197 (28.4)	206 (29.7)		298 (40.9)	315 (43.3)		41 (22)	50 (26.9)		220 (33.7)	210 (32.2)		1,021 (34)	1,113 (37.1)		584 (34)	617 (35.9)	
Sugared beverages	4 or less	435 (62.8)	423 (61)	0.315	427 (58.7)	421 (57.8)	0.642	121 (65.1)	122 (65.6)	1	393 (60.2)	386 (59.1)	0.585	1,810 (60.4)	1,850 (61.7)	0.098	1,157 (67.3)	1,119 (65.1)	0.056
	5 or more	258 (37.2)	270 (39)		301 (41.3)	307 (42.2)		65 (34.9)	64 (34.4)		260 (39.8)	267 (40.9)		1,189 (39.6)	1,149 (38.3)		561 (32.7)	599 (34.9)	
Fats and oils	4 or less	509 (73.4)	482 (69.6)	0.026	512 (70.3)	502 (69.0)	0.444	152 (81.7)	148 (79.6)	0.596	493 (75.5)	469 (71.8)	0.040	2,376 (79.2)	2,287 (76.3)	0	1,257 (73.2)	1,185 (69.0)	0
	5 or more	184 (26.6)	211 (30.4)		216 (29.7)	226 (31.0)		34 (18.3)	38 (20.4)		160 (24.5)	184 (28.2)		623 (20.8)	712 (23.7)		461 (26.8)	533 (31.0)	

TABLE 4 | Food groups consumption among countries in the MENA region, before and during COVID-19 pandemic.

		Egypt *N (%)*			Jordan *N (%)*			Lebanon *N (%)*			Palestine *N (%)*		
		Before	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**
Fruit (fresh or frozen)	4 or less	346 (47.1)	324 (44.1)	0.086	1,821 (68.1)	1,836 (68.6)	0.538	1,178 (51.6)	1,300 (57)	0	465 (54.1)	521 (60.7)	0
	5 or more	388 (52.9)	410 (55.9)		854 (31.9)	839 (31.4)		1104 (48.4)	982 (43)		394 (45.9)	338 (39.3)	
Vegetables (fresh or frozen)	4 or less	290 (39.5)	283 (38.6)	0.625	1,233 (46.1)	1,448 (54.1)	0	822 (36)	979 (42.9)	0	342 (39.8)	424 (49.4)	0
	5 or more	444 (60.5)	451 (61.4)		1,442 (53.9)	1,227 (45.9)		1,460 (64)	1,303 (57.1)		517 (60.2)	435 (50.6)	
Legumes/pulses	4 or less	614 (83.7)	584 (79.6)	0.008	2,257 (84.4)	2,195 (82.1)	0.004	1,848 (81)	1,775 (77.8)	0.001	722 (84.1)	694 (80.8)	0.027
	5 or more	120 (16.3)	150 (20.4)		418 (15.6)	480 (17.9)		434 (19)	507 (22.2)		137 (15.9)	165 (19.2)	
Nuts	4 or less	609 (83)	577 (78.6)	0.003	2,173 (81.2)	2,147 (80.3)	0.239	1,920 (84.1)	1,947 (85.3)	0.147	686 (79.9)	695 (80.9)	0.497
	5 or more	125 (17)	157 (21.4)		502 (18.8)	528 (19.7)		362 (15.9)	335 (14.7)		173 (20.1)	164 (19.1)	
Processed meat/poultry/ fish/vegetarian alternatives	4 or less	617 (84.1)	650 (88.6)	0.003	2,044 (76.4)	2,262 (84.6)	0	1,857 (81.4)	1,991 (87.2)	0	694 (80.8)	724 (84.3)	0.022
	5 or more	117 (15.9)	84 (11.4)		631 (23.6)	413 (15.4)		425 (18.6)	291 (12.8)		165 (19.2)	135 (15.7)	
Unprocessed fish	4 or less	688 (93.7)	676 (92.1)	0.134	2,441 (91.3)	2,376 (88.8)	0	2,152 (94.3)	2,140 (93.8)	0.366	808 (94.1)	781 (90.9)	0.003
	5 or more	46 (6.3)	58 (7.9)		234 (8.7)	299 (11.2)		130 (5.7)	142 (6.2)		51 (5.9)	78 (9.1)	
Unprocessed poultry	4 or less	613 (83.5)	593 (80.8)	0.06	2,010 (75.1)	1,989 (74.4)	0.387	2,032 (89)	2,033 (89.1)	1	663 (77.2)	657 (76.5)	0.683
	5 or more	121 (16.5)	141 (19.2)		665 (24.9)	686 (25.6)		250 (11)	249 (10.9)		196 (22.8)	202 (23.5)	
Unprocessed red meat	4 or less	643 (87.6)	624 (85)	0.048	2,307 (86.2)	2,255 (84.3)	0.009	2,043 (89.5)	2,041 (89.4)	0.948	763 (88.8)	748 (87.1)	0.18
	5 or more	91 (12.4)	110 (15)		368 (13.8)	420 (15.7)		239 (10.5)	241 (10.6)		96 (11.2)	111 (12.9)	
Sweet snacks	4 or less	583 (79.4)	552 (75.2)	0.007	1,931 (72.2)	1,829 (68.4)	0	1,664 (72.9)	1,734 (76)	0.001	646 (75.2)	595 (69.3)	0
	5 or more	151 (20.6)	182 (24.8)		744 (27.8)	846 (31.6)		618 (27.1)	548 (24)		213 (24.8)	264 (30.7)	

(Continued)

TABLE 4 | Continued

		Egypt *N (%)*			Jordan *N (%)*			Lebanon *N (%)*			Palestine *N (%)*		
		Before	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**	**Before**	**During**	***p*-value**
Wholewheat bread, pasta, grains	4 or less	535 (72.9)	519 (70.7)	0.195	2,092 (78.2)	1,966 (73.5)	0	1,757 (77)	1,694 (74.2)	0.003	646 (75.2)	608 (70.8)	0.008
	5 or more	199 (27.1)	215 (29.3)		583 (21.8)	709 (26.5)		525 (23)	588 (25.8)		213 (24.8)	251 (29.2)	
White bread, pasta, grains	4 or less	482 (65.7)	433 (59)	0	1,767 (66.1)	1,728 (64.6)	0.122	1,491 (65.3)	1,484 (65)	0.79	556 (64.7)	529 (61.6)	0.063
	5 or more	252 (34.3)	301 (41)		908 (33.9)	947 (35.4)		791 (34.7)	798 (35)		303 (35.3)	330 (38.4)	
Milk	4 or less	318 (43.3)	298 (40.6)	0.045	1,962 (73.3)	1,892 (70.7)	0.001	1,678 (73.5)	1,693 (74.2)	0.433	553 (64.4)	537 (62.5)	0.164
	5 or more	416 (56.7)	436 (59.4)		713 (26.7)	783 (29.3)		604 (26.5)	589 (25.8)		306 (35.6)	322 (37.5)	
Other dairy products	4 or less	277 (37.7)	277 (37.7)	1	1,399 (52.3)	1,416 (52.9)	0.488	1,039 (45.5)	1,155 (50.6)	0	414 (48.2)	416 (48.4)	0.941
	5 or more	457 (62.3)	457 (62.3)		1,276 (47.7)	1,259 (47.1)		1,243 (54.5)	1,127 (49.4)		445 (51.8)	443 (51.6)	
Sugared beverages	4 or less	422 (57.5)	428 (58.3)	0.634	1,494 (55.9)	1,516 (56.7)	0.371	1,282 (56.2)	1,359 (59.6)	0	421 (49)	438 (51)	0.216
	5 or more	312 (42.5)	306 (41.7)		1,181 (44.1)	1,159 (43.3)		1,000 (43.8)	923 (40.4)		438 (51)	421 (49)	
Fats and oils	4 or less	637 (86.8)	612 (83.4)	0.017	2,081 (77.8)	1,979 (74.0)	0	1,814 (79.5)	1,878 (82.3)	0.001	668 (77.8)	648 (75.4)	0.123
	5 or more	97 (13.2)	122 (16.6)		594 (22.2)	696 (26.0)		468 (20.5)	404 (17.7)		191 (22.2)	211 (24.6)	

TABLE 5 | Food consumption score of studied population before and during the COVID-19 pandemic.

Main Outcome		Bahrain *N* (%)	Egypt *N* (%)	Jordan *N* (%)	Kuwait *N* (%)	Lebanon *N* (%)	Oman *N* (%)	Qatar *N* (%)	KSA *N* (%)	UAE *N* (%)	Palestine *N* (%)	*p*-value	EMR *N* (%)	GULF *N* (%)	MENA *N* (%)	*p*-value
FCS before COVID-19		107.7 ± 43.4	104.8 ± 44.3	93.8 ± 46.3	105.9 ± 46.6	93.9 ± 41.9	117.5 ± 41.9	108.1 ± 44	101.6 ± 47.3	106 ± 48	96.8 ± 46.1	0	100.3 ± 45.9	104.8 ± 46.7	95.5 ± 44.7	0
FCS during COVID-19		111.2 ± 48	109.5 ± 44.7	93.6 ± 50.8	105.3 ± 51.7	88.1 ± 44.4	112.1 ± 41.7	107.9 ± 48.6	101.7 ± 51.4	108 ± 51.2	96.5 ± 50.3	0	99.8 ± 49.8	105.5 ± 50.7	93.9 ± 48.3	0
p-value		0.003	0	0.783	0.616	0	0.011	0.869	0.791	0.013	0.838		0.138	0.086	0	
FCS-before COVID-19	Low	38 (5.5)	62 (8.4)	333 (12.4)	48 (6.6)	211 (9.2)	8 (4.3)	40 (6.1)	287 (9.6)	139 (8.1)	90 (10.5)	0	1,256 (9.3)	560 (8.0)	696 (10.6)	0
	High	655 (94.5)	672 (91.6)	2,342 (87.6)	680 (93.4)	2,071 (90.8)	178 (95.7)	613 (93.9)	2,712 (90.4)	1,579 (91.9)	769 (89.5)		12,271 (90.7)	6,417 (92)	5,854 (89.4)	
FCS-during COVID-19	Low	38 (5.5)	48 (6.5)	411 (15.4)	68 (9.3)	315 (13.8)	10 (5.4)	45 (6.9)	340 (11.3)	147 (8.6)	118 (13.7)	0	1,540 (11.4)	648 (9.3)	892 (13.6)	0
	High	655 (94.5)	686 (93.5)	2,264 (84.6)	660 (90.7)	1,967 (86.2)	176 (94.6)	608 (93.1)	2,659 (88.7)	1,571 (91.4)	741 (86.3)		11,987 (88.6)	6,329 (90.7)	5,658 (86.4)	
Percentage of decline in the NA FCS		0	−1.90	3	2.7	4.6	1.10	0.8	1.70	0.50	3.2		2.1	1.30	3	
p-value		1	0.099	0	0.011	0	0.625	0.472	0.001	0.516	0.004		0	0	0	

MENA region (*p*-value = 0.000, *p*-value = 0.000 and *p*-value = 0.000, respectively). When comparing the consumption of legumes and pulses between GCC and MENA countries, before and during the lockdown, no difference was observed (*p*-value = 0.8 and *p*-value = 0.6, respectively) (**Table 2**). Furthermore, the intake of legumes and pulses, before and during the pandemic, were around 20% or less in all the countries studied. An increase ranging between 2 and 4% of legumes and pulses intake was observed in Saudi Arabia (*p*-value = 0.001), Jordan (*p*-value = 0.004), Lebanon (*p*-value = 0.001), Palestine (*p*-value = 0.027), Kuwait (*p*-value = 0.012), UAE (*p*-value = 0.000), and Egypt (*p*-value = 0.008) (**Tables 3**, **4**).

Nuts Group

Three quarters of the population were consuming nuts lower than or equal to 4 times a week. As per **Table 2**, the percentage of people consuming frequently nuts and derivatives was higher in the GCC countries (22% before the lockdown and 23.5% during the lockdown) compared to the MENA countries (17.7% before the lockdown and 18.1% during the lockdown) before and during the lockdown (*p*-value = 0.000 and *p*-value = 0.000, respectively). A slight significant increase (around 1%) in the consumption of nuts group was observed during the pandemic in the overall population and in the GCC countries only (*p*-value = 0.000 and *p*-value = 0.000, respectively). This was not the case in the MENA countries (*p*-value = 0.51). Per country, a slight increase of 1.6% was observed in Saudi Arabia (*p*-value = 0.025), of 3% in UAE (*p*-value = 0.014) and of 4% in Egypt (*p*-value = 0.003) only. The lowest consumption of nuts group was observed in Lebanon (15.9% before the lockdown and 14.7% during the lockdown) and the highest intake was in Bahrain (29% before the lockdown and 31.5% during the lockdown) (**Tables 3**, **4**).

Processed Meat/Poultry/Fish/Vegetarian Alternatives

A range between 14 and 26% of people living in the EM countries were consuming frequently (equals five times a week or more) processed meat/poultry/fish and vegetarian alternatives, before and during the pandemic. The consumption of this food group was higher in the GCC countries before and during the pandemic (26.2 and 19.8%, respectively) compared to the MENA countries (20.4% and 14.1%, respectively) (*p*-value = 0.000 and *p*-value = 0.000). A decrease of 6% in the consumption of this food group was observed during the lockdown in the EM countries together and in each GCC and MENA countries alone (*p*-value = 0.000, *p*-value = 0.000 and *p*-value = 0.000, respectively) (**Table 2**). The per-country analysis of data on processed meat/poultry/fish/vegetarians' alternatives intake showed a decrease of 5% in Bahrain (*p*-value = 0.005), 4% in Kuwait (*p*-value = 0.015), 12% in Oman (*p*-value = 0.001), 6% in Qatar (*p*-value = 0.001), 8% in Saudi Arabia (*p*-value = 0.000), 5% in UAE (*p*-value = 0.000), 4% in Egypt (*p*-value = 0.003), 8% in Jordan (*p*-value = 0.000), 6% in Lebanon (*p*-value = 0.000), and 4% in Palestine (*p*-value = 0.022) (**Tables 3**, **4**).

Unprocessed Fish, Unprocessed Poultry, and Unprocessed Meats

It was observed that <30% of the population ate frequently unprocessed fish, poultry, and meats. The frequency of consumption of this food group was higher in the GCC countries compared to the MENA countries, before and during the pandemic (p-value = 0.000 and p-value = 0.000, respectively). A slight significant increase (1–3%) was observed in the frequency of consumption of this group during the pandemic in the EM countries together (fish-p-value = 0.000, poultry-p-value = 0.009 and meat-p-value = 0.000) and in the GCC countries (fish-p-value = 0.000, poultry-p-value-0.027 and meat-p-value = 0.000). Same trend was observed in the MENA countries, except for the consumption of poultry group which remained unchanged before and during the pandemic (p-value = 0.16) (**Table 2**). The lowest consumption of unprocessed fish (5.7% before and 6.2% during the lockdown), poultry (11% before and 10.9% during the lockdown), and meats (10.5% before and 10.6% during the lockdown) was observed in Lebanon (**Table 4**). The intake of fish increased during the pandemic in a range between 2 and 4% significantly in Bahrain (p-value = 0.006), in Qatar (p-value = 0.000), in Saudi Arabia (p-value = 0.00), in UAE (p-value = 0.002), in Jordan (p-value = 0.000), and in Palestine (p-value = 0.003) and remained unchanged in the other countries (**Tables 3**, **4**). The intake of poultry had increased around 4% during the pandemic in Bahrain only (p-value = 0.03) and remained stable in all the remaining countries. The percentage of people consuming red meats equals five times a week or more, increased during the pandemic in Egypt (3%, p-value = 0.048), Jordan (5%, p-value = 0.009), Qatar (3%, p-value = 0.027), Saudi Arabia (4%, p-value = 0.000), and UAE (3%, p-value = 0.001) only.

White and Whole Wheat, Bread, Pasta, and Grains

Only 30% of the EM population in this study were consuming wholewheat bread, pasta, and grains in a frequency equals five times a week or more. An increase of 3% was observed during the pandemic (p-value = 0.00). The frequency of consumption of this food group in the GCC countries (30.5% before the lockdown and 32.7% during the lockdown) was higher than that observed in the MENA region (23.2% before the lockdown and 26.9% during the lockdown) (p-value = 0.000 and p-value = 0.000, respectively). On the other hand, the percentage of people consuming white bread, pasta, and grains were relatively high in the MENA countries as well as in GCC countries compared to those who consumed whole grains frequently. Furthermore, no significant differences were observed between the frequent consumption of these two food groups among the GCC and the MENA countries (p-value = 0.5 and p-value = 0.1, respectively) (**Table 2**). Before the pandemic, the highest intake of wholewheat and white breads/pasta and grains was observed in Oman (33.9% before and 38.7% during the lockdown, respectively) and during the lockdown the highest intake of this group was observed in Palestine (38.4%) and in Egypt (41%) (p-value = 0.000). It was observed that the consumption of wholewheat food groups increased during the lockdown of 3% in UAE (p-value = 0.008), 5% in Jordan (p-value = 0.00), 2% in Lebanon (p-value = 0.003), and 5% in Palestine during the lockdown (p-value = 0.008) and remained unchanged in the other countries. However, the consumption of white breads/pasta and grains increased during the lockdown of 6% in Bahrain (p-value = 0.002), of 4% in Kuwait (p-value = 0.015) of 2% in Saudi Arabia (p-value = 0.06) and of 7% in Egypt (p-value = 0.000) (**Tables 3**, **4**).

Milk and Dairy Products Group

More than half the population were consuming milk and dairy products lower than or equal to 4 times a week. The consumption of milk and dairy products, during the pandemic, were higher in the GCC countries (44.3 and 52.9%) compared to the MENA countries (32.5 and 50.2%) (p-value = 0.000 and p-value =0.001, respectively). Overall, during the lockdown, a slight increase was remarkable in the consumption of milk (0.6%, p-value = 0.03) along with a slight decrease in the consumption of other dairy products e.g., Cheese and yogurt (0.9%, p-value = 0.014) (**Table 2**). The analyses per country showed an increase in the milk intake of 3% in Egypt (p-value = 0.045) and Jordan (p-value = 0.001) and a decrease in other dairy products consumption of 5% in Lebanon (p-value = 0.000) (**Tables 3**, **4**).

Sugar Group (Products and Beverages)

A range between 40 and 45% of the population studied consumed this group equals five times a week or more. Despite the increase in the frequency of consumption of sugary beverages products in the studied EM countries (p-value = 0.000), in the GCC countries (p-value = 0.000) and in the MENA countries (p-value = 0.002), more than 36% of the population consumed this group 4 times and more, per week (**Table 2**). An increase of 3–6% in the consumption of sweet products was observed during the lockdown in Saudi Arabia (p-value = 0.000), Egypt (p-value = 0.007), Jordan (p-value = 0.000), and Palestine (p-value = 0.000) along with a decrease of 3% in Lebanon (p-value = 0.001). The intake of sugary beverages did not differ between the 2 periods of time except in Lebanon in which the consumption decreased of 3% (p-value = 0.000) (**Tables 3**, **4**).

Fats and Oils Group

It was observed that added fats and oils were less frequently consumed in the EM countries studied (around 25% of the total population). A slight increase of 1–4% was observed among the EMR, GCC, and MENA countries (p-value = 0.000, p-value = 0.000 and p-value = 0.014, respectively). All in all, the consumption of added fats and oils was higher in the GCC compared to the MENA countries, before (24 vs. 20%; p-value = 0.000) and during the lockdown (27 vs. 22%; p-value = 0.000) (**Table 2**). At the GCC countries level, the consumption of food groups increased of 3% during the lockdown in Bahrain (p-value = 0.026), in Qatar (p-value = 0.04), in Saudi Arabia (p-value = 0.00), and in UAE (p-value = 0.00). Similarly, an increase of up to 4% was observed in Egypt (p-value = 0.017) and Jordan (p-value = 0.00) along with a decrease of 3% in Lebanon (p-value = 0.001). Prior to and during the lockdown, the lowest intake of added fats and oils was observed in Egypt (13 vs. 16%, respectively) and the highest was in Kuwait (around 30% in both study periods) (**Tables 3**, **4**).

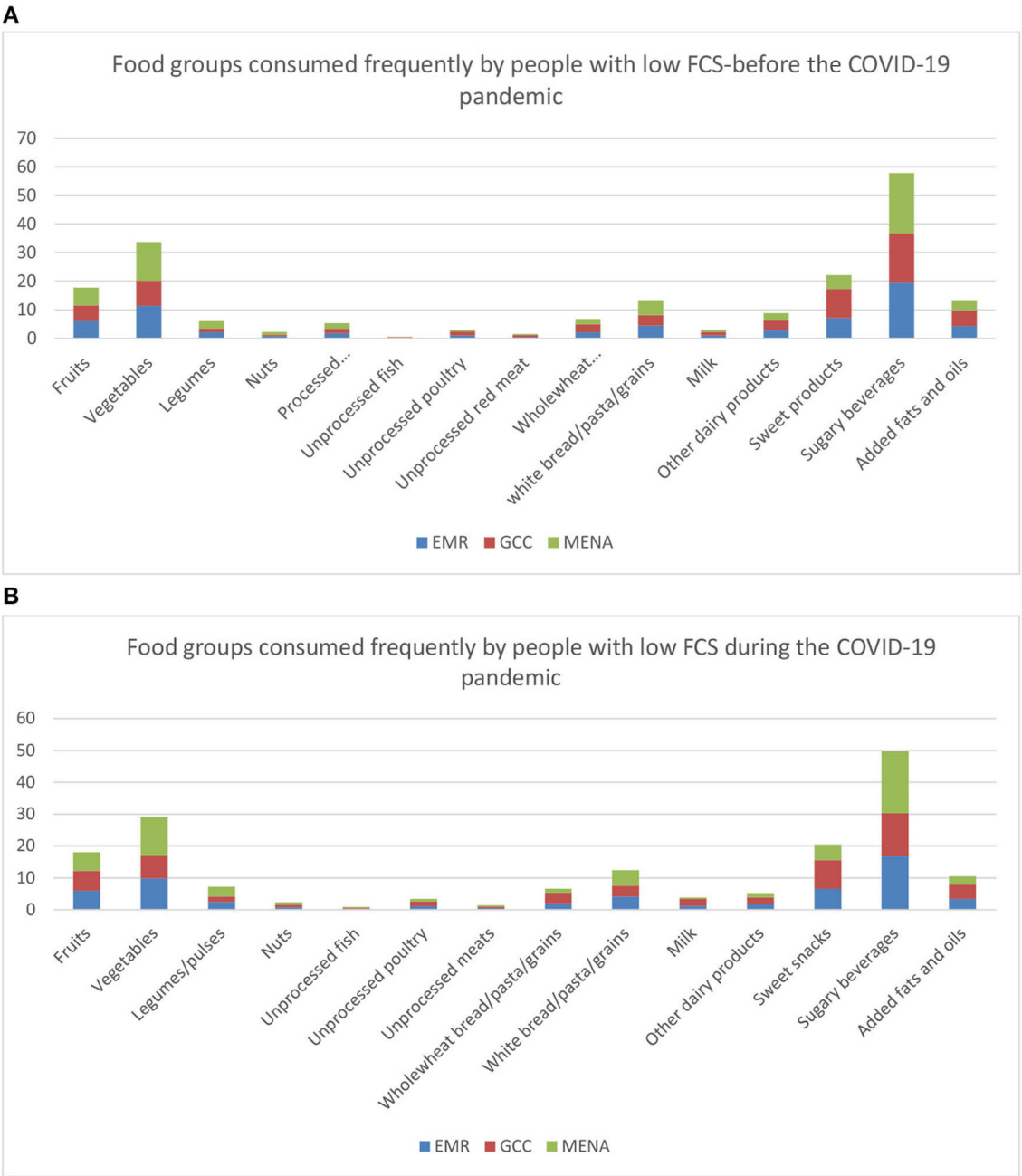


FIGURE 1 | (A) Food groups consumed frequently by people having low FCS in the EM countries prior to the pandemic. **(B)** Food groups consumed frequently by people having low FCS in the EM countries during the pandemic.

The Food Consumption Score was calculated based on the equation explained previously. Compared to the period preceding the pandemic, the mean levels, and SD of the FCS in all the countries studied was equal to 100.3 ± 45.9 and it remained unchanged during the pandemic (p-value = 0.13). Before the pandemic, the FCS in the GCC countries (104.8 ± 46.7) was higher than that of the MENA countries (95.5 ± 44.7) (p-value = 0.000). However, during the pandemic, the FCS declined in the MENA countries from 95.5 to 93.9 (p-value = 0.00) but remained unchanged in the GCC countries (p-value = 0.08). The lowest FCS values were observed in the MENA countries: Jordan, Lebanon, and Palestine (**Table 5**). The percentage of people having low FCS (<42) increased from 9.3 to 11.4% in the overall EM countries studied during the lockdown. Moreover, in the GCC and the MENA countries, the percentage of people having low FCS increased from to 8% to 9.3% and from 10.8 to 13.6%, respectively (p-value = 0.00 and p-value = 0.00, respectively). The percentage of people with high FCS decreased of 3% in

Jordan, 2.7% in Kuwait, 4.6% in Lebanon, 1.7% in Saudi Arabia, and 3.2% in Palestine (p-value = 0.00) (**Table 5**). However, this was not significant for three countries which includes UAE, Oman, and Qatar. The percentage of people having high FCS increased insignificantly of 1.9% in Egypt (p-value = 0.09) and remained stable in Bahrain. **Figures 1A,B** showed the percentage of food groups consumed frequently by people with low FCS. These households were mainly dependent on sugary beverages and vegetables intake rather than other nutritious food groups. Same trends were observed before and during the pandemic (**Figures 1A,B**).

Food Consumption Patterns and Mitigation Measures

Cooking Practices and Barriers

Table 3 shows that most cooking practices (11 out of 13) showed a significant increase during the lockdown. The highest increase was recorded for cooking with leftover foods (60.4% positive answers before lockdown compared to 65.7% during lockdown) (p-value = 0.00). The only practices that showed a significant decrease during lockdown was throwing away food leftovers (33.8% before lockdown compared to 32.5% during lockdown) (p-value = 0.00). It was observed that the attitudes of "planning a nutritious-varied diet" and "thinking about healthy choices" increased of 4.7% and 2.6% during the lockdown (p-value = 0.00 and p-value = 0.00), respectively, despite the null change in the practice of "cooking meals using healthy ingredients" (p-value = 0.3) and despite the null change also in "feeling confident about managing money to buy healthy food" (p-value = 0.6). Similarly, a significant increase of around 4.5% was observed in the practice of "reading of nutrition panels to make healthy choices" (p-value = 0.00). More than 65% of people were "changing recipes to make them healthier," were "cooking with leftovers" and were avoiding "throwing away foods." As for barriers against healthy cooking, almost 34–38% of people "didn't have the funds or the access for the foods/ingredients they needed or wanted to buy" and 28% of them "didn't have access to cooking facilities (stove, oven…)" (p-value = 0.00). At the level of the GCC and the MENA countries, we noticed a range between 23–47% and 20–50%, respectively, of people who were ignoring planning varied diet, avoiding thinking about healthy choices, disregard managing money to buy healthy food, pay no attention to cook meals at home using healthy ingredients, avoid changing recipes to make them healthier and ignore the nutrition panel to make healthy choices. Moreover, three quarters of the people living in GCC countries and 60% of those living in the MENA countries, were having monetary access to buy health food, were having access to food and also to cooking facilities. This trend decreases significantly in a range between 2 and 6% in the GCC countries and a range of 2% to 10% in the MENA countries, during the lockdown, ameliorating by this the cooking practices during this period of time in both regions (**Supplementary Table S1**). The analysis by gender shows the same significant trends as in the overall population (Data not shown). All in all, it was observed that during the pandemic, men witnessed a significant modification in cooking practices of which planning to consume healthy varied diet (p-value = 0.00), cooking healthy meals and recipes (p-value = 0.00) from leftovers (p-value = 0.00). Similar trend was also shown in women (Data not shown).

Criteria for Recipe Selection

With regards to the criteria for recipes selection, the lockdown due to the COVID-19 pandemic was found to significantly increase the percentage of agreeing responses for all criterions. For instance, during the lockdown, more than 70% of people selected their recipes with few ingredients (71.5%) that are easily available at home (79.4%) or at store (79.3%), inexpensive (68%), and healthy (72.8%) (**Supplementary Table S2**). Before the pandemic, more than half to three quarters the people living in the EM countries studied, were selecting recipes that were achievable with few ingredients, were available at home or can be easily found at the store, inexpensive to prepare, healthy, and cheap. During the lockdown, an increase ranging between 2 and 20%, was observed in these patterns (**Supplementary Table S2**).

Dietary Shopping Practices

Shopping practices have also been affected during the lockdown. Indeed, more than 60% of respondents agreed that they search more for cheapest prices before and during the lockdown. While, this increase was not very important and not significant, we observed a significant similar trend when analyzing by gender (p-value = 0.00) (**Supplementary Table S3**).

During the lockdown, respondents admitted significantly a reduction of 12.8% less going physically to select and buy food and that they preferred to order their food products online (variation of 1.2%) and have it delivered at home rather than being delivered at a seller's point (4.4%) (p-value = 0.00). Regarding places of groceries shopping, there was a significant decrease during the lockdown whatever was the place. In addition, it is remarkable that respondents had shown a disinterest of buying food at organic/ fair trade shops or specialty stores during lockdown. Before the pandemic, in the GCC countries, there was a decrease in shopping patterns of which a decrease of 17% in shopping foods physically from markets (p-value = 0.00), of 10% in shopping groceries from supermarkets (p-value = 0.001), of 6% in shopping from corner stores (p-value = 0.00), a range of 7% to 16% in shopping from farmer or organic stores, of 19% in shopping from specialties store (butcher, bakery, etc.…) (p-value = 0.00) and of 5% in buying meal boxes (p-value = 0.00). However, a 4% increase in making online food orders (p-value = 0.00) was observed. At the MENA countries, we noticed the same trends in shopping patterns, however, people living in these countries were making less orders online to buy groceries and reach markets more frequently compared to people living in the MENA countries (**Supplementary Table S3**).

Food Stock

Food storage was also affected during the pandemic. **Figure 2** shows the distribution of food groups in term of storage in the overall countries and by regions. We observed a huge increase in storage for pasta, rice, or other grains, for water,

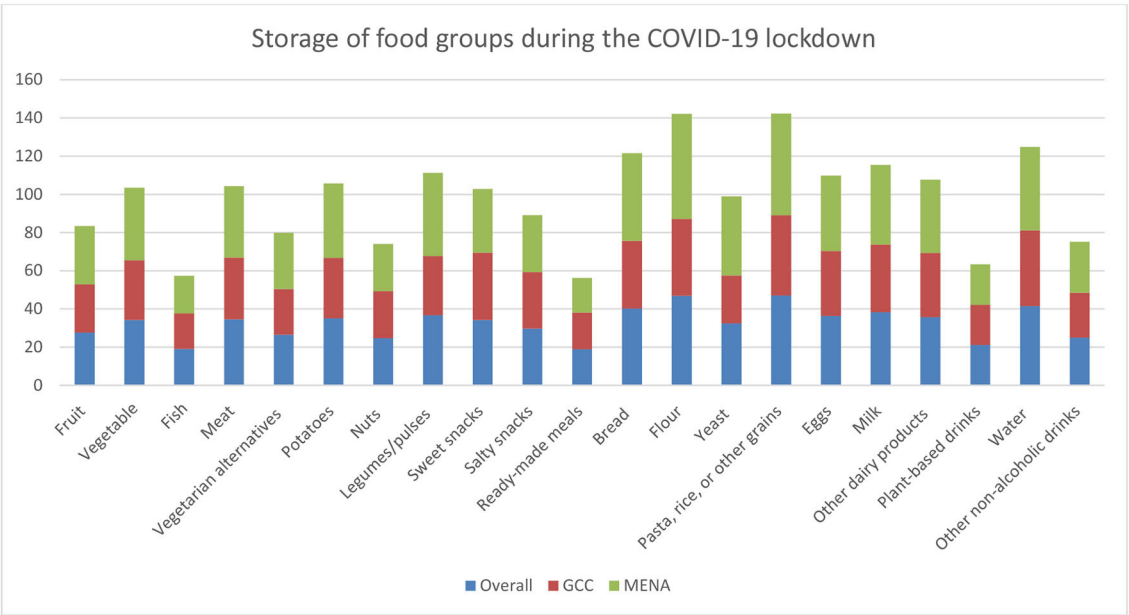


FIGURE 2 | Food stock patterns during the pandemic, overall and by regions.

and for flour. This increase was to a less extent for potatoes, legumes/pulses, bread, eggs, milk, and other dairy products. On the other hand, ready-made meals and fish (fresh, frozen and canned) were less stored during lockdown. Furthermore, lockdown did not show any impact on storage of fruits in any of its forms as well as vegetarian alternatives and salty snacks. When comparing the regions, we observed a high storage of flour (39%), pasta (38.4%), water (32.2%), and bread (30.9%) in the MENA countries. On the other hand, pasta (26.6%), water (26.2%), flour (23%), and milk (19%) were the more stored in the GCC countries.

Determinants of Food Insecurity in the Overall Population

Many factors affected the FCS of the people living in the EM countries studied. Before the pandemic, the percentage of people, living in the GCC countries, and having low FCS was 8% and increased to reach 9.3% during the pandemic. On the other hand, 10.6 and 13.6% of the MENA population studied had a low FCS before the pandemic and during the pandemic, respectively (**Table 6**). The determinants of food insecurity indicated by "low FCS" in the overall population, before and during the pandemic, is conditioned by many variables of which the region, gender, age categories, some cooking practices, cooking with leftovers and education. To explain, prior to the pandemic, the odds of low FCS in the MENA countries was 1.3 higher than in the GCC countries [OR:1.3; 95% CI (1.23- 1.56)]. Moreover, women were witnessing a FCS of 1.3 times higher than men [OR:1.3; 95% CI (1.19–1.59)]. Compared to adolescents (18 years), adults and elderly people were had a high FCS compared to younger people [OR:0.34; 95% CI (0.14-0.81)] and [OR:0.36; 95% CI (0.15–0.85)], respectively. Some cooking practices affected the FCS of the population studied. For instance, planning meals to include a variety of food [OR:1.4; 95% CI (1.21–1.64)], thinking about healthy choices when deciding the food choices [OR:1.2; 95% CI (1.06–1.47)], cooking meals at home using healthy ingredients [OR:1.3; 95% CI (1.10–1.57)], managing financially the healthy meal's content confidently [OR:1.4; 95% CI (1.17–1.68)], and cooking with leftovers [OR:1.17; 95% CI (1.02–1.33)], all together increased the FCS of around 1.4 odds compared to people who did not practiced these patterns. As for the education, it appears that people with high school diploma or bachelor's degree or master's degree had a 70% [OR:0.3; 95% CI (0.23–0.58)], 30% [OR:0.6; 95%CI (0.40–0.92)], and 35% [0.65; 95%CI (0.43–0.97)] higher FCS compared to those who attained lower levels of education. During the pandemic, the binary logistic regression analysis shows that people living in the MENA countries had a lower FCS of 1.5 times compared to those living in the GCC countries [OR:1.59; 95%CI (1.42–1.78)]. In addition, women were having a higher FCS of 1.11 times more [OR:1.11; CI (0.96–1.27)] compared with men. The age categories youth, adults and elderly had 60% [OR: 0.39; 95%CI (0.16–0.96)], 65% [OR: 0.39; 95%CI (0.16–0.96)], and 70% [OR: 0.39; 95%CI (0.16–0.96)], higher FCS respectively, compared with adolescent category. With regards to cooking practices, planning healthy meals [OR:1.34; 95%CI (1.15–1.57)], managing financially and confidently the preparation of healthy meals [OR:1.26; 95%CI (1.08–1.46)], cooking meals at home using healthy ingredients [OR:1.59; 95%CI (1.33–1.90)] and cooking with leftovers [OR:1.14; 95%CI (1.01–1.29)] all together had an impact on the FCS by increasing it in a range between 1.1 and 1.3 times. As for the educational level, people with higher education e.g., high school diploma and bachelor's degree had a higher FCS of 57% [OR:0.43; 95% CI (0.29–0.65)] and 35% [OR:0.65; 95% CI (0.45–0.93)] more

TABLE 6 | Backwards Odds ratios (OR) according to food consumption score.

Independent variable	Binary logistic regression		
Before lockdown	**Odds ratio**	**OR confidence interval**	***p*-value**
Region: MENA vs. GULF	1.389	[1.230–1.569]	0
Gender: Female vs. Male	1.382	[1.196–1.598]	0
Age group: Youth vs. Adolescents	0.45	[0.184–1.101]	0.08
Age group: Adults vs. Adolescents	0.345	[0.146–0.813]	0.015
Age group: Elderly vs. Adolescents	0.367	[0.158–0.852]	0.02
Plan meals to include all food groups: positive vs. negative	1.413	[1.215–1.644]	0
Think about healthy choices when deciding what to eat: positive vs. negative	1.253	[1.066–1.474]	0.006
Feel confident about managing money to buy healthy food: positive vs. negative	0.873	[0.750–1.016]	0.078
Use the nutritional information panel: positive vs. negative	0.894	[0.758–1.055]	0.185
Use other parts of food label to make food choices: positive vs. negative	1.16	[0.983–1.367]	0.078
Cook meals at home using healthy ingredients: positive vs. negative	1.322	[1.109–1.575]	0.002
Feel confident about cooking a variety of healthy meals: positive vs. negative	1.41	[1.178–1.686]	0
Change recipes to make them healthier: positive vs. negative	1.061	[0.905–1.244]	0.463
Cook with leftover food: positive vs. negative	1.17	[1.029–1.331]	0.017
Throw away leftover food: positive vs. negative	0.938	[0.828–1.063]	0.318
Education level: High school diploma vs. under a high school diploma	0.374	[0.239–0.585]	0
Education level: Bachelor's degree vs. under a high school diploma	0.61	[0.402–0.926]	0.02
Education level: Master's degree vs. under a high school diploma	0.653	[0.438–0.974]	0.037
Education level: Doctorate vs. under a high school diploma	0.985	[0.634–1.531]	0.947
Employment status: I worked vs. I was a student	1.144	[0.927–1.411]	0.21
Employment status: I didn't work vs. I was a student	1.144	[0.961–1.363]	0.13
During lockdown	**Odds ratio**	**OR Confidence Interval**	***P*-value**
Region: MENA vs. GULF	1.594	[1.425–1.782]	0
Gender: Female vs. Male	1.111	[0.968–1.275]	0.133
Age group: Youth vs. Adolescents	0.399	[0.165–0.965]	0.042
Age group: Adults vs. Adolescents	0.355	[0.151–0.835]	0.018
Age group: Elderly vs. Adolescents	0.292	[0.126–0.677]	0.004
Plan meals to include all food groups: positive vs. negative	1.346	[1.150–1.576]	0
Think about healthy choices when deciding what to eat: positive vs. negative	1.09	[0.922–1.288]	0.313
Feel confident about managing money to buy healthy food: positive vs. negative	1.26	[1.085–1.463]	0.002
Use the nutritional information panel: positive vs. negative	0.903	[0.760–1.072]	0.243
Use other parts of food label to make food choices: positive vs. negative	1.045	[0.879–1.241]	0.618
Cook meals at home using healthy ingredients: positive vs. negative	1.593	[1.335–1.902]	0
Feel confident about cooking a variety of healthy meals: positive vs. negative	1.106	[0.922–1.327]	0.278
Change recipes to make them healthier: positive vs. negative	1.036	[0.884–1.213]	0.665
Cook with leftover food: positive vs. negative	1.147	[1.015–1.296]	0.028
Throw away leftover food: positive vs. negative	0.97	[0.862–1.091]	0.612
Education level: High school diploma vs. under a high school diploma	0.437	[0.294–0.651]	0
Education level: Bachelor's degree vs. under a high school diploma	0.652	[0.452–0.939]	0.022
Education level: Master's degree vs. under a high school diploma	0.742	[0.524–1.052]	0.094
Education level: Doctorate vs. under a high school diploma	1.07	[0.729–1.571]	0.73
Employment status: I worked vs. I was a student	0.898	[0.738–1.092]	0.28
Employment status: I didn't work vs. I was a student	1.081	[0.920–1.269]	0.344

compared to people with lower educational level. It was noticed that there was no impact of reading the nutritional panel, changing recipes to make them healthier, throwing away leftovers and employment on FCS, neither before nor during the lockdown (**Table 6**).

DISCUSSION

The present study, the first of its kind in the region, aimed to assess the food consumption patterns, and the household's dietary diversity through the assessment of food consumption score and

food-related patterns in 10 Eastern Mediterranean countries. At regional level, before and during the lockdown, the majority of food groups were consumed in a frequency of <3 times per week in the 10 Eastern Mediterranean countries: fruits (3 out of 5 persons), vegetables (1 over 2 persons), legumes and pulses (4 over 5 persons), nuts (3 out of 4 persons), unprocessed fish, poultry, and meats (3 out of 5 persons), milk and other dairy products (one over two persons), and added fats and oils (around one over 4 person). On the other hand, some food groups were consumed frequently (more than 4 times per week): each 13 over 50 persons were consuming processed meat/poultry/fish and vegetarian alternatives, each 9 over 20 persons consume sugary products, 3 out of 10 and 9 over 25 people were consuming wholewheat groups and white grains group, respectively. The confinement due to COVID-19 induced an increase in the consumption of legumes and pulses (3%, p-value = 0.00), nuts (1%, p-value = 0.009), unprocessed meats, poultry and fish (1–3%, p-value = 0.00), white grains group (2%, p-value = 0.00), whole wheat groups (3%, p-value = 0.00), milk (0.6%, p-value = 0.00), sugar (2%, p-value = 0.00), and added fats and oils (2%, p-value = 0.00). In contrast, a decrease of 4%, 6% and 0.9% was observed in the consumption of vegetables (p-value = 0.00), processed meats, poultry, and fish (p-value = 0.00) and other dairy products (p-value = 0.01), respectively. The consumption of fruits remained unchanged (p-value = 0.09). The FCS decreased of 3% in Jordan, 2.7% in Kuwait, 4.6% in Lebanon, 1.7% in Saudi Arabia and 3.2% in Palestine. It remained unchanged in UAE, Oman, Qatar, Bahrain, and Egypt. The most cooking practices (11 out of 13) showed a significant increase during the lockdown in the overall population and the proportions of food stocked have been changing since the start of COVID-19 and higher amounts of pasta, rice and other grains were stocked with an unchanged consumption rate of fruits and vegetables. Well, several challenges were observed throughout the epidemic such as absence of food, going to several places to find it, inability to afford some types, worries on food safety, and finding the best-price shops for buying some foods. Consumers tend to limit food types they cannot afford such as meat and fish and start consuming higher quantities of starchy food due to their wide availability and cheap prices (7). The mental status and anxiety related to food availability can push food insecure consumers toward more consumption of fruits, savory snacks, sweets, and candies which in turn can cause weight gain, as appeared in many other studies (9–11). Furthermore, COVID-19 pandemic was acquainted by a need for mitigation measures to compensate for household economic crisis. Consumers were forced to change their food consumption patterns involuntarily, rely on savings, sell household durable assets and livestock, buy foods with high shelf-life, eat less, buy cheaper food, and accept food from friend as a mean of mitigation measures (7). In many countries, physical distancing requirements and the international restrictions on travel along with the fear of disease have led to quarantining millions of people and affecting the global economy, social lives, tourism, and the hospitality industries that imposed disruption of supply chains for fresh produce, perishable and nutritious foods, such as fruits and vegetables, meat, milk and other dairy products that often requires many people to work in presence to cultivate, harvest and process. Moreover, it is affecting the production and transportation of manufactured food products. The pandemic also closed the informal markets exacerbating the inaccessibility of nutritious foods as well as livelihoods of vulnerable people. In high- and upper-middle-income countries, the cheap, highly processed, packaged foods with longer shelf life bombarded with high amounts of trans fats, fats, sugars, and salt may be consumed in higher amounts lowering by this the diet quality (1). Concerns have been raised regarding the impact of the COVID-19 curfew on food availability, consumption, access, and dietary diversity as part of food security in the EMR. The FCS is a composite score that evaluate the dietary diversity and food frequency when assessing food security. The decrease in the FCS in the five countries: Jordan, Kuwait, Lebanon, Saudi Arabia, and Palestine may be related to several factors such as the critical political and economic situations affecting the region with a more important decrease in the MENA countries compared to the GCC region (7). Beyond the causes of food insecurity in the Arab region, clashes, tensions and civil insecurity have remained the foremost critical drivers of food insecurity nowadays due to numerous factors such as razing farm land, killing live stocks, bombs, blocking access to markets, refugee migration in addition to ongoing other conflicts (12). In this study, other factors were influencing the FCS in different directions. Specifically, as planning meals and giving many concerns to variety foods, education level and money management to buy healthy food during the lockdown varied, FCS increased too. Whereas, as region, gender and managing money to buy healthy food before the lockdown changes, FCS decreased. All these factors may be directly related to meal organization abilities, knowledge, economic status, person responsible for preparing food and the cultural differences between countries in term of food consumption. To mitigate the effects of income losses and decrease in purchasing power, people started to adjust to these shortages through different mitigation strategies. Among these strategies, a significant change in most of cooking practices was observed such as cooking more with leftovers in addition to minimizing food wastes. Furthermore, COVID-19 had led people suffer a significant increase in barriers to cooking healthy meals due to the unavailability of money and less accessibility to food and cooking facilities. During the curfew, people searched more for inexpensive recipes that can be achieved with fewer ingredients throughout the cooking process. These can be explained by the financial struggle communities are having to preserve food leftovers rather than throwing them away and ensuring enough resources for healthy cooking with a high emphasis on the cultural role of females in cooking. Even when purchasing ingredients, people tend to search more for cheaper prices and less organic foods but order them online rather than going physically to the stores (13–17). These statements came hand by hand with our findings where the most cooking practices (11 out of 13) showed a significant increase during the lockdown. Besides, proportions of food stocked have been changing since the start of COVID-19 and higher amounts of pasta, rice and other grains were stocked with an unchanged consumption rate of fruits and vegetables, due to their longer shelf life and easier

storage conditions. This may be related to the need for these food groups and their cheap prices as considered as staple foods especially in the EMR.

Comparison With Other International Countries

When comparing our results with other countries' findings, we observed that the pandemic caused some modifications in food-related activities in Russia, of which a decrease of meat consumption and sweet products was observed in 1,047 adults along with an adoption of healthier consumption patterns (18). In addition, in an American survey ($n = 484$ adult participants), food insecure respondents were reducing their fruits and vegetables consumption since the start of the pandemic, and they perceived cost as barrier to eating these foods (19). The findings of the American study, along with our findings, came hand in hand with 2 Italian surveys in which 18% of the respondents reported consuming fewer fresh fruits while in the other study 8.7% of the respondents reported consuming fewer fresh fruits and vegetables (20, 21). Similarly, in Italy, 2,768 adults showed an improvement in the diet quality along with an increase in the consumption of fruit (24.4%), vegetables (28.5%), legumes (22.1%), nuts (12%), and fish or shellfish (14%). However, it was observed that the excessive consumption of sweets or pastries (36.9%) increased during the lockdown (22). According to Enriquez-Martinez et al., the survey conducted in Argentina, Brazil, Mexico, Peru, and Spain on 6,325 adults shows that most participants (61.6%), mainly those from Spain didn't show any improving or worsening in their food pattern. Argentina and Brazil showed a high improvement toward a healthier food consumption patterns. Fewer changes in food consumption patterns were observed among Peruvians and Mexicans (OR: 0.51; 95% CI: 0.4–0.6 and OR: 0.69; 95% CI: 0.4–0.8, respectively), when compared to Argentinians (23). A Polish survey enrolled in Poland ($n = 2,381$ adults) shows that 30% of respondents improved their food patterns through increased intake of vegetables, milk and milk products. In addition, 75%, 50% and 20% of the respondents reduced their intake of fast food and commercial pastry, of confectionary and salty snacks, and of sugar-sweetened beverages and alcohol, respectively (24). In France, the COVID-19 pandemic strongly affected the nutritional quality of the respondents' diet ($n = 938$) during the first lockdown. Moreover, an increase in the consumption of fruits, vegetables, pulses, fish and seafood was observed along with a sharp increase in processed meat, sweet-tasting beverages and alcoholic beverages consumption that negatively affected the quality of diet (25). In addition, a French web-based survey that encompassed 37,252 adults showed a reduction in the intake of fresh products of which 17% of participants decreased their consumption of fresh fruits, 18% for fresh vegetables, 22% for fresh red meats, and 31% for fresh fish. On the other hand, 22% of people increased their consumption of sweets and chocolate, cookies, and cakes (20%) and cheese (18%) along with a decreased consumption of sandwiches, pizzas, or savory pies (17%) (26). The Lithuanian COVIDiet Study ($n = 2,447$ participants) showed an increment in the frequency of consumption of sweets, biscuits, and cakes associated with a reduction in fruits and vegetables intake and increased consumption of frozen and canned foods. In addition, more frequent cooking and eating out of control were reported by the study participants. On the other hand, processed meats and carbonated or sugary drinks were less consumed (27). The findings from a survey conducted by three European countries on a total of 1,071 adults: from Poland ($n = 407$), Austria ($n = 353$) and the United Kingdom ($n = 311$) showed an increased frequency in purchasing frozen goods and food with long shelf life and in the daily intake of dairy products, grains, fats, vegetables, and sweets (28). In Belgium, an online questionnaire interviewed 8,640 adults where 10.4% of Belgians were showing food shortages, 5 % had limited monetary access to food and 10·3 % couldn't afford eating a healthy diet during lockdown. This status of food insecurity was associated with a change in most dietary behaviors (29). The people living in Denmark, Germany and Slovenia witnessed, during the pandemic, a reduction in their consumption of fresh food. This change was due to the decrease in the frequency of shopping in all the three countries and women were more likely to increase their consumption of fresh fruits compared with men (30). Three studies in Brazil were conducted between 2020 and 2021 in which more than 50,000 adults were interviewed through web-based questionnaires. The first study showed an increase in the consumption of high energy density foods (potato fries, chocolate, and ice cream) and ultra-processed foods among Brazilian adults (31). In the second study, an increase in the consumption of vegetables, fruits, and legumes along with a stability in the consumption of ultra-processed foods was observed (32). The third study revealed a decrease in the consumption of fruits and vegetables along with an increase in the consumption of candies and fast-food (33). In Chile ($n = 700$ adults), negative eating habits were dominating, such as low consumption of legumes and water and high consumption of junk food (e.g., food with low food quality, low contribution of micronutrients and with a high contribution of sugar, saturated fat, and sodium) and fried foods (34). In China ($n = 2,702$ adults), no changes were observed in the habitual diet, while 38.2% of participants reported an increase in their snack intake, during the lockdown. These results were interpreted that basic food supplies were guaranteed in China since the start of the lockdown. These findings were consistent with another cross-sectional study among adults in Netherlands where 83% of participants reported no change in their eating patterns during the COVID-19 lockdown (35). A scoping review was designed to assess the literature on the impact of lockdown on dietary changes in various population groups (US, Asia including Palestine, India, and China, Europe including Italy, France, Spain, Poland, and the UK, Australia, and Zimbabwe) in which in a total of ten studies an increase in the number of snacks consumed was observed, while in six studies, participants increased the quantity and the frequency of meal intakes during quarantine. Eleven studies reported improvement in dietary habits, an increase in fresh produce and home cooking along with a decrease in the intake of alcohol and comfort food. Additional nine studies found a decrease in fresh produce, with a further six showing an increase in comfort foods

intake including sweets, fried food, snack foods, and processed foods (36).

Comparison With Other Regional Countries

At regional level, in Jordan, among a total of 3129 Jordanians, 23.1% were severely affected by food insecurity, 36.1% were moderate food insecure and 40.7% were food secure. Carbohydrates and the meat group were significantly related to food insecurity (p-value was <0.001 for both groups) where food insecure people were consuming fewer meats and carbohydrates compared to food secure people (9). In addition, the impact of COVID-19 pandemic on food purchasing and dietary behaviors was studied in three Kuwaiti surveys on 1,935 respondents in Kuwait. In the first study, the consumption of vegetables, fruits, and carbohydrates increased. It was associated with a decreased consumption of fish and sugary drinks (37). Otherwise, in the second study, no significant differences were found before and during the lockdown in terms of the weekly frequency of food groups consumption, except in the case of fish and seafood (14). One over two participants in the third study indicated that their food consumption patterns remained unchanged (44%). In addition, 50.3% reported that they ate more fruits and vegetables, legumes, and pulses (41.5%), and fewer fast food (2.3%) (15). In Lebanon, 44.7% and 35% of study participants weren't eating fruits and vegetables daily, 28% reported consuming sweets or desserts once per day, 30.9% consumed salty snacks (nuts, crackers, chips) each day and 24.7% of people consumed sweetened drinks at least once per day (16). Moreover, according to Hoteit et al., 9 in every 16 households ate <2 meals per day and more than 70% of them skipped their meals to spare food. Even though half the Lebanese population studied had a low food consumption score (7). Another study conducted in three countries of which Lebanon was included, showed that 33% and 31% of the respondents stated that they shopped for food once a week and two to three times a week during the COVID-19 pandemic, respectively. In comparison, 25% purchased food less than once a week. Obtaining food and groceries by supermarkets or food shops' delivery services was not common in the three countries (10%) (Lebanon, Tunisia, and Jordan) and was significantly the least reported among the Tunisians (17). All in all, it appears that households with dietary restrictions were more likely to experience both pre-pandemic and pandemic-related incident or worsening food insecurity than households without restrictions (38).

LIMITATIONS

The present study aimed at investigating one of the accurate proxy indicators of food security, the FCS. Some limitations should be considered when evaluating the results of this study. It included retrospective data that was based on the respondents' memory to recall the food groups consumption and patterns before the lockdown, which may affect the presented eating habits. The questionnaire was quite long and was more often completed by people with higher education who had access to good quality of internet.

CONCLUSION

Due to the social isolation implemented during the COVID-19 pandemic, some changes in the food consumption patterns occurred in the study population. The changes were remarkable in the frequency of consumption of food products such as vegetables and other dairy products e.g., cheese. No increase in the consumption of fruits was observed. Nevertheless, an increase in the consumption of legumes and pulses, nuts, meats, poultry, fish, white bread, whole wheat bread, and milk occurred. In the short term, with some exceptions, the results obtained may suggest that nutrition patterns did not change much during lockdown, nor does it affect much the frequency of consumption of healthy products in the diet. Nerveless, the most cooking practices showed a significant increase during the lockdown in the overall population and the proportions of food stocked have been changing since the start of the pandemic where higher amounts of pasta, rice, and other grains were stocked with an unchanged storage rate of fruits and vegetables. To conclude, the 2020 COVID-19 crisis revealed how unprepared the region was to respond appropriately to the pandemic. It showed in particular how supply chains vary in complexity and vulnerability to disruption. Their capacity to respond effectively will depend on the resilience of the distribution chains, and the readiness to improve. As such, a definitive capacity to ricochet back and recuperate from a shock doesn't rely exclusively upon the force/seriousness of the underlying shock, however on the effect of that shock's joined with the reactions that entertainers (independently, or as networks or society) set up to alleviate or check the underlying impact of that shock. Additionally, building strength and resilience in food systems and frameworks is tied in with building capacities. For the greater part of the entertainers in the EMR's local food system, creating capacities that are more in accordance with the qualities and casualness of their current circumstance will require more planned research. Better admittance to data, more grounded participation, more incorporation, and more elevated levels of earning and self-adequacy for those entertainers will make the local nations personally reliant upon one another which helps adopting a regional food system resilience framework that assists in better understanding the intricacy of the circumstance and the potential expanding influences which might go through the whole food system once one part is affected later.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

ETHICS STATEMENT

The study was conducted according to the guidelines of the Declaration of Helsinki, and approved by the Ethical Committee for the Social Sciences and Humanities of the University of Antwerp (file number 20_46) as well as in all other

concerned countries. The patients/participants provided their written informed consent to participate in this study.

CORONA COOKING SURVEY REGIONAL STUDY GROUP

Belgium: Charlotte De Backer, Kathleen Van Royen, Lauranna Teunissen, Isabelle Cuykx, Paulien Decorte, Gaëlle Ouvrein, Karolien Poels, Heidi Vandebosch, Katrien Maldoy (University of Antwerp); Sara Pabian (Tilburg University), Christophe Matthys, Tim Smits, Jules Vrinten (KULeuven); Ann DeSmet (University of Antwerp, Université Libre de Bruxelles); Nelleke Teughels, Maggie Geuens, Iris Vermeir, Viktor Proesmans, Liselot Hudders (Ghent University); Bahrain: Tariq Abdulkarim Alalwan (University of Bahrain); Jordan: Nahla Al-Bayyari (Al-Balqa Applied University), Mohammed O. Ibrahim (Mu'tah University), Fadwa Hammouh (American University of Madaba); Kuwait: Basma Dashti (Kuwait Institute for Scientific Research), Dhuha Alkharaif (Public Authority for Applied Education & Training), Amani Alshatti (Public Authority for Applied Education & Training), Maryam Al Mazedi (Public Authority for Applied Education & Training); Lebanon: Elissa Naim (Lebanese University), Carla Ibrahim (Lebanese University & Holy Spirit University of Kaslik); Palestine: Motasem Hamdan, Diala Abu Al Halawa, Hazem Agha (Al Quds University); Qatar: Manal Othman (Hamad Medical Corporation), Jaafar Pakari, Allam Abu Farha, Rasha Abu-El-Ruz (Qatar University; QU-Health); Saudi Arabia: Jamila Arrish [National Nutrition Committee (NNC) at Saudi Food and Drug Authority (Saudi FDA)]; United Arab Emirates: Zainab Taha (Zayed University), Ayesha Aldhaheri (United Arab Emirates University).

AUTHOR CONTRIBUTIONS

CB, LT, IC, PD, SP, and KR: conceptualization, software, validation, supervision, project administration, and funding acquisition. CB, LT, IC, PD, SP, KR, MH, HM, AJ-J, RM, MA, KB, RT, HA, LC, RQ, RA, IK, SD, SA, MA-M, HB, MW: methodology. MH and HM: formal analysis, data curation, and writing—original draft preparation. MH: investigation. CB, LT, IC, PD, SP, KR, and AJ-J: resources. All authors and the research group contributed to the article and approved the submitted version.

FUNDING

This research was funded by the Research Foundation Flanders (G047518N) and Flanders Innovation and Entrepreneurship (HBC.2018.0397). These funding sources had no role in the design of the study, the analysis and interpretation of the data or the writing of, nor the decision to publish the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.813154/full#supplementary-material

REFERENCES

1. FAO, IFAD, UNICEF, WFP and WHO. *In Brief to the State of Food Security and Nutrition in the World 2020. Transforming Food Systems for Affordable Healthy Diets*. Rome, FAO (2020)
2. Food Security Information Network (FSIN). *2020 Global Report on Food Crises: Joint Analysis for Better Decisions*. Rome; Washington, DC: Food and Agriculture Organization (FAO); World Food Programme (WFP); and International Food Policy Research Institute (IFPRI) (2020). Available online at: https://www.fsinplatform.org/global-report-food-crises-2020 (accessed March 17, 2021).
3. *2020 State of Food Security and Nutrition in the World report: Rising Hunger and COVID-19 Present Formidable Challenges*. International Food Policy Research Institute. Available online at: https://www.ifpri.org/blog/2020-state-food-security-and-nutrition-world-report-rising-hunger-and-covid-19-present/ (accessed January 30, 2021).
4. *Arab Horizon 2030: Prospects for Enhancing Food Security in the Arab Region*. FAO (2017).
5. FAO, IFAD, UNICEF, WFP, WHO and ESCWA. *Regional Overview of Food Security and Nutrition in the Near East and North Africa 2020 - Enhancing resilience of food systems in the Arab States*. Cairo: FAO (2021).
6. *COVID-19 Level 3 Emergency | External Situation Report #17*. (2020). World Food Program. FAO-WFP early warning analysis of acute food insecurity hotspots October 2020. Available online at: https://reliefweb.int/sites/reliefweb.int/files/resources/WFP_EXTERNAL_REPORT_A4_EN_17.pdf; http://www.fao.org/3/cb1907en/CB1907EN.pdf (accessed February 5, 2021).
7. Hoteit M, Al-Atat Y, Joumaa H, Ghali SE, Mansour R, Mhanna R, et al. Exploring the impact of crises on food security in lebanon: results from a national cross-sectional study. *Sustainability*. (2021) 13:8753. doi: 10.3390/su13168753
8. FAO, IFAD, UNICEF, WFP and WHO. *Regional Overview of Food Security and Nutrition in the Near East and North Africa 2019 – Rethinking Food Systems for Healthy Diets and Improved Nutrition* (2020).
9. Elsahoryi N, Al-Sayyed H, Odeh M, McGrattan A, Hammad F. Effect of Covid-19 on food security: a cross-sectional survey. *Clin Nutr ESPEN*. (2020) 40:171–8. doi: 10.1016/j.clnesp.2020.09.026
10. FAO. *Food Security and Livelihoods Assessment of Lebanese Host Communities*. (2015). Available online at: http://www.fao.org/documents/card/en/c/926b8083-6cc6-42d9-8a28-84cf0e19be94/ (accessed May 1, 2021).
11. Mumena W. Impact of COVID-19 curfew on eating habits, eating frequency, and weight according to food security status in Saudi Arabia: a retrospective study. *Progr Nutr*. (2021) 22:e2020075. doi: 10.23751/pn.v22i4.9883
12. United Nations General Assembly (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development. General Assembly Resolution A/RES/70/1, 25 September*. New York, NY: United Nations. Available online at: http://www.un.org/en/development/desa/population/migration/generalassembly/docs/globalcompact/A_RES_70_1_E.pdf (accessed April 1, 2021).
13. Niles MT, Bertmann F, Belarmino EH, Wentworth T, Biehl E, Neff R. The early food insecurity impacts of COVID-19. *Nutrients*. (2020) 12:2096. doi: 10.3390/nu12072096
14. Husain W, Ashkanani F. Does COVID-19 change dietary habits and lifestyle behaviours in Kuwait: a community-based cross-sectional study. *Environ Health Prev Med*. (2020) 25:61. doi: 10.1186/s12199-020-00901-5
15. AlTarrah D, AlShami E, AlHamad N, AlBesher F, Devarajan S. The impact of coronavirus COVID-19 pandemic on food purchasing, eating

behavior, and perception of food safety in Kuwait. *Sustainability*. (2021) 13:8987. doi: 10.3390/su13168987
16. Cheikh Ismail L, Hashim M, Mohamad MN, Hassan H, Ajab A, Stojanovska L, et al. Dietary habits and lifestyle during coronavirus pandemic lockdown: experience from Lebanon. *Front Nutr*. (2021) 8:730425. doi: 10.3389/fnut.2021.730425
17. Faour-Klingbeil D, Osaili TM, Al-Nabulsi AA, Jemni M, Todd E. An on-line survey of the behavioral changes in Lebanon, Jordan and Tunisia during the COVID-19 pandemic related to food shopping, food handling, and hygienic practices. *Food Control*. (2021) 125:107934. doi: 10.1016/j.foodcont.2021.107934
18. Hassen TB, El Bilali H, Allahyari MS, Berjan S, Fotina O. Food purchase and eating behavior during the COVID-19 pandemic: a cross-sectional survey of Russian adults, *Appetite*. (2021) 165:105309. doi: 10.1016/j.appet.2021.105309
19. Litton MM, Beavers AW. The Relationship between food security status and fruit and vegetable intake during the COVID-19 pandemic. *Nutrients*. (2021) 13:712. doi: 10.3390/nu13030712
20. Renzo LD, Gualtieri P, Pivari F, Soldati L, Attinà A, Cinelli G, et al. Eating habits and lifestyle changes during COVID-19 lockdown: an Italian survey. *J Transl Med*. (2020) 18:1–15. doi: 10.21203/rs.3.rs-30403/v1
21. Scarmozzino F, Visioli F. Covid-19 and the subsequent lockdown modified dietary habits of almost half the population in an Italian sample. *Foods*. (2020) 9:675. doi: 10.3390/foods9050675
22. Grant F, Scalvedi ML, Scognamiglio U, Turrini A, Rossi L. Eating habits during the COVID-19 lockdown in Italy: the nutritional and lifestyle side effects of the pandemic. *Nutrients*. (2021) 13:2279. doi: 10.3390/nu13072279
23. Enriquez-Martinez OG, Martins M, Pereira T, Pacheco S, Pacheco FJ, Lopez KV, et al. Diet and lifestyle changes during the COVID-19 pandemic in Ibero-American countries: Argentina, Brazil, Mexico, Peru, and Spain. *Front Nutr*. (2021) 8:671004. doi: 10.3389/fnut.2021.671004
24. Górnicka M, Drywień ME, Zielinska MA, Hamułka J. Dietary and lifestyle changes during COVID-19 and the subsequent lockdowns among polish adults: a cross-sectional online survey PLifeCOVID-19 Study. *Nutrients*. (2020) 12:2324. doi: 10.3390/nu12082324
25. Marty L, de Lauzon-Guillain B, Labesse M, Nicklaus S. Food choice motives and the nutritional quality of diet during the COVID-19 lockdown in France. *Appetite*. (2021) 157:105005. doi: 10.1016/j.appet.2020.105005
26. Deschasaux-Tanguy M, Druesne-Pecollo N, Esseddik Y, de Edelenyi FS, Allès B, Andreeva VA, et al. Diet and physical activity during the coronavirus disease 2019 (COVID-19) lockdown (March-May 2020): results from the French NutriNet-Santé cohort study. *Am J Clin Nutr*. (2021) 113:924–38. doi: 10.1093/ajcn/nqaa336
27. Kriaucioniene V, Bagdonaviciene L, Rodríguez-Pérez C, Petkeviciene J. Associations between changes in health behaviours and body weight during the COVID-19 Quarantine in Lithuania: the Lithuanian COVIDiet study. *Nutrients*. (2020) 12:3119. doi: 10.3390/nu12103119
28. Skotnicka M, Karwowska K, Kłobukowski F, Wasilewska E, Małgorzewicz S. Dietary habits before and during the COVID-19 epidemic in selected European countries. *Nutrients*. (2021) 13:1690. doi: 10.3390/nu13051690
29. Vandevijvere S, De Ridder K, Drieskens S, Charafeddine R, Berete F, Demarest S. Food insecurity and its association with changes in nutritional habits among adults during the COVID-19 confinement measures in Belgium. *Public Health Nutr*. (2021) 24:950–6. doi: 10.1017/S1368980020005005
30. Janssen M, Chang B, Hristov H, Pravst I, Profeta A, Millard J. Changes in food consumption during the COVID-19 pandemic: analysis of consumer survey data from the first lockdown period in Denmark, Germany, and Slovenia. *Front Nutr*. (2021) 8:635859. doi: 10.3389/fnut.2021.635859
31. Malta DC, Szwarcwald CL, Barros M, Gomes CS, Machado ÍE, Souza Júnior P, et al. The COVID-19 Pandemic and changes in adult Brazilian lifestyles: a cross-sectional study, 2020. A pandemia da COVID-19 e as mudanças no estilo de vida dos brasileiros adultos: um estudo transversal, 2020. *Epidemiol Servicos Saude*. (2020) 29:e2020407. doi: 10.1590/s1679-49742020000400026
32. Steele EM, Rauber F, Costa C, Leite MA, Gabe KT, Louzada M, et al. Dietary changes in the NutriNet Brasil cohort during the covid-19 pandemic. *Revista Saude Publica*. (2020) 54:91. doi: 10.11606/s1518-8787.2020054002950
33. Souza TC, Oliveira LA, Daniel MM, Ferreira LG, Della Lucia CM, Liboredo JC, et al. Lifestyle and eating habits before and during COVID-19 quarantine in Brazil. *Public Health Nutr*. (2021) 10:1–11. doi: 10.1017/S136898002100255X
34. Reyes-Olavarría D, Latorre-Román PÁ, Guzmán-Guzmán IP, Jerez-Mayorga D, Caamaño-Navarrete F, Delgado-Floody P. Positive and negative changes in food habits, physical activity patterns, and weight status during COVID-19 confinement: associated factors in the Chilean population. *Int J Environ Res Public Health*. (2020) 17:5431. doi: 10.3390/ijerph17155431
35. Poelman MP, Gillebaart M, Schlinkert C, Dijkstra SC, Derksen E, Mensink F, et al. Eating behavior and food purchases during the COVID-19 lockdown: a cross-sectional study among adults in the Netherlands. *Appetite*. (2021) 157:105002. doi: 10.1016/j.appet.2020.105002
36. Bennett G, Young E, Butler I, Coe S. The impact of lockdown during the COVID-19 outbreak on dietary habits in various population groups: a scoping review. *Front Nutr*. (2021) 8:626432. doi: 10.3389/fnut.2021.626432
37. Salman A, Sigodo KO, Al-Ghadban F, Al-Lahou B, Alnashmi M, Hermassi S, et al. Effects of COVID-19 lockdown on physical activity and dietary behaviors in Kuwait: a cross-sectional study. *Nutrients*. (2021) 13:2252. doi: 10.3390/nu13072252
38. Guillaume JD, Jagai JS, Makelarski JA, Abramsohn EM, Lindau ST, Verma R, et al. COVID-19-related food insecurity among households with dietary restrictions: a national survey. *J Allergy Clin Immunol*. (2021) 9:3323–30.e3. doi: 10.1016/j.jaip.2021.06.015

Author Disclaimer: The views expressed in this paper are those of the author(s) and do not necessarily reflect those of the WHO and SFDA or its stakeholders. Guaranteeing the accuracy and the validity of the data is a sole responsibility of the research team.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Nutrition

ORIGINAL RESEARCH
published: 28 February 2022
doi: 10.3389/fnut.2022.815000

Feeding Patterns, Mother-Child Dietary Diversity and Prevalence of Malnutrition Among Under-Five Children in Lebanon: A Cross-Sectional Study Based on Retrospective Recall

Huguette Abi Khalil[1†], *Mariam Hawi*[1†] *and Maha Hoteit*[1,2,3*]

[1] Faculty of Public Health, Lebanese University, Beirut, Lebanon, [2] PHENOL Research Group (Public Health Nutrition Program-Lebanon), Faculty of Public Health, Lebanese University, Beirut, Lebanon, [3] Lebanese University Nutrition Surveillance Center (LUNSC), Lebanese Food Drugs and Chemical Administrations, Lebanese University, Beirut, Lebanon

OPEN ACCESS

Edited by:
Nahla Al-Bayyari,
Al-Balqa Applied University, Jordan

Reviewed by:
Mai Abdullah,
Zarqa Private University, Jordan
Seyed Mostafa Nachvak,
Kermanshah University of Medical Sciences, Iran

***Correspondence:**
Maha Hoteit
m.hoteit@ul.edu.lb

[†] These authors have contributed equally to this work

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: 14 November 2021
Accepted: 24 January 2022
Published: 28 February 2022

Citation:
Abi Khalil H, Hawi M and Hoteit M (2022) Feeding Patterns, Mother-Child Dietary Diversity and Prevalence of Malnutrition Among Under-Five Children in Lebanon: A Cross-Sectional Study Based on Retrospective Recall. Front. Nutr. 9:815000. doi: 10.3389/fnut.2022.815000

Background: Despite demonstrated benefits, most countries fall short of meeting international targets for breastfeeding patterns, optimal complementary feeding, mother-children's quality diet, and malnutrition among under-five children.

Rationale: Since mothers usually play the most vital role in the healthcare of their children, research is needed to illuminate maternal factors that might promote a child's health and nutritional status.

Aim: The purpose of this study is to retrospectively (1) examine the under-five children's (0–59 months) feeding habits including exclusive breastfeeding, exclusive bottle feeding, continued breastfeeding, and complementary feedings, (2) investigate the mother-child's dietary diversity, and (3) identify any factors that cause less optimal nutrition due to a lack of food diversity in children aged 6 to 59 months. Moreover, (4) the prevalence of wasting, stunting, underweight, and overweight in the under-five offspring living in households located in the main two provinces in Lebanon (Beirut and Mount Lebanon) was determined.

Methods: The data for this analysis were collected from a representative sample of 384 households [384 mothers (21–49 years old) and children (0–59 months)] between February 2019 and June 2019. A questionnaire was used to inquire mothers of children ages 0–23 months about exclusive breastfeeding (EBF), continuous breastfeeding (CBF), exclusive bottle feeding (EBOT), mixed feeding (MF), and complementary feeding patterns. Moreover, additional questions regarding dietary diversity were asked to mothers of children aged 6 to 59 months. This score was calculated based on the 24 h recall of the mother and her child's consumption of 7 food groups, during the 24 h prior to the survey. Moreover, stunting, wasting, overweight, and underweight were calculated using the z-score for height-for-age (HAZ), weight-for-height (WHZ), and weight-for-age (WAZ), respectively. Binary logistic regression was used to explore the

dietary diversity among children (ages 6–59 months) adjusting for covariates at maternal and household levels.

Results: Around 44% of children (0–59 months) had normal body weight. In addition, 9.3% were underweight (WAZ<-2SD to −3SD), 6.5% were at risk of being overweight, 24.45% were overweight, 9.3% were stunted (HAZ<-2SD to −3SD), and 6.25% (WHZ<-2SD to −3SD) were wasted. In total, among under-five children, the prevalence of EBF at 40 d and 6 months was 27 and 30%, respectively. The prevalence of CBF was 23%. Around 60% of mothers breastfed their offspring between 0 and 6 months and half of them introduced infant formula at earlier stages between 0–6 months. Furthermore, 78.4% of mothers introduced food to their children between 4 and 6 months (of which 40% before 6 months) and 62.5% of them introduced sugary drinks before 6 months. As for dietary diversity (DD), one out of two mothers and one out of three children (ages 6–59 months) had a low DD score (DDS) (46 and 32%, respectively). The children's and mother's DD were strongly found to be correlated (p-value = 0.034). Regression analysis showed that children's DD increased around 2 times [AOR = 1.7; 95% CI (1.042–2.914)] in context of high maternal DDS, and about 12 times [AOR = 11.7; 95% CI (1.2–111)] when a member of the highest-income households.

Conclusions: Our findings demonstrated low rates of EBF and CBF, high prevalence of EBOT, and early introduction of complementary foods among children ages 0–59 months. Furthermore, for children ages 6–59 months, there was poor mother-child dietary diversity and a high prevalence of overweight and stunted children in the main two Lebanese provinces. This suggests the alarming need for continuous nutrition intervention to improve infant feeding patterns and dietary diversity to reduce the malnutrition rates.

Keywords: dietary diversity, maternal, malnutrition, children under five, overweight, underweight

INTRODUCTION

It was long believed that malnutrition among children concerned only the underdeveloped countries; however, it also poses a serious challenge in developing countries (1). Childhood undernutrition contributes to 45% of mortality globally in children aged under 5 years (1). Malnutrition has been defined by the World Health Organization (WHO) as "deficiencies, excesses or imbalances in a person's energy intake or nutrient intake" (2). In addition, the term *malnutrition* refers to three broad groups which are under-nutrition, micronutrient-related malnutrition, and overweight/obesity (2). According to WHO, in 2020, globally, 149.2 million children under the age of 5 years were stunted (22%), 45.4 million were wasted (13.6%), and 38.9 million were overweight (5.7%), respectively (3). Chronic childhood malnutrition (stunting) remains a major challenge in the Eastern Mediterranean Region (EMR) including Lebanon (4). Millions of children under 5 years old in the region have had their growth stunted by chronic malnutrition, with serious lifelong consequences for their health and development (4). In Lebanon, the prevalence of stunting ranged between 16% in 2000 to 10.4% in 2020 (5). As for overweight and obesity, in 2018, the estimated weighted average prevalence among children under 5 years old was 8.42% in the EMR, and between 17.6 and 19.7% in Lebanon (5). EBF for under 6 months children, CBF for under 2 years children, appropriate complementary feeding practices, and adequate dietary diversity (DD) are needed at this particular age to ensure proper growth and development (2). The WHO and the United Nations International Children's Emergency Fund (UNICEF) recommend starting breastfeeding within 1 h of birth, EBF for the first 6 months of life, and introducing nutritionally adequate and safe complementary (solid) foods at 6 months with CBF for 2 years or longer (6). The WHO initially set a global target of 50% prevalence of exclusive breastfeeding by 2025 (6). Recently, it was updated to at least 70% prevalence by 2030 (6). Previous research has shown that proportion of exclusively breastfed children remains low in many lower- and middle-income countries (7). However, according to a recent geospatial analysis of EBF prevalence estimates from 2000 to 2018 across 94 low-middle-income countries (LMICS), the total prevalence of EBF increased from 27% to 39% across all countries (2000–2018) (8). It is estimated to be extrapolated to 43% by 2025 (8). Although this could be positive progress, it falls short of the 70% goal (8). Between conception and the child's second birthday, the first 1,000 days of life offer a golden chance for nutrition and lifestyle

changes to shape the child's growth (9). Throughout this phase, optimal breastfeeding and complementary feeding practices are crucial for supporting fetal growth and development, maternal health, newborn and toddler growth (10), and for preventing a child's malnutrition and the development of non-communicable diseases (NCDs) (11). Despite the inconsistencies in the current guidelines regarding when to introduce complementary solid foods, all guidelines agree that complementary feeding should not be introduced before the age of 4 months (12). Although introducing complementary feeding earlier may contribute to more rapid weight gain during infancy and increased risk of childhood obesity in affluent populations (13), the introduction of complementary feeding before 4 months is common in many countries. For instance, the percentage of infants introduced to complementary solid foods before the age of 4 months was 37% in a birth cohort born in 2007 and 2008 in Northwest Italy (14), 30% across the UK in 2010 (15), and 40% among infants born between 2005 and 2007 participating in a national study in the United States (16). To the best of our knowledge, no study has reported the prevalence of introducing complementary feeding before 6 months in Lebanon. Lebanon, a middle-income country, has a low rate of breastfeeding (17). Misconceptions about breastfeeding among mothers and communities, a lack of professional lactation support, a failure to implement national policies that promote and protect breastfeeding practices, a lack of social support, particularly at the family level, and other socio-demographic factors are all barriers to breastfeeding (18). Diets high in starch-based staples but low in animal products, fresh fruits, or vegetables can result in micronutrient deficiencies, which can leave children vulnerable to undernutrition and its sequelae (2). According to the WHO and the UNICEF, the amount of various foods or food groups ingested over a certain reference period is referred to as DD (6, 19). It reflects household access to a variety of foods. DD serves as a proxy indicator for nutrient sufficiency in mothers and children's diets, particularly micronutrient adequacy, which is an important aspect of diet quality (6, 19). Abbreviated as DDS (dietary diversity score) is a tally of food types consumed over a specific time period, usually 24 h (6, 19). Women should consume more than or equal to five food groups in the prior 24 h to achieve the minimum requirement for a healthy diet, while children should consume more than or equal to four food groups (6, 19). At the household level, there are many causes that can contribute to malnutrition, including inadequate sanitation and water supply, low wealth and socioeconomic status, food insecurity, low status of women, poor caregiver education, inappropriate intra-household food allocation, inadequate quality foods, contaminated food and water, and infection. Other contributing factors include poor maternal nutrition and inadequate care, breastfeeding, or complementary feeding (4). There are many aspects of the wider context that can contribute, including food prices and trade policy, marketing regulations, political stability, poverty, access to healthcare, agriculture and food systems, education, society, and culture, as well as aspects of the environment (4). According to a recent meta-analysis, child age, child sex, complementary food, poor DD, diarrheal diseases, maternal education, maternal height, residential area, and socioeconomic status were significant risk factors for undernutrition (20). Thus, identification of potentially modifiable determinants of nutritional status in children is a priority in regions with a high burden of undernutrition.

Understanding mother/child DD and its influence on nutritional status in Lebanon may aid in the development of interventions to reduce malnutrition at a national level. To our knowledge, no study in Lebanon has reported the association between mother-child dietary diversity. Here we assess the under-five children's feeding habits (EBF, EBOT, CBF, and complementary feedings), the mother-child's DD, and any factors that cause less optimal nutrition due to a lack of food diversity in children aged 6 to 59 months. Moreover, the prevalence of wasting, stunting, underweight, and overweight in the under-five offspring living in households located in the main two provinces in Lebanon (Beirut and Mount Lebanon) was determined.

MATERIALS AND METHODS

Sampling Strategy

A total of 400 mothers and children were included in the sample. Of these, 384 were included in the analyses. Thus, the data for this analysis were collected from a representative sample of 384 households located in the two main Lebanese provinces—Beirut and Mount Lebanon—and using a stratified cluster sampling design. Within each district, households were selected following a probability proportional to size approach. Housing units constituted the primary sampling unit in the two districts. A single population formula was used to determine the sample size. Accordingly, the formula for sample size determination used was $n = [p\ (1\text{-}p)] * [(Z_{\alpha/2})^2 / (e)^2]$, where n denotes the sample size, $Z_{\alpha/2}$ is the reliability coefficient of the standard error at 5% level of significance = 1.96, p represents the probability of under-five children who were unable to practice preventive measures against the diseases (50%, no previous study), and e refers to the level of standard error tolerated (5%) as stated by Hosmer and Lemeshow. Based on this formula, it was determined that the minimum acceptable sample size of 300 respondents would be sufficient to identify differences by respondent's characteristics.

Data Collection

A total of 384 mothers (21–49 years old) and children (0–59 months) were included in this study between February 2019 and June 2019. Trained nutritionists administered the survey through face-to-face interviews with the mothers. A questionnaire was used to inquire mothers of children ages between 0 and 23 months about EBF, CBF (duration exceeding 6 months), EBOT, MF, and complementary feeding patterns. Moreover, additional questions regarding DD were asked to mothers of children ages 6 to 59 months. This score was calculated according to the WHO guidelines and based on the 24 h recall of the mother and her child's consumption of 7 food groups, during the 24 h prior to the survey (6, 19). The same food groups were used to compose both maternal and child DDS. Food groups considered were cereals/roots, vegetables, fruits, legumes/lentils, meat/fish/eggs, and milk/dairy products. If an individual consumes any quantity of any food group at least once per day, it was taken into

count. Therefore, DDS was calculated without considering a minimum intake for the food group. To meet the minimum requirement for a healthy diet, mothers should obtain more than or equal to five while children above or equal to four food groups over the preceding 24 h (6, 19). Anthropometric measurements of the mother and child were collected. Stunting, wasting, overweight, and underweight were calculated using the z-score for height-for-age (HAZ), weight-for-height (WHZ), and weight-for-age (WAZ), respectively. We defined wasted, stunted, and underweight based on the z-scores of the 2006 WHO growth standards (6) as follows: wasted: weight for height z-score (WHZ) <-2SD to −3SD; stunted: height for age z-score (HAZ) <-2SD to −3SD; underweight: weight for age z-score (WAZ) <-2SD to −3SD. Binary logistic regression was used to explore the DD among children (6–59 months) adjusting for covariates at maternal and household levels.

Eligibility Criteria and Definition of Feeding Practices

Mother-child dyads were eligible to participate in the study if the mother was Lebanese, aged 19–49 years. Children were eligible if they were five years old or younger, were born at term (gestational age between 37 and 42 weeks), and had no chronic medical conditions, inborn errors of metabolism, or physical malformations that interfered with feeding patterns and body composition.

Infant feeding practices were defined as follows:

1. Exclusive breastfeeding (EBF): The infant received breast milk from their mother or expressed breast milk and no other fluids or solids.
2. Mixed feeding: The infant received breast milk with formula milk and/or other fluids and/or solid food.
3. Exclusive bottle feeding (EBOT): The infant received formula milk with or without other fluids.

Statistical Analyses

The statistical analysis of this study was performed using the Statistical Analysis Package for Social Science (SPSS, version 25) and the significance level was set at $p < 0.05$. Frequencies and descriptive statistics were performed for the general variables. Chi-square test was used to compare the categorical variables in the study as well as determine the prevalence of obesity, overweight, underweight, stunting, and wasting according to the child's age category. Chi-square was also used to assess the association between the mother's DDS and the child's DDS. In addition to that, independent *t*-test was conducted to compare the means between two unrelated groups (low child's DDS and high child's DDS) on the same continuous, dependent variable (mother's age). Binary logistic regression was used to explore the association between mothers' and children's DD adjusting for covariates at maternal and household levels with analyses represented as odds ratios and 95% confidence intervals.

Ethics

Ethical approval was obtained from the Ethical Committee at the Lebanese University (#CU201907). The mother of the child

TABLE 1 | Socio-demographic, weight status, and household characteristics of Lebanese infants and young children aged less than 5 years old.

	Population characteristics N (%)
Mother's age (years)	
Mean ± SD	32 ± 5
Mother's age categories (years) *N* (%)	
20–24	20 (5.2)
25–29	95 (24.7)
30–34	153 (39.8)
35–39	98 (25.5)
40–45	17 (4.4)
Governorate of residency *N* (%)	
Beirut	77 (20.1)
Mount Lebanon	307 (79.9)
Children at home <5 years *N* (%)	
1 child	199 (51.8)
2 children	161 (41.9)
3 children and more	24 (6.3)
Household number *N* (%)	
<5 members	229 (59.6)
≥5 members	155 (40.4)
Mother's employment status *N* (%)	
Employed	232 (60.4)
Homemaker	152 (39.6)
Mother's education level *N* (%)	
Primary education	3 (0.8)
Intermediate education	26 (6.8)
Secondary education or technical diploma	61 (15.9)
University degree and higher	294 (76.6)
ousehold's income *N* (%)	
<750,000 L.L.	5 (1.3)
750,000–1,500,000 L.L.	65 (16.9)
1,500,001–2,250,000 L.L.	77 (20.1)
2,250,001–3,000,000 L.L.	68 (17.7)
>3,000,000 L.L	169 (44)
Child age *N* (%)	
0–6 months	74 (19.3)
6–59 months	310 (80.7)
Mean	23.8 ± 17.3
Child gender *N* (%)	
Male	190 (49.5)
Female	194 (50.5)
Under-five children (*n* = 384)	
Normal body weight	170 (44.2)
Underweight (WAZ< −2SD to −3SD)∧	36 (9.3)
At risk for overweight	25 (6.5)
Overweight	93 (24.45)
Stunting (HAZ< −2SD to −3SD)∧	36 (9.3)
Wasting (WHZ< −2SD to −3SD)∧	24 (6.25)
Under-two children (*n* = 200)	
Normal body weight	97 (48.5)
Underweight (WAZ< −2SD to −3SD)∧	14 (7)
Overweight	40 (62.5)
Stunting (HAZ< −2 SD to −3SD)∧	25 (12.5)
Wasting (WHZ< −2 SD to −3SD)∧	24 (37.5)

∧ *Adapted from: http://ebook.ecog-obesity.eu/chapter-growth-charts-body-composition/world-health-organization-reference-curves/.*

TABLE 2 | Exclusive breastfeeding, continuous breastfeeding, exclusive bottle feeding, and complementary feedings among children aged 0–23 months (n = 200) and children aged 24–59 months (n = 184).

Feeding patterns	0–23 months children *N* (%)	24–59 months *N* (%)	0–59 months *N* (%)
Currently breastfeeding			
Yes	72 (36)	6 (3.3)	78 (20)
No	128 (64)	177 (96.7)	306 (80)
Duration of breastfeeding			
0–40 d	52 (26)	53 (29)	105 (27.3)
40 d–6 months	51 (25.5)	64 (35)	115 (29.9)
>6 months (continued breastfeeding)	24 (12)	62 (33.9)	87 (22.7)
Exclusive breastfeeding			
Yes	35 (17.5)	2 (1.1)	37 (9.6)
No	165 (82.5)	181 (98.9)	347 (90.4)
Infant formula (IF)			
Yes	161 (80.5)	150 (82)	312 (81.3)
No	39 (19.5)	33 (18)	72 (18.8)
Both (BF+IF) (from birth)	37 (18.5)	4 (2.2)	41 (10.6)
Initiation of infant formula			
At birth–40 d	104 (52.8)	99 (54.1)	203 (52.9)
40 d–6 months	41 (20.8)	43 (23.5)	84 (21.9)
At 4 months	14 (7.1)	38 (20.8)	53 (13.8)
>6 months	38 (19.3)	3 (1.6)	41 (10.7)
Introduction of food			
At < 4 months	2 (1)	3 (1.6)	5 (1.3)
4–6 months (6 not included)	81 (40.5)	70 (38.3)	151 (39.3)
At 6 months	55 (27.5)	94 (51.4)	150 (39.1)
>6 months	7 (3.5)	16 (8.7)	23 (6)
No food yet	55 (27.5)	-	55 (14.3)
Introduction of juices and sugary drinks			
<4 months	26 (13)	35 (19.1)	61 (15.9)
4–6 months	51 (25.5)	60 (32.8)	112 (29.2)
6 months	56 (28)	72 (39.3)	128 (33.3)
>6 months	14 (7)	16 (8.7)	30 (7.8)
No food yet	53 (26.5)	-	53 (13.8)

This data was derived from cross-sectional and retrospective recalls.

signed a consent form, and the questionnaires were administered after the families agreed to participate in the study.

RESULTS

Socio-Demographic Characteristics of Households and Study Participants: Mothers and Children

A total of 400 mothers and children were included in the sample. Of these, 384 were included in the analyses. The remaining 16 were excluded from the analysis because of missing data. Socio-demographic details are shown in **Table 1**. The mean age of mothers selected for this study was 32 ± 5 years old while the mean age for children was 23.8 ± 17.3 months. Half of the children were females. There were 200/384 children aged under 2 years and 183/384 children aged more than 2 years. Most mothers were educated and held a university degree (77%) and 60% of them were employed. More than half the households encompassed 1 child (52%) or 2 children (42%) aged less than 5 years and enclosed less than 5 members per household (60%). Around half the household's income ranged between 750,000 Lebanese Pound (LBP) and 3 million LBP (54%) (**Table 1**).

Prevalence of Stunting, Wasting, Overweight, and Obesity

Most of the children aged under 5 in this study had a normal body weight (44%). In addition, 9.3% were underweight (WAZ<-2SD to −3SD), 6.5% were at risk of being overweight, 24.45% were overweight, 9.3% were stunted (HAZ<-2SD to −3SD), and 6.25% (WHZ<-2SD to −3SD) were wasted. The prevalence of stunting, wasting, and overweight among under 2 children was 12.5, 37.5, and 62.5%, respectively (**Table 1**).

Exclusive Breastfeeding, Exclusive Bottle Feeding, Continuous Breastfeeding, Mixed Feeding, and Complementary Feedings

Children 0–23 Months

The prevalence of EBF, EBOT, MF, and complementary feeding among children ages 0–23 months is shown in **Table 2**. The prevalence of EBF at 40 d was 26%, at 6 months was 25.5%, and the prevalence of CF (exceeding 6 months) was 12%. On the other hand, the prevalence of EBOT at birth was 52.8%, at 40 d was 80.5%, at 4 months was 7.1%, and at more than 6 months it was 19.3%. Moreover, the MF since birth was 18.5%. Around half the mothers breastfed their offspring between 0 and 6 months (51.5%) and introduced infant formula at earlier stages between 0 and 6 months. In addition, 68% of them introduced food to their children between 4 and 6 months (of which 40% before 6 months) and 53.5% of them introduced sugary drinks before 6 months (**Table 2**).

Children 0–59 Months

The prevalence of EBF, EBOT, MF, and complementary feeding among children ages 0–59 months is shown in **Table 2**. The prevalence of EBF at 40 d was 27%, at 6 months was 30%, and the prevalence of continued breastfeeding (exceeding 6 months) was 23%. On the other hand, the prevalence of EBOT at birth was 52.9%, at 40 d was 81.3%, at 4 months was 13.8%, and at more than 6 months, it was 10.7%. Moreover, the MF since birth was 10.6%. Around 60% of mothers breastfed their offspring between 0 and 6 months. Half the women introduced infant formula at earlier stages between 0 and 6 months, 78.4% of them introduced food to their children between 4 and 6 months (of which 40% before 6 months), and 62.5% of them introduced sugary drinks before 6 months (**Table 2**).

Household Consumption of Food Groups and Calculation of Mother-Children DDS

Table 2 shows the frequency of consumption of food groups and the DDS among the mothers and their children (6–59 months). There was mother-child agreement in the consumption of staple foods (91.4/91.1%), dairy products (66.7/94.7%), flesh food (74.3/66.8%), and fruits and vegetables poor in vitamin A (74.3/75.7%). Eggs (5/10.5%) and fruits and vegetables that are

TABLE 3 | Frequency of a food group's consumption and dietary diversity score of mothers and children.

	Children (6–59 months)		Mothers	
Food groups	**Consumed *N* (%)**	**Not consumed *N* (%)**	**Consumed *N* (%)**	**Not consumed *N* (%)**
Staples	277 (91.1)	27 (8.9)	277 (91.4)	26 (8.6)
Fruits and vegetables rich in vitamin A	50 (16.4)	254 (83.6)	28 (9.2)	275 (90.8)
Other fruits and vegetables	230 (75.7)	74 (24.3)	225 (74.3)	78 (25.7)
Meat, fish, and poultry	203 (66.8)	101 (33.2)	225 (74.3)	78 (25.7)
Eggs	32 (10.5)	272 (89.5)	15 (5)	288 (95)
Legumes and nuts	88 (28.9)	216 (71.1)	94 (31)	209 (69)
Dairy products	288 (94.7)	16 (5.3)	202 (66.7)	101 (33.3)
	DDS		**DDS**	
	High DDS*	**Low DDS***	**High DDS***	**Low DDS***
	206 (68)	97 (32)	165 (54.5)	138 (45.5)

**WHO cutoffs in children: High DDS ≥4 food groups out of 7 consumed, Low DDS < 4 food groups out of 7 consumed. * WHO cutoffs in mothers: High DDS≥5 food groups out of 7 consumed, Low DDS < 5 food groups out of 7 consumed.*

sources of vitamin A (9.2/16.4%) were the least consumed among food groups. Aged under 5 years, 32% of respondent's children did not get a variety of types of food or provision of food types and were eating less than four kinds of food groups the day before the survey. Similarly, 46% of respondent's mothers were facing a low DDS indicating a poor diversity of food groups at meals (**Table 3**).

The association between a child's DDS, socio-demographic characteristics, mother's nutritional status, and child's nutritional status is shown in **Table 4**. There was a strong correlation between the maternal and offspring's DDS. There were 40% of mothers with low DDS shown to have children with low DDS too (p-value = 0.003). Most children with high DDS (75%) had employed mothers (p-value = 0.005). Moreover, the children's DDS was related to the mother's education. Mothers holding a university degree had children who were eating an adequate diversified diet (p-value = 0.045).

Binary Logistic Regression Analysis

The DD among children (6–59 months) adjusting for covariates at maternal and household levels is described in **Table 5**. The backward logistic regression showed that the main two factors that are strongly associated with the children's DD are the family income and the mother's DD status. Children's DD increases around 2 times [AOR = 1.7, 95% CI (1.042–2.914)] in context of high maternal DDS, and about 12 times [AOR = 11.7, 95% CI (1.2–111)] when the member of the highest-income households (**Table 5**).

DISCUSSION

The current study examines the feeding patterns including breastfeeding, formula-feeding, complementary feeding, and the prevalence of malnutrition in under-five children living in two main Lebanese provinces (Beirut and Mount Lebanon). This study also investigates the mother-child's DD and identifies the factors that cause less optimal nutrition due to a lack of food diversity in children aged 6 to 59 months. Our findings demonstrated that in the main two Lebanese provinces, there are low rates of EBF, high rates of EBOT, early initiation of complementary feeding, and early introduction of infant formula among under-two children. These results were reported retrospectively also by mothers of under-five children. Furthermore, for children aged 6–59 months, there was poor mother-child DD, and a high prevalence of overweight and stunted children. In Lebanon, based on a recent report published by UNICEF (21), the early initiation of EBF in 2004 was reported as 41.3% in under-two children. Moreover, according to national data, in 2010, about 40% of infants under 2 months of age were exclusively breastfed, dropping to only 2% between 4–5 months of age (22). In fact, only 37.6% of infants had breast milk as their first food after birth (22). Another national data collected from under-five children's mothers showed that the prevalence of EBF in 2012 at 40 d was 41.5%, which is higher than that reported in our study (27%) (23). Moreover, the same study showed that the prevalence of MF at 40 d was 38.1 and 20.2% were EBOT (23). However, in our study, the MF was 10.6% and the EBOT was 2 times higher (53%). Another recent retrospective cross-sectional Lebanese study published in 2019 showed that the average duration of exclusive breastfeeding was 15 d, while the average age at which formula was introduced was 2.03 months (24). Exclusive breastfeeding began at a mean age of 10.56 h, and half of the toddlers had been exposed to formula milk since the first day after birth (24). In addition, at global and Eastern Mediterranean level, the prevalence of EBF (44 and 44%, respectively) and the early initiation of EBF (48 and 35%, respectively) for children aged under 2 years, between 2014 and 2020 was higher than our findings (26%) (21). This indicates a negative deviation in the pattern of breastfeeding along with an increase in the use of infant formula at birth in Lebanon. All in all, both national, regional, and international prevalence were below the WHO new global target of exclusive breastfeeding (70%) by 2030 (6). The findings of these studies and ours shed light on the lower rate of exclusive breastfeeding and the higher rate of early introduction of formula-feeding, generally in the Eastern Mediterranean Region and specifically in

TABLE 4 | Association between the child's dietary diversity score and the mother's socio-demographic, education, and nutrition related factors.

	Low DDS child	High DDS child	P-value
	Count (%)		
Mother's age categories* ($n = 303$)			0.23*
20–24	5 (41.7)	7 (58.3)	
25–29	27 (37.5)	45 (62.5)	
30–34	30 (24.8)	91 (75.2)	
35–39	28 (34.1)	54 (65.9)	
40–45	7 (43.8)	9 (56.3)	
Mother DDS ($n = 303$)			0.003*
Low DDS	56 (40.6)	82 (59.4)	
High DDS	41 (24.8)	124 (75.2)	
BMI* mother ($n = 303$)			0.775
Severe underweight	2 (66.7)	1 (33.3)	
Underweight	1 (25)	3 (75)	
Normal weight	60 (32.1)	127 (67.9)	
Overweight	22 (31)	49 (69)	
Obese	12 (31.6)	26 (68.4)	
Mother's employment ($n = 303$)			0.005*
Employed	48 (25.9)	137 (74.1)	
Unemployed	49 (41.5)	69 (58.5)	
Education level ($n = 303$)			0.045*
Primary education	2 (66.7)	1 (33.3)	
Intermediate education	11 (55)	9 (45)	
Secondary education or technical diploma	18 (36)	32 (64)	
University degree and higher	66 (28.7)	164 (71.3)	
Mother's dieting ($n = 303$)			0.969
Yes	21 (31.8)	45 (68.2)	
No	76 (32.1)	161 (67.9)	
Children at home < 5 years old ($n = 303$)			0.985
1	49 (31.6)	106 (68.4)	
2	42 (32.3)	88 (67.7)	
3 or more	6 (33.3)	12 (66.7)	
Household number ($n = 303$)			0.799
<5	58 (32.6)	120 (67.4)	
5 or more	39 (31.2)	86 (68.8)	
Family income ($n = 303$)			0.000*
< 750,000 L.L.	4 (80)	1 (20)	
750,000–1,500,000 L.L.	23 (48.9)	25 (51.1)	
1,500,001–2,250,000 L.L.	27 (42.2)	37 57.8)	
2,250,001–3,000,000 L.L.	15 (27.3)	40 (72.7)	
>3,000,000 L.L.	28 (21.4)	103 (78.6)	

**BMI, Body mass index.*
**https://www.who.int/healthinfo/paper31.pdf.*

TABLE 5 | Adjusted odds ratio for child dietary diversity score according to family income and the mother's diet diversity score.

	AoR* = Exp (β) (95%CI)	*P*-value
Family income		
<750,000 L.L.	1	0.252
750,000–1,500,000 L.L.	3.8 (0.3–36.9)	0.175
1,500,001–2,250,000 L.L.	4.8 (0.4–45.8)	0.054*
2,250,001–3,000,000 L.L.	9.5 (0.9–92.8)	0.032*
>3,000,000 L.L.	11.7 (1.2–111.0)	
DDS mother		0.034*
Low DDS	1	
High DDS	1.7 (1.042–2.914)	

**Calculated through backward logistic regression model.*

Lebanon. Hence, raising awareness sessions during the pre- and post-natal period and highlighting the successful and vital role of breastfeeding for both the child and the mother are critical.

Regarding complementary feeding, our data found that more than 60% of the mothers introduced complementary foods before the age of 6 months from which 40% started introducing solid foods and 53.5% introduced sugary juices. In our study, only 31% of mothers adhered to the WHO recommendations to introduce foods at 6 months. This finding was below the complementary feeding prevalence reported by UNICEF for the EMR which is 68% and at global level which is 73% (21). However, early introduction of complementary foods and sugary juices have a negative impact on the infant's nutrient intake and may increase the risk of developing non-communicable diseases in later stages (13). Besides, if complementary foods are not handled and stored appropriately, they may expose infants to harmful germs (25). Many factors can be associated with early introduction of solid foods. A previous cross-sectional study conducted in Lebanon showed that women who worked outside the home were nearly twice as likely to start solid foods before the age of 4 months (26). This finding was in line with our findings.

Our current study examined the concordance between maternal and child dietary diversity and factors affecting the concordance. Our study showed that the proportion of discordant is few ($p = 0.03$). This is to mean that the more food groups the mothers consumed, the more likely their children achieved their DD and vice versa. As the mothers' DD increased, the percentage of children (0–59 months) meeting this criterion increased dramatically. Even though there is a dearth of literature on concordance between maternal and child dietary diversity in the EMR and in Lebanon, a related study on maternal and child DD associations in Bangladesh, Vietnam, and Ethiopia showed a fair association between the two (27). This finding is consistent with previous studies conducted in Ghana and South Hampton (28). Mothers belonging to a high-income household and having a high DD score were the two major correlates that lead to an adequate diversified diet among children (6–59 months). This finding came hand in hand with a study published in Nigeria (29), and in line with another study conducted in Madagascar which showed that participants with a low economic status were 1.8 times more likely to have children eating poor diets (30). To explain, lower income households purchase less healthful foods compared with higher income households. Food purchasing patterns may mediate income differences in dietary intake quality. In our study, it was shown that maternal education and employment were correlated with the diversification in mothers and children's diets. This result is consistent with many studies conducted in Ethiopia (31) and Madagascar (30), but not in Nigeria (29). The likely reason might be as the education level of the mother increased and as the mother engaged in paid work, there was access to more information on educational

messages and different mass media like radio, television, and newspapers. They also participate actively in health education sessions and child feeding demonstrations in health facilities; as a result, their children are more likely to fulfill the DD requirement. In this study, on average, three food groups composed the diets of under-five Lebanese children, which are staples (grains/cereals, roots, and tubers) (91%), dairy products (milk, yogurt, and cheese) (94.7%), and fruits and vegetables (76%), whereas the least two food groups consumed were eggs (10.5%) and fruits and vegetables rich in vitamin A (16.4%). Consequently, one out of two mothers and one out of three children (6–59 months) had a low DDS (46 and 32%, respectively). Our findings were found to be consistent with different studies such as Pakistan (75.2% for staples and 50.5% for the dairy products) (32). In Nigeria, the most consumed two food groups are cereals (0.78 ± 0.29) and vegetables (0.78 ± 0.3), while the least consumed food group is eggs (0.15 ± 0.25) (29). In Ethiopia, the consumption of grains and staples is 85%, that of eggs is 90%, and that of vitamin A rich fruits and vegetables is 80% (27). As for Vietnam, food consumption of staples was 97% and eggs were 75%, and Bangladesh's staple consumption was 90 and 80% for eggs (27).

As for malnutrition, most of the children aged under 5 in this study had a normal body weight (44%). In addition, 9.3% were underweight (WAZ<-2SD to −3SD), 6.5% were at risk of being overweight, 24.45% were overweight, 9.3% were stunted (HAZ<-2SD to −3SD), and 6.25% (WHZ<-2 SD to −3SD) were wasted. The prevalence of stunting, wasting, and overweight among under-two children was 12.5, 37.5, and 62.5%, respectively. According to WHO, in 2020, globally, 149.2 million children under the age of 5 years were stunted (22%), 45.4 million wasting (13.6%), and 38.9 million overweight (5.7%), respectively (3). According to the UNICEF database, published in 2021, the global prevalence of stunting among under-five children ranged between 33.9% in 2000 and 27.9% in 2020 (33). Moreover, the prevalence of overweight among children aged 0–59 months ranged between 33.3 and 42.4% between 2000 and 2020 (34). Also, the prevalence of wasting in 2020 was 13.6% (34). At the EMR level, according to a new published review, stunting, wasting, and underweight had an average prevalence of 28, 8.69, and 18%, respectively (35). In Lebanon, the prevalence of stunting ranged between 16% in 2000 to 10.4% in 2020 (5). As for overweight and obesity, in 2018, the estimated weighted average prevalence in children aged under 5 years was 8.42% in the EMR and between 17.6 and 19.7% in Lebanon (5). For the prevalence of wasting in Lebanon and Jordan, national surveys conducted in 2012 showed that the prevalence of stunting ranged between 7.3 and 7.7% (36, 37), between 1.1 and 2.4% for wasting, and between 1.6 and 3% for underweight (36, 38). The annual rates of change in the prevalence of stunting were estimated to be −6.9 % in Lebanon (2004–2012) and −3.3% in Jordan (2002–2012). The prevalence of wasting was found to be stable over time in Jordan (2.4% in 2002 and 2012) and decreasing in Lebanon (from 6.6% in 2004 to 1.1% in 2012) (39). All in all, our findings were in line with UNICEF's data in 2020 concerning stunting's prevalence (5), were lower than the EMR's data and the UNICEF's data regarding wasting's prevalence (34, 35), were higher than the previously published national data (5) and lower than the UNICEF data concerning the prevalence of overweight (5, 34).

LIMITATIONS AND STRENGTHS

The study offers a unique lens into infant feeding practices related to under-five children in Lebanon. However, it has several limitations. First, it is a cross-sectional study with unclear chronology of the factors associated with infant feeding patterns. Second, mothers reported infant feeding practices of their children, with potential for more recall bias among mothers of older children due to a longer time since delivery; however, almost half of the children were younger than 5 years of age.

CONCLUSION AND FUTURE PERSPECTIVES

Our findings demonstrated low rates of EBF and continuous BF, high use of IF, and early introduction of complementary feeding among children aged 0–23 months. Furthermore, for children 6–59 months, there was poor mother/child DD, and a high prevalence of overweight and stunted children in the main two Lebanese provinces. This suggests the alarming need for continuous nutrition intervention to improve the DD and to reduce the malnutrition rates. Future research should investigate the factors associated with EBF, complementary feeding practices, and DD in prospective cohort studies and help to better understand the cultural factors limiting the adherence to international guidelines. Such research can guide effective planning for interventions to improve infant feeding practices and ultimately children's health status.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ethical Committee Lebanese University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MHo: conceptualization, methodology, supervision, and writing—reviewing and editing. HA and MHa: data curation, writing—original draft preparation, visualization, and investigation. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

We would like to acknowledge Carla Ibrahim and Hala Mohsen for reviewing this manuscript.

REFERENCES

1. World Health Organization. (2020). Children: Improving survival and well-being. Available online at https://www.who.int/news-room/fact-sheets/detail/children-reducing-mortality. (accessed January 18, 2022)
2. World health Organization (2021). Malnutrition. Available online at https://www.who.int/news-room/fact-sheets/detail/malnutrition/. (accessed January 12, 2022)
3. World Health Organization (2021). Joint Child Malnutrition Estimates. Available online at https://www.who.int/data/gho/data/themes/topics/joint-child-malnutrition-estimates-unicef-who-wb. (accessed January 18, 2022)
4. Jawaldeh AA, Doggui R, Borghi E, Aguenaou H, Ammari LE, Abul-Fadl A, et al. Tackling childhood stunting in the eastern mediterranean region in the context of COVID-19. *Children.* (2020) 7:239. doi: 10.3390/children7110239
5. UNICEF/WHO/World Bank Joint Child Malnutrition Estimates Database (2021). Available online at https://data.unicef.org/resources/jme-report-2021. (accessed January 18, 2022)
6. World Health Organization (2021). Infant and Young Child Feeding. Available online at https://www.who.int/news-room/fact-sheets/detail/infant-and-young-child-feeding. (accessed December 14, 2021)
7. Amugsi D. Breastfeeding trends show most developing countries may miss global nutrition targets. The Conversation. (2021). Available online at https://theconversation.com/breastfeeding-trends-show-most-developing-countries-may-miss-global-nutrition-targets-166853. (accessed January 18, 2022)
8. Bhattacharjee N. Mapping inequalities in exclusive breastfeeding in low- and middle-income countries, 2000–2018. Institute for Health Metrics and Evaluation. (2021). Available online at https://www.healthdata.org/research-article/mapping-inequalities-exclusive-breastfeeding-low-and-middle-income-countries-2000. (accessed January 18, 2022)
9. Al Maamari S, Al Shammakhi S, Alghamari I, Jabbour J, Al-Jawaldeh A. Young children feeding practices: an update from the sultanate of Oman. *Children.* (2021) 8:818. doi: 10.3390/children8090818
10. Beluska-Turkan K, Korczak R, Hartell B, Moskal K, Maukonen J, Alexander DE, et al. Nutritional gaps and supplementation in the first 1000 days. *Nutrients.* (2019) 11:2891. doi: 10.3390/nu11122891
11. Walters CN, Rakotomanana H, Komakech JJ, Stoecker BJ. Maternal determinants of optimal breastfeeding and complementary feeding and their association with child undernutrition in Malawi (2015-2016). *BMC Public Health.* (2019) 19:1503. doi: 10.1186/s12889-019-7877-8
12. World Health Organization. (2018). Complementary feeding. Available online at https://apps.who.int/nutrition/topics/complementary_feeding/en/index.html. (accessed January 18, 2022)
13. Wang L, Van Grieken A, Van Der Velde LA, Vlasblom E, Beltman M, L'Hoir MP, et al. Factors associated with early introduction of complementary feeding and consumption of non-recommended foods among Dutch infants: the BeeBOFT study. *BMC Public Health*. (2019) 19:388. doi: 10.1186/s12889-019-6722-4
14. Carletti C, Pani P, Monasta L, Knowles A, Cattaneo A. Introduction of complementary foods in a cohort of infants in Northeast Italy: do parents comply with who recommendations? *Nutrients*. (2017) 9:34. doi: 10.3390/nu9010034
15. McAndrew F, Thompson J, Fellows L, Large A, Speed M, Renfrew MJ. *Infant feeding survey 2010. Leeds: health and social care information centre*. (2012).
16. Clayton HB, Li R, Perrine CG, Scanlon KS. Prevalence and reasons for introducing infants early to solid foods: variations by milk feeding type. *Pediatrics*. (2013) 131:e1108–14. doi: 10.1542/peds.2012-2265
17. Oueidat H, Charafeddine L, Nimer H, Hussein H, Nabulsi M. Knowledge and attitudes of Lebanese women towards Baby Friendly Hospital Initiative practices. *PLoS ONE.* (2020) 15:e0238730. doi: 10.1371/journal.pone.0238730
18. Nabulsi M, Tamim H, Shamsedine L, Charafeddine L, Yehya N, Kabakian-Khasholian T, et al. A multi-component intervention to support breastfeeding in Lebanon: a randomized clinical trial. *PLoS ONE.* (2019) 14:e0218467. doi: 10.1371/journal.pone.0218467
19. Bosha T, Lambert C, Riedel S, Melesse A, Biesalski HK. Dietary diversity and anthropometric status of mother-child pairs from enset (false banana) staple areas: a panel evidence from Southern Ethiopia. *Int J Environ Res Public Health.* (2019) 16:2170. doi: 10.3390/ijerph16122170
20. Abdulahi A, Shab-Bidar S, Rezaei S, Djafarian K. Nutritional status of under five children in Ethiopia: a systematic review and meta-analysis. *Ethiop J Health Sci.* (2017) 27:175–88. doi: 10.4314/ejhs.v27i2.10
21. United Nations Children's Fund, Division of Data, Analysis, Planning and Monitoring. *Global UNICEF Global Databases: Infant and Young Child Feeding*. Ever breastfed, Early initiation of breastfeeding, exclusively breastfed for the first two days after birth, New York. (2021).
22. Akik C, Ghattas H, Filteau S, Knai C. Barriers to breastfeeding in lebanon: a policy analysis. *J Public Health Policy*. (2017) 38:314–26. doi: 10.1057/s41271-017-0077-9
23. Chehab RF, Nasreddine L, Zgheib R, Forman MR. Exclusive breastfeeding during the 40-day rest period and at six months in lebanon: a cross-sectional study. *Int Breastfeed J.* (2020) 15:1–10. doi: 10.1186/s13006-020-00289-6
24. Mattar L, Hobeika M, Zeidan RK, Salameh P, Issa C. Determinants of exclusive and mixed breastfeeding durations and risk of recurrent illnesses in toddlers attending day care programs across Lebanon. *J Pediatr Nurs.* (2019) 45:e24–34. doi: 10.1016/j.pedn.2018.12.015
25. Mohammed S, Getinet T, Solomon S, Jones AD. Prevalence of initiation of complementary feeding at 6 months of age and associated factors among mothers of children aged 6 to 24 months in Addis Ababa, Ethiopia. *BMC nutrition.* (2018) 4:54. doi: 10.1186/s40795-018-0264-5
26. Batal M, Boulghourjian C, Akik C. Complementary feeding patterns in a developing country: a cross-sectional study across Lebanon. *Eastern Mediterranean Health J.* (2010) 16:180–86. doi: 10.26719/2010.16.2.180
27. Nguyen PH, Avula R, Ruel MT, Saha KK, Ali D, Tran LM, et al. Maternal and child dietary diversity are associated in Bangladesh, Vietnam, and Ethiopia. *J Nutr.* (2013) 143:1176–83. doi: 10.3945/jn.112.172247
28. Amugsi DA, Mittelmark MB, Oduro A. Association between maternal and child dietary diversity: an analysis of the ghana demographic and health survey. *PLoS ONE.* (2015) 10:e0136748. doi: 10.1371/journal.pone.0136748
29. Opaneye AA. Maternal formal education and the four-child policy in Nigeria. *J Royal Soc Health.* (1990) 110:220–1. doi: 10.1177/146642409011000609
30. Rakotonirainy NH, Razafindratovo V, Remonja CR, Rasoloarijaona R, Piola P, Raharintsoa C, et al. Dietary diversity of 6- to 59-month-old children in rural areas of Moramanga and Morondava districts, Madagascar. *PLoS ONE.* (2018) 13:e0200235. doi: 10.1371/journal.pone.0200235
31. Solomon D, Aderaw Z, Tegegne TK. Minimum dietary diversity and associated factors among children aged 6-23 months in Addis Ababa, Ethiopia. *Int J Equity Health.* (2017) 16:181. doi: 10.1186/s12939-017-0680-1
32. Iqbal S, Zakar R, Zakar MZ, Fischer F. Factors associated with infants' and young children's (6-23 months) dietary diversity in Pakistan: evidence from the demographic and health survey 2012-13. *Nutr J.* (2017) 16:78. doi: 10.1186/s12937-017-0297-7
33. UNICEF. Malnutrition. Available online at https://data.unicef.org/topic/nutrition/malnutrition/. (accessed January 3, 2022)
34. UNICEF, WHO. World Bank Group Joint Malnutrition Estimates, April 2021 Edition. Overweight prevalence 2000-2020.
35. Nasreddine L, Ayoub JJ, Al Jawaldeh A. Review of the nutrition situation in the Eastern Mediterranean region. *Eastern Mediterranean Health J.* (2018) 24:77–91. doi: 10.26719/2018.24.1.77
36. Jordan Population and Family Health Survey (2012). Department of Statistics [Jordan] and ICF International. Available online at https://dhsprogram.com/pubs/pdf/FR282/FR282.pdf. (accessed January 3, 2022)
37. Saliba AE. Overweight and obesity among preschool-aged children in Lebanon: prevalence and associated factors (thesis). American University of Beirut. (2014). Available online at https://ulib.aub.edu.lb/thesis/st-6071.pdf. (accessed January 1, 2022)
38. Zgheib RS. Infant and young child feeding practices in Lebanon: a national cross-sectional study (Thesis). American University of Beirut. (2014). Available online at http://library.aub.edu.lb/search$\sim$S1?/Xa:(rasha)&SORT=D&m=x&m=y&m=z/Xa:(rasha)&SORT$=$D&m$=$x&m$=$y&m$=$z&SUBKEY$=$a%3A(rasha)/1%2C24%2C24%2CB/frameset&FF$=$Xa:(rasha)&SORT$=$D&m$=$x&m$=$y&m$=$z&3%2C3%2C. (accessed January 1, 2022)
39. Nasreddine LM, Kassis AN, Ayoub JJ, Naja FA, Hwalla NC. Nutritional status and dietary intakes of children amid the nutrition transition:

the case of the Eastern Mediterranean Region. *Nutr Res.* (2018) 57:12–27. doi: 10.1016/j.nutres.2018.04.016

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict ofinterest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Nutrition

PERSPECTIVE
published: 03 March 2022
doi: 10.3389/fnut.2022.858475

Perspective: Are Online Food Delivery Services Emerging as Another Obstacle to Achieving the 2030 United Nations Sustainable Development Goals?

Si Si Jia[1]*, *Alice A. Gibson*[2,3], *Ding Ding*[3,4], *Margaret Allman-Farinelli*[3,5], *Philayrath Phongsavan*[3,4], *Julie Redfern*[1,6] and *Stephanie R. Partridge*[1,3,4]

[1] Engagement and Co-design Hub, School of Health Sciences, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia, [2] Menzies Centre for Health Policy and Economics, Sydney School of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia, [3] Charles Perkins Centre, The University of Sydney, Sydney, NSW, Australia, [4] Prevention Research Collaboration, Sydney School of Public Health, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia, [5] Nutrition and Dietetics Group, Faculty of Medicine and Health, The University of Sydney, Sydney, NSW, Australia, [6] The George Institute for Global Health, The University of New South Wales, Sydney, NSW, Australia

OPEN ACCESS

Edited by:
Maha Hoteit,
Lebanese University, Lebanon

Reviewed by:
Jana Jabbour,
Modern University for Business and Science, Lebanon
Sabika Allehdan,
The University of Jordan, Jordan

***Correspondence:**
Si Si Jia
sisi.jia@sydney.edu.au

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *20 January 2022*
Accepted: *07 February 2022*
Published: *03 March 2022*

Citation:
Jia SS, Gibson AA, Ding D, Allman-Farinelli M, Phongsavan P, Redfern J and Partridge SR (2022) Perspective: Are Online Food Delivery Services Emerging as Another Obstacle to Achieving the 2030 United Nations Sustainable Development Goals? Front. Nutr. 9:858475. doi: 10.3389/fnut.2022.858475

Online food delivery usage has soared during the 2019 novel coronavirus (COVID-19) pandemic which has seen increased demand for home-delivery during government mandated stay-at-home periods. Resulting implications from COVID-19 may threaten decades of development gains. It is becoming increasingly more important for the global community to progress toward sustainable development and improve the wellbeing of people, economies, societies, and the planet. In this perspective article, we discuss how the rising use of these platform-to-consumer delivery operations may impede advances toward the United Nations 2030 Sustainable Development Goals (SDGs). Specifically, online food delivery services may disrupt SDGs that address good health and wellbeing, responsible consumption and production, climate action and decent work and economic growth. To mitigate potential negative impacts of these meal delivery apps, we have proposed a research and policy agenda that is aligned with entry points within a systems approach identified by the World Health Organization. Food industry reforms, synergised public health messaging and continuous monitoring of the growing impact of online food delivery should be considered for further investigation by researchers, food industry, governments, and policy makers.

Keywords: online food delivery, sustainable development goals, global health, public health, systems approach

INTRODUCTION

Unhealthy diets, non-communicable diseases, urbanization, and climate change are recognized as significant challenges to global health (1). The United Nations have urged countries to act on 17 Sustainable Development Goals (SDGs) across economic, social and environmental dimensions to promote healthy lives and wellbeing and make cities inclusive, safe, and sustainable by 2030 (2). Online food delivery services (OFDS) are potentially impeding our progress toward the

SDGs—impacting the way we eat, work, and care for the environment. Defined as "platform-to-consumer delivery operations" of ready-to-consume meals, OFDS offer delivery of a wide variety of takeout foods and beverages from kitchens to doorsteps (3).

The OFD industry is now widespread across the globe and big multinational corporations are dominating the market. Billion-dollar companies such as UberEats, DoorDash, and Just Eat operate in thousands of cities and show no sign of slowing down. Globally, OFDS market revenue increased by 27% in 2020, reaching $136.4 billion USD (4). These services are likely to proliferate further, as UberEats estimates that despite the return to dine-in restaurants, consumers are now spending three times more on OFDS compared to pre-pandemic levels (5). Furthermore, Just Eat or otherwise known as Menulog, reported a 79% increase in total orders between 2020 and 2021, across its 17 operating countries including UK, Germany, Canada, and Netherlands (6).

Considering the growing prevalence and market influence of OFDS, it is important to track the impact of OFDS on key public health challenges, such as increasing accessibility of unhealthy foods, promotion of excessive consumption, poor working conditions of delivery couriers in a gig economy and the environmental implications of takeout food packaging. This perspective piece will discuss how OFDS may disrupt progress toward SDGs that address good health and wellbeing, responsible consumption and production, climate action and decent work and economic growth.

JUNK FOOD ON DEMAND: IMPACT ON NUTRITION, HEALTH, AND WELLBEING

OFDS may pose a considerable risk to the aim of SDG 3 to "Ensure healthy lives and promote wellbeing for all at all ages". Research has shown that these OFDS have an abundant offering of menu items that are of poor nutritional quality. From an investigation of 680 popular food outlets on the market leading OFDS in Sydney, Australia, 37.6% (256/680) of popular outlets were classified as a "fast-food franchise" store, and out of the 2,463 most popular menu items identified, 2,358 (95.7%) were identified as "discretionary foods" (7), characterized as high in saturated fat, sodium and sugar, and not essential for health.

Moreover, the two leading OFDS (UberEats, Menulog) in Australia are partnered with the top 10 fast food franchise stores (Subway, McDonalds, Dominos, KFC, Hungry Jacks, Red Rooster, Nando's, Pizza Hut, Zambero, Oporto) (8). This signifies the dominance of fast-food franchise outlets on these platforms which are now another additional avenue for consumers to access their menu items. It is well-known that offerings from fast food franchise outlets are "energy-dense and nutrient poor" (9) and evidence has highlighted the strong association between high fast-food consumption and obesity (10). Furthermore, research has shown that diets high in inflammatory foods such as refined grains, sugary drinks, processed meats and other "junk foods", have been associated with increased inflammation in the body and can elevate subsequent risk of heart disease by 46% and stroke by 28% (11). These highly inflammatory foods are widely available on these online food delivery platforms as shown in findings from a recent cross-sectional study (12). From over 196 independent takeaway food outlets available on UberEats in Sydney, Australia, discretionary cereal-based mixed meals was the largest category found within complete menus (42.3%, 5849/13,841). These include foods such as pizzas, burgers, pides, pasta, wraps, and sandwiches (12).

A Canadian study analyzed the full menus of retailers partnering with a large OFDS and similarly found low Healthy Eating Index-2015 scores—ranging from 19.95 to 50.78 out of 100 (with a score of 100 being the healthiest) (13). This study also found a mean delivery distance of 3.7 km or 2.3 miles measuring from postal codes in Ontario to online food retailers (13). Australian research has likewise, demonstrated that the mean delivery distance from food outlet to suburbs was 3 km, and around 90% of delivery distances were greater than 1 km (7)—a distance that typically defines the neighborhood food environment. The neighborhood food environment reflects the spatial extent of an individual's typical shopping behavior which could be reasonably walked by an adult in 15–20 min (14). As such, these platform-to-consumer services may be expanding local neighborhood food environments.

Altogether, findings suggest OFDS are expanding the traditional definition of the neighborhood food environment, increasing the accessibility of food outlets which mostly offer items with poor nutritional quality.

OVER-CONSUMPTION AND EXCESS PROMOTION

In addition to increasing accessibility of food outlets, OFDS further encourage excessive consumption with aggressive marketing and promotion tactics. Macromarketing researchers are wary of the current marketing systems which promote an era of excess as business models choose to "create" rather than "address" consumer needs, without consideration of the waste generated from overall consumption (15). OFDS may add further burden to unsustainable practices of mass consumerism which threaten progress toward SDG 12: "Ensure sustainable consumption and production patterns".

UberEats and Menulog frequently distribute promotional vouchers that offer free meals, discounts, and free delivery (16, 17). These are often disseminated through emails to past customers signed up to the OFD platform (18) or handed-out in person at high-traffic locations such as train stations (19). Moreover, there is evidence that OFD companies "COVID-wash" their social media promotions—a practice where companies align themselves with social or health issues of COVID-19 to enhance their own image (20). In a content analysis of Instagram posts from leading OFDS in 2020 during the pandemic, the most used COVID-19 marketing strategy was related to "combatting the pandemic" (76/123, 62%) (21). This theme helped brands position themselves to be "in this together" and encourage consumers to "support their local businesses". These findings were echoed in another content analysis study conducted in New

Zealand. The most used theme in 36% of all COVID-19 related social media posts intended to generate feelings of community support during the challenging time. Fast-food brands were also found to be the largest proponents of COVID-washing, accounting for 46% of all COVID-19 posts (20).

Furthermore, during the pandemic, an increase in social media posts promoting "junk foods" from leading OFD brands was observed. In a recent study, we found junk foods accounted for 69.1% of all food and beverage items featured, compared to 58.3% in 2019 (21). Similarly, a study from Brazil indicated widespread presence of unhealthy food advertising as ultra-processed beverages such as soft drinks were among the most shown in advertisements for OFDS throughout COVID-19. Free delivery also prevailed in advertisements of junk food items such as ice cream, candy, high sodium snacks, and pizza (22). More research found that menus offering unhealthy meals had more photos and discounts compared to meals offering unprocessed and/or minimally processed foods (23). Taken together, OFDS continue to facilitate fast-food delivery at heavily discounted prices and excess promotions, perpetuating the culture of excessive consumption.

UNSUSTAINABLE PLASTIC WASTE AND CO2 EMISSIONS

Plastic waste is a key global environmental concern with annual plastic consumption currently at over 300 million tons, which is expected to double in the next 20 years (24). High volumes of online food delivery consumption exacerbates plastic waste and adds to the increasing contamination of natural environments such as the ocean, freshwater systems, and terrestrial areas (25). Subsequently, OFDS may have a huge climate cost and are another impediment to SDG 13: "Take urgent action to combat climate change and its impacts".

Takeout meals ordered from OFDS can come with extensive quantities of plastic material, namely food containers, cutlery, napkins, and plastic bags among others (26). These materials are often single-use, requiring large quantities of energy and raw materials to produce, transport, and be disposed (27). A study on the environmental impacts of takeout food containers revealed that single-use polypropylene containers are the worst packaging material for takeout food, with many negative impacts on the environment (26). In China, researchers found that the total amount of packaging waste from food delivery surged from 0.2 million metric tons in 2015 to 1.5 million metric tons in 2017 (28). Plastic containers made from polypropylene and polystyrene foam accounted for approximately 75% of the total food delivery packaging waste in weight. COVID-19 lockdowns further aggravated China's plastic waste dilemma: during the lockdown in Wuhan, an average of 130,000 takeout orders were made per day, which totaled to more than 279,500 m of lunchboxes over a 6-week period (29).

Excessive energy consumption and carbon emissions are associated with the waste produced from food delivery. Based on annual online food delivery data of 179.2 million active users, a 2016 Chinese study found an average ordering frequency of 2 times/week and average delivery distances of 25 km (30), which resulted in an estimated Green House Gas (GHG) emission of 73.89 Gigatonnes (Gt) carbon dioxide-equivalent emissions (CO_{2eq}) (30). In Australia, COVID-19 lockdowns led to a 20% increase in household solid wastes, partly due to a surge in food deliveries which contributed sizeable amounts of paper, plastic packaging waste and single-use waste (31). Another study found in 2018, the disposal of single use packaging from online food orders in Australia led to 5,600 tons of CO_{2eq} (32). With online food orders expected to increase to 65 million in 2024, researchers project a 132% rise in carbon emissions to 13,200 tons of CO_{2eq} (32). As such, the environmental threat of OFDS is progressively evident and needs to be considered as governments globally move toward carbon emission reduction targets.

FUELLING THE GIG ECONOMY

Instead of steering toward the SDG 8: "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all", OFDS stimulate the gig economy and may veer away from sustainable economic growth that will create quality jobs. While OFDS have facilitated new job opportunities and increased flexibility of work, the quality of these jobs is questionable with little-to-no employment rights and poor work health and safety conditions (33).

Advances in online technology have fuelled the rise of the "gig economy"—a free market system in which mobile apps or websites connect consumers with individual workers providing services. Gigs are denoted by short-term, one-off employment contracts mediated by online platforms which include online food delivery. Although spending on gig economy in Australia declined severely during the period of early COVID-19 lockdown restrictions in March 2020, it increased to 40% above pre-lockdown levels. This growth was almost entirely driven by the online food delivery sector, which itself increased by more than 100% between August and October 2020 (34). Indeed, UberEats Australia, a leading OFDS, has reported providing 59,000 work opportunities during 2020 which is an eight-fold increase since 2016 (5).

In a report on digital platform work in Australia, it has been revealed that food delivery workers choose to work with OFDS for flexibility and to supplement existing income streams (35). However, food delivery workers are more dependent on income generated from meal delivery compared to gig workers on other digital platforms (35). This report also suggests food delivery workers were more likely to work longer hours in a week and were more likely to say the income was essential for meeting basic needs (35). Moreover, food delivery platforms may vary in their contractual agreements where workers may be independent contractors rather than employees. This places workers at risk of insecure income, no insurance, personal or paid leave, no workers compensation, superannuation or certain taxes. Over a long term, gig work as a food delivery worker may be financially untenable. A gig worker who spends 5–10 years in the gig economy full

TABLE 1 | Proposed action points to mitigate negative impacts of online food delivery services and address the 2030 UN Sustainable Development Goals and entry points identified in the WHO Meal Delivery Apps Report.

	Action	UN sustainable development goal	WHO MDA entry point	Current and emerging research
1	Advocate for major reforms to the gig economy sector to recognize full employment rights for food delivery workers to improve working conditions	SDG 3 SDG 8	Labor, Road Safety	Menulog Australia has started a pilot employment program around Sydney's Central Business District—giving their worker's rights to a minimum wage and superannuation contributions by directly employing them (42)/ New Zealand's second-largest private sector trade union, "FIRST Union" has launched a class action lawsuit against Uber to seek better conditions and security of rideshare and food-delivery work (43).
2	To create healthier neighborhood food environments by developing cycle-friendly or convenient and walkable pathways within transport networks and city infrastructures.	SDG 3 SDG 8 SDG 13	Labor, Physical activity, Environment	To improve potential access to healthier foods and reduce the reliance on getting takeaway meals delivered, a "15-min" city may be a possible solution. Proposed by Moreno and colleagues, a "15-min city" is an urban planning concept that advocates for the provision of basic urban amenities at distances that would take local citizens no more than 15 min to access by foot or by bicycle (44). This urban planning concept has inspired many cities to embrace becoming more cyclable and walkable. The city of Paris is leading the "15-min city" transformation (45) while other cities have also seen notable action such as Melbourne (46), Shanghai (47), Singapore (48), Portland (49), and Bogota (50).
3	Disincentivise unhealthy food and beverage choices through regulatory pressure to limit promotions such as monthly subscriptions and junk food advertising on social media while promoting healthier food options on these platforms.	SDG 12 SDG 3	Alcohol consumption, Nutrition	Research on the monitoring of social media food marketing content targeted toward children and adolescents is still in its infancy. However, this is a high priority for global bodies such as the World Health Organization. Further research may benefit by aligning with the proposed tools and initiatives from WHO to monitor food and beverage marketing to children via television and the Internet (51). In addition, the UK government has announced a ban on junk food advertising online and before 9 p.m. on TV from 2023 (52). This ban will affect all paid-for forms of digital marketing—from Facebook ads to paid search results on Google, text message promotions, and paid activity on sites such as Instagram and Twitter. More work should also focus on the potential benefits of online food delivery services—as many healthier food options can be promoted and selected instead. Digital nudging interventions have shown promising results with improvement to the nutritional quality of online school canteen lunch orders (53). Intervention participants had significantly lower energy content and saturated fat content than control lunch orders.
4	Generate clear public health messaging on both the nutritional quality and environmental impacts of OFDS usage in relation to sustainability.	SDG 3 SDG 12 SDG 13	Nutrition, Environment	Adding nutritional labeling requirements to online food delivery service platforms may be a feasible policy option to inform individuals of the nutritional quality of menu items. The UK has expanded its menu calorie-labeling policies to all restaurants, cafes and takeaways—including online food delivery and this will be implemented in April 2022 (54). Ecolabeling, a method of identifying products or services that are environmentally preferable (55), may also be a potential avenue to changing individual dietary choices while also advocating for environmental sustainability. A recent systematic review has shown promising results to suggest ecolabeling is associated with the selection and purchase of more sustainable food products (56).
5	Investigate sustainable and food safe takeaway packaging options and implement across food outlets partnered with OFDS	SDG 3 SDG 13	Environment, Food safety	Research on sustainable packaging is also growing and there have been suggestions that reusable packaging systems have better environmental benefits over single-use systems. There is an increasing number of companies now providing alternatives to single-use cups for restaurants and cafes—CupClub (U.K.), Meu Copo Eco (Brazil), Globelet (Australia), ReCup (Germany), and Revolv (Indonesia). Companies such as GoBox (US), recircle (Switzerland), Returnr (Austria), Ozarka, and Sharepack (The Netherlands) are leasing reusable containers to restaurants, cafes, bars, and food trucks. It remains unclear however, how this could be applied to all online food delivery outlets considering the need for customers to return empty packaging that will be cleaned and refilled for future use (57).

time, could potentially be $40,000–$100,000 AUD worse off in accumulated superannuation at retirement compared to a minimum wage earner (34). Major reforms of OFD work in the gig economy are required to increase the quality of these jobs, improve the livelihood of workers and be sustainable in the long term.

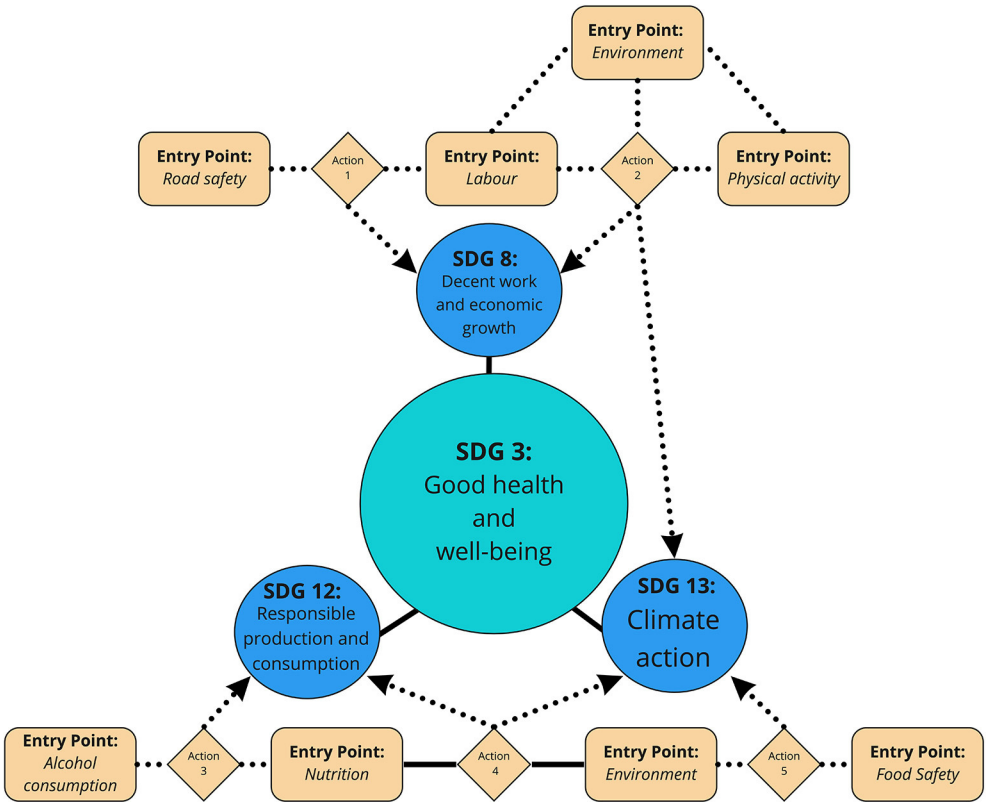


FIGURE 1 | Conceptual diagram identifying areas for entry points and Sustainable Development Goals relating to online food delivery services to merge, forming action points to ultimately address SDG 3 Good Health and Wellbeing. Actions are defined and described in detail in **Table 1**.

DISCUSSION

Existing reports shows achieving the 2030 UN SDGs will require tremendous efforts ahead by governments and industries globally given the considerable setback induced by the COVID-19 pandemic (36). A systems approach to the complexities of public health issues has been proposed by notable researchers—as outlined in the 2011 and 2015 Lancet Series on Obesity (37, 38) and has been a developing research area to inform the National Institute for Health and Care Excellence guidelines on obesity prevention (39). The synergising of goals and targets within and between systems affecting health including manufacturing, financial, transportation, and food, may be essential to meaningful progress. The EAT-Lancet commission on Food, Planet, and Health is an example which shows the power of goal alignment (40). This report has outlined the role of diet with human health and environmental sustainability—addressing both the rise in unhealthy diets, the targets of the UN Sustainable Development Goals and the Paris Agreement. As research on the impacts of OFDS is still in its infancy, robust solutions to resolving the issues outlined in this perspective have yet to be developed. However, using a similar systems-based approach, the following calls to action identify areas for existing systems to merge.

PROPOSED CALLS TO ACTION

The World Health Organization (WHO) (41) has now acknowledged the growing impact of online food environments on people's diet choices. In a recently published report, WHO Europe has proposed the use of a systems approach to make informed decisions on potential interventions and/or regulation of these OFDS or otherwise known as "Meal Delivery Apps" (MDA). Taking a systems approach, several entry points to change were identified. These include Nutrition, Physical Activity, Alcohol consumption, Labor, Road Safety, Food Safety which are key elements that use existing mechanisms to solve complex issues (41). The entry points align with the SDGs discussed in this perspective and may benefit from collective action by food industry, governments, policy makers and researchers.

In **Table 1**, we propose a research and policy agenda with action points that address SDGs and entry points from the WHO report. We have also illustrated examples of current and emerging research across these action points. **Figure 1** was designed to demonstrate how these action points can work together to strive toward SDG 3: "Good Health and Wellbeing" for the benefit of public health. The proposed action points may also later converge with

recommendations outlined from WHO Europe's commentary piece (58).

As research on the impact of OFDS continues to grow, ongoing monitoring and evaluation is critical to the development of policy options for regulating the digital food environment. Dashboards are considered as useful tools to help users visualize and understand complex information in a snapshot. They have been developed to monitor global food systems (59) and food environments (60) and may also be essential to tracking progress of online food delivery services. We therefore also propose the inclusion of online food settings within existing monitoring and evaluation frameworks of food systems and food environments (60).

CONCLUSION

In a world now grappling with ongoing repercussions of the COVID-19 pandemic, resulting societal and environmental changes exacerbated by COVID may further derail the trajectory toward meeting the SDGs set by the United Nations. OFDS are likely to proliferate, providing valued convenience in an increasingly fast-paced modern society. However, the potential disruption to our health and the environment is substantial, interfering with overarching SDGs. Food industry reforms synergised public health messaging and continuous monitoring of the growing impact of OFDS may be part of the solution to collectively address the issues of sustainability, environmental health, decent work and economic growth and nutrition. Multidisciplinary action and research are urgently needed to further investigate such solutions.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

SJ and SP contributed to the conceptualization of the manuscript. SJ wrote the first draft of the manuscript and designed all tables and figures included in submission. SP provided primary supervision of SJ, reviewing the first draft of the manuscript. AAG, DD, PP, MA-F, and JR edited and reviewed the manuscript drafts. All authors contributed to manuscript revision, read, and approved the submitted version.

FUNDING

SJ was supported by the Australian Government's Research Training Program Stipend Scholarship, AAG receives funding from the National Health and Medical Research Council, NSW Health and Diabetes Australia, JR receives fellowship and research grants from the National Health and Medical Research Council, NSW Health, and Medical Research Future Fund, DD receives funding from the National Health and Medical Research Council and NSW Health, MA-F receives funding from the National Health and Medical Research Council, Australian Research Council, NSW Health and Cancer Council NSW, PP receives funding from NSW Health, SP receives funding from the National Health and Medical Research Council, National Heart Foundation, NSW Health and the Medical Research Future Fund.

REFERENCES

1. Giles-Corti B, Vernez-Moudon A, Reis R, Turrell G, Dannenberg AL, Badland H, et al. City planning and population health: a global challenge. *Lancet.* (2016) 388:2912–24. doi: 10.1016/S0140-6736(16)30066-6
2. United Nations. *Transforming our World: The 2030 Agenda for Sustainable Development: United Nations.* (2015). Available online at: https://sdgs.un.org/2030agenda (accessed January 10, 2022).
3. Statista. *Online Food Delivery: Statista.* (2021). Available online at https://www.statista.com/outlook/dmo/eservices/online-food-delivery/australia (accessed January 10, 2022).
4. AJOT. *Online Food Delivery Market to Hit $151.5B in Revenue and 1.6B Users in 2021 A 10% Jump in a Year.* (2021). Available online at: https://ajot.com/news/online-food-delivery-market-to-hit-151.5b-in-revenue-and-1.6b-users-in-2021-a-10-jump-in-a-year (accessed January 10, 2022).
5. Accenture Strategy. *Making Delivery Work for Everyone* (2021).
6. Just Eat Takeaway.com. *Trading Update.* Amsterdam (2021).
7. Partridge SR, Gibson AA, Roy R, Malloy JA, Raeside R, Jia SS, et al. Junk food on demand: a cross-sectional analysis of the nutritional quality of popular online food delivery outlets in Australia and New Zealand. *Nutrients.* (2020) 12:3107. doi: 10.3390/nu12103107
8. Franchise Buyer. *The 10 Biggest Fast Food Franchises in the Australian Market.* (2020). Available online at: https://www.franchisebuyer.com.au/articles/the-10-biggest-fast-food-franchises-in-the-australian-market (accessed October 18, 2021).
9. Kirkpatrick SI, Reedy J, Kahle LL, Harris JL, Ohri-Vachaspati P, Krebs-Smith SM. Fast-food menu offerings vary in dietary quality, but are consistently poor. *Public Health Nutr.* (2014) 17:924–31. doi: 10.1017/S1368980012005563
10. Rosenheck R. Fast food consumption and increased caloric intake: a systematic review of a trajectory towards weight gain and obesity risk. *Obes Rev.* (2008) 9:535–47. doi: 10.1111/j.1467-789X.2008.00477.x
11. Li J, Lee DH, Hu J, Tabung FK, Li Y, Bhupathiraju SN, et al. Dietary inflammatory potential and risk of cardiovascular disease among men and women in the U.S. *J Am Coll Cardiol.* (2020) 76:2181–93. doi: 10.1016/j.jacc.2020.09.535
12. Wang C, Korai A, Jia SS, Allman-Farinelli M, Chan V, Roy R, et al. Hunger for home delivery: cross-sectional analysis of the nutritional quality of complete menus on an online food delivery platform in Australia. *Nutrients.* (2021) 13:905. doi: 10.3390/nu13030905
13. Brar K, Minaker LM. Geographic reach and nutritional quality of foods available from mobile online food delivery service applications: novel opportunities for retail food environment surveillance. *BMC Public Health.* (2021) 21:458. doi: 10.1186/s12889-021-10489-2
14. Smith G, Gidlow C, Davey R, Foster C. What is my walking neighbourhood? A pilot study of English adults' definitions of their local walking neighbourhoods. *Int J Behav Nutr Phys Act.* (2010) 7:34. doi: 10.1186/1479-5868-7-34
15. Wooliscroft B, Ganglmair-Wooliscroft A. Growth, excess and opportunities:marketing systems' contributions to society. *J Macromarket.* (2018) 38:355–63. doi: 10.1177/0276146718805804
16. Mott B. 10 takeaway and delivery food tips. In: Berry L, editor. *Money Saving Expert* (2021). Available online at: https://www.moneysavingexpert.com/deals/deals-hunter/2021/01/takeaway-and-delivery-food-tips/ (accessed June 21, 2021).
17. Business Insider. *Londoners Are Gaming UberEats to Get Free Food.* (2016). Available online at: https://www.businessinsider.com.au/how-to-get-free-

ubereats-vouchers-promotions-food-hundreds-pounds-london-2016-9?r=US&IR=T (accessed September 20, 2021).
18. Sun T. *Uber Annoying Angry Uber Eats Customers Left Hungry After Discount Code Doesn't Work and 'Everything Is Unavailable'*. (2019). Available online at: https://www.thesun.co.uk/money/10627147/uber-eats-discount-code-doesnt-work-everything-unavailable/ (accessed September 20, 2021).
19. Wongm Rail Gallery. *Handing Out Uber Eats Vouchers on the Main Concourse at Southern Cross Station*. Melbourne, VIC (2018). Available online at: https://railgallery.wongm.com/commercialising-commuters/F129_5537.jpg.html (accessed September 14, 2021).
20. Gerritsen S, Sing F, Lin K, Martino F, Backholer K, Culpin A, et al. The timing, nature and extent of social media marketing by unhealthy food and drinks brands during the COVID-19 pandemic in New Zealand. *Front Nutr.* (2021) 8:65. doi: 10.3389/fnut.2021.645349
21. Jia SS, Raeside R, Redfern J, Gibson AA, Singleton A, Partridge SR. #SupportLocal: how online food delivery services leveraged the COVID-19 pandemic to promote food and beverages on Instagram. *Public Health Nutr*. (2021) 24:4812–22. doi: 10.1017/S1368980021002731
22. Horta PM, Matos JdP, Mendes LL. Digital food environment during the coronavirus disease 2019 (COVID-19) pandemic in Brazil: an analysis of food advertising in an online food delivery platform. *Brit J Nutr*. (2020) 126:767–72. doi: 10.1017/S0007114520004560
23. Horta PM, Souza JPM, Rocha LL, Mendes LL. Digital food environment of a Brazilian metropolis: food availability and marketing strategies used by delivery apps. *Public Health Nutr.* (2021) 24:544–8. doi: 10.1017/S1368980020003171
24. Closing the plastics loop. *Nat Sustain*. (2018). 1:205. doi: 10.1038/s41893-018-0075-3
25. Barnes DK, Galgani F, Thompson RC, Barlaz M. Accumulation and fragmentation of plastic debris in global environments. *Philos Trans R Soc Lond B Biol Sci.* (2009) 364:1985–98. doi: 10.1098/rstb.2008.0205
26. Gallego-Schmid A, Mendoza JMF, Azapagic A. Environmental impacts of takeaway food containers. *J Clean Product.* (2019) 211:417–27. doi: 10.1016/j.jclepro.2018.11.220
27. Yi Y, Wang Z, Wennersten R, Sun Q. Life cycle assessment of delivery packages in China. *Energy Proc.* (2017) 105:3711–9. doi: 10.1016/j.egypro.2017.03.860
28. Song G, Zhang H, Duan H, Xu M. Packaging waste from food delivery in China's mega cities. *Resour Conserv Recycl.* (2018) 130:226–7. doi: 10.1016/j.resconrec.2017.12.007
29. Liu J, Vethaak AD, An L, Liu Q, Yang Y, Ding J. An environmental dilemma for china during the COVID-19 pandemic: the explosion of disposable plastic wastes. *Bull Environ Contam Toxicol.* (2021) 106:237–40. doi: 10.1007/s00128-021-03121-x
30. Jia X-x, Klemeš J, Varbanov P, Wan Alwi SR. Energy-emission-waste nexus of food deliveries in China. *Chem Eng Trans.* (2018) 70:661–6. doi: 10.3303/CET1870111
31. Infrastructure Australia. *Infrastructure Beyond COVID-19: A National Study on the Impacts of the Pandemic on Australia*. Australian Government (2020).
32. Arunan I, Crawford RH. Greenhouse gas emissions associated with food packaging for online food delivery services in Australia. *Resour Conserv Recycl.* (2021) 168:105299. doi: 10.1016/j.resconrec.2020.105299
33. Sprint Law. *The Gig Economy And Australian Law: What's Next?* (2021). Available online at: https://sprintlaw.com.au/gig-economy-in-australia/ (accessed September 14, 2021).
34. Actuaries Institute. *The Rise of the Gig Economy and its Impact on the Australian Workforce.* (2020). Available online at: https://www.actuaries.digital/2020/12/16/the-rise-of-the-gig-economy-and-its-impact-on-the-australian-workforce/
35. McDonald P, Williams P, Stewart A, Oliver D, Mayes, R. *Digital Platform Work in Australia: Preliminary Findings from a National Survey*. Victorian Department of Premier and Cabinet (2019).
36. Hughes BB, Hanna T, McNeil K, Bohl DK, Moyer, J.D. *Pursuing the Sustainable Development Goals in a World Reshaped by COVID-19*. Denver, CO; New York, NY: Frederick S. Pardee Center for International Futures and United Nations Development Programme (2021).
37. Rutter H. Where next for obesity? *Lancet.* (2011) 378:746–7. doi: 10.1016/S0140-6736(11)61272-5
38. Kleinert S, Horton R. Rethinking and reframing obesity. *Lancet.* (2015) 385:2326–8. doi: 10.1016/S0140-6736(15)60163-5
39. Garside R, Pearson M, Hunt H, Moxham T, Anderson R. *Identifying the Key Elements and Interactions of a Whole System Approach to Obesity Prevention*. Exeter: Peninsula Technology Assessment Group (PenTAG) (2010).
40. Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. *Lancet.* (2019) 393:447–92. doi: 10.1016/S0140-6736(18)31788-4
41. World Health Organisation Europe. *Digital Food Environments: Factsheet 2021*. (2021). Available online at: https://www.euro.who.int/en/health-topics/disease-prevention/nutrition/publications/2021/digital-food-environments-factsheet-2021
42. Bonyhardy NW, Shane E. *The Right Thing To Do: Menulog's Move to Employ Couriers Ups Pressure on Gig Economy*. Sydney Morning Herald (2021).
43. Corlett E. *New Zealand Uber Drivers Launch Class Action Against Ride Share Company*. Wellington: The Guardian (2021).
44. Moreno C, Allam Z, Chabaud D, Gall C, Pratlong F. Introducing the "15-minute city": sustainability, resilience and place identity in future post-pandemic cities. *Smart Cities.* (2021) 4:93–111. doi: 10.3390/smartcities4010006
45. Willsher K. *Paris Mayor Unveils '15-Minute City' Plan in Re-election Campaign*. Paris: The Guardian. (2020).
46. Grodach C, Kamruzzaman L, Harper L. *20-Minute Neighbourhood - Living Locally Research*. Melbourne, VIC: Monash University (2019).
47. Weng M, Ding N, Li J, Jin X, Xiao H, Zhi-ming H, et al. The 15-minute walkable neighborhoods: measurement, social inequalities and implications for building healthy communities in urban China. *J Transport Health.* (2019) 13:259–73. doi: 10.1016/j.jth.2019.05.005
48. Land Transport Authority Singapore. *Land Transport Master Plan 2040*. Singapore: Land Transport Authority (2020).
49. City of Portland. *20-Minute Neighbourhoods Portland, United States of America.* (2021). Available online at: https://www.portlandonline.com/portlandplan/index.cfm?a=288098&c=52256
50. Guzman LA, Arellana J, Oviedo D, Moncada Aristizábal CA. COVID-19, activity and mobility patterns in Bogotá. Are we ready for a '15-minute city'? *Travel Behav Soc.* (2021) 24:245–56. doi: 10.1016/j.tbs.2021.04.008
51. World Health Organisation. *Monitoring Food and Beverage Marketing to Children via Television and the Internet. A Proposed Tool for the WHO European Region*. Copenhagen: WHO Regional Office for Europe (2016).
52. Sweney M. *UK to Ban Junk Food Advertising Online and Before 9pm on TV from 2023*. London: The Guardian (2021).
53. Wyse R, Delaney T, Stacey F, Zoetemeyer R, Lecathelinais C, Lamont H, et al. Effectiveness of a multistrategy behavioral intervention to increase the nutritional quality of primary school students' web-based canteen lunch orders (click & crunch): cluster randomized controlled trial. *J Med Internet Res.* (2021) 23:e26054. doi: 10.2196/26054
54. Coles J. *Calorie-Labelled Menus Set for Cafes, Restaurants and Takeaways in England*. Available online at: https://www.mirror.co.uk/news/uk-news/calorie-labelled-menus-set-cafs-24095206 (accessed May 12, 2021).
55. Global Ecolabelling Network. *What is Ecolabelling?* (2021). Available online at: https://globalecolabelling.net/what-is-eco-labelling/#:$\sim$:text=Ecolabelling%20is%20a%20voluntary%20method,preferable%20within%20a%20specific%20category
56. Potter C, Bastounis A, Hartmann-Boyce J, Stewart C, Frie K, Tudor K, et al. The effects of environmental sustainability labels on selection, purchase, and consumption of food and drink products: a systematic review. *Environ Behav.* (2021) 53:891–925. doi: 10.1177/0013916521995473
57. Coelho PM, Corona B, ten Klooster R, Worrell E. Sustainability of reusable packaging-Current situation and trends. *Resour Conserv Recycl X*. (2020) 6:100037. doi: 10.1016/j.rcrx.2020.100037
58. Halloran A, Faiz M, Chatterjee S, Clough I, Rippin H, Farrand C, et al. The cost of convenience: potential linkages between noncommunicable diseases and meal delivery apps. *Lancet Region Health Eur.* (2022) 12:100293. doi: 10.1016/j.lanepe.2021.100293
59. Fanzo J, Haddad L, McLaren R, Marshall Q, Davis C, Herforth A, et al. The Food Systems Dashboard is a new tool to inform better food policy. *Nature Food.* (2020) 1:243–6. doi: 10.1038/s43016-020-0077-y

60. INFORMAS G, Institute for Health Transformation, Deakin University, The University of Queensland, University of Wollongong, The University of Newcastle, The George Institute for Global Health, Obesity Policy Coalition, VicHealth. *Australia's Food Environment Dashboard.* (2021). Available online at: https://foodenvironmentdashboard.com.au/

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers in Nutrition

REVIEW
published: 16 March 2022
doi: 10.3389/fnut.2022.817808

Unhealthy Dietary Habits and Obesity: The Major Risk Factors Beyond Non-Communicable Diseases in the Eastern Mediterranean Region

Ayoub Al-Jawaldeh[1] *and Marwa M. S. Abbass*[1,2]*

[1] World Health Organization (WHO), Regional Office for the Eastern Mediterranean (EMRO), Cairo, Egypt, [2] Oral Biology Department, Faculty of Dentistry, Cairo University, Cairo, Egypt

There are 22 countries in the Eastern Mediterranean Region (EMR) expanding from Morocco in the west to Pakistan and Afghanistan in the east, containing a population of 725,721 million in 2020. In the previous 30 years, the illness burden in the EMR has transmitted from communicable diseases to non-communicable diseases such as diabetes, cardiovascular diseases, and cancer. In 2019, cardiovascular mortality in the EMR was mostly attributed to ischemic heart disease, the first reason for mortality in 19 countries in the region. Stroke was the second reason for death in nine countries followed by diabetes, which was ranked as the second reason for death in two countries. The prominent nutrition-related NCDs risk factors in EMR include obesity, hypertension, high fasting plasma glucose, and upregulated unhealthy diet consumption. Most of the EMR population are unaware of their NCDs risk factor status. These risk factors, even if treated, are often poorly controlled, therefore, inhibiting their existence by changing the lifestyle to proper dietary habits and sufficient physical activity is mandatory. In this review, the epidemiology and nutrition-related risk factors of NCDs in the EMR will be discussed and illustrated, aiming to scale up action and support decision-makers in implementing cost effective strategies to address obesity and NCDs prevention and management in the region.

Keywords: NCDs, unhealthy diet, obesity, risk factors, EMR

OPEN ACCESS

Edited by:
Reema Fayez Tayyem, Qatar University, Qatar

Reviewed by:
Radwan Qasrawi, Al-Quds University, Palestine
Jagmeet Madan, SNDT Women's University, India

***Correspondence:**
Marwa M. S. Abbass
marwa.magdy@dentistry.cu.edu.eg

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *18 November 2021*
Accepted: *11 January 2022*
Published: *16 March 2022*

Citation:
Al-Jawaldeh A and Abbass MMS (2022) Unhealthy Dietary Habits and Obesity: The Major Risk Factors Beyond Non-Communicable Diseases in the Eastern Mediterranean Region. Front. Nutr. 9:817808. doi: 10.3389/fnut.2022.817808

INTRODUCTION

The Eastern Mediterranean Region (EMR) encompasses 22 countries including [Afghanistan, Bahrain, Djibouti, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Pakistan, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates (UAE), and Yemen], with a population of ∼725,720 million (1).

In the past three decades, similar to other developing regions in the world, the EMR has undergone a transmission in the disease burden from primarily communicable disorders, such as lower respiratory infections, to non-communicable diseases (NCDs). NCDs include cardiovascular diseases, cancer, diabetes, and chronic respiratory diseases. In 2012, the rate of death from NCDs in the EMR (654 per 100,000 persons) was higher than the global rate (539 per 100,000 persons) and

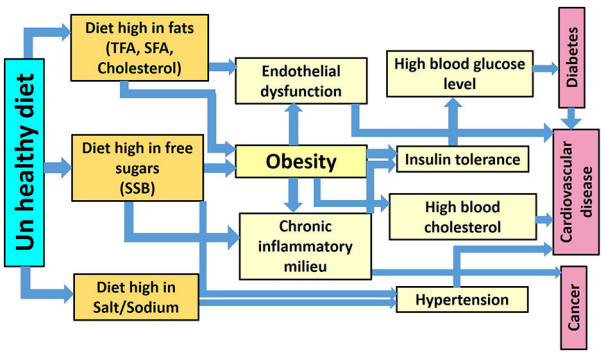


FIGURE 1 | The interdisciplinary relationship between unhealthy diet consumption, obesity, and other NCDs risk factors.

is expected to peak by 2030. In 2015, nearly 58.4% of total deaths in the EMR were due to NCDs, with the chief cause being CVDs (27.4% of total deaths) (2, 3).

NCDs are the essential global cause of death and are responsible for over 70% of deaths worldwide (3). NCDs were responsible for 41 million of the 57 million fatalities worldwide, 15 million of which were premature (30–70 years). The burden is the greatest among low- and middle-income countries, where 78% of global NCDs fatalities and 85% of premature deaths took place (4). Moreover, globally, NCDs were responsible for 1.62 billion DALYs in 2019, with an increase from 43.2% in 1990 to 63.8% in 2019 (5). In 2019, the number of fatalities in EMR due to CVDs was 1,464,672 million, 431,312 thousand individuals died from cancer, and 186,841 thousand died from diabetes (6).

The NCDs share the key four modifiable behavioral risk factors including tobacco usage, unhealthy diet, physical inactivity, and excessive use of alcohol, these factors, in turn, lead to nutritional- physiological related risk factors including overweight/obesity, raised blood pressure, high fasting blood glucose, and high blood cholesterol. The relationship between NCDs and the risk factors involved in their incidence is intermingled and the risk factors are also associated with each other (**Figure 1**). It is noteworthy that the behavioral risk factors linked with NCDs are closely related to the demographic and socioeconomic status (SES) in the region (7).

Despite NCDs being a critical health obstacle in all EMR countries, tackling NCDs and their key risk factors requires an imperative understanding of the current status and progress at the country and region level. This review discusses nutrition-related NCDs burden and the associated risk factors in the EMR. The current challenges and areas requiring further attention will be also highlighted.

METHODOLOGY

In this paper, the prevalence of NCDs and the associated nutrition-related risk factors in the WHO-EMR are discussed and illustrated. Data for the prevalence of CVDs, diabetes, and cancer as well as different risk factors including overweight/obesity, raised blood pressure, high fasting blood glucose, and high blood cholesterol in the WHO –EMR are summarized. Age-standardized estimates were obtained from the NCDs Risk Collaboration, which in turn, are based on data provided to WHO and the NCDs Risk Factor Collaboration or obtained through a literature review (8). For those estimates, adjustments had been made to standardize risk factor definition, age groups, reporting year, and representativeness of the population. Age-standardized prevalence estimates were calculated to adjust for differences in age/sex structure between populations and to enable comparisons between countries (8). The definition of being overweight or having obesity was used for people with a BMI of 25 kg/m^2 or higher and a BMI of 30 kg/m^2 or higher, respectively.

Data regarding the number of deaths and probability of death attributed to CVDs, diabetes, and cancer among adults in EMR were obtained from the global health observatory (9). Raised fasting blood glucose, raised blood pressure, and diabetes prevalence in EMR was also obtained from the global health observatory (6). Cancer trends in EMR data including the number of cancer cases, cancer rates/100,000 (Age-standardized) as well as cumulative cancer risk were obtained from the Global Cancer Observatory (9). Data regarding the food consumption in EMR were collected from the FAO food balance sheets (10). Concerning estimated sodium intakes (g/day) for persons aged 20 and over data were attained from the systematic analysis of 24 h urinary sodium excretion and dietary surveys worldwide (11). Data relating to the mean salt intake for adults (g/day) were obtained from the non-communicable diseases country profiles (4). Saturated fat (% energy), Omega-6 PUFA (% energy), Trans fat (% energy), Dietary cholesterol (mg/d), Seafood omega-3 fat (mg/d), and Plant omega-3 fat (mg/d) data were obtained from the systematic analysis nutrition surveys including 266 countries (11). Data relating to sugar-sweetened beverage consumption in EMR were harvested from a systematic assessment of beverage intake in 187 countries (12).

The data from the Global Burden of Disease Study 2019 presented in this review included the rank of the nutrition related risk factors that caused deaths in EMR countries in 2019 as well as the percentage change in these risk factors between 2009 and 2019 (13).

The policies relating to actions to reduce NCDs in EMR, as well as the policies associated with healthy diets in the countries of the WHO-EMR, are tabulated. Data have been extracted from various sources. These include the WHO's global (6) and regional health observatories (14), data collected for the second WHO Global Nutrition Policy Review 2016–2017 (15), the WHO Global Database on the Implementation of Nutrition Action (GINA) (16), communication about country-level action from WHO country offices and national government nutrition focal points, and other relevant academic papers (17–20). Specifically, data were collected on the policy areas related to a healthy diet that features in the new regional nutrition strategy (21).

Data are presented in narrative or tabular form. To group countries according to the income level, the World Bank classification was used to identify the income level of each country (22). The low-income group includes Afghanistan,

Somalia, Sudan, Syria, and Yemen. The lower middle-income group includes Djibouti, Egypt, Morocco, Pakistan, Tunisia, and the occupied Palestinian Territory. The upper middle-income group includes: Iran, Iraq, Jordan, Lebanon, and Libya. The high-income level includes: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and United Arab Emirates (UAE).

RESULTS

Nutrition Related Non-Communicable Diseases

Cardiovascular Diseases

Worldwide, in 2019, cardiovascular diseases were responsible for 393 million DALYs and 18.6 million deaths in both sexes (23). In EMR, the high number of NCDs deaths was attributed to CVDs (1,464,672 million) in 2019. Pakistan recorded the highest number (449,905) followed by Egypt (252,650), Iran (157,018) then Morocco (126,562) (6) (**Table 1**).

Diabetes, smoking, high blood pressure, high BMI, stress, high cholesterol levels, poor nutrition, and insufficient physical exercise are all considered risk factors responsible for the incidence of CVDs (24). According to Franklin and Wong, hypertension is the main cause of cardiovascular disease, which worsens with age and may be the world's leading cause of mortality (25).

A cross-sectional study conducted among the local population of 53 cities in Punjab, Pakistan, reported that CVDs impacted 17.5% of the population, with females having a higher incidence rate than males and start occurring at a younger age. An inactive lifestyle, low level of activity and family history of disease could be disease risk factors (26). CVDs are also responsible for 40% and 37% of deaths in Egypt and Saudi Arabia, respectively. A comparative cross-sectional study involved students from two medical of both sexes from Saudi Arabia and Egypt revealed a relatively high prevalence of a sedentary life style, obesity, and abdominal obesity. Saudi students revealed a significantly higher prevalence of obesity while male Egyptian students recorded a significantly higher prevalence of hypertension. Both populations were at an elevated risk of acquiring fatal cardiovascular disease within 10 years (23.9% of Saudi students and 16.7% of Egyptian students) (27). In Iran despite the slight recession in the number of smokers, total cholesterol, and blood pressure, adverse trends in physical activity, unhealthy diet, obesity, and fasting plasma glucose must be addressed immediately at a public health level in order to battle the advancement of CVDs (28).

According to the Global Burden of Disease Study 2019, ischemic heart disease is the most common reason for death in EMR and it is the first reason for death in 19 countries in EMR (Afghanistan, Bahrain, Egypt, Iran, Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Sudan, Syrian Arab Republic, Tunisia, United Arab Emirates, and Yemen) (13). Globally, on concomitant ischemic heart disease was the leading cause of death in people aged between 30 and 70 years in 146 (83%) countries for men and 98 (55.7%) for women. For men, the risk reached as high as 20% and for women as high as 13% in some countries. Other regions that suffer from this high risk of dying from ischemic heart disease were eastern Europe, central Asia, and south Asia (29). The highest increase in the ischemic heart disease percentage between 2009 and 2019, in the EMR, was reported in UAE (130.6%) followed by Jordan (86.3%) then Djibouti (67.9 %) and Egypt (62.9 %). Stroke is the second reason for death in nine countries (Iraq, Jordan, Kuwait, Lebanon, Libya, Morocco, Palestine, Syrian Arab Republic, and Tunisia). The highest increase in stroke percentage between 2009 and 2019, was reported in UAE (105.2%) followed by Jordan (78.5%) then Djibouti (52.7%) (13).

Diabetes Mellitus

In 2019, diabetes mellitus caused 70.9 million (2.8%) of total global DALYs (30). 9.3 percent (463 million people) was the conservative estimate for the prevalence of diabetes in 2019 which is expected to rise by 2030 to 10.2% (578 million) and by 2045 to 10.9% (700 million). The prevalence is higher in urban (10.8%) than rural (7.2%) areas, and in high-income (10.4%) than low-income countries (4.0%). Nearly, half of people (51%) living with diabetes are not aware of that they are diabetics. Impaired glucose tolerance affected 7.5% of the world's population (374 million) in 2019, rising to 8.0% (454 million) by 2030 and 8.6% (548 million) by 2045 (31). Notably, in 2019 the prevalence of diabetes was the highest in the EMR (11.96%) compared with all other regions. Sudan, Qatar, Iran, Bahrain, Somalia, and Djibouti revealed the highest percentage of Diabetes among individuals aged 20–80 years (22.1, 19.9, 17.2, 16.3, 15.8, and 15.6%, respectively) (32) (**Table 2**; **Figure 2**).

In EMR, the total number of fatalities due to diabetes was 186,841 thousand in 2019. Pakistan recorded the highest number (80,976) followed by Egypt (26,844), Iran (157,018) then Morocco (17,947) (6) (**Table 1**). According to the 2019 Global Burden of Disease Study, diabetes is the second cause of death in two countries (Bahrain and Jordan) and the third reason for death in three countries (Iraq, Palestine, and Qatar) in the region. The highest increase in diabetes percentage between 2009 and 2019 in EMR was reported in UAE (124.2%) followed by Palestine (89.1%) then Bahrain (88.1%), Iran (80.8%), and Jourdan (69.7%) (13).

The mortality rate due to diabetes in Bahrain was 14% in 2016. A cross sectional study reported that type 2 diabetes exerts a significant pressure on Bahrain's healthcare system—primarily due to costly diabetes-related complications. Thereby, reducing the risk factors for diabetes is mandatory to minimize disabling and expensive complications (33). Additionally, multivariate analysis for a wide community-based survey in Pakistan using glycated hemoglobin revealed a significant link between type 2 diabetes and old age. Increase in body mass index, central obesity, positive family history, and having hypertension with type 2 diabetes were inversely related to education (34).

Egypt has been identified by the International Diabetes Federation as the ninth leading country in the world for the number of type 2 diabetes patients. The frequency of type 2 diabetes has nearly tripled in the last two decades in Egypt. This dramatic increase could be due to an increase in the typical risk factors for type 2 diabetes, such as obesity and physical inactivity, as well as a shift in dietary habits, or to other risk factors specific

TABLE 1 | Number of deaths and probability of death attributed to CVDs, diabetes, and cancer among adults in EMR (6).

	Number of deaths attributed to CVDs			Number of deaths attributed to diabetes			Number of deaths attributed to cancer			Probability of dying from any NCDs between (30–70)			Probability of death due to CVDs	Probability of death due to cancer	Probability of death due to diabetes
	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Males	Females	Both	Both	Both
	2019			2019			2019			2019				2016	
Afghanistan	71,264	33,793	37,471	8,060	2,612	5,448	15,565	7,756	7,809	35.27	34.37	36.16	21.00	8.00	3.00
Bahrain	1,450	913	537	820	485	336	640	336	303	16.06	16.38	15.43	28.00	16.00	14.00
Djibouti	1,730	913	817	345	196	150	508	206	302	22.01	23.43	20.6	19.00	7.00	2.00
Egypt	252,650	135,587	117,063	26,844	12,863	13,981	85,226	46,452	38,774	28.03	32.74	23.22	40.00	13.00	3.00
Iran	157,018	90,226	66,793	17,947	9,008	8,940	61,063	36,388	24,676	14.80	17.57	11.96	43.00	16.00	4.00
Iraq	62,913	33,304	29,609	9,762	4,731	5,031	15,004	7,594	7,409	23.55	27.52	19.99	27.00	11.00	4.00
Jordan	9,739	4,732	5,007	2,253	1,027	1,227	6,075	3,260	2,815	15.30	17.03	13.57	37.00	12.00	6.00
Kuwait	3,315	2,855	460	321	232	90	1,815	981	835	11.89	13.76	8.03	41.00	15.00	3.00
Lebanon	17,544	10,392	7,151	1,352	783	569	9,078	4,858	4,220	19.87	24.18	15.21	47.00	16.00	5.00
Libya	10,717	5,188	5,530	1,234	514	719	3,557	1,993	1,564	18.59	19.7	17.56	35.00	12.00	4.00
Morocco	126,562	60,732	65,830	10,851	4,346	6,505	33,845	19,293	14,552	24.13	25.97	22.25	38.00	14.00	6.00
Oman	7,848	4,551	3,296	1,143	643	500	1,750	1,131	619	21.48	22.46	20.26	36.00	11.00	8.00
Pakistan	449,905	245,135	204,770	80,976	37,892	43,084	124,328	64,049	60,279	29.41	31.84	26.85	29.00	8.00	3.00
Qatar	1,487	926	561	526	291	235	716	467	248	10.74	10.08	13.24	27.00	16.00	9.00
Saudi Arabia	60,291	38,233	22,058	7,203	4,311	2,892	10,615	6,176	4,438	20.90	22.36	18.44	37.00	10.00	3.00
Somalia	20,301	11,759	8,542	3,475	2,107	1,368	8,335	3,109	5,226	30.41	34.02	26.72	10.00	4.00	1.00
Sudan	76,772	38,548	38,223	4,597	2,096	2,502	17,892	7,646	10,246	22.80	24.34	21.36	28.00	6.00	2.00
Syria	39,037	19,188	19,849	2,247	953	1,294	13,742	6,803	6,939	22.11	26.07	18.31	25.00	9.00	1.00
Tunisia	33,906	17,334	16,572	2,550	1,186	1,364	10,246	6,150	4,095	15.73	19.16	12.38	44.00	12.00	5.00
UAE	7,579	6,121	1,459	1,707	1,312	396	2,103	1,089	1,014	18.50	19.8	15.49	40.00	12.00	5.00
Yemen	52,644	27,059	25,585	2,627	1,114	1,512	9,210	4,300	4,910	27.60	30.64	24.76	33.00	6.00	2.00

TABLE 2 | Obesity, raised fasting blood glucose, raised blood pressure, diabetes prevalence, and cancer trends in EMR (6).

	Diabetes (%) Age 20–79	Cancer cases (*N*)	Cancer Rates/ 100,000 (Age St.)	Cumulative cancer risk	Obesity prevalence among adults, BMI ≥30 (Age St.) (%)			Hyper-tension (%) (Age St.)	Raised blood pressure (SBP ≥ 140 Or DBP ≥ 90)	Raised fasting blood glucose (≥7.0) mmol/L	Mean total cholesterol (Age St.)			Mean non-HDL cholesterol (Age St.)
	Both 2019	Both 2020	Both 2020	Both 2020	Both 2016	M 2016	F 2016	Both 2019	Both 2015	Both 2014	Both 2018	M 2018	F 2018	Both 2018
Afghanistan	9.2	20,975	175.4	20	5.5	3.2	7.6	33.7	30.6	11.9	4.1	4.0	4.2	3
Bahrain	16.3	1,177	180.6	26.66	29.8	25.5	36.8	28.6	21.4	11.5	4.5	4.5	4.6	3.3
Djibouti	15.6	737	146.6	15.21	13.5	8.6	18.3	24.1	26.8	8.1	4.2	4.1	4.3	2.8
Egypt	5.1	129,577	258	31.39	32	22.7	41.1	33.3	25	17.9	4.4	4.2	4.5	3.3
Iran	17.2	127,548	245.2	35.6	25.8	19.3	32.2	23.6	19.7	12.1	4.4	4.3	4.5	3.1
Iraq	9.6	31,801	217.6	25.86	30.4	23.4	37	40.7	25.2	17.4	4.7	4.6	4.7	3.4
Jordan	8.8	11,107	251.8	29.63	35.5	28.2	43.1	33.2	21	16.8	4.8	4.7	4.9	3.5
Kuwait	12.7	3,716	185.3	27.97	37.9	33.3	45.6	33.5	23.6	19.6	4.8	4.8	4.9	3.5
Lebanon	12.2	11,287	252.5	30.53	32	27.4	37	32.2	20.7	13.4	5.0	5.0	5.0	3.7
Libya	11.2	7,388	212.8	28.17	32.5	25	39.6	34.2	23.7	15.9	4.3	4.2	4.4	3
Morocco	10.2	57,772	238.8	26.96	26.1	19.4	32.2	29.5	26.1	13.7	4.1	4.0	4.2	2.8
Oman	7	3,557	165.4	17.58	27	22.9	33.7	38.6	24.8	13.5	4.6	4.6	4.7	3.4
Pakistan	10.1	170,668	178.7	19.81	8.6	6	11.3	34.2	30.5	12.4	4.2	4.1	4.3	3.1
Qatar	19.9	1,435	172.2	28.55	35.1	32.5	43.1	31.1	22.4	18.9	4.3	4.3	4.5	2.9
Saudi Arabia	15.6	26,505	152.1	20.13	35.4	30.8	42.3	31.9	23.3	17.4	4.6	4.5	4.6	3.3
Somalia	15.8	9,140	189.7	20.24	8.3	3.9	12.3	27.1	32.9	6.8	4.2	4.1	4.3	3.1
Sudan	22.1	25,347	153.4	17.85	8.6	3.8	12.4	27.4	30.2	8.9	4.1	3.9	4.3	3
Syria	5.1	20,193	241.5	28.61	27.8	20.9	34.8	33.5	24.5	14.6	4.5	4.5	4.6	3.3
Tunisia	13.5	19,031	214.9	28.05	26.9	19.1	34.3	32.1	23.2	12.5	4.3	4.1	4.5	3
UAE	8.5	4,611	170.7	28.49	31.7	27.5	41	27.7	21.1	15.1	4.6	4.5	4.7	3.4
Yemen	5.4	14,848	154.4	21.81	17.1	12	22	34.8	30.7	11.3	4.5	4.4	4.6	3.4

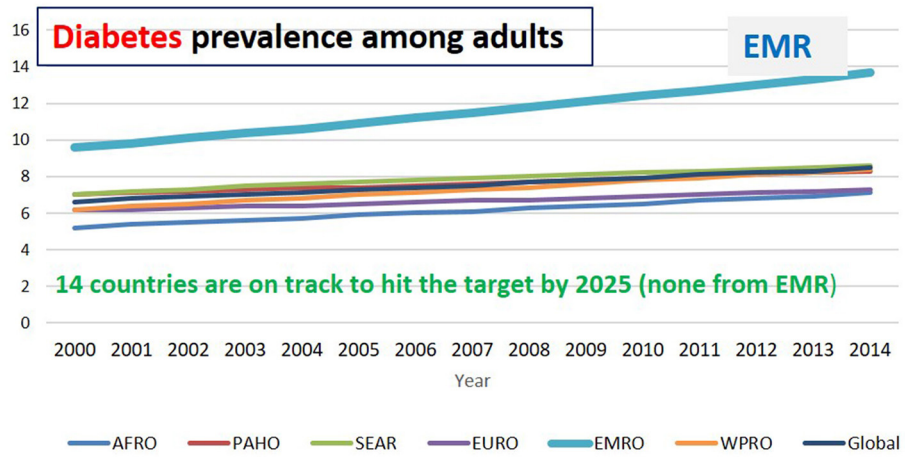


FIGURE 2 | Diabetes prevalence among adults in different regions (6).

to Egypt. Increased exposure to environmental risk factors such as pesticides and a higher prevalence of chronic hepatitis C are two examples (35).

In a population-level mathematical model among Qatari, the baseline scenario revealed that type 2 diabetes prevalence would be upregulated from 16.7% in 2016 to 24.0% in 2050. By lowering obesity prevalence by 10–50%, type 2 diabetes prevalence would reduced by 7.8–33.7%, while by reducing physical inactivity prevalence by 10–50%, type 2 diabetes prevalence would reduced by 0.5–6.9% by 2050 (36).

Cancer

Globally in 2019, total cancers recorded 23.6 million incident cases, 10.0 million deaths, and 250 million DALYs. Total cancers were the second-ruling reason for death and DALYs in 2019 worldwide (13). Globally in 2020, an estimated 19.3 million new cancer cases (18.1 million excluding non-melanoma skin cancer) and almost 10.0 million cancer deaths (9.9 million excluding non-melanoma skin cancer) occurred (37). According to long-term projections, the EMR countries will suffer from a disturbing rise in the number of cancer patients reaching a 1.8 fold by 2030 (38). The highest number of cancer cases in EMR in 2020 has been recorded in Pakistan (170,668) thousand individuals followed by Egypt (129,577), then Iran (127,548) (9) (**Table 2**). Bahrain, Qatar, Iran, and Lebanon reported a 16% mortality rate due to cancers, Kuwait reported 15% while Egypt reported 13% (4).

Bahrain, which is among the high income gulf countries, suffers from a rising burden of cancer (39, 40). Breast, colorectal, and lung cancers, followed by non-Hodgkin lymphoma and leukemia, are the five most frequently diagnosed cancers in Bahrain (41). Obesity, smoking, a sedentary lifestyle, and a high-fat/low-fiber diet are among the significant risk factors for colorectal cancer in Bahrain. Nearly one-third of the population of Bahrain is overweight or obese (42, 43).

A systematic review investigating the epidemiological aspects of gastric cancer in Iran based on articles published during the years 1970–2020 showed that poor levels of economic position and food insecurity raised the probabilities of stomach cancer by 2.42- and 2.57-times, respectively. Moreover, there was a link between dairy products, processed red meat, fruit juice, legumes, smoked and salty fish, salt, strong as well as hot tea consumption with the risk of stomach cancer. There was also an inverse link between fresh fruit, citrus, and garlic consumption and stomach cancer (44).

The global age-standardized rate as reported by the American Institute for Cancer Research, 2018 for all cancers (including non-melanoma skin cancer) for both genders was 197.9 per 100,000 in 2018. Men revealed a higher rate (218.6 per 100,000) than women (182.6 per 100,000) (45). Most of the EMR countries revealed a relatively high rate of cancer incidence as nine countries in the region have cancer rates of more than (200 per 100,000). The highest cancer rates as revealed in 2020 have been reported in Egypt (258 per 100,000) followed by Lebanon (252.5 per 100,000) then Jordan (251.8 per 100,000) then Iran (245.2 per100,000) followed by Syria (241.5 per 100,000), and then Morocco (238.8 per 100,000) (9) (**Table 2**).

In EMR, the total number of fatalities due to cancer (431,312) in 2019. Pakistan recorded the highest number (124,328) followed by Egypt (85,226), Iran (61,063), then Morocco (33,845) (6) (**Table 1**). By 2050, a three-fold increase in cancer incidence relative to 2013 was estimated to occur in Egypt (46). The highest increase in cancer percentage between 2009 and 2019 in EMR was reported in the UAE (241.7% increase in pancreatic cancer) followed by Jordan and Qatar (103.7 and 95.2%, respectively increase in lung cancer) (13).

Risk Factors Burden

A dramatic increase in NCDs-related risk factors has been reported in the EMR in the past 10 years (13). The risk factors of NCDs comprise metabolic-physiological-related conditions (including obesity, high blood pressure, high fasting plasma glucose, high blood cholesterol) as well as behavioral-related activities (including smoking, low physical activity, unhealthy

diet consumption, excessive use of alcohol). An analytic review published in 2019 reported that individuals who followed healthy lifestyle practices including regular physical activity, sound nutrition, weight management, and non-smoking revealed a significant downregulation of CVDs risk by >80% and diabetes by >90% (47). Additionally, another study outlined that around 40% of cancer cases could be prevented by reducing exposure to cancer risk factors including diet, nutrition, and physical activity (45).

Dietary Risks or Unhealthy Diet Consumption

Dietary risk is defined as eating a diet low in whole grains, nuts, seeds, fruit, vegetables, fibers, legumes, omega-3 fatty acids, PUFA, milk, and calcium as well as a diet high in sodium, trans fats, red or processed meat, and sugar-sweetened beverages (SSB). Globally in 2019, dietary risks were responsible for 188 million DALYs and 7.94 million deaths among adults aged 25 and older. It was the fifth-ruling risk factor for attributable DALYs (48). Dietary risk is the third risk factor in Syria and the fourth risk factor in 6 countries in the EMR (Afghanistan, Morocco, Oman, Pakistan, KSA, and Yemen) responsible for the most deaths and disabilities. The highest increase in dietary risk percentage between 2009 and 2019 in EMR was reported in UAE (136.9%), followed by Jordan (84.7%) then Qatar (66.8%) (13), as shown in **Table 5**.

Fruits and Vegetables

An adequate daily intake of fruits and vegetables is associated with reduced risks of CVDs (49), stroke (50), type 2 diabetes (51), and certain types of cancer (52, 53), which are the major causes of mortality and morbidity in the EMR. The 2002 Joint FAO/WHO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases recommends a minimum of 400 g per day of fruits and vegetables, an equivalent of ≥5 servings of fruits and vegetables per day, excluding starchy roots (54).

In 2013, the rate of fruits and vegetables intake among individuals living in the EMR was 280 g per day, which is lower than WHO recommendation for the prevention of NCDs. Furthermore, it has been reported that the mean daily intake of fruits in the Middle East and North Africa region was <130 g per day, and the mean intake of vegetables was less than 200 g per day (2). According to the food balance sheets 2019, the mean fruits and vegetables intake among EMR countries is 32 kg/capita/year (10), see **Table 3**. It is noteworthy, that data concerning fruits and vegetables intake in EMR are limited.

Most individuals living in the EMR have an insufficient intake of fruits and vegetables. It has been established that only 7.3% of individuals from Saudi Arabia aged 15–64 years were consuming the WHO-recommended five servings of fruits and vegetables per day and only 2.6% met the CDC guidelines for daily consumption of fruits and vegetables (55). In a more recent cross-sectional study conducted on 1,437 individuals, aged ≥ 18 years, 88% of the subjects recorded low intake of fruits and vegetables with a significant increase in fast food consumption (56). The relationship between food consumption patterns and expenditure was investigated in village Kabal in rural areas of Pakistan, using a sample size of 100 households. The study outlined that an adult consumes nearly 74.68 g of meat, 166.34 g of milk, 372.51 g of flour, 70.29 g of rice, 28.31 g of pulses, 177.12 g of vegetables, 66.39 g of fruits, 6.76 g of black tea, 53.60 g of fats, and 73.21 g of sugar daily (57). Furthermore, an assessment of fruits and vegetables consumption among 473 medical students in Egypt outlined that 8.2% of students knew the recommended five daily servings for fruits and vegetables, and 23.26% consumed the five daily servings. Healthy food items were tried by only 35.7% of students (58).

Fat Consumption

Fat consists of trans-fatty acids (TFAs), saturated fatty acids (SFA), and unsaturated fatty acids (59). Saturated fatty acids can be found in animal products like milk, butter, cheese, as well as most plant oils, particularly palm and coconut oil, which are high in SFA. Lauric acid, myristic acid, and palmitic acid (PA) are all major sources of SFA, and they all raise low-density lipoprotein cholesterol (LDL-c) (60). Increased inflammation, oxidative stress, and decreased nitric oxide and insulin signaling is some of the impacts of PA, which is found in palm oil (61, 62). The American Heart Association recommends a healthy dietary pattern that achieves 5–6% of calories from saturated fat (about 13 g of saturated fat per day). In EMR, three countries have exceeded 13% of energy from saturated fats, Djibouti (15.2% of energy) followed by Yemen (13.9% of energy), and KSA (13.5% of energy) (63) (see **Table 4**). In Saudi Arabia, a significant positive association was found between the intake of fats, protein, and calories and the risk of breast cancer. Adjusted odds ratios for the highest quartile of intake versus the lowest were 1.88 for cholesterol, 2.12 for polyunsaturated fat, 2.25 for animal protein, 2.43 for saturated fat, and 2.69 for total energy from dietary intake (64).

A diet high in trans-fatty acids is defined as any intake (in percentage daily energy) of trans fat from all sources, primarily partially hydrogenated vegetable oils and ruminant products. TFAs are typically found in processed food, fast food, snack food, fried food, pies, cookies, margarine, and spreads (59). In 2019, a diet high in TFAs was responsible for 14.2 million DALYs and 645,000 deaths. It was the seventh-ruling dietary risk factor for attributable DALYs (65).

The consumption of TFAs increases the risk of death from any cause by 34% and coronary heart disease by 28% (66). An increase in coronary heart disease mortality estimated by 12% occurs as a result of every 1% increase in daily energy obtained from TFAs (67). Industrial TFAs intake has also been related to an increased risk for other NCDs and associated conditions such as ovarian cancer (68), infertility, endometriosis, Alzheimer's disease, diabetes, and obesity (59, 69). Higher consumption of hydrogenated vegetable oils was associated with an increased risk of myocardial infarction in a cohort study conducted among an Iranian population (70).

Despite WHO recommendations that total trans fat intake should not exceed 1% of total energy intake, which translates to >2.2 g/day for a 2,000-calorie diet (71), in 2010, four countries in the region have exceeded this level (Iran, Bahrain, Pakistan,

TABLE 3 | Food consumption in EMR (2019) (10).

	Legume	Eggs	Fruits and vegetables		Fish		Meat	Milk	Dietary oils and fats										Carbohydrates				Honey, sugar and sweeteners		
	Beans	Eggs	Vegetables	Fruits	Fresh water fish	Marine fish			Fats, animals	Nuts	Butter	Coconut oil	Olive oil	Cotton seed oil	Palm oil	Sesame oil	Soybean oil	Sunflower oil	Potatoes	Rice	Sweet potatoes	Wheat	Honey	Sugar raw	sweeteners
Afghanistan		0.82	54.58	6.64	0.24		0.31	38.04	0.23	1.44	1.06	0.01	0.02	0.1	4.46	0.04	0.29	1.47	25.7	15.16	0	161.9	0.04	17.08	0.54
Bahrain																									
Djibouti	1.97	0.98	47.51	12.83	0.02	0.27	0.72	19.58	0.48	0.04	0.15	0.18	0.15		9.6	0	0.83	0.58	16.65	49.38	0	121.8	0.02	41.18	3.46
Egypt	0.5	2.85	66.16	24.01	13.55	0.14	0.8	24.8	0.22	0.39	1.31	0.05	0.12	0.01	0		3.23	2	28.38	50.92	2.97	145.9	0.03	25.89	0.73
Iran	1.57	8.33	69.35	54.69	5.86	0.39	0.09	23.24	0.18	9.81	2.7	0.09	0.14	0.02		0.17	6.38	4.68	31.1	40.29		156	0.86	27.22	3.64
Iraq	1.63	10.16	54.75	22.24	2.4	0.13	0.03	26.22	0.18	1.32	0.24	0.02	0.05	0.01	4.25	0.12	1.13	6.97	18.08	50.89	0	135.8	0.02	17.3	3.69
Jordan	0.32	5.3	57.27	5	0.56	0.9	0.06	48.19	1.26	1.78	0.28	0.06	2.18		3.86	0.81	3.77	6.78	20.77	20.27	0.12	96.7	0.11	29.94	8.71
Kuwait	0.3	14.2	100.3	13.31	2.55	1.56	2.17	39.38	0.04	2.34	2.08		1.05	0.02	4.24	0.03	2.46	0.61	38.71	51.98	0.2	102.1	0.24	34.52	1.61
Lebanon	1.03	5.83	61.23	30.73	1.33	1.48	0	76.92	0.49	5.52	0.76	0	2.21	0.01		0.87	6.9	4.93	41.4	12.49	0.31	123.9	0.23	39.68	3.54
Libya	0.61	9.29	79.23	29.91	0.04	0.21	0.87	49.19	0.2	5.75	0.3	0.03	1.9	0.27	0	0	1.3	3.21	25.21	22.47	0	129.4	0.23	28.13	16.3
Morocco	0.12	8.69	58.54	23.48	0.49	1.05	1.9	25.42	0.55	3.23	1.42	0.01	4.02			0	6.04	1.52	41.34	2.1	0.21	176.9	0.18	33.51	0.84
Oman	0.25	8.99	103.53	45.59	0.47	3.04	2.8	86.64	0.76	1.23	0.9	0.18	0.04		6.03	0.03	0.56	1.08	21.27	51.13	0.03	74.9	0.38	20.66	10.21
Pakistan	0.97	3.47	13.7	23.02	1.23	0	0	113.6	0.93	0.31	5.21	0	0.01	0.27	4.08	0	1.2	0	14.74	19.73	0.07	103.9	0.02	21.06	0.3
Qatar																									
KSA	0.24	8.72	42.04	7.94	4.26	0.37	1.55	44.84	0.52	1.37	1.19	0.1	0.6	0.43	11.36	0.7	0.57	1.73	16.99	53.25	0.15	97.6	0.38	30.27	1.67
Somalia																									
Sudan	0.18	1.36	27.51	20.64	0.97	0.05	3.41	92.57	0.61		0.01	0	0.01	0.29	0.58	0.54	0	2.18	9.31	1.23	5.57	61.6	0.02	28.21	0.44
Syria	0.29	9.43	76.79	20.65	0.41	0.04	0.13	82.76	0.99	6.73	0.5	0.06	5.94	0.1	0.31	0.17	1.68	7.2	26.91	10.46	0	132.9	0.13	20.91	13.75
Tunisia	0.43	7.15	159.76	30.3	0.28	0.43	0.28	91.32	0.64	6.47	0.82	0.28	3.92		2.77	0.02	3.85	1.35	29.09	1.53	0	198.5	0.29	33.06	0.76
UAE																									
Yemen	0.69	1.5	10.17	13.76			0.09	10.13	0.33	0.39	0.04	0.01	0.04	0.05	5.21	0.23	0.02	0.36	6.15	28.61	0.01	115.2	0.06	24.35	1.5

TABLE 4 | Salt, fat, and sugar-sweetened beverage consumption in EMR (4, 11, 12, 63).

	Salt						Dietary fats and oils						Sugar-Sweetened Beverages								
	Estimated sodium intakes (g/day) in 2010			Mean population salt intake, adults (g/day) in 2016			Saturated fat (% energy)	Omega-6 PUFA (% energy)	Trans fat fat (% energy)	Dietary cholesterol (mg/d)	Seafood omega-3 fat (mg/d)	Plant omega-3 fat (mg/d)	Mean juice intake (servings/day)			Mean SSB intake (servings/day)			Mean milk intake (servings/day)		
	Both	M	F	Total	Total	Total	Total	Total	Total	Total	Total	Total	F	M	Both	F	M	Both	F	M	Both
Afghanistan	3.39	3.55	3.22	9	8	9	10.8	4.6	1.3	212	30	665	0.03	0.02	0.03	0.34	0.37	0.36	0.36	0.34	0.35
Bahrain	5.38	5.57	5.05	14	13	14	8.9	6.4	3.2	245	52	1,451	0.26	0.22	0.24	0.50	0.53	0.51	0.79	0.70	0.75
Djibouti	2.36	2.48	2.24	6	6	6	15.2	3.7	0.7	213	13	640	0.02	0.02	0.02	0.75	0.81	0.78	0.49	0.45	0.47
Egypt	3.68	3.85	3.52	10	9	9	9.6	4.8	6.5	402	42	568	0.14	0.12	0.13	0.32	0.34	0.33	0.61	0.55	0.58
Iran	4.02	4.21	3.83	11	10	10	10.8	6.2	2.4	232	77	1,195	0.34	0.28	0.31	0.17	0.17	0.17	0.62	0.56	0.59
Iraq	3.76	3.95	3.59	10	9	10	10.3	4.4	1.7	288	50	922	0.14	0.11	0.13	0.37	0.40	0.38	0.52	0.44	0.48
Jordan	4.13	4.31	3.95	11	10	10	11.3	6.6	1.6	239	44	1,410	0.15	0.13	0.14	0.60	0.67	0.64	0.72	0.65	0.68
Kuwait	3.88	4.01	3.65	10	9	10	12.8	5.7	1.8	214	47	1,159	0.11	0.09	0.10	0.42	0.46	0.44	0.69	0.64	0.66
Lebanon	3.13	3.3	2.98	8	8	8	11.2	9.9	1.6	287	76	1,918	0.20	0.17	0.18	0.69	0.74	0.72	0.33	0.29	0.31
Libya	4.24	4.45	4.03	11	10	11	7.4	7.8	1.6	194	8	1,265	0.16	0.14	0.15	0.40	0.44	0.42	0.63	0.57	0.60
Morocco	4.31	4.53	4.11	12	10	11	9	6.4	1	239	60	1,283	0.13	0.10	0.12	0.46	0.50	0.48	0.29	0.26	0.28
Oman	3.78	3.93	3.56	10	9	10	10.3	5.9	1.8	253	45	1,181	0.16	0.14	0.15	0.40	0.43	0.42	0.56	0.50	0.53
Pakistan	3.91	4.05	3.75	10	10	10	3.8	3.5	5.8	157	16	277	0.05	0.04	0.04	0.45	0.50	0.48	0.54	0.50	0.52
Palestine	3.86	4.04	3.69	_	_	_	8.6	5.2	1.9	258	63	973	0.16	0.14	0.15	0.43	0.46	0.44	0.62	0.56	0.59
Qatar	4.21	4.29	3.9	11	10	11	10.2	6.8	1.7	220	8	1,505	0.23	0.19	0.21	0.48	0.51	0.50	0.73	0.65	0.69
KSA	3.2	3.33	3.03	8	8	8	13.5	4.1	1.1	286	50	656	0.37	0.31	0.34	0.38	0.42	0.40	0.68	0.61	0.64
Somalia	2.07	2.17	1.97	6	5	5	10.9	3.8	0.7	170	48	337	0.01	0.01	0.01	0.23	0.26	0.25	0.17	0.15	0.16
Sudan	2.37	2.49	2.26	_	_	8.2*	9.1	4.7	1.1	278	1,291	526	0.05	0.04	0.05	0.59	0.66	0.62	1.03	0.93	0.98
Syria	4.18	4.37	3.99	11	10	11	9.7	5.6	1.5	251	58	1,134	0.20	0.16	0.18	0.50	0.54	0.52	0.81	0.73	0.77
Tunisia	4.43	4.63	4.24	12	11	11	9.8	7.5	1	286	17	2,215	0.12	0.10	0.11	0.40	0.43	0.42	0.63	0.58	0.61
UAE	3.67	3.76	3.43	10	9	9	10.7	5.2	1.1	262	377	962	0.28	0.23	0.25	0.43	0.47	0.45	0.73	0.67	0.70
Yemen	3.37	3.55	3.21	9	8	9	13.9	3.6	1.5	224	52	362	0.12	0.09	0.10	0.44	0.49	0.46	0.34	0.30	0.32

and Egypt) (63) (**Table 4**). Laboratory analysis was conducted for profiling TFAs, saturated, and unsaturated fatty acids in the products that are mostly consumed in the major governorates in Egypt. On average, 34% of the products exceeded the TFAs limit (more than 2 g TFA/100 g of fat). The study revealed that around one third of products in the Egyptian market have a high TFAs content (72). Iran has achieved a marked improvement in the reduction of TFAs as early studies recorded 12.3 g as a mean intake in 2007, while in 2013 this has been reduced to 1.42 and 1.5 g in 2018 (73–76).

The 2019 American College of Cardiology/American Heart Association Guideline on the Primary Prevention of Cardiovascular Disease concluded that a diet containing reduced amounts of cholesterol and sodium could be beneficial to decrease atherosclerotic CVDs risk (77). Every increase in dietary cholesterol by 100 mg/day predicted an increase in LDL-c from 1.90 to 4.58 mg/dl depending on the model (78). The 2015 National Lipid Association Recommendations for Patient-Centered Management of Dyslipidemia, recommend limiting dietary cholesterol to <200 mg/d to lower LDL-c and non–high-density lipoprotein cholesterol (HDL-c) concentrations, however, insufficient evidence among populations doesn't exist (79). Within EMR, all of the countries are beyond the previous recommended level, particularly Egypt where the recorded dietary cholesterol level was 402 mg/day, followed by Iraq 288 mg/day, then Lebanon 287 mg/day, then KSA and Tunisia 286 mg/day (63) (**Table 4**).

High Sugar Diet

The term "sugars" includes intrinsic sugars, from intact fruit and vegetables; milk, as well as free sugars, which are added to foods and beverages, and sugars naturally present in honey, syrups, fruit juices, and fruit juice concentrates (80).

There is uprising worry regarding the free sugars' intake, particularly in the form of SSB that increases the overall energy consumption and may reduce healthy food items' intake. This leads to unhealthy dietary habits, subsequent weight gain, and increased risk of NCDs (54, 81–83). Another concern is the association between intake of free sugars and dental caries (54, 84–86). Dental diseases are the most prevalent NCDs globally (87, 88).

The established dietary goal for free sugars' intake is <10% of total energy but ideally less than 5% of total energy intake. This 10% ratio is equivalent to 50 g for a person of healthy body weight consuming about 2,000 calories per day (54).

Juice and SSB Consumption

A diet high in SSB is defined as any intake (in grams per day) of beverages with ≥50 kcal per 226.8 g serving, including sodas, carbonated beverages, energy drinks, and fruit drinks, but excluding 100% fruit and vegetable juices. In 2019, a diet high in sugar-sweetened beverages was responsible for 6.31 million DALYs and 242 000 deaths. It was the 13th-leading dietary risk factor for DALYs (89).

The average consumption of raw sugar in EMR is 80 g per day, while the recommended amount of sugar is equivalent to 50 g. The highest mean consumption of SSB among EMR countries has been recorded in Djibouti 0.78 serving/day followed by Lebanon 0.72, then Jordan 0.64, then Sudan 0.62, then Syria 0.52, and Bahrain 0.51. The highest juice intake in EMR has been recorded in KSA 0.34 serving/day followed by Iran 0.31, then UAE 0.25 and Bahrain 0.24 (12) (as outlined in **Table 4**).

A review of the literature reveals that SSBs contribute partly to the obesity epidemic, as reported by epidemiologic studies, which emphasized the link between SSB consumption and long-term weight gain, type 2 diabetes mellitus, and CVDs risk. It is hypothesized that SSB contribute to weight gain due to their high added sugar content, low satiety, and potential partial compensation for total energy leading to increased energy intake (90, 91). In addition, because of their large consumed quantities besides their high contents of rapidly absorbable carbohydrates such as different forms of sugar and high-fructose corn syrup, SSB could be responsible for increased type 2 diabetes mellitus and CVDs incidence. Independent of obesity, SSB could serve as a contributor to a high dietary glycemic load leading to inflammation, insulin resistance, and impaired ß-cell function (92). Fructose from any sugar or high-fructose corn syrup may also increase blood pressure, and enhance the cumulative effects of visceral adiposity, dyslipidemia, and ectopic fat precipitation due to upregulated hepatic *de novo* lipogenesis (93).

Salt/Sodium Intake

Salt consumption within the WHO-recommended level for adults is <5 g per person per day (2 g per day of sodium). Excessive salt consumption is linked to adverse health outcomes, such as the increased risk of hypertension (raised blood pressure), which in turn leads to stroke and heart disease (94). The current salt intake in the Region averages more than 10 g per person per day, which is double the recommended level set by WHO. In 2010, within EMR countries the highest mean salt intake has been recorded in Bahrain (14 g/day) followed by Libya, Morocco, Qatar, Syria, and Tunisia (11 g/day) (11) (see **Table 4**). Conversely, according to more recently collected data based on urinary excretion, the highest level of salt intake was observed in Morocco (10.6 g/day), while the lowest was observed in Lebanon (5.6 g/day) and the UAE (6.8 g/day) (19). Based on dietary assessment questionnaires, the highest levels of salt intake were observed amongst Iranian children and adolescents (14.3–16.2 g/day) and adults in Bahrain (9.3–13.3 g/day) and Lebanon (10.9 g/day). Per capita estimates were also high in Oman (11.5 g/day) and Tunisia (10.2 g/day) (19). Sodium is an essential nutrient necessary for the maintenance of plasma volume, acid-base balance, the transmission of nerve impulses, and normal cell function (95). In our diet, the main source of sodium is salt, despite it can be attained from sodium glutamate, used as a food additive in many processed foods (95). In 2019, a diet high in sodium (more than 3 g) was responsible for 44.9 million DALYs and 1.89 million deaths. It was the leading dietary risk factor for causing DALYs (96). The highest mean sodium intake has been recorded in Bahrain (5.8 g/day) followed by Tunisia (4.43 g/day), then Morocco (4.31 g/day), Libya (4.24 g/day), Qatar (4.21 g/day), Syria (4.18 g/day), and Jordan (4.13 g/day) (11) (see **Table 4**).

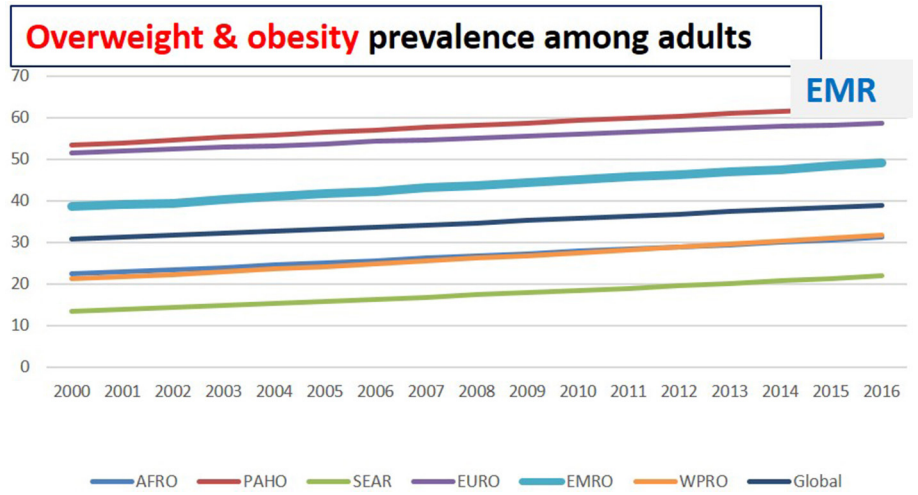


FIGURE 3 | Overweight and obesity prevalence among adults in different regions (6).

The EMR population should be aware of how much salt they consume as the disease burden of CVDs, resulting mainly due to salt and subsequent high blood pressure, is very high in the region (97). In a recent study, the salt intake levels were estimated in 15 out of the 22 countries in EMR, national salt reduction initiatives were identified in 13 countries including Bahrain, Egypt, Iran, Jordan, KSA, Kuwait, Lebanon, Morocco, Oman, Palestine, Qatar, Tunisia, and the UAE. The majority of countries were discovered to be implementing complex reduction measures, which included two or more implementation strategies. Taxation was the least popular implementation option, whereas reformulation was the most popular (100%), followed by consumer education (77%), initiatives in specialized situations (54%), and front-of-pack labeling (46%) (19).

Obesity

The prevalence of obesity (BMI $\geq$ 30 kg/m^2) has almost tripled worldwide since 1975. There were 650 million obese adults aged 18 years in 2016, with a global prevalence of nearly 13%. High body-mass index (BMI) was responsible for 160 million DALYs and 5.02 million deaths in 2019. It was the seventh-ruling risk factor for attributable DALYs in 2019 (98). Being obese is usually linked to an increased risk of hypertension and many NCDs (including diabetes, CVDs, and cancers) (99). Shifts in eating behavior toward diets containing energy-dense foods, high in fat and sugars, and less physical activity due to the sedentary nature of many forms of work and modes of transportation are contributing to the rise in obesity. The prevalence of obesity in the EMR is the third-highest across all global regions (4). The current prevalence of obesity is estimated at 25.1%, while the prevalence of overweight is around 56.41%. Among the EMR, the gulf countries revealed the highest rate of obesity. The highest prevalence of obesity in EMR has been reported in Kuwait (37.9%), Jordan (35.5%), Saudi Arabia (35.4%), Qatar (35.1), Libya (32.5%), Egypt (32%), Lebanon (32%), and UAE (31.7%). According to the latest estimates, the prevalence of excess BMI in adults in EMR has increased by 3% between 2012 and 2016 (6) (**Table 2**; **Figure 3**).

The high prevalence of people who are overweight or have obesity in Saudi Arabia is considered a public health concern, as revealed in a cross-sectional study carried out on a representative sample of 1,681 adult patients. Being overweight and having obesity were found to be prevalent in 38.3% and 27.6% of the population, respectively. Obesity was not shown to be connected with smoking, although it was found to be associated with hypertension. The risk of overweight or obesity was significantly inversely correlated with the monthly income (100).

The most recent national survey conducted in Egypt revealed that 39.8% of adult Egyptians suffered from obesity with a more prevalent in adult females than males, nearly 25% have normal BMI while the rest are either obese or overweight (101). A study analyzing the health effects of being overweight and having obesity conducted over 25 years in 195 countries, revealed that 19 million Egyptians suffer from obesity, representing 35% of all adults, which is the highest rate in the world. Moreover, the study outlined that 3.6 million children (10.2% of Egyptian children) suffer from obesity (102).

Research published in 2020 indicated that almost three-quarters of men and women in Jordan were overweight or obese. Obesity rates in men were around twice as high in 2017 as they were in 2009. In the multivariate analysis, age, region of residence, and marital status were significantly associated with obesity in both genders. Obesity was significantly linked with increased odds of diabetes mellitus, hypertension, elevated triglycerides, and low high-density lipoprotein cholesterol after adjusting for age (103).

Ultimately, obesity is the first reported risk factor responsible for the total number of DALYs in 2019 in eight countries in the region (Bahrain, Jordan, Kuwait, Libya, Oman, Qatar, Saudi Arabia, and UAE). It is the second reported risk factor in the other seven countries (Egypt, Iran, Iraq, Morocco,

TABLE 5 | The rank of the nutrition related risk factors that causes deaths in 2019 and the percentage change between 2009–2019 (13).

	High body mass index	High blood pressure	Malnutrition	High fasting plasma glucose	Dietary risks	High LDL	Low physical activity
Afghanistan	80.1	25.1	−23	39	23.4	31.1	
Bahrain	86.9	55.7	−16.2	93.8	61.8	48.6	96.1
Djibouti	106.5	56.9	−31.5	63.2	52.7		
Egypt	41.6	26.9	−46.8	72.1	31.7	28.7	
Iran	45.3	24.2	−57.4	56	26.1	20	
Iraq	40.5	35	−44.9	47.4	28.7	28	50.9
Jordan	96.3	87.8	11.2	85.9	84.7	86.9	
Kuwait	66.3	37	7.5	63.4	47	42	
Lebanon	38	25.1	−25.9	30.6	22.8	26.3	34
Libya	54.4	49.9	−34.5	64.8	61.5	57	
Morocco	46.1	25.5	−53.2	53.9	29.4	27.6	
Oman	41.1	14.3	21.4	43.1	18.3	14.5	
Pakistan	53	38.4	17	41	28.6	31.1	
Palestine	64.6	32.6	−47.6	57.3	40.1	39.3	
Qatar	88	62.3	21.7	85.9	66.8	51.9	
Saudi Arabia	56.3	29.4	−41.8	53.3	37	39.1	71.4
Somalia		36.1	−7.1	39.7	32.6		
Sudan	51.1	21.1	−41.2	41.6	19.6	26.1	
Syria	23.5	24.9	−57.5	44.8	23.7	20.2	
Tunisia	41.2	25.8	−45.5	43.2	24.7	24.5	
UAE	133.4	140.1		147	136.9	141.5	
Yemen	64.2	43.4	−29.2	66.8	47.4	47.4	
Color code							
First		**Second**		**Third**		**Fourth**	
Fifth		**Sixth**		**Seventh**		**Eighth**	
Ninth		**Tenth**		**Eleventh**			

Palestine, Syria, and Tunisia). The highest increase in obesity percentage between 2009 and 2019 in EMR was reported in UAE (133.4%) followed by Djibouti (106.5), then Jordan (96.3%), Qatar (88%), Bahrain (86.9%), and Afghanistan (80.1%). The dramatic increase in obesity involves low-income countries in the region also including Djibouti and Afghanistan (13) (as indicated in **Table 5**). The prevalence figures revealed that obesity constitutes a significant public health concern in EMR because of its significant correlation to NCDs (see **Figures 4**, **5**).

Physical Inactivity

In 2016 a study revealed that globally, 28% of all adults aged 18 years and older were insufficiently physically active, and not following the WHO recommendation to implement at least 150 min of moderate-intensity physical activity per week (104). According to the 2019 Global Burden of Disease Study, low physical activity was ranked 18th in attributable DALYs in 2019, accounting for 198.4 age-standardized DALYs per 100,000 and 11.1 age-standardized deaths per 100,000. The EMR has the highest prevalence of insufficient physical activity than any other region. There is a clear relationship between physical inactivity and country income group globally (4). In 2016, high-income countries had more than double the prevalence of physical inactivity (37%) than low-income countries (16%), however, the situation is reversed among EMR countries where the insufficient physical activity was the highest in Kuwait followed by Saudi Arabia and UAE while the lowest was recorded in Jordan (6). According to data from the UAE national health survey 2017–2018, 70.8% of the participants did not fulfill WHO standards for adequate physical exercise. Insufficient physical activity was reported by women at a higher rate than men (74.8 and 66.8%, respectively). When compared to non-Emirates, Emiratis had a higher percentage of insufficient physical activity (80.2 and 69.2%, respectively) (105).

Physical inactivity is also a modifiable factor that is involved in upregulating the magnitude of NCDs. People who are deficiently physically active have an enhanced risk of all-cause mortality, as compared to those who perform at least 30 min of moderate-intensity physical activity on most days of the week. Additionally, physical activity lowers the risk of stroke, hypertension, and depression (106).

Other Risk Factors Mediated by Unhealthy Diet and Obesity

Hypertension

Hypertension or raised blood pressure is defined as systolic and/or diastolic blood pressure greater than, or equal to, 140/90

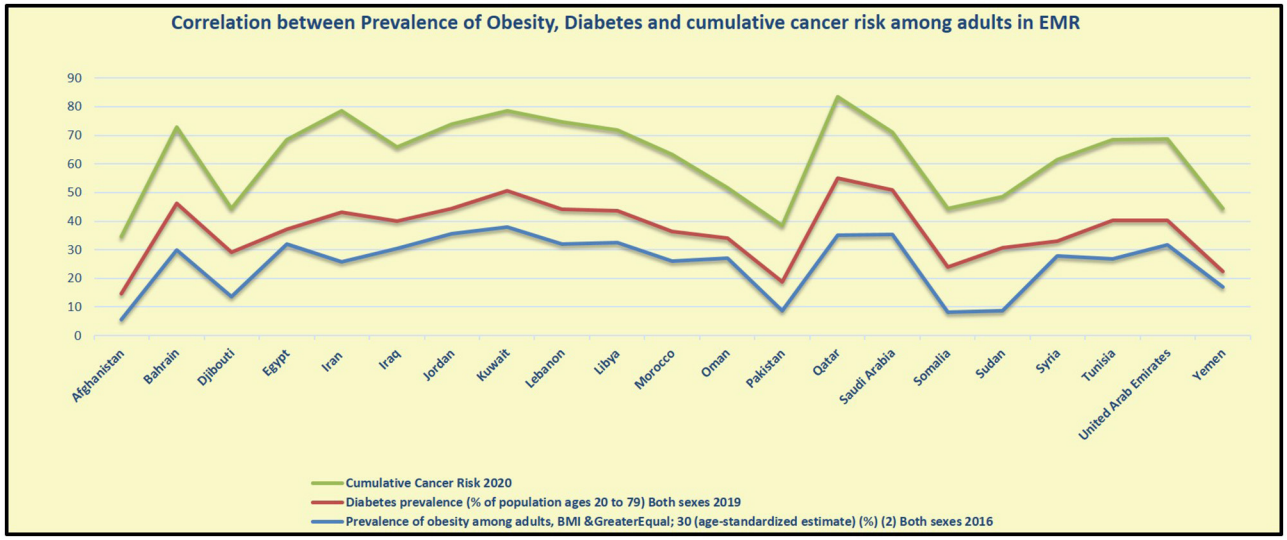


FIGURE 4 | Correlation between the prevalence of obesity, diabetes, and cumulative cancer risk among adults in EMR (6, 26).

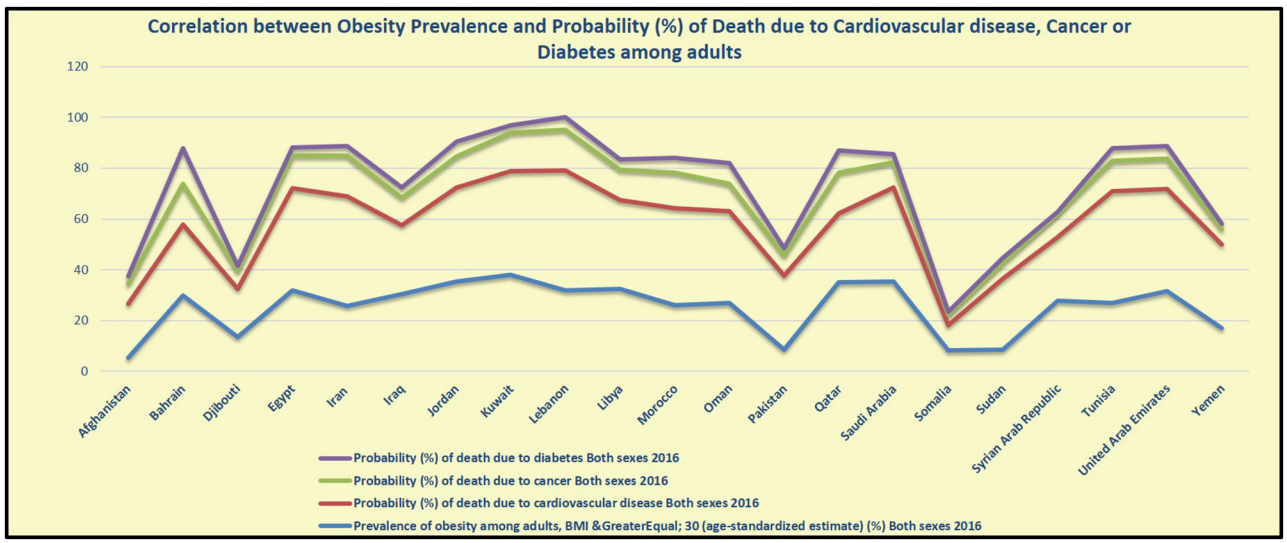


FIGURE 5 | Correlation between the prevalence of obesity, probability of death due to CVDs, cancers, and diabetes among adults in EMR (6).

mmHg. Hypertension is a major risk factor for heart failure, ischemic heart disease, peripheral vascular disease, renal failure, retinal hemorrhage, stroke, and dementia (107). In 2019, high blood pressure was the second-leading contributor to 235 million (95% UI 211–261) DALYs and 10.8 million (9.51–12.1) deaths in 2019 (108). Several risk factors could be involved in the upregulated blood pressure, including high salt intake, being overweight or obese, excessive use of alcohol, low or lack of physical activity, stress, air pollution, and smoking (95). Globally, in 2015, one in four men, and one in five women (i.e., 22% of the adult population aged 18 years and older) had raised blood pressure. In 2015, 28% of the population in low-income countries had high blood pressure, compared with 18% of the population in high-income countries. Reviewing the current trends demonstrated that the number of adults with high blood pressure increased from 594 million in 1975 to 1.13 billion in 2015, with the peak revealed significantly in low- and middle-income countries (109).

Among all the WHO-geographical regions, EMR was the second-highest in the incidence of raised blood pressure after Africa (4). In 2015, within the EMR, the prevalence of raised blood pressure is the highest in Somalia (32.9%), then Yemen (30.7%), Afghanistan, and Pakistan (30.6% and 30.5%), respectively. In 2019, the highest prevalence of hypertension

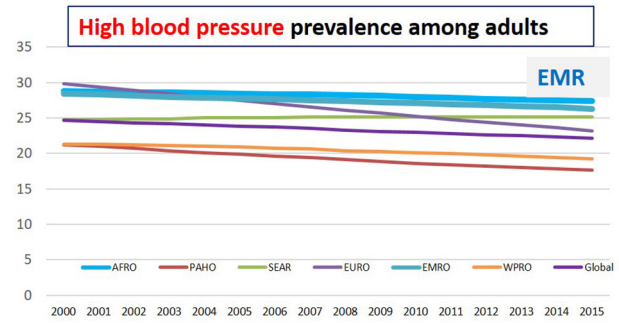


FIGURE 6 | High blood pressure prevalence among adults in different regions (6).

among adults was recorded in Iraq (40.7%) followed by Oman (38.6%), UAE (34.8%), Afghanistan (33.7%), Sudan (33.5%), and Kuwait (33.5%), followed by Egypt (33.2%) (6) (**Table 2**; **Figure 6**).

Raised blood pressure is the second risk factor responsible for the total number of DALYs worldwide. Among EMR countries, hypertension is the first reported risk factor responsible for the total number of DALYs in six countries (Egypt, Iran, Iraq, Morocco, Syria, and Tunisia) while it is the second reported risk factor in other nine countries (Jordan, Lebanon, Libya, Oman, Saudi Arabia, Sudan, UAE, and Yemen). The highest increase in blood pressure percentage between 2009 and 2019 in EMR was reported in UAE (140.1%) followed by Jordan (87.8%), Qatar (62.3%), Djibouti (56.9%), then Bahrain (55.7%). The increase in hypertension in the region has involved high-income countries including UAE, Qatar, and Bahrain (13) (**Table 5**).

High Fasting Blood Glucose

Accordingly, all body tissues are affected by high blood glucose including the heart, blood vessels, eyes, kidneys, and nerves, with subsequent complications including heart attack, stroke, kidney failure, lower limb amputation, blindness, and nerve damage (110). Nearly 9% of the global population had raised blood glucose levels in 2014 (111). In 2019, high fasting plasma glucose (>4.8–5.4 mmol/L) was ranked as the sixth most prevalent DALYs risk factor worldwide, accounting for 2,223.8 all-age DALYs per 100,000 and 84.0 all-age deaths per 100,000 (112). The EMR showed the highest levels (14% of the population), while 7–9% of the population from other regions had high levels of blood glucose. The upper-middle-income group tended to have higher levels (9%) (4). Within the EMR countries, the highest percentage of fasting blood glucose (≥7.0) mmol/L has been reported in Kuwait (19.6%), Qatar (18.9%), Egypt (17.9%), Saudi Arabia, Iraq (17.4%), and Jordan (16.8%) (6) (**Table 2**).

According to the 2019 Global Burden of Disease Study, raised fasting plasma glucose is the first reported risk factor accounted for the total number of DALYs in Palestine, while it is the second reported risk factor in three countries in the region (Bahrain, Kuwait, and Qatar) and it is the third risk factor in other seven countries (Iran, Iraq, Libya, Morocco, Oman, Saudi Arabia, and Tunisia). The highest increase in fasting plasma glucose percentage between 2009 and 2019 in EMR was reported in UAE (147%) followed by Bahrain (93.8%), Jordan and Qatar (85.9%), and Egypt (72.1%) (13) (**Table 5**).

High Cholesterol

Blood cholesterol is one of the most important risk factors for ischemic heart disease and ischemic stroke (113). The global prevalence of elevated total cholesterol (≥5 mmol/l) among adults aged ≥25 years was 38.9% (37.3% for men and 40.2% for women). Among the WHO-designated regions, the prevalence of hyper-cholesterolemia was the third highest in the EMR, at 38.4% (40.4% for women and 36.2% for men) (6). In 2018, global age-standardized mean total cholesterol was 4.6 mmol/l for women and 4.5 mmol/l for men (114) while the mean total cholesterol in the EMR is 4.4 mmol/l for both sexes, 4.4 mmol/l for men, and 4.5 mmol/l for women (6). It is noteworthy that blood non-HDL cholesterol is strongly associated with the long-term risk of atherosclerotic cardiovascular diseases. In 2018, global age-standardized mean non-HDL cholesterol was 3.3 mmol/l for women and 3.3 mmol/l (3.3–3.4) for men (114) while the mean non-HDL cholesterol in EMR in 2018, was 3.2 mmol/l for both sexes. In 2018, the highest recorded mean total cholesterol was in Lebanon 5 mmol/l followed by Kuwait and Jordan 4.8 mmol/l followed by UAE 4.6 mmol/l then Egypt and Iraq 4.4 mmol/l. Within EMR countries, the highest mean non-HDL cholesterol in 2018 was recorded in Lebanon at 3.7 mmol/l, followed by Kuwait and Jordan 3.5 mmol/l, then Oman, UAE, and Yemen 3.4 mmol/l (6) (**Table 2**).

According to the 2019 Global Burden of Disease Study, high LDL-c was the eighth-directing risk factor for DALYs. It contributed to 98.6 million DALYs and 4.40 million deaths in 2019 (115). High LDL-c is the fifth reported risk factor in three countries in the region (Morocco, Oman, and UAE), while it is the sixth reported risk factor in six countries in the region (Egypt, Iran, Lebanon, Libya, Syria, and Tunisia). The highest increase in fasting plasma glucose percentage between 2009 and 2019 in EMR was reported in UAE (141.5%) followed by Jordan (86.9), then Bahrain (48.6%), and Yemen (47.4%) (13) (**Table 5**).

Interdisciplinary Relationships Between NCDs and Related Risk Factors

Both overweight and obesity-related to unhealthy dietary habits as well as insufficient physical activity are the key risk factors for NCDs (116). For instance, TFA consumption induces low-grade systemic inflammation and is positively correlated with endothelial dysfunction (a non-obstructive coronary artery disease) (117–121). Being overweight and having obesity also enhances low-grade systematic inflammation, creates a higher concentration of pro-inflammatory cytokines, and further endothelial dysfunction, all of which are metabolic risk factors for nutrition-related NCDs, and in particular, heart disease (122, 123) (**Figure 1**).

Nevertheless, its association with other risk factors, including diabetes, high body cholesterol, elevated blood pressure, and metabolic syndrome, obesity could serve as an independent risk

factor for CVDs (124). Since abdominal obesity is an independent risk factor for coronary heart disease, the distribution of body fat represents an additional risk. The intra-abdominal fat buildup promotes insulin resistance, which can lead to glucose intolerance, elevated triglycerides, and low HDL as well as hypertension (125). Ultimately, obesity is the key risk factor for type 2 diabetes, cardiovascular disease, cancer, and premature death (126). Individuals who decreased 7% of their body weight significantly reduced all cardiovascular risk variables except LDL cholesterol levels, however, the rate of cardiovascular events did not decrease during the trial (127).

In a statewide cross-sectional study done by phone interviews in June 2020 in Saudi Arabia, obesity was found to be prevalent at 24.7%, and overweight at 21.7%. Type 2 diabetes, hypertension, hypercholesterolemia, sleep apnea, lung diseases, rheumatoid arthritis, colon diseases, and thyroid issues have all been significantly linked to obesity (128). A further study conducted in Qatar confirmed that obesity risk factors (c-peptide, insulin, albumin, and uric acid) and obesity-related comorbidities such as diabetes (e.g., HbA1c, glucose), liver function (e.g., alkaline phosphatase, gamma-glutamyl transferase), lipid profile (e.g., triglyceride, LDL-c, HDL-c), as well as most of the dual-energy x-ray absorptiometry measurements (e.g., bone area, bone mineral composition, bone mineral density, etc.) were significantly ($p < 0.05$) higher in the obese group (129).

Substantially, elevated blood pressure has been linked to the consumption of food high in salt and NCDs. An intervention trial that included 9,000 adults with baseline systolic blood pressure between 130 and 180 mmHg indicated that a lower blood pressure target was accompanied by a significantly lower incidence of myocardial infarction, acute coronary syndrome, stroke, heart failure, or death (130). Diabetes also is a recognized and significant risk factor for CVDs (131). CVDs is the leading cause of morbidity and mortality among individuals with diabetes. It is therefore recommended that individuals with diabetes should have a target blood pressure of <130/80 mmHg to prevent the incidence of CVDs (132).

DISCUSSING THE CULTURAL AND SOCIODEMOGRAPHIC EFFECT ON THE NCDS RELATED RISK FACTORS

Of the 22 countries and territories in the EMR, 16 are considered low-income or middle-income countries. Several countries in the EMR have lengthy histories of political instability, war, and social conflict, which have resulted in the large-scale internal and external displacement of citizens; half of the region's countries and territories are now under an acute or chronic state of emergency. These socioeconomic determinants of health, as well as accompanying inequities, have an impact on health status and access to care throughout the EMR as well as access to healthy food, which is unsurprising. Moreover, disease epidemiological data on disease incidence, prevalence, and management are scarce and lacking (133). Furthermore, NCDs mortality, and its social, environmental, behavioral, nutritional, and clinical determinants are not distributed evenly within countries (134). The most deprived communities have a higher risk of premature death than those in the most affluent. Therefore, reducing national-level NCDs risk requires actions that address the disproportionate burden in deprived communities (29).

The lowest risk of NCDs mortality is seen in high-income countries in western Europe, Asia-Pacific, Australia, and Canada, whereas, the highest risk was observed in low-income and middle-income countries. The highest probabilities were seen in parts of sub-Saharan Africa, and Guyana. In EMR, Yemen, and Afghanistan (one in four to one in three people are at risk of dying from NCDs), people are about 3–7 times more likely to die than those in high-income countries. Similarly, the probability of dying from NCDs between the age of 30 and 70 in EMR is 24.5% (one in four adults will die before the age of 70) (29).

Literature on this subject usually shows a positive association between socioeconomic status and obesity in low-income countries. However, contrary to this, a multinomial regression analysis study conducted in Cairo, Egypt reported no significant associations between most SES spectrum and overweight/obesity in the studied population. The study suggested that obesity programs and policies should be targeted at all socioeconomic status groups in Egypt (135). A study conducted in Jordan revealed that the prevalence of overweight/obese women was 70.6%. Furthermore, the association between age and overweight/obesity was significant ($p < 0.0001$). The high prevalence of overweight/obesity among women in Jordan was related to high parity and low education level (136). Conversely, in research conducted in Saudi Arabia, the prevalence of overweight and obesity in men was 35.1% and 34.8%, respectively, and in women, it was 30.1% and 35.6%. Obesity and overweight increased in prevalence until 60 years of age, then declined in both sexes in the oldest age group. After adjusting for age, earning a postgraduate degree raised the risk of obesity in men, but increased physical activity decreased it in both sexes. Obese women had a higher risk of prediabetes and diabetes, obese males had a higher risk of hypertension, and both sexes had a higher risk of dyslipidemia. A familial history of dyslipidemia was linked to a lower risk of obesity in women, whereas women who were overweight were more liable to develop prediabetes, diabetes, and dyslipidemia, while men who were overweight were more liable to hypertension (137).

Analyzing the data from a population-based cross-sectional survey of diabetes and obesity in Kuwait, revealed that the prevalence of overweight, obesity, and central obesity were 40.6%, 42.1%, and 73.7%, respectively. Men were 26% more likely than women to be overweight, while women had 54% and seven-fold higher probabilities of obesity and central obesity, respectively. Young adults aged 18–29 years have a significant prevalence of obesity and overweight. Obesity/central obesity was associated with higher educational attainment, physical activity, and being non-Kuwaiti. Smoking history, high blood pressure, higher income, and marital status are all linked to an increased risk of obesity/central obesity (138). In another cross-sectional study conducted among 3,915 Kuwaiti adults, obesity prevalence was 40.3% (men, 36.5%; women, 44.0%); and overweight prevalence was 37% (men, 42%; women, 32.1%). Obesity prevalence was linked to female sex, age, diabetes history,

and marital status in both men and women, but was inversely linked to education level in women. Men were more likely to have an increased waist-to-hip ratio (46.91%) as compared to women (37.9%). In both men and women, waist circumference, waist-hip, and waist-height ratios were found to be directly associated with diabetes and negatively associated with education level in women (139).

In a study conducted in Libya that explored the key risk and protective factors beyond the high prevalence rates of overweight and obesity, 11 factors were identified to be associated with obesity among men and women. These include socio-demographic and biological factors, socioeconomic status, unhealthy eating behaviors, knowledge about obesity, social-cultural influences, healthcare facilities, physical activity, the effect of the neighborhood environment, sedentary behavior, food-subsidy policy, and suggestions for preventing and controlling obesity (140). Another cross-sectional survey revealed that the prevalence of obesity, overweight, and normal weight among Libyan adults was 42.4%, 32.9%, and 24.7%, respectively. Women were more likely than men to be overweight or obese (the prevalence of overweight was 33.2% in women vs. 32.4% in men, and the prevalence of obesity was 47.4% in women versus 33.8% in men) (141).

SUSTAINABLE DEVELOPMENT GOALS TARGET 3.4: PATHWAYS AND FORWARD STEPS

The Sustainable Development Goals (SDGs) target 3.4 is to reduce NCDs-related premature mortality by a third by 2030 compared to 2015 levels, as well as to enhance mental health and wellbeing through prevention and treatment (142). It has been reported that the progress in most international countries is too slow to meet this goal (143).

Although SDG target 3.4 is the same, differences exist between countries in terms of risk of dying from various NCDs (29, 144). Throughout this review, the percentages of different risk factors associated with NCDs incidence have been elaborated. This is important to highlight the pathways through which each country can achieve SDG target 3.4 and to guide governments and donors in prioritizing resources and interventions in their national NCDs response.

Based on 2010–2016 trends, women in 17 of 176 (9.7%) countries and men in 15 of 176 (8.5%) countries are expected to achieve SDG target 3.4 by 2030. The high-income countries that are on track include Denmark, Luxembourg, New Zealand, Norway, Singapore, and South Korea as well as central and eastern European countries. Furthermore, NCDs death rates among men and women in EMR countries as Iran are falling quickly enough to meet the 2030 target. Kuwaiti women and Bahraini men are likewise on pace (29). In contrast, the risk of dying from NCDs is expected to remain stable or increased among women in 14 (8%) countries and men in 20 (11.4%) countries according to 2010 and 2016 trends. Bangladesh (men), Egypt (women) from EMR, Ghana (men and women), Côte d'Ivoire (men and women), Kenya (men and women), Mexico (men), Sri Lanka (women), Tanzania (men), and the United States (women) were involved. This could be referred to the changes in population size and age structure, even if the risk of dying from NCDs reduces, the number of deaths from NCDs may continue to rise (29).

According to a new World Health Organization report, if low and lower-middle income nations invest less than a dollar per person per year in the prevention and treatment of NCDs, close to seven million deaths could be avoided by 2030 (145)[1]. These include low-cost strategies for reducing tobacco and alcohol use, improving diets, increasing physical activity, lowering the risk of cardiovascular disease and diabetes, and preventing cervical cancer (145) (see text footnote 1).

The regional framework for action on obesity prevention 2019–2023 (146), set a road map for countries of the region to accelerate the action on NCDs and obesity prevention. It sets out six key action areas for improving nutrition and food security including, sustainable, resilient food systems for healthy diets; aligned health systems providing universal coverage of essential nutrition actions; social protection and nutrition education; trade and investment for improved nutrition; safe and supportive environm ents for nutrition at all ages; and strengthened governance and accountability for nutrition (17, 146)[2].

By investing in the Best Buy policies, countries will protect people from NCDs. Best Buy actions include increasing health taxes, restrictions on marketing and sales of unhealthy dietary products, food labeling, and education. They also include actions connected to managing metabolic risk factors, such as hypertension and diabetes, to prevent more severe disease or complications (145) (see text footnote 1). **Table 6** reveals the key policies and action plans available and implemented among EMR countries (6, 17–20).

The interventions have already been used successfully in many countries around the world. Among EMR countries that are on track to meet SDG target 3.4 are Iran, Kuwait, and Bahrain (29). These three countries have policies to reduce salt/sodium consumption, tax on sugar sweetened beverages, policy to eliminate industrially produced trans-fatty acids, policy to limit saturated/ trans-fatty acids intake, policy to reduce the impact of marketing of food to children, and policy on salt iodization (6, 17–20) (see **Table 6**).

CONCLUSION

Among the top causes of morbidity and mortality related to nutrition in EMR are cardiovascular heart diseases followed by cancer and then diabetes. Globally, the disease burden attributable to hypertension, alcohol consumption, high body mass index, high fasting blood glucose, high sodium intake, and unhealthy diet consumption is increasing significantly, while the disease burden attributable to children being underweight, suboptimal breastfeeding, and micronutrient deficiencies have all decreased significantly. Among the EMR countries, UAE

[1] Available online at: https://www.who.int/news/item/13-12-2021-investing-1-dollar-per-person-per-year-could-save-7-million-lives-in-low-and-lower-middle-income-countries.

[2] Available online at: https://apps.who.int/iris/bitstream/handle/10665/346443/EMRC68INFDOC8-eng.pdf.

TABLE 6 | The polices available and implemented in EMR countries.

	Development of national nutrition strategy or action plan	Plan of action for obesity prevention	Front-of-pack nutrition labeling	Policy to reduce salt/sodium consumption	Policy to limit trans-fatty acids intake	Policy to reduce the impact of marketing of food to children	Tax on sugar sweetened beverages	Food-based dietary guidelines
Afghanistan	✓ (16)	✘ (16)	✘ (19)	✘ (6)	✘ (6)	✘ (6)	✘ (6, 17)	✓ (16)
Bahrain	✓ (16)	✓ (16)	✘ (18)	✓ (6, 16, 19)	✓ (6, 16, 20)	✓ (6, 16)	✓ (6, 17, 147)	✓ (16)
Djibouti	✓ (148)	✘ (16)	✘ (19)	✘ (6)	✘ (6)	✘ (6)	✘ (6, 17)	✘ (16)
Egypt	✓ (16, 149)*	✓ (16)	✘ (19)	✓ (6, 16, 19)	✓ (20)	✓ (16)*	✓ (149)	✘ (16)
Iran	✓ (16)	✓ (16)	✓ (16, 18, 19)	✓ (6, 16, 19)	✓ (6, 16, 20)	✓ (6, 16)	✓ (6, 17)	✓ (16)
Iraq	✓ (16)	✘ (16)	✘ (19)	✓ (6, 17)	✓ (20)	✘ (6)	✘ (6, 17)	✘ (16)
Jordan	✓ (16, 149)*	✓ (16)	✘ (19)	✓ (6, 16, 17, 19)	✓ (6, 16, 20)	✓ (16)*	✘ (6, 17)	✓ (16)
Kuwait	✓ (16)	✓ (16)	✘ (19)	✓ (6, 16, 19)	✓ (6, 16, 20)	✓ (16)*	✓ (147)	✘ (16)
Lebanon	✓ (16)	✓ (16)	✘ (19)	✘ (6)	✘ (6)	✓ (16)*	✘ (6, 17)	✓ (16)
Libya	✘ (16)	✓ (16)	✘ (19)	✘ (6)	✘ (6)	✘ (6)	✘ (6, 17)	✓ (149)
Morocco	✓ (16)	✓ (16)	✓ (16, 18, 19)	✓ (6)	✓ (6, 20)	✓ (6, 16)*	✓ (6, 17)	✓ (16)
Oman	✓ (16)	✓ (16)	✘ (19)	✓ (6, 16, 19)	✓ (6, 16, 20)	✓ (6, 16)*	✓ (6, 17, 147)	✓ (16)
Pakistan	✓ (16)	✘ (16)	✘ (19)	✘ (19)	✓ (20)	✓ (149)	✘ (6, 17)	✘ (16)
Palestine	✓ (149)	✓ (149)*	✘ (19)	✓ (17, 19)	✓ (20)	✘ (6)	✓ (149)	✓ (149)*
Qatar	✓ (16)	✓ (16)	✘ (19)	✓ (6, 19)	✓ (6, 16, 20)	✓ (16)	✓ (17, 147)	✓ (16)
Saudi Arabia	✓ (16)	✓ (16)	✓ (16, 18, 19)	✓ (6, 16, 19)	✓ (6, 16, 20)	✓ (16)	✓ (6, 17, 147)	✓ (16)
Somalia	✓ (16)	✘ (16)	✘ (19)	✘ (6)	✘ (6)	✘ (6)	✘ (6, 17)	✘ (16)
Sudan	✓ (16)	✓ (16)	✘ (19)	✘ (6)	✘ (6)	✘ (6)	✘ (6, 17)	✓ (16)
Syria	✓ (16)	✓ (16)	✘ (19)	✘ (6)	✘ (20)	✘ (6)	✘ (149)	✓ (16)
Tunisia	✓ (16)	✓ (16)	✓ (16, 18, 19)	✓ (6, 19)	✓ (6, 20)	✘ (6)	✓ (6, 17)	✘ (16)
UAE	✓ (16)	✘ (16)	✓ (16, 18, 19)	✓ (6, 19)	✓ (6, 20)	✓ (149)*	✓ (6, 17, 147)	✓ (16)
Yemen	✓ (16)	✓ (16)	✘ (19)	✘ (6)	✘ (2)	✘ (6)	✘ (6)	✘ (16)

followed by Jordan revealed a significant increase in the percentage change of nearly all the risk factors that are involved in NCDs causing morbidity and mortality (150).

The data and correlation figures included in this study represent evidence that constitutes a significant public health concern about the relationship between unhealthy diet consumption and obesity that further induces other risk factors including (hypertension, insulin resistance, and a systemic inflammatory milieu), leading to NCDs (**Figure 1**). It is therefore important to recognize the key therapeutic modalities for treating and prohibiting NCDs, which are to fight against weight gain and obesity and to advocate lifestyle-based therapies; including proper nutrition and regular physical activity. These are the key therapeutic modalities that will reduce the risk of NCDs. Additionally, body mass index should be used as a first step in establishing the criteria to judge potential health risks.

Countries in the EMR need to continue building on the achieved progress and scale up action across the region while boosting efforts in areas where concrete action is absent through the following key stakeholders to reach the agreed global and regional goals relating to nutrition and diet-related NCDs. This could be achieved through the following key stakeholders, Governments can provide and improve access to quality NCDs and obesity care, as well as develop and implement policies that promote and normalize healthy eating and living, in addition to banning the marketing of unhealthy foods and beverages high in fat, sugar, and salt. Civil society groups, including non-governmental organizations and the media, can work with individuals and communities to educate and diffuse key messages on the root causes of NCDs and obesity, the importance of prevention and treatment, as well as the impact of adopting healthy behaviors like keeping physically active and choosing healthy food and drinks. Health care professionals, whether working directly in NCDs and obesity care or supporting and working with those living with obesity, can learn more about obesity, expand their knowledge, and have up-to-date, evidence-based obesity management resources to help them understand and address the root causes of this disease. Individuals and families can adopt healthier behaviors, share experiences, as well as ask for support, whilst also supporting others to improve their health and well-being and that of their children (17) (see text footnote 2).

Countries in EMR are encouraged to adopt and implement the regional nutrition strategy for nutrition 2020–2030 (21), the regional framework for action on obesity prevention 2019–2023 (151), and the regional framework for action to implement the United Nations Political Declaration on the NCDs (152).

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

1. World Bank. *Population, Total | Data*. Worldbank.org. (2020). Available online at: https://data.worldbank.org/indicator/SP.POP.TOTL (accessed September 1, 2021).
2. World Health Organization. *Global Status Report on Noncommunicable Diseases 2014* (2014).
3. World Health Organization. *Noncommunicable Diseases: Progress Monitor* (2020).
4. World Health Organization. *Noncommunicable Diseases Country Profiles* (2018).
5. *Non-Communicable Diseases - Level 1 Cause*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/non-communicable-diseases-level-1-cause (accessed August 30, 2021).
6. World Health Organization. *Global Health Observatory*. Indicators. www.who.int. Available online at: https://www.who.int/data/gho/data/indicators (accessed August 31, 2021).
7. Musaiger AO, Al-Hazzaa HM. Prevalence and risk factors associated with nutrition-related noncommunicable diseases in the Eastern Mediterranean region. *Int J Gen Med.* (2012) 5:199–217. doi: 10.2147/IJGM.S29663
8. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in body-mass index, underweight, overweight, and obesity from1975 to 2016: apooledanalysis of 2416 population-basedmeasurement studies in 128.9million children, adolescents, and adults. *Lancet.* (2017) 390:2627–42.
9. Global Cancer Observatory. *Global Cancer Observatory*. Iarc.fr (2018). Available online at: https://gco.iarc.fr/ (accessed October 16, 2021).
10. Food and Agricultural Organization. *Food Balance Sheets*. Available online at: http://www.fao.org/faostat/en/#data/FBS (accessed December 25, 2021).
11. Powles J, Fahimi S, Micha R, Khatibzadeh S, Shi P, Ezzati M, et al. Global, regional and national sodium intakes in 1990 and 2010: a systematic analysis of 24 h urinary sodium excretion and dietary surveys worldwide. *BMJ Open.* (2013) 3:e003733. doi: 10.1136/bmjopen-2013-003733
12. Singh GM, Micha R, Khatibzadeh S, Shi P, Lim S, Andrews KG, et al. Global burden of diseases nutrition and chronic diseases expert group (NutriCoDE), 2015. Global, regional, and national consumption of sugar-sweetened beverages, fruit juices, and milk: a systematic assessment of beverage intake in 187 countries. *PLoS One.* (2015) 10:e0124845. doi: 10.1371/journal.pone.0124845
13. Institute for Health Metrics and Evaluation. *Institute for Health Metrics and Evaluation* (2018). Available online at: http://www.healthdata.org (accessed August 30, 2021).
14. World Health Organization. *Regional Office for the Eastern Mediterranean*. Regional Health Observatory. Available online at: http://www.emro.who.int/entity/statistics/regional-health-observatory.html (accessed August 19, 2020).
15. World Health Organization. *Global Nutrition Policy Review 2016-2017*. Geneva: WHO (2018).
16. *Global Database on the Implementation of Nutrition Action (GINA)*. Available online at: https://extranet.who.int/nutrition/gina/ (accessed October 16, 2021).
17. Al-Jawaldeh A, Hammerich A, Doggui R, Engesveen K, Lang K, McColl K. Implementation of WHO recommended policies and interventions on healthy diet in the countries of the Eastern Mediterranean Region: from policy to action. *Nutrients.* (2020) 12:3700. doi: 10.3390/nu12123700
18. Al-Jawaldeh A, Rayner M, Julia C, Elmadfa I, Hammerich A, McColl K. Improving nutrition information in the eastern Mediterranean region: implementation of front-of-pack nutrition labelling. *Nutrients.* (2020) 12:330. doi: 10.3390/nu12020330
19. Al-Jawaldeh A, Taktouk M, Chatila A, Naalbandian S, Al-Thani AA, Alkhalaf MM, et al. Salt reduction initiatives in the Eastern Mediterranean Region and evaluation of progress towards the 2025 global target: a systematic review. *Nutrients.* (2021) 13:2676.
20. Al-Jawaldeh A, Taktouk M, Chatila A, Naalbandian S, Abdollahi Z, Ajlan B, et al. A systematic review of trans fat reduction initiatives in the Eastern Mediterranean Region. *Front Nutr.* (2021) 8:771492. doi: 10.3389/fnut.2021.771492
21. World Health Organization Regional Office for the Mediterranean. *Strategy on Nutrition for the Eastern Mediterranean Region 2020-2030.* Cairo: WHO (2019).
22. World Bank. *World Bank Country and Lending Groups*. Available online at: https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups (accessed August 20, 2021).
23. *Cardiovascular Diseases - Level 2 Cause*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/cardiovascular-diseases-level-2-cause (accessed August 30, 2021).
24. Ueshima H, Sekikawa A, Miura K, Turin TC, Takashima N, Kita Y, et al. Cardiovascular disease and risk factors in Asia: a selected review. *Circulation.* (2008) 18:2702–9. doi: 10.1161/CIRCULATIONAHA.108.790048
25. Franklin SS, Wong ND. Hypertension and cardiovascular disease: contributions of the Framingham Heart Study. *Glob Heart.* (2013) 8:49–57. doi: 10.1016/j.gheart.2012.12.004
26. Zubair F, Nawaz SK, Nawaz A, Nangyal H, Amjad N, Khan MS. Prevalence of cardiovascular diseases in Punjab, Pakistan: a cross-sectional study. *J Public Health.* (2018) 26:523–9. doi: 10.1007/s10389-018-0898-4
27. Mahmoud AE. Prevalence of cardiovascular disease risk factors among Egyptian and Saudi medical students: a comparative study. *J Egypt Public Health Assoc.* (2015) 90:35–9. doi: 10.1097/01.EPX.0000460969.93981.c2
28. Rahmani F, Asgari S, Khalili D, Moeini ASH, Tohidi M, Azizi F, et al. National trends in cardiovascular health metrics among Iranian adults using results of three cross-sectional STEPwise approaches to surveillance surveys. *Sci Rep.* (2021) 11:1–11. doi: 10.1038/s41598-020-79322-x
29. Countdown NC. NCD Countdown 2030: pathways to achieving Sustainable Development Goal target 3.4. *Lancet.* (2020) 396:918–34. doi: 10.1016/S0140-6736(20)31761-X
30. *Diabetes Mellitus - Level 3 Cause*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/diabetes-mellitus-level-3-cause (accessed August 30, 2021).
31. Smokovski I. Burden of diabetes prevalence. In: *Managing Diabetes in Low Income Countries*. Cham: Springer (2021). p. 1–12.
32. *Diabetes Prevalence (% of Population Ages 20 to 79) | Data*. Worldbank.org (2017). Available online at: https://data.worldbank.org/indicator/SH.STA.DIAB.ZS (accessed August 28, 2021).
33. Salman RA, AlSayyad AS, Ludwig C. Type 2 diabetes and healthcare resource utilisation in the Kingdom of Bahrain. *BMC Health Serv Res.* (2019) 19:939. doi: 10.1186/s12913-019-4795-5
34. Aamir AH, Ul-Haq Z, Mahar SA, Qureshi FM, Ahmad I, Jawa A, et al. Diabetes Prevalence Survey of Pakistan (DPS-PAK): prevalence of type 2 diabetes mellitus and prediabetes using HbA1c: a population-based survey from Pakistan. *BMJ Open.* (2019) 9:e025300. doi: 10.1136/bmjopen-2018-025300
35. Hegazi R, El-Gamal M, Abdel-Hady N, Hamdy O. Epidemiology of and risk factors for type 2 diabetes in Egypt. *Ann Glob Health.* (2015) 81:814–20. doi: 10.1016/j.aogh.2015.12.011
36. Awad SF, O'Flaherty M, El-Nahas KG, Al-Hamaq AO, Critchley JA, Abu-Raddad LJ. Preventing type 2 diabetes mellitus in Qatar by reducing obesity, smoking, and physical inactivity: mathematical modeling analyses. *Popul Health Metr.* (2019) 17:1–13. doi: 10.1186/s12963-019-0200-1
37. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers in 185 countries. *CA Cancer J Clin.* (2021) 71:209–49. doi: 10.3322/caac.21660
38. Arafa MA, Rabah DM, Farhat KH. Rising cancer rates in the Arab World: now is the time for action. *East Mediterr Health J.* (2020) 26:638–40. doi: 10.26719/emhj.20.073
39. Hamadeh RR, Abulfatih NM, Fekri MA, Al-Mehza HE. Epidemiology of breast cancer among bahraini women: data from the Bahrain Cancer Registry. *Sultan Qaboos Univ Med J.* (2014) 14:e176–e82.
40. Nasaif HA, Al Qallaf SM. Knowledge of colorectal cancer symptoms and risk factors in the Kingdom of Bahrain: a cross- sectional study. *Asian Pac J Cancer Prev.* (2018) 19:2299–304. doi: 10.22034/APJCP.2018.19.8.2299
41. *Cancer Today*. gco.iarc.fr. Available online at: https://gco.iarc.fr/today/data/factsheets/populations/48-bahrain-fact-sheets.pdf (accessed August 30, 2021).
42. *Countries - The World Factbook*. www.cia.gov. Available online at: https://www.cia.gov/the-world-factbook/countries/Bahrain (accessed July 20, 2021).

43. Kingdom of Bahrain Ministry of Health. *National Non-communicable Disease Risk Factors Survey 2007*. Report of the National Non-Communicable Diseases STEPwise Survey (2009). Available online at: http://www.who.int/ncds/surveillance/steps/2007_STEPS_Survey_Bahrain.pdf (accessed July 20, 2021).
44. Kalan Farmanfarma K, Mahdavifar N, Hassanipour S, Salehiniya H. Epidemiologic study of gastric cancer in Iran: a systematic review. *Clin Exp Gastroenterol.* (2020) 13:511–42. doi: 10.2147/CEG.S256627
45. *Global Cancer Data by Country | World Cancer Research Fund International*. WCRF International. Available online at: https://www.wcrf.org/dietandcancer/global-cancer-data-by-country/ (accessed August 29, 2021).
46. Ibrahim AS, Khaled HM, Mikhail NN, Baraka H, Kamel H. Cancer incidence in Egypt: results of the national population-based cancer registry program. *J Cancer Epidemiol.* (2014) 2014:437971. doi: 10.1155/2014/437971
47. Rippe JM. Lifestyle strategies for risk factor reduction, prevention, and treatment of cardiovascular disease. *Am J Lifestyle Med.* (2018) 13:204–12. doi: 10.1177/1559827618812395
48. *GBD 2019 Cause and Risk Summaries: Dietary-Risks-Level-2-Risks*. Institute for Health Metrics and Evaluation. Available online at: http://www.healthdata.org/results/gbd_summaries/2019/dietary-risks-level-2-risk (accessed August 30, 2021).
49. Mirmiran P, Noori N, Zavareh MB, Azizi F. Fruit and vegetable consumption and risk factors for cardiovascular disease. *Metabolism.* (2009) 58:460–8. doi: 10.1016/j.metabol.2008.11.002
50. Bazzano LA, He J, Ogden LG, Loria CM, Vupputuri S, Myers L, et al. Fruit and vegetable intake and risk of cardiovascular disease in US adults: the first National Health and Nutrition Examination Survey Epidemiologic Follow-up Study. *Am J Clin Nutr.* (2002) 76:93–9. doi: 10.1093/ajcn/76.1.93
51. Carter P, Gray LJ, Troughton J, Khunti K, Davies MJ. Fruit and vegetable intake and incidence of type 2 diabetes mellitus: systematic review and meta-analysis. *BMJ.* (2010) 341:c4229. doi: 10.1136/bmj.c4229
52. Maynard M, Gunnell D, Emmett P, Frankel S, Davey Smith G. Fruit, vegetables, and antioxidants in childhood and risk of adult cancer: the Boyd Orr cohort. *J Epidemiol Community Health.* (2003) 57:218–25. doi: 10.1136/jech.57.3.218
53. Papas MA, Giovannucci E, Platz EA. Fiber from fruit and colorectal neoplasia. *Cancer Epidemiol Biomarkers Prev.* (2004) 13:1267–70.
54. Nishida C, Uauy R, Kumanyika S, Shetty P. The joint WHO/FAO expert consultation on diet, nutrition and the prevention of chronic diseases: process, product and policy implications. *Public Health Nutr.* (2004) 7:245–50. doi: 10.1079/phn2003592
55. El Bcheraoui C, Basulaiman M, AlMazroa MA, Tuffaha M, Daoud F, Wilson S, et al. Fruit and vegetable consumption among adults in Saudi Arabia, 2013. *Nutr Diet Suppl.* (2015) 7:41–9. doi: 10.2147/NDS.S77460
56. Alzeidan RA, Rabiee F, Mandil AA, Hersi AS, Ullah AA. Changes in dietary habits, physical activity and status of metabolic syndrome among expatriates in Saudi Arabia. *East Mediterr Health J.* (2018) 23:836–44. doi: 10.26719/2017.23.12.836
57. Karim R, Khan S, Ibrahim M, Nasrullah N. Estimation of per capita food consumption patterns and related poverty in Kabal. *Bus Eco J.* (2018) 99:2–6. doi: 10.4172/2151-6219.1000357
58. Sabbour SM, Hussein WM, Amin GE. Fruit and vegetable consumption among medical students in an Egyptian University: knowledge, practice, and attitude towards accessible healthy food. *Egypt J Commun Med.* (2018) 36:75–93. doi: 10.21608/ejcm.2018.6871
59. Downs SM, Thow AM, Leeder SR. The effectiveness of policies for reducing dietary trans fat: a systematic review of the evidence. *Bull World Health Organ.* (2013) 91:262–9. doi: 10.2471/BLT.12.111468
60. Fats and fatty acids in human nutrition. Report of an expert consultation. *FAO Food Nutr Pap.* (2010) 91:1–166. Available online at: https://www.fao.org/3/i1953e/i1953e.pdf
61. Risérus U, Willett WC, Hu FB. Dietary fats and prevention of type 2 diabetes. *Prog Lipid Res.* (2009) 48:44–51. doi: 10.1016/j.plipres.2008.10.002
62. Mancini A, Imperlini E, Nigro E, Montagnese C, Daniele A, Orrù S, et al. Biological and nutritional properties of palm oil and palmitic acid: effects on health. *Molecules.* (2015) 20:17339–61. doi: 10.3390/molecules200917339
63. Micha R, Khatibzadeh S, Shi P, Fahimi S, Lim S, Andrews KG, et al. Global, regional, and national consumption levels of dietary fats and oils in 1990 and 2010: A systematic analysis including 266 country-specific nutrition surveys. *BMJ.* (2014) 348:g2272. doi: 10.1136/bmj.g2272
64. Alothaimeen A, Ezzat A, Mohamed G, Muammar T, Al-Madouj A. Dietary fat and breast cancer in Saudi Arabia: a case-control study. *East Mediterr Health J.* (2004) 10:879–86. doi: 10.26719/2004.10.6.879
65. *Diet High in Trans Fatty Acids - Level 3 Risk*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/diet-high-in-trans-fatty-acids-level-3-risk (cited November 2, 2021).
66. de Souza RJ, Mente A, Maroleanu A, Cozma AI, Ha V, Kishibe T, et al. Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies. *BMJ.* (2015) 351:h3978. doi: 10.1136/bmj.h3978
67. Pearson-Stuttard J, Hooton W, Critchley J, Capewell S, Collins M, Mason H, et al. Cost-effectiveness analysis of eliminating industrial and all trans fats in England and Wales: modelling study. *J Public Health (Oxf).* (2017) 39:574–82. doi: 10.1093/pubmed/fdw095
68. Yammine S, Huybrechts I, Biessy C, Dossus L, Aglago EK, Naudin S, et al. Dietary and circulating fatty acids and ovarian cancer risk in the European prospective investigation into cancer and nutrition. *Cancer Epidemiol Biomarkers Prev.* (2020) 29:1739–49. doi: 10.1158/1055-9965.EPI-19-1477
69. Micha R, Mozaffarian D. Trans fatty acids: effects on cardiometabolic health and implications for policy. *Prostaglandins Leukot Essent Fatty Acids.* (2008) 79:147–52. doi: 10.1016/j.plefa.2008.09.008
70. Sadeghi M, Simani M, Mohammadifard N, Talaei M, Roohafza H, Hassannejad R, et al. Longitudinal association of dietary fat intake with cardiovascular events in a prospective cohort study in Eastern Mediterranean region. *Int J Food Sci Nutr.* (2021) 72:1095–104. doi: 10.1080/09637486.2021.1895725
71. World Health Organization. *Guidelines: Saturated Fatty Acid and Trans-Fatty Acid Intake for Adults and Children* (2018).
72. Ismail G, Abo El Naga R, El Sayed Zaki M, Jabbour J, Al-Jawaldeh A. Analysis of fat content with special emphasis on trans isomers in frequently consumed food products in Egypt: the first steps in the trans fatty acid elimination roadmap. *Nutrients.* (2021) 13:3087. doi: 10.3390/nu13093087
73. Mozaffarian D, Abdollahi M, Campos H, Houshiarrad A, Willett WC. Consumption of trans fats and estimated effects on coronary heart disease in Iran. *Eur J Clin Nutr.* (2007) 61:1004–10. doi: 10.1038/sj.ejcn.1602608
74. Nowrouzi F, Samimi B. *The Food Balance Sheet of Iran, 1989-2001*. Tehran: Agricultural Planning and Economic Research Institute (2002).
75. Amerzadeh M, Takian A. Reducing sugar, fat, and salt for prevention and control of noncommunicable diseases (NCDs) as an adopted health policy in Iran. *Med J Islam Repub Iran.* (2020) 34:136. doi: 10.47176/mjiri.34.136
76. Saghafi Z, Zargaraan A, Tabibiazar M, Hosseini H. Is trans fatty acid still an issue for policy makers in Iran? A Technical Report. *Nutr Food Sci Res.* (2018) 5:47–51. doi: 10.29252/nfsr.5.2.47
77. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA guideline on the primary prevention of cardiovascular disease: a report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. *Circulation.* (2019) 140:e596–e646. doi: 10.1161/CIR.0000000000000678
78. Carson JAS, Lichtenstein AH, Anderson CAM, Appel LJ, Kris-Etherton PM, Meyer KA, et al. Dietary cholesterol and cardiovascular risk: a science advisory from the American Heart Association. *Circulation.* (2020) 141:e39–e53. doi: 10.1161/CIR.0000000000000743
79. Jacobson TA, Maki KC, Orringer CE, Jones PH, Kris-Etherton P, Sikand G, et al. National lipid association recommendations for patient-centered management of dyslipidemia: part 2. *J Clin Lipidol.* (2015) 9(6 Suppl.):S1–S122.e1. doi: 10.1016/j.jacl.2015.09.002
80. Guideline: *Sugars Intake for Adults and Children*. Geneva: World Health Organization (2015).
81. Hauner H, Bechthold A, Boeing H, Brönstrup A, Buyken A, Leschik-Bonnet E, et al. Evidence-based guideline of the German Nutrition Society:

carbohydrate intake and prevention of nutrition-related diseases. *Ann Nutr Metab.* (2012) 60(Suppl. 1):1–58. doi: 10.1159/000335326
82. Malik VS, Pan A, Willett WC, Hu FB. Sugar-sweetened beverages and weight gain in children and adults: a systematic review and meta-analysis. *Am J Clin Nutr*. (2013) 98:1084–102. doi: 10.3945/ajcn.113.058362
83. Malik VS, Popkin BM, Bray GA, Després JP, Willett WC, Hu FB. Sugar-sweetened beverages and risk of metabolic syndrome and type 2 diabetes: a meta-analysis. *Diabetes Care.* (2010) 33:2477–83. doi: 10.2337/dc10-1079
84. Moynihan P, Petersen PE. Diet, nutrition and the prevention of dental diseases. *Public Health Nutr*. (2004) 7:201–26. doi: 10.1079/PHN2003589
85. Sheiham A, James WP. A reappraisal of the quantitative relationship between sugar intake and dental caries: the need for new criteria for developing goals for sugar intake. *BMC Public Health.* (2014) 14:863. doi: 10.1186/1471-2458-14-863
86. Sheiham A, James WP. A new understanding of the relationship between sugars, dental caries and fluoride use: implications for limits on sugars consumption. *Public Health Nutr.* (2014) 17:2176–84. doi: 10.1017/S136898001400113X
87. Petersen PE. The World Oral Health Report 2003: continuous improvement of oral health in the 21st century–the approach of the WHO Global Oral Health Programme. *Community Dent Oral Epidemiol.* (2003) 31(Suppl. 1):3–23. doi: 10.1046/j.2003.com122.x
88. Marcenes W, Kassebaum NJ, Bernabé E, Flaxman A, Naghavi M, Lopez A, et al. Global burden of oral conditions in 1990-2010: a systematic analysis. *J Dent Res.* (2013) 92:592–7. doi: 10.1177/0022034513490168
89. *Diet High in Sugar-Sweetened Beverages - Level 3 Risk*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/diet-high-in-sugar-sweetened-beverages-level-3-risk (accessed August 30, 2021)
90. DiMeglio DP, Mattes RD. Liquid versus solid carbohydrate: effects on food intake and body weight. *Int J Obes Relat Metab Disord.* (2000) 24:794–800. doi: 10.1038/sj.ijo.0801229
91. Mattes RD. Dietary compensation by humans for supplemental energy provided as ethanol or carbohydrate in fluids. *Physiol Behav*. (1996) 59:179–87. doi: 10.1016/0031-9384(95)02007-1
92. Schulze MB, Liu S, Rimm EB, Manson JE, Willett WC, Hu FB. Glycemic index, glycemic load, and dietary fiber intake and incidence of type 2 diabetes in younger and middle-aged women. *Am J Clin Nutr.* (2004) 80:348–56. doi: 10.1093/ajcn/80.2.348
93. Stanhope KL, Schwarz JM, Keim NL, Griffen SC, Bremer AA, Graham JL, et al. Consuming fructose-sweetened, not glucose-sweetened, beverages increases visceral adiposity and lipids and decreases insulin sensitivity in overweight/obese humans. *J Clin Invest.* (2009) 119:1322–34. doi: 10.1172/JCI37385
94. *Policy Statement and Recommended Actions to Lower National Salt Intake and Death Rates From High Blood Pressure and Stroke in the Eastern Mediterranean Region.* Cairo: WHO Regional Office for Eastern Mediterranean (2015). Available online at: http://www.emro.who.int/noncommunicable-diseases/publications/guidelines.html (accessed October 16, 2021).
95. *Fiscal Policies for Diet and Prevention of Noncommunicable Diseases: Technical Meeting Report.* Geneva (2015). Available online at: https://apps.who.int/iris/bitstream/handle/10665/155294/salt-factsheet-web.pdf?sequence=1&isAllowed=y (accessed October 16, 2021).
96. Institute for Health Metrics and Evaluation (IHME). *GBD 2019 Cause and Risk Summary: Diet-High-in- Sodium).* Seattle, WA: IHME, University of Washington (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/diet-high-in-sodium-level-3-risk (accessed August 30, 2021).
97. Farrand C, He FJ, MacGregor GA. Reducing population salt intake in the Eastern Mediterranean Region - time for urgent action. *East Mediterr Health J.* (2015) 20:761–4. doi: 10.26719/2014.20.12.761
98. *GBD 2019 Cause and Risk Summaries: High-Body-Mass-Index-Level-2-Risks*. Institute for Health Metrics and Evaluation. Available online at: http://www.healthdata.org/results/gbd_summaries/2019/high-body-mass-index-level-2-risk (cited November 2, 2021).
99. *Report of the Commission on Ending Childhood Obesity*. Geneva: World Health Organization (2016). Available online at: http://apps.who.int/iris/bitstream/handle/10665/204176/9789241510066_eng.pdf (accessed October 29, 2021).
100. Al-Qahtani AM. Prevalence and predictors of obesity and overweight among adults visiting primary care settings in the Southwestern Region, Saudi Arabia. *Biomed Res Int.* (2019) 2019:8073057. doi: 10.1155/2019/8073057
101. Aboulghate M, Elaghoury A, Elebrashy I, Elkafrawy N, Elshishiney G, Abul-Magd E, et al. The Burden of Obesity in Egypt. *Front Public Health.* (2021) 9:718978. doi: 10.3389/fpubh.2021.718978
102. GBD 2015 Obesity Collaborators, Afshin A, Forouzanfar MH, Reitsma MB, Sur P, Estep K, et al. Health effects of overweight and obesity in 195 countries over 25 years. *N Engl J Med.* (2017) 377:13–27. doi: 10.1056/NEJMoa1614362
103. Ajlouni K, Khader Y, Batieha A, Jaddou H, El-Khateeb M. An alarmingly high and increasing prevalence of obesity in Jordan. *Epidemiol Health*. (2020) 42:e2020040. doi: 10.4178/epih.e2020040
104. Guthold R, Stevens GA, Riley LM, Bull FC. Worldwide trends in insufficient physical activity from 2001 to 2016: a pooled analysis of 358 population-based surveys with 1·9 million participants. *Lancet Glob Health.* (2018) 6:e1077–e86. doi: 10.1016/S2214-109X(18)30357-7
105. *The Ministry of Health and Prevention (United Arab of Emirates)* (2018). Available online at: https://www.mohap.gov.ae/Files/MOH_OpenData/1556/UAE_NHS_2018.pdf (accessed November 20, 2021).
106. *Global Recommendations on Physical Activity for Health*. Geneva: World Health Organization (2010).
107. World Health Organization. *A Global Brief on Hypertension: Silent Killer, Global Public Health Crisis: World Health Day 2013*. Available online at: https://apps.who.int/iris/bitstream/handle/10665/79059/W?sequence=1 (accessed September 19, 2021).
108. *High Systolic Blood Pressure - Level 2 Risk*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/high-systolic-blood-pressure-level-2-risk (cited November 2, 2021).
109. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in blood pressure from 1975 to 2015: a pooled analysis of 1479 population-based measurement studies with 19·1 million participants. *Lancet.* (2017) 389:37–55. doi: 10.1016/S0140-6736(16)31919-5
110. *Global Report on Diabetes*. World Health Organization (2017). Available online at: https://www.who.int/diabetes/global-report/en/ (accessed September 15, 2021).
111. NCD Risk Factor Collaboration (NCD-RisC). Worldwide trends in diabetes since 1980: a pooled analysis of 751 population-based studies with 4.4 million participants. *Lancet.* (2016) 387:1513–30. doi: 10.1016/S0140-6736(16)00618-8
112. *High Fasting Plasma Glucose - Level 2 Risk*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/high-fasting-plasma-glucose-level-2-risk (cited November 2, 2021).
113. Global Burden of Metabolic Risk Factors for Chronic Diseases Collaboration. Cardiovascular disease, chronic kidney disease, and diabetes mortality burden of cardiometabolic risk factors from 1980 to 2010: a comparative risk assessment. *Lancet Diabetes Endocrinol.* (2014) 2:634–47. doi: 10.1016/S2213-8587(14)70102-0
114. NCD Risk Factor Collaboration (NCD-RisC). Repositioning of the global epicentre of non-optimal cholesterol. *Nature.* (2020) 582:73–7. doi: 10.1038/s41586-020-2338-1
115. *High LDL Cholesterol - Level 2 Risk*. Institute for Health Metrics and Evaluation (2020). Available online at: http://www.healthdata.org/results/gbd_summaries/2019/high-ldl-cholesterol-level-2-risk (cited November 2, 2021).
116. Rippe JM. Lifestyle medicine: the health promoting power of daily habits and practices. *Am J Lifestyle Med.* (2018) 12:499–512. doi: 10.1177/1559827618785554
117. Bendsen NT, Stender S, Szecsi PB, Pedersen SB, Basu S, Hellgren LI, et al. Effect of industrially produced trans fat on markers of systemic inflammation: evidence from a randomized trial in women. *J Lipid Res.* (2011) 52:1821–8. doi: 10.1194/jlr.M014738
118. Lopez-Garcia E, Schulze MB, Meigs JB, Manson JE, Rifai N, Stampfer MJ, et al. Consumption of trans fatty acids is related to plasma biomarkers of inflammation and endothelial dysfunction. *J Nutr.* (2005) 135:562–6. doi: 10.1093/jn/135.3.562
119. Mozaffarian D, Rimm EB, King IB, Lawler RL, McDonald GB, Levy WC. trans fatty acids and systemic inflammation in heart failure. *Am J Clin Nutr.* (2004) 80:1521–5. doi: 10.1093/ajcn/80.6.1521

120. Mozaffarian D, Pischon T, Hankinson SE, Rifai N, Joshipura K, Willett WC, et al. Dietary intake of trans fatty acids and systemic inflammation in women. *Am J Clin Nutr.* (2004) 79:606–12. doi: 10.1093/ajcn/79.4.606
121. Esmaillzadeh A, Azadbakht L. Home use of vegetable oils, markers of systemic inflammation, and endothelial dysfunction among women. *Am J Clin Nutr.* (2008) 88:913–21. doi: 10.1093/ajcn/88.4.913
122. Kim J, Nam JH. Insight into the relationship between obesity-induced low-level chronic inflammation and COVID-19 infection. *Int J Obes (Lond).* (2020) 44:1541–2. doi: 10.1038/s41366-020-0602-y
123. Sanchis-Gomar F, Lavie CJ, Mehra MR, Henry BM, Lippi G. Obesity and outcomes in COVID-19: when an epidemic and pandemic collide. *Mayo Clin Proc.* (2020) 95:1445–53. doi: 10.1016/j.mayocp.2020.05.006
124. Eckel RH, Krauss RM. American Heart Association call to action: obesity as a major risk factor for coronary heart disease. AHA Nutrition Committee. *Circulation.* (1998) 97:2099–100. doi: 10.1161/01.CIR.97.21.2099
125. Després JP. Abdominal obesity as important component of insulin-resistance syndrome. *Nutrition.* (1993) 9:452–9.
126. Hu F. *Obesity Epidemiology*. New York, NY: Oxford University Press (2008).
127. Restrepo BJ, Rieger M. Denmark's policy on artificial trans fat and cardiovascular disease. *Am J Prev Med.* (2016) 50:69–76. doi: 10.1016/j.amepre.2015.06.018
128. Althumiri NA, Basyouni MH, AlMousa N, AlJuwaysim MF, Almubark RA, BinDhim NF, et al. Obesity in Saudi Arabia in 2020: prevalence, distribution, and its current association with various health conditions. *Healthcare (Basel).* (2021) 9:311. doi: 10.3390/healthcare9030311
129. Khondaker MTI, Khan JY, Refaee MA, Hajj NE, Rahman MS, Alam T. Obesity in Qatar: a case-control study on the identification of associated risk factors. *Diagnostics (Basel).* (2020) 10:883. doi: 10.3390/diagnostics10110883
130. SPRINT Research Group, Wright JT Jr, Williamson JD, Whelton PK, Snyder JK, Sink KM, et al. A Randomized trial of intensive versus standard blood-pressure control. *N Engl J Med.* (2015) 373:2103–16. doi: 10.1056/NEJMoa1511939
131. American Diabetes Association. 9. Cardiovascular disease and risk management. *Diabetes Care.* (2017) 40(Suppl. 1):S75–S87. doi: 10.2337/dc17-S012
132. Whelton PK, Carey RM, Aronow WS, Casey DE Jr, Collins KJ, Dennison Himmelfarb C, et al. 2017 ACC/AHA/AAPA/ABC/ACPM/AGS/APhA/ASH/ASPC/NMA/PCNA Guideline for the prevention, detection, evaluation, and management of high blood pressure in adults: a report of the American College of Cardiology/American Heart Association Task Force on clinical practice guidelines. *J Am Coll Cardiol.* (2018) 71:e127–e248. doi: 10.1016/j.jacc.2017.11.006
133. Turk-Adawi K, Sarrafzadegan N, Fadhil I, Taubert K, Sadeghi M, Wenger NK, et al. Cardiovascular disease in the Eastern Mediterranean region: epidemiology and risk factor burden. *Nat Rev Cardiol.* (2018) 15:106–19. doi: 10.1038/nrcardio.2017.138
134. Allemani C, Matsuda T, Di Carlo V, Harewood R, Matz M, Nikšić M, et al. Global surveillance of trends in cancer survival 2000-14 (CONCORD-3): analysis of individual records for 37 513 025 patients diagnosed with one of 18 cancers from 322 population-based registries in 71 countries. *Lancet.* (2018) 391:1023–75. doi: 10.1016/S0140-6736(17)33326-3
135. Mowafi M, Khadr Z, Kawachi I, Subramanian SV, Hill A, Bennett GG. Socioeconomic status and obesity in Cairo, Egypt: a heavy burden for all. *J Epidemiol Glob Health.* (2014) 4:13–21. doi: 10.1016/j.jegh.2013.09.001
136. Bustami M, Matalka KZ, Mallah E, Abu-Qatouseh L, Abu Dayyih W, Hussein N, et al. The prevalence of overweight and obesity among women in Jordan: a risk factor for developing chronic diseases. *J Multidiscip Healthc.* (2021) 14:1533–41. doi: 10.2147/JMDH.S313172
137. Al-Raddadi R, Bahijri SM, Jambi HA, Ferns G, Tuomilehto J. The prevalence of obesity and overweight, associated demographic and lifestyle factors, and health status in the adult population of Jeddah, Saudi Arabia. *Ther Adv Chronic Dis.* (2019) 10:2040622319878997. doi: 10.1177/2040622319878997
138. Oguoma VM, Coffee NT, Alsharrah S, Abu-Farha M, Al-Refaei FH, Al-Mulla F, et al. Prevalence of overweight and obesity, and associations with socio-demographic factors in Kuwait. *BMC Public Health.* (2021) 21:667. doi: 10.1186/s12889-021-10692-1
139. Weiderpass E, Botteri E, Longenecker JC, Alkandari A, Al-Wotayan R, Al Duwairi Q, et al. The prevalence of overweight and obesity in an adult Kuwaiti population in 2014. *Front Endocrinol (Lausanne).* (2019) 10:449. doi: 10.3389/fendo.2019.00449
140. Lemamsha H, Papadopoulos C, Randhawa G. Understanding the risk and protective factors associated with obesity amongst Libyan adults - a qualitative study. *BMC Public Health.* (2018) 18:493. doi: 10.1186/s12889-018-5411-z
141. Lemamsha H, Randhawa G, Papadopoulos C. Prevalence of overweight and obesity among Libyan men and women. *Biomed Res Int.* (2019) 2019:8531360. doi: 10.1155/2019/8531360
142. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*. Available online at: https://sdgs.un.org/sites/default/files/ publications/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf (accessed August 19, 2020).
143. NCD Countdown 2030 collaborators. NCD Countdown 2030: worldwide trends in non-communicable disease mortality and progress towards Sustainable Development Goal target 3.4. *Lancet.* (2018) 392:1072–88. doi: 10.1016/S0140-6736(18)31992-5
144. Ezzati M, Pearson-Stuttard J, Bennett JE, Mathers CD. Acting on non-communicable diseases in low- and middle-income tropical countries. *Nature.* (2018) 559:507–16. doi: 10.1038/s41586-018-0306-9
145. World Health Organization. *Tackling NCDS: 'Best Buys' and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases.* Geneva: WHO (2017).
146. *Assessing National Capacity for the Prevention and Control of Noncommunicable Diseases: Report of the 2019 Global Survey.* Geneva: World Health Organization (2020). Available online at: https://www.who.int/publications/i/item/ncd-ccs-2019 (accessed December 16, 2021).
147. Al-Jawaldeh A, Megally R. Impact evaluation of soft drink taxes as part of nutrition policies in Gulf Cooperation Council countries: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and United Arab Emirates. *F1000Res.* (2021) 9:1287. Available online at: https://doi.org/10.12688/f1000research.27097.2
148. World Food Program. *Operation Database.* (2020). Available online at: https://www.wfp.org/operations/dj02-djibouti-country-strategic-plan-2020-2024
149. WHO, Eastern Mediterranean Regional Office data base.
150. GBD 2019 Risk Factors Collaborators. Global burden of 87 risk factors in 204 countries and territories, 1990-2019: a systematic analysis for the Global Burden of Disease Study 2019. *Lancet.* (2020) 396:1223–49. doi: 10.1016/S0140-6736(20)30752-2
151. World Health Organization. *Regional Office for the Eastern Mediterranean. Regional Framework for Action on Obesity Prevention 2019-2023*. Cairo: WHO (2018).
152. World Health Organization. *Regional Office for the Eastern Mediterranean. Regional Regional Framework for Action to Implement the United Nations Political Declaration on Noncommunicable Diseases* (2019).

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers in Nutrition

ORIGINAL RESEARCH
published: 17 March 2022
doi: 10.3389/fnut.2022.824305

Adherence to the United States Department of Agriculture Dietary Recommendations Pre- and During the Coronavirus Disease-19 Pandemic Among Pregnant Women in Arab Countries

Maha Hoteit[1,2,3], Reem Hoteit[4], Ayoub Al-Jawaldeh[5], Mariane Abou Nasr[1], Sara Obeid[1], Chadi Fakih[6], Mohamad El Hajj[1], Radwan Qasrawi[7,8], Rania Abu Seir[9], Sabika Allehdan[10], Mahmoud Samy Ismail[11,12], Khlood Bookari[13], Jamila Arrish[14], Nahla Al-Bayyari[15] and Reema Tayyem[16]**

[1] Faculty of Public Health, Lebanese University, Beirut, Lebanon, [2] PHENOL Research Group Public Health Nutrition Program-Lebanon, Faculty of Public Health, Lebanese University, Beirut, Lebanon, [3] Lebanese University Nutrition Surveillance Center (LUNSC), Lebanese Food Drugs and Chemical Administrations, Lebanese University, Beirut, Lebanon, [4] Hariri School of Nursing, American University of Beirut, Beirut, Lebanon, [5] World Health Organization Regional Office for the Eastern Mediterranean, Cairo, Egypt, [6] Al Hadi Laboratory and IVF Center, Beirut, Lebanon, [7] Department of Computer Science, Al-Quds University, Jerusalem, Palestine, [8] Department of Computer Engineering, Istinye University, Istanbul, Turkey, [9] Department of Medical Laboratory Sciences, Al-Quds University, Jerusalem, Palestine, [10] Department of Biology, College of Science, University of Bahrain, Zallaq, Bahrain, [11] Department of Obstetrics and Gynecology, King Hamad University Hospital, Busaiteen, Bahrain, [12] Department of Obstetrics and Gynecology, College of Medicine and Medical Sciences, Arabian Gulf University, Manama, Bahrain, [13] Department of Clinical Nutrition, Faculty of Applied Medical Sciences, Taibah University, Madinah, Saudi Arabia, [14] National Nutrition Committee (NNC), Saudi Food and Drug Authority (Saudi FDA), Riyadh, Saudi Arabia, [15] Department of Nutrition and Food Technology, Al-Huson University College, Al-Balqa Applied University, As-Salt, Jordan, [16] Department of Human Nutrition, College of Health Sciences, Qatar University, Doha, Qatar

OPEN ACCESS

Edited by:
Uma Tiwari, Technological University Dublin, Ireland

Reviewed by:
Aida Turrini, Independent Researcher, Rome, Italy
Roberta Masella, National Institute of Health (ISS), Italy

***Correspondence:**
Maha Hoteit
m.hoteit@ul.edu.lb
Reema Tayyem
Reema.tayyem@qu.edu.qa

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *29 November 2021*
Accepted: *17 February 2022*
Published: *17 March 2022*

Citation:
Hoteit M, Hoteit R, Al-Jawaldeh A, Abou Nasr M, Obeid S, Fakih C, El Hajj M, Qasrawi R, Abu Seir R, Allehdan S, Ismail MS, Bookari K, Arrish J, Al-Bayyari N and Tayyem R (2022) Adherence to the United States Department of Agriculture Dietary Recommendations Pre- and During the Coronavirus Disease-19 Pandemic Among Pregnant Women in Arab Countries. Front. Nutr. 9:824305. doi: 10.3389/fnut.2022.824305

During pregnancy, woman's diet is one of the most preeminent factors affecting mother and child's health. Prior to the coronavirus disease-19 (COVID-19) pandemic, inadequate maternal diet and low adherence to dietary guidelines was reported among pregnant women in the Arab countries. Nowadays, COVID-19 infection during pregnancy is widely discussed among literature. However, there is limited data on the health impacts of the COVID-19 pandemic on non-infected pregnant women. This substantially larger group also suffered significant lifestyle changes during the lockdown period. The aim of the study is to characterize dietary patterns, intake and adherence to the United States Department of Agriculture (USDA) pregnancy guidelines before and during the COVID-19 pandemic in Arab pregnant women. Using a specially designed questionnaire and using the snowball sampling method, the survey was carried out among a convenient sample of 1,939 pregnant women from five Arab countries. Our study found an increment in the consumption of cereals, fruits, vegetables, dairy products, meats, and nuts that occurred during the pandemic compared to the preceding period. Despite this noticeable increase during the pandemic, the Arab pregnant women in this study had significantly lower adherence to the USDA pregnancy

guidelines. The daily consumption of almost all food groups was lower than the USDA's daily recommendations, except for fruits intake, which was higher than the daily standard. Demonstrated poor adherence to prenatal USDA dietary guidelines by Arab pregnant women can lead to numerous deficiencies and health risks among their offspring. In conclusion, our study showed that before and during the COVID-19 pandemic, poor adherence to dietary recommendations occurred in a considerable number of Arab pregnant women. The findings emphasize the need for nutritional education and intervention during prenatal visits.

Keywords: pregnant women, COVID-19, maternal nutrition, USDA recommendations, adherence

INTRODUCTION

By March 21, 2020, the novel 2019 coronavirus disease (COVID-19) had infected over 292,000 confirmed cases worldwide, with 18,000 confirmed cases in the Eastern Mediterranean countries (1). Because of the new COVID-19's extremely contagious nature, numerous governments have taken exceptional measures to prevent disease transmission, such as suspending public transportation and restricting the whole social life (2). These measures affected the lifestyles of many people, including pregnant women, in a significant way. In the time of pandemics, mother's nutritional patterns become of high-priority for the mother's and child's health (2). Healthy eating habits and adherences to evidenced-based guidelines is one of the requirements for a successful pregnancy (3). Poor adherence to dietary standards and guidelines can lead to nutritional deficits that affects the pregnancy's progress and the child's healthy growth (2, 3). During crises, good dietary patterns, combined with adequate intake, increases the likelihood of an optimal pregnancy outcomes (2, 4). During pregnancy, the development of maternal tissues, fetal growth, and breast milk production increase nutritional requirements (4). Different national and international organizations advocate dietary improvement, such as adhering to the USDA pregnancy guidelines which show the amount of food recommended for pregnant women including fruits, vegetables, grains, dairy, and protein foods (5). Despite evidence supporting the importance of maternal nutrition, various studies reveal that few women follow adequate diets (6). A study conducted in Jordan showed low adherence to dietary guidelines among 99% of pregnant women during the pre-COVID-19 time (6). This study was conducted to provide a situational analysis with regards to maternal nutrition and to assess the adherence to the USDA's guidelines among pregnant women in five Arab countries (Lebanon, Palestine, Jordan, Saudi Arabia, and Bahrain). Due to unavailability of common Eastern Mediterranean guidelines, USDA guidelines were adopted in this study to determine cutoffs of serving size consumption, which may not fully reflect the situation of Eastern Mediterranean women. The selection of countries was based on a collaborative work between researchers from these countries. Despite the availability of nutrition awareness information, the working hypothesis anticipated in this study that most pregnant women ignore the appropriate advice and do not adhere to the USDA dietary guidelines.

MATERIALS AND METHODS

Questionnaire

A cross-sectional study, using the snowball sampling method, was conducted during the COVID-19 pandemic in five Arab countries (Lebanon, Palestine, Jordan, Saudi Arabia and Bahrain). A web-based questionnaire was disseminated through social media websites (available at the link https://www.palnut.org/frontend/web/index.php?r=survey/survey/index) to collect data from pregnant women. The questionnaire used in our survey was previously validated in two published data (6, 7). The current survey investigated pregnant women's sociodemographic characteristics, maternal medical history, eating patterns, food consumption, physical activity patterns, anthropometric data, smoking, anxiety, and depression. The first section of the questionnaire inquired about pregnancy and its progression. It includes questions about the mother's age, health status, and diseases. Moreover, the socio-demographic characteristics included education, residency, and economic situation. The second section questioned about the daily serving sizes from each food group (bread, pasta, cereal, vegetables, fruits, meat, poultry, fish, nuts, sweets, fast food, fats, and oils) consumed during the day and week prior to completing this survey. Participants were also asked about their mental health (anxiety and depression) and smoking habits, as well as any physical activities they engaged in. In the current study, we did not cover the pre-pregnancy period, but rather the period preceding the COVID-19 pandemic and the pandemic period only. The questionnaire had various questions, some with only one option for each topic and others with open-ended answers.

Variables and Measurements

Body Mass Index

The pregnant women's pre-pregnancy body mass index (BMI) was calculated according to the World Health Organization (WHO)'s instructions (8).

Depression

Depression was assessed using the validated Patient Health Questionnaire (PHQ-9). It was selected according to its effectiveness in identifying depression (9). This questionnaire encompasses nine depression-related issues. Depression

levels were classified as: no depression = 0–4, mild = 5–9, moderate = 10–14, moderately severe = 15–19, and severe = >20.

Anxiety

The clinically validated tool entitled "seven-item Generalized Anxiety Disorder-7 (GAD-7)" was used to assess anxiety symptoms (10). Respondents rank items on a four-point scale ranging from 0 (never) to 3 (nearly every day). Anxiety severity was defined by total scores of 0–4 for no anxiety, 5–9 for mild, 10–14 for moderate, and 15 or higher for severe anxiety (10).

Physical Activity

Pregnant woman was considered active if she claimed that she engaged in any degree of physical activity (low, moderate, or high) for at least half an hour per day (11).

Dietary Guideline for Pregnant Women

Recommended amounts of food were classified based on the USDA's guideline for pregnant women (12). The food group's consumption was dichotomized based on USDA guidelines' cutoff points (5). Each food group was assigned a score 0 or 1, with 0 indicating lower intake than the USDA's daily recommendations and 1 indicating higher intake.

For the food group bread, rice, and other cereals, less than six servings indicate a lower intake, and greater than or equal to six servings indicate a higher intake. A lower intake of fruit is equal to less than two servings, while a higher intake is greater than or equal to two servings. Less than 2.5 servings of vegetables suggest a lower intake, while 2.5 servings or more indicate a higher intake. Less than 5.5 servings in the protein food group indicates a lower intake, while greater than or equal to 5.5 servings indicates a higher intake. As for the dairy food group, a lower intake is equal to three servings, while a higher intake is greater than or equal to three servings.

Additionally, the adherence score to the USDA guidelines was derived by adding the adherence to recommendations for each food group. This variable was then dichotomized into two categories: low adherence score (0–2) and high adherence score (3–5).

Inclusion/Exclusion Criteria

The following criteria conditioned the data collection: (i) pregnancy since the pre-COVID-19 pandemic period; (ii) pregnancy of normal course; (iii) the woman's age > 18; (iv) place of residence—the listed five countries; (v) replying to all questions; (vi) consenting participating in the study. Moreover, the exclusion criteria were conception during the intra-COVID-19 pandemic period and some risk factors such as miscarriage.

Ethical Consideration

The study design obtained written approval of the Ethics Committee in Scientific Research of Lebanese University (CUER#30-2020), as well as universities from all participating countries. Before completing the questionnaire, each participant was informed of the study's goal and ensured the confidentiality of their information. The completion of the questionnaire was voluntary and anonymous. Consenting to participate in the study was considered as a necessary component.

Statistics and Data Analysis

Continuous variables were expressed as means and standard deviations (SDs), while categorical variables were shown as frequencies and percentages. Chi-square test was used to compare variables among the five countries, while ANOVA test was applied for continuous variables. The Paired sample *t*-test was used to compare continuous variables before and during the pandemic, while the McNemar test (a marginal homogeneity test for paired data) was used to compare categorical variables. The statistical significance level was set at p-value < 0.05, and the statistical analysis was carried out using IBM Corp. Released 2017. IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.

RESULTS

A total number of 1,939 women participated in the current survey. **Table 1** shows the sociodemographic characteristics of the study participants. The respondents' mean (±SD) age was 28.5 (±5.4) years. Highest age was reported among Saudi pregnant women [29.6 (±5.7)] while the youngest pregnant women were from Palestine [27.7 (±5.5)]. Similarly, the vast majority (77%) were young adults, with Saudi Arabia having the highest proportion (83%). Palestine, on the other hand, had the highest number of youth (32%) (p-value < 0.001). Around two-thirds (62%) of the participants had received a bachelor's or graduate's degree, with Saudi Arabia having the highest percentage (81%) and Jordan having the lowest (53%). Lebanon, however, was among the best in terms of graduate degrees (28%). Only 38% of women worked, with Bahrein having the highest rate (49%) and Saudi Arabia having the lowest (31%) (p-value < 0.001). Furthermore, Saudi Arabia had the greatest proportion of unemployed pregnant women (69%). Most pregnant women (64%) reported a drop in household income, with Jordan having the greatest rate (84%) and Bahrain having the lowest (36%). Participants from Lebanon also reported the largest income loss, with a 9% decrease.

The health characteristics of the respondents are summarized in **Table 2**. The mean value of the pre-pregnancy BMI for respondents was 25.1 (±8) kg/m^2, with more than half having normal BMI (55%), 28.4% being overweight, 12% being obese (class I, II, and III), and the remaining (5%) being underweight. Bahrain had the highest pre-pregnancy BMI 27.5 (±12.1) and Palestine had the lowest 24.5 (±7.2). Furthermore, Bahrein had the highest proportions of overweight and obese (52%) and Palestine the lowest (34%) (p-value < 0.001). COVID-19 was diagnosed in only a small percentage of the respondents (7%). Saudi Arabia had the greatest percentage of infection (14%) while Palestine had the lowest (3%) (p-value < 0.001). Around 40% of pregnant women said they had health complications, with Jordan placing first (72%) and Bahrein last (43%). Most people stated they did not have diabetes (97%) or gestational diabetes (95%) or hypertension (98%) or thyroid disorders (96%). Nearly a third of the individuals (31%) suffered from moderate to severe depression, with Jordan topping the list (53%) and Bahrein trailing behind (33%) (p-value 0.001). Furthermore,

TABLE 1 | Socio-economic characteristics of the study participants, by country.

Variable	Jordan *n* = 531 *n* (%)	Palestine *n* = 609 *n* (%)	Lebanon *n* = 363 *n* (%)	Saudi Arabia *n* = 256 *n* (%)	Bahrain *n* = 180 *n* (%)	*P*-value
Age (Year: mean ± SD)	28.8 ± 5.5	27.7 ± 5.5	28.3 ± 4.8	29.6 ± 5.7	29.2 ± 4.9	<0.001
Youth (18–24)	128 (24.1)	192 (31.6)	91 (25.1)	43 (16.8)	33 (18.3)	
Young adults (>25)	403 (75.9)	416 (68.3)	272 (74.9)	213 (83.2)	147 (81.7)	
Education level						<0.001
Less than high school	33 (6.2)	49 (8.0)	11 (3.0)	2 (0.8)	16 (8.9)	
High school diploma	107 (20.2)	125 (20.5)	28 (7.7)	20 (7.8)	36 (20.0)	
Diploma	109 (20.5)	71 (11.7)	82 (22.6)	25 (9.8)	19 (10.6)	
Bachelor's degree	250 (47.1)	319 (52.4)	142 (39.1)	175 (68.4)	95 (52.8)	
Graduate degree	32 (6.0)	45 (7.4)	100 (27.5)	34 (13.3)	14 (7.8)	
Employment status						<0.001
Employed	204 (38.4)	194 (31.9)	169 (46.6)	79 (30.9)	89 (49.4)	
Unemployed	327 (61.6)	414 (68.0)	194 (53.4)	177 (69.1)	91 (50.6)	
Family income						<0.001
Decreased	446 (84.0)	434 (71.3)	181 (49.9)	111 (43.4)	64 (35.6)	
Increased	8 (1.5)	26 (4.3)	33 (9.1)	12 (4.7)	15 (8.3)	
No change	77 (14.5)	149 (24.5)	149 (41.0)	133 (52.0)	101 (56.1)	

roughly 16% were anxious, with Palestine having the highest rate (19%) and Bahrein having the lowest (7%). Around two-thirds of the participants (64%) were physically active, with Jordan having the most (77%) and Saudi Arabia having the least (64%) active persons (46%) (p-value < 0.001). Last but not least, more than a quarter of pregnant women (27%) smoked during their pregnancy, with Jordan having the highest percentage (67%) and Bahrein having the lowest (8%) (p-value < 0.001).

Daily Intake of the Main Food Groups

Table 3 shows the dietary intake among pregnant women from the five countries before and during the pandemic.

The consumption of cereals, fruits, vegetables, dairy products and protein group increased significantly during the pandemic compared to the period before (p-value < 0.001; **Table 3**). Additionally, before and during the pandemic, women's daily consumption of almost all food groups was lower than the USDA's daily recommendations, with the exception of fruit consumption, which was higher than the daily standard.

Bread, Rice and Other Cereals Group

Prior to the pandemic, in the five countries, more than half of women consumed less than six servings of breads, rice and other cereals. However, it was shown that the number of servings consumed per day of breads, rice and other cereals increased significantly during the pandemic (p-value < 0.001). For instance, around 64% of women in Jordan, 44.2% in Palestine, 30.66% in Lebanon, 22.8% in Saudi Arabia and 45.3% in Bahrain consumed more than six servings of this food group per day during the pandemic (p-value < 0.001). The lowest number of servings consumed was observed in Saudi Arabia (3.1 ± 2.3 versus 3.9 ± 3.2) and the highest was in Jordan (6.5 ± 6.7 versus 8.2 ± 8.4) (p-value < 0.001).

Fruits Group

Before the pandemic, more than 60% of pregnant women living in Jordan (63.6%) and Palestine (64.8%) and more than half of women living in Lebanon (56.4%) and Bahrain (56.1%) were adhering to the USDA's recommendations related to fruits intake (≥2 servings per day). This was not the case of Saudi pregnant women who consumed less than two servings per day of fruits before the pandemic. Nevertheless, an increase in the consumption of fruits was remarkable during the pandemic ($p < 0.001$). Before and during the pandemic, the lowest number of fruits servings was observed among Saudi women (1.4 ± 1 versus 1.8 ± 1.2). On the other hand, Jordanian women ranked first in consuming fruits before and during the pandemic (2.8 ± 2.9 versus 3 ± 2.4) (p-value < 0.001).

Vegetables Group

Prior to the pandemic, most of pregnant women in the five countries showed poor adherence to USDA's recommendations with regards to vegetable intake (≥2.5 servings per day). Nevertheless, the percentage of women showing acceptable adherence to USDA recommendations increased during the pandemic in all countries except in Lebanon (decrease of 3%) (p-value < 0.001). The lowest percentage of vegetable consumption was observed among Saudi women of which 86.8 and 82.7% consumed less than 2.5 servings per day, before and during the pandemic, respectively (p-value < 0.001). Otherwise, in both study periods, the highest percentage of pregnant women who consume vegetables was observed in Jordan (**Table 3**).

Milk and Dairy Products Group

Before the COVID-19 pandemic, around three quarter of pregnant women in all countries showed poor consumption of milk and dairy products (<3 servings per day). The lowest consumption was seen among Lebanese pregnant women of

TABLE 2 | Health characteristics of the study participants, by country.

Variable	Jordan *n* = 531 *n* (%)	Palestine *n* = 609 *n* (%)	Lebanon *n* = 363 *n* (%)	Saudi Arabia *n* = 256 *n* (%)	Bahrain *n* = 180 *n* (%)	*P*-value
Pre-pregnancy BMI (mean ± SD) kg/m^2	25.2 ± 6.0	24.5 ± 7.2	24.7 ± 9.7	24.9 ± 5.8	27.5 ± 12.1	<0.001
Pre-pregnancy BMI categories						<0.001
Normal	272 (54.1)	313 (60.2)	173 (58.6)	104 (49.5)	72 (44.7)	
Underweight	14 (2.8)	30 (5.8)	17 (5.7)	16 (7.6)	6 (3.7)	
Overweight	176 (34.9)	127 (24.4)	69 (23.4)	62 (29.5)	45 (27.9)	
Obese class I	32 (6.4)	39 (7.5)	28 (9.5)	18 (8.6)	24 (14.9)	
Obese class II	6 (1.2)	7 (1.4)	5 (1.7)	9 (4.3)	7 (4.4)	
Obese class III	3 (0.6)	4 (0.8)	3 (1.0)	1 (0.5)	7 (4.4)	
Diagnosed with COVID-19						<0.001
No	479 (90.2)	591 (97.1)	350 (96.4)	220 (85.9)	159 (88.3)	
Yes	52 (9.8)	18 (2.9)	13 (3.6)	36 (14.1)	21 (11.7)	
Health problems						<0.001
No	148 (27.87)	205 (33.66)	148 (40.8)	111 (43.4)	103 (57.2)	
Yes	383 (72.13)	404 (66.3)	215 (59.2)	145 (56.6)	77 (42.8)	
Diabetes						0.005
No	509 (95.9)	598 (98.2)	358 (98.6)	248 (96.9)	169 (93.9)	
Yes	22 (4.1)	11 (1.8)	5 (1.4)	8 (3.1)	11 (6.1)	
Gestational diabetes						<0.001
No	504 (94.9)	590 (96.9)	353 (97.3)	247 (96.5)	138 (76.7)	
Yes	27 (5.1)	19 (3.1)	10 (2.7)	9 (3.5)	42 (23.3)	
Hypertension						0.003
No	511 (96.2)	598 (98.2)	362 (99.7)	253 (98.8)	178 (98.9)	
Yes	20 (3.8)	11 (1.8)	1 (0.3)	3 (1.2)	2 (1.1)	0.908
Thyroid disorders						
No	512 (96.4)	581 (95.4)	347 (95.6)	244 (95.3)	172 (95.6)	
Yes	19 (3.6)	28 (4.6)	16 (4.4)	12 (4.7)	8 (4.4)	
Depression status						<0.001
No depression	27 (9.2)	31 (12.6)	19 (13.6)	14 (16.5)	26 (26.3)	
Mild	110 (37.5)	102 (41.3)	72 (51.4)	34 (40.0)	40 (40.4)	
Moderate	91 (31.1)	63 (25.5)	25 (17.9)	24 (28.2)	20 (20.2)	
Moderately severe	46 (15.7)	35 (14.2)	17 (12.1)	11 (12.9)	11 (11.1)	
Severe	19 (6.5)	16 (6.5)	7 (5.0)	2 (2.4)	2 (2.0)	
Anxiety status						0.004
No anxiety	172 (42.9)	77 (31.3)	63 (44.4)	32 (37.6)	50 (50.0)	
Mild	156 (38.9)	122 (49.6)	63 (44.4)	45 (52.9)	43 (43.0)	
Moderate	64 (16.0)	38 (15.4)	14 (9.9)	7 (8.2)	7 (7.0)	
Severe anxiety	9 (2.2)	9 (3.7)	2 (1.4)	1 (1.2)	0 (0)	
Physical activity						<0.001
Inactive	439 (36.0)	108 (23.3)	144 (38.3)	74 (45.1)	60 (54.5)	53 (50.5)
Active	780 (64.0)	356 (76.7)	232 (61.7)	90 (54.9)	50 (45.5)	52 (49.5)
Smoking status during pregnancy						<0.001
No	493 (72.6)	31 (33.3)	166 (73.1)	116 (71.6)	107 (90.7)	73 (92.4)
Yes	186 (27.4)	62 (66.7)	61 (26.9)	46 (28.4)	11 (9.3)	6 (7.6)

which only 9% adhered to the USDA recommendations. During the pandemic, the number of milk and dairy product's servings increased significantly in all countries, except in Lebanon (p-value < 0.001).

White, Red Meats, and Nuts Group

Prior to the pandemic, around half the pregnant women in Jordan, 80% in Palestine, 80% in Lebanon, 93% in Saudi Arabia, and 79% in Bahrein consumed less than 5.5 servings of white or red meats or nuts. The percentage of adherence to the USDA recommendations for meats and nuts group increased significantly during the pandemic except in Palestine and Lebanon (p-value < 0.001).

Adherence to the United States Department of Agriculture Recommendations Among Countries

According to **Table 3**, 83.8% of women in Jordan, 83.9% in Palestine, 86.5% of women in Lebanon, 91.5% in Saudi Arabia,

TABLE 3 | Number of servings consumed per day and adherence to United States Department of Agriculture (USDA) recommendations of the major food groups consumed by pregnant women before and during the coronavirus disease-19 (COVID-19) pandemic, by country.

	Number of servings (mean ± SD) and percentage of adherence to USDA before the COVID-19 pandemic						Number of servings (mean ± SD) and percentage of adherence to USDA during the COVID-19 pandemic						
Food groups	**Jordan**	**Palestine**	**Lebanon**	**Saudi Arabia**	**Bahrain**	***p*-value**	**Jordan**	**Palestine**	**Lebanon**	**Saudi Arabia**	**Bahrain**	***p*-value**	***p*-value[#]**
Bread, rice and other cereals (*N* = 593)	6.9 ± 6.7	5.1 ± 4.7	5.0 ± 6.5	3.1 ± 2.3	5.3 ± 4.0	<0.001	8.2 ± 8.4	5.8 ± 5.2	5.3 ± 7.5	3.9 ± 3.2	5.4 ± 4.4	<0.001	<0.001
Bread, rice and other cereals						<0.001						<0.001	<0.001
<6 servings	68 (50.4)	180 (67.7)	59 (70.2)	48 (85.7)	37 (56.1)		49 (36.3)	145 (55.8)	59 (69.4)	44 (77.2)	35 (54.7)		
≥6 servings	67 (49.6)	86 (32.3)	25 (29.8)	8 (14.3)	29 (43.9)		86 (63.7)	115 (44.2)	26 (30.6)	13 (22.8)	29 (45.3)		
Fruits (*N* = 543)	2.8 ± 2.9	2.4 ± 1.9	2.2 ± 1.6	1.4 ± 1.0	2.0 ± 1.3	0.002	3.0 ± 2.4	2.5 ± 2.0	2.3 ± 2.0	1.8 ± 1.2	2.3 ± 1.5	0.001	<0.001
Fruits						0.001						0.001	<0.001
<2 servings	59 (36.4)	74 (35.2)	34 (43.6)	32 (66.7)	25 (43.9)		37 (23.4)	62 (29.2)	29 (37.2)	27 (55.1)	20 (35.1)		
≥2 servings	103 (63.6)	136 (64.8)	44 (56.4)	16 (33.3)	32 (56.1)		121 (76.6)	150 (70.8)	49 (62.8)	22 (44.9)	37 (64.9)		
Vegetables (*N* = 566)	2.6 ± 2.4	2.4 ± 2.5	2.2 ± 1.7	1.6 ± 1.2	1.8 ± 1.4	0.014	3.1 ± 2.9	2.6 ± 2.6	2.3 ± 2.1	1.8 ± 1.3	2.3 ± 2.0	0.008	<0.001
Vegetables						0.005						<0.001	<0.001
<2.5 servings	96 (63.2)	178 (73.6)	54 (72.0)	46 (86.8)	45 (81.8)		75 (50.3)	173 (71.2)	56 (74.7)	43 (82.7)	38 (69.1)		
≥2.5 servings	56 (36.8)	64 (26.4)	21 (28.0)	7 (13.2)	10 (18.2)		74 (49.7)	70 (28.8)	19 (25.3)	9 (17.3)	17 (30.9)		
Milk and milk products (*N* = 559)	2.4 ± 2.4	1.8 ± 1.8	1.6 ± 1.4	1.7 ± 1.6	2.0 ± 1.9	0.015	2.9 ± 2.6	2.1 ± 2.2	1.5 ± 1.3	1.9 ± 1.8	2.1 ± 1.9	<0.001	<0.001
Milk and milk products						0.002						<0.001	<0.001
<3 servings	127 (71.3)	182 (83.5)	65 (90.3)	41 (87.2)	44 (75.9)		98 (56.6)	173 (77.6)	68 (90.7)	37 (78.7)	43 (74.1)		
≥3 servings	51 (28.7)	36 (16.5)	7 (9.7)	6 (12.8)	14 (24.1)		75 (43.3)	50 (22.4)	7 (9.3)	10 (21.3)	15 (25.9)		
White and red meats and nuts (*N* = 565)	5.26 ± 3.7	4.5 ± 5.6	4.2 ± 4.6	3.3 ± 4.1	3.8 ± 2.2	0.011	5.8 ± 3.6	4.9 ± 6.2	3.7 ± 3.2	3.4 ± 2.5	4.6 ± 5.6	0.001	0.001
White and red meats and nuts						<0.001						<0.001	<0.001
<5.5 servings	166 (57.6)	124 (80.0)	55 (79.7)	40 (93.0)	40 (78.4)		133 (48.8)	116 (79.5)	55 (83.3)	35 (83.3)	38 (71.7)		
≥5.5 servings	121 (42.2)	31 (20.0)	14 (20.3)	3 (7.0)	11 (21.6)		142 (51.6)	30 (20.5)	11 (16.7)	7 (16.7)	15 (28.3)		
Adherence to food groups (score)						0.559						0.082	<0.001
No/Low (0–2)	274 (83.8)	240 (83.9)	83 (86.5)	54 (91.5)	55 (82.1)		263 (80.9)	231 (81.9)	86 (89.6)	52 (88.1)	49 (74.2)		
Moderate/High (3–5)	53 (16.2)	46 (16.1)	13 (13.5)	5 (8.5)	12 (17.9)		62 (19.1)	51 (18.1)	10 (10.4)	7 (11.9)	17 (25.8)		

p < 0.001.

[#]*Comparison between pre-COVID-19 and intra-COVID-19 periods.*

and 82.1% in Bahrein showed poor adherence to the USDA's recommendations before the COVID-19 pandemic. Nevertheless, the percentage of adherence increased significantly during the pandemic (p-value = 0.001). It increased of 3% in Jordan, 2% in Palestine, 3.4% in Saudi Arabia and 8% in Bahrein. However, it decreased of 3.1% in Lebanon (p-value < 0.001).

DISCUSSION

This study describes the food consumption and adherence to the USDA's guidelines among pregnant women in five Arab countries. The food consumption in the pre-COVID-19 period as well as during the pandemic was unfavorable regarding almost all food groups. Notably, indecorous dietary patterns and poor adherence to the USDA recommendations (in more than 80% of pregnant women) was obvious. This finding came hand in hand with data reported by Tayyem et al. (6) where only 1.1% of pregnant women adhered to dietary guidelines in the pre-COVID-19 time (6).

Comparison With International Studies

Otherwise, our findings concerning the increase in the consumption of all food groups were concordant with the findings of a longitudinal Chinese study which found that the consumption of vegetables, fruits, dairy products, and cereals was significantly higher among pregnant women during the pandemic (13). Furthermore, Hillier et al. revealed a substantial increase in the consumption of fruit and vegetable along with a decrease in egg, fried fast foods, coffee and tea consumption from pre-pregnancy period to during pregnancy in the pre-COVID-19 time (14).

Starchy carbohydrates and fiber containing whole grain cereals and vegetables are the fundamental of a healthy diet. According to the USDA guidelines, the intake of 18–24 g of fiber during the second and third trimester allow for good body's

functioning (5). Due to its richness in minerals, vitamins and dietary fibers, pregnant women are recommended to include wholegrain cereal products in their daily diet. Although the primary source of energy and nutrients should be derived from this food group and should be part of each main meal, 65% of the women in this study consume less than six portions per day from this food group.

A large number of antioxidants (vitamin A, C, and E, carotenoids and flavonoids) are derived from the inclusion of vegetables and fruits in pregnant women's diets. They provide also folates, potassium and fiber. According to the USDA's recommendations, an amount of 300 and 350 g per day in the first semester, and in the second and third trimester—300 g and 450 per day of fruits and vegetables, respectively, should be included in pregnant women's diet (5). Similarly, according to WHO, the intake of vegetables and fruit in the diet of pregnant women should be of high-priority (15). In this study, women mostly consumed fruits in a way higher than the daily standard. In comparison with data from pre-COVID-19-time, our findings came hand by hand with the results obtained in the study conducted by Dere'n et al. (16), where the majority of the women consumed fruit between meals, and one third outstretched for sweets during pregnancy (16). Another study conducted by Kobiołka et al. (17) showed that, between meals, fruit was the most preferred snack consumed by pregnant women (17).

According to many international dietary standards, protein intake should be increased throughout pregnancy, particularly in the second and third trimesters. Referring to the USDA guidelines, 165–195 g (second and third trimester) of protein sources allow for a proper functioning of the body (5). Protein is required for the tissue and placenta of both the mother and the fetus (18). Primary sources of protein could be derived from animal sources (red, lean meat and its products, skimmed milk and its products, fish and poultry). Thus, the daily intake should increase of 1, 8, and 26 g in the first trimester, the second trimester, and in the third trimester of pregnancy (19). Our findings revealed that a significant proportion of respondents consumed poorly this food group (70% in pre-COVID-19 period compared to 65% in the intra-COVID-19 period). Our results are tied well with the literature where Abd-Elmohdy Emara (20) investigated that 37, 31, and 27% of pregnant women consumed white meat 3–4 times per week, 2–3 times per week, and at least once per day, respectively. Furthermore, according to the same study, 43, 12, and 33% of women ate red meat 3–4 times per week, 2–3 times per week, and occasionally, respectively (20).

Moreover, during pregnancy, the body's demand for iron rises, and red meats are a rich source of iron (21). Because of their increased vitamin B_{12} and iron content, pregnant women should have white and red meats in their weekly diet. Our findings indicated that a significant proportion of respondents consumed poorly this food group (70% in pre-COVID-19 period compared to 65% in the intra-COVID-19 period), which may result in anemia in the short term and low birth weight in the long term (22). Our results backs up findings from a systematic analysis by Caut et al. (23), which found that in 91 and 55% of included studies, pregnant women were not adhering to iron and calcium dietary recommendations, respectively (23).

Dairy products, rich in protein, riboflavin and calcium, are essential for pregnant women, alongside bread, vegetables, fruits, and meat (24). According to WHO, a dietary intake of 1,200 mg/day of calcium for pregnant women is recommended (15). To meet this need, a pregnant woman should drink daily three cups of skimmed milk (5). Fermented milk drinks, rich in nutritious protein, vitamin B_2, and calcium are widely recommended in the diets of pregnant women because they provided probiotic bacteria (3). According to our findings, pregnant women's diets have a low percentage of milk and dairy products. In our study, 80% of the subjects were drinking milk and fermented milk drinks less than three servings per day. The research of Kobus-Cisowska et al. (25) and Suliga (26) yielded similar results (25, 26). Likewise, 43% of pregnant women in the study by Dere'n et al. (16), consumed dairy products once a day, and 48% more often (16). Regular physical activity during pregnancy, known to be beneficial to both physical and mental health, in addition to a balanced diet, has an impact on the mother's and child's short and long-term health (27–29). Nevertheless, most pregnant women in our study (64%) show usually high levels of physical activity. According to WHO, at least 150 min of moderate intensity physical activity per week is recommended for adults (30). Unless there are medical restrictions, regular and moderate exercise is recommended for pregnant women (27–29). Due to the need to adapt the physiological and psychological changes during pregnancy, pregnant women may struggle with the sedentary behavior and become physically inactive (3). Finally, despite the well-known health benefits related to practicing regular physical activity during pregnancy, over 40% of women do not adhere to the recommendations.

Comparison With Arab Countries' Data

To our knowledge, no data was published among Arab countries that investigate the consumption patterns of pregnant women amid the COVID-19 pandemic. Thus, our findings were compared to many data published in which the food consumption was reported for the whole population. In Lebanon, the findings of a national study aligned our findings in which a significant increase in the number of meals consumed per day during the pandemic compared to before the pandemic (all $p < 0.001$) was observed (31). However, there was a significant decrease in physical activity engagement during the lockdown compared to before the pandemic (all $p < 0.001$) (31). Another study in Lebanon showed that home isolation due to COVID-19 induced an increase in the consumption of legumes and pulses (3.2%, p-value = 0.001) and whole wheat groups (2.8%, p-value = 0.03). In contrast, a decrease of 5.4, 6.9, 5.8, 5.1, 3.1, 3.4, and 2.8% was observed in the

consumption of fruits (p-value = 0), vegetables (p-value = 0), processed meats, poultry, and fish (p-value = 0) and other dairy products (p-value = 0), respectively. In Lebanon, since the ordeals of COVID-19, economic crisis, and the Beirut port explosions, food insecurity became an immediate problem for households in Lebanon. Between November 2020 and March 2021, 9 in every 16 households ate less than two meals per day and more than 70% of them skipped their meals to spare food. This explains the difference in term of food consumption among Lebanese pregnant women compared to other countries (32). At the Arab countries level, a recent study conducted in 10 countries including Jordan, Palestine, Lebanon, Saudi Arabia and Bahrain showed that, before and during the pandemic, most food groups were consumed less or equal to four times per week which indicated a poor dietary diversity among the countries' population (33). This finding along with our findings describe the nutritional situation and food consumption patterns among pregnant women on one side and the whole population on the other side.

Limitations

This study has some limitations. First, this study was conducted online through convenience sampling that could probably lead to skewed sample characteristics in some countries. Second, respondents were asked to recall the food categories' consumption patterns prior to lockdown, which could have caused recall bias. Third, although this sampling method does not always guarantee the generalizability of the results, it can remain an effective method for estimating the likelihood of potential relationships between variables (34–36). Finally, although it is necessary that all Arab countries adhere to evidenced-based guidelines, multiple factors can limit guidelines' adherence, including income, food availability and affordability, individual beliefs and preferences, cultural traditions, and educational, social, geographical, and environmental aspects.

CONCLUSION

Although it is clear that most Arab pregnant women ameliorated their food consumption patterns amid the COVID-19 pandemic, however, the food consumption in the pre-COVID-19 period as well as during the pandemic was unfavorable. Obviously, most Arab pregnant women showed low adherence to the USDA pregnancy recommendations. Thus, prenatal nutrition education and intervention are required. More research is needed to uncover modifiable variables and dietary concerns in pregnant women.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Lebanese University. The patients/participants provided their written informed consent to participate inthis study.

AUTHOR CONTRIBUTIONS

MH and RT: conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, and writing—original draft preparation. RH: data curation, methodology, writing—original draft preparation, and writing—review and editing. AA-J, CF, MH, RA, and MI: methodology and writing—review and editing. MA, SO, RQ, SA, KB, JA, and NA-B: data curation, methodology, and writing—review and editing. All authors have read and agreed to the published version of the manuscript.

FUNDING

The authors would like to acknowledge the support of Qatar University for funding this publication.

ACKNOWLEDGMENTS

The authors would like to thank the following for assisting in data collection: Elissa Naim, Manal Fardon (Lebanon); Narmeen Al-Awwad (The Hashemite University, Jordan); Asma Bash and Eman Badran (The University of Jordan); Nouf Ali Behzad: Salmaniya Medical Complex, Bahrain); Shreen Sulten and Nada Omar Abduljawad (King Hamad University Hospital); Diala Abu Al Halawa (Al-Quds University, Palestine); Firas Abdel Jawad (Makassed Hospital); Nabil Thawabteh (Makassed Hospital); Hazem Agha (Al-Quds University); Majid AlKhalaf (National Nutrition Committee, Saudi FDA); Areej Alamery (Ministry of Health, Saudi Arabia).

REFERENCES

1. WHO. *Coronavirus Disease 2019 (COVID-19) Situation Report – 62*. (2020). Available online at: https://www.who.int/docs/default-source/coronaviruse/situation-reports/20200322-sitrep-62-covid-19.pdf?sfvrsn=755c76cd_2 (accessed November 23, 2021.)
2. Zhong B-L, Luo W, Li H-M, Zhang Q-Q, Liu X-G, Li W-T, et al. Knowledge, attitudes, and practices towards COVID-19 among Chinese residents during the rapid rise period of the COVID-19 outbreak: a quick online cross-sectional survey. *Int J Biol Sci*. (2020) 16:1745. doi: 10.7150/ijbs.45221
3. Ługowska K, Kolanowski W. The nutritional behaviour of pregnant women in Poland. *Int J Environ Res Public Health*. (2019) 16:4357. doi: 10.3390/ijerph16224357
4. Koletzko B, Godfrey KM, Poston L, Szajewska H, Van Goudoever JB, De Waard M, et al. Nutrition during pregnancy, lactation and early childhood and its implications for maternal and long-term child health: the early

nutrition project recommendations. *Ann Nutr Metab.* (2019) 74:93–106. doi: 10.1159/000496471
5. USDA. *Nutrition During Pregnancy National Agricultural Library*. U.S. Department of Agriculture (2021). Available online at: https://wicworks.fns.usda.gov/sites/default/files/media/document/Tips_for_Pregnant_Women_English.pdf (accessed October 21, 2021).
6. Tayyem R, Allehdan SS, Al-Awwad NJ, Alatrash RM, Mahfouz IA, Alasali F. Food group intake of pregnant jordanian women based on the three pregnancy trimesters. *Prev Nutr Food Sci.* (2020) 25:346. doi: 10.3746/pnf.2020.25.4.346
7. Tayyem RF, Allehdan SS, Alatrash RM, Asali FF, Bawadi HA. Adequacy of nutrients intake among Jordanian pregnant women in comparison to dietary reference intakes. *Int J Environ Res Public Health.* (2019) 16:3440. doi: 10.3390/ijerph16183440
8. WHO. *Diet, Nutrition and the Prevention of Chronic Diseases*. Geneva: World Health Organization (2002).
9. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* (2001) 16:606–13.
10. Spitzer RL, Kroenke K, Williams JB, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med.* (2006) 166:1092–7.
11. Kaiser LL, Campbell CG. Practice paper of the academy of nutrition and dietetics abstract: nutrition and lifestyle for a healthy pregnancy outcome. *J Acad Nutr Diet.* (2014) 114:1447.
12. USDA. *Tips for Pregnanct Women*. USDA (2016). Available online at: https://wicworks.fns.usda.gov/resources/tips-pregnant-moms
13. Zhang J, Zhao A, Ke Y, Huo S, Ma Y, Zhang Y, et al. Dietary behaviors in the post-lockdown period and its effects on dietary diversity: the second stage of a nutrition survey in a longitudinal Chinese study in the COVID-19 era. *Nutrients.* (2020) 12:3269. doi: 10.3390/nu12113269
14. Hillier SE, Olander EK. Women's dietary changes before and during pregnancy: a systematic review. *Midwifery.* (2017) 49:19–31. doi: 10.1016/j.midw.2017.01.014
15. WHO. *Global Strategy on Diet, Physical Activity and Health*. World Health Organization. (2021). Available online at: http://www.who.int/dietphysicalactivity/en/ (accessed October 20, 2021)
16. Dere'n K, Gaweł M, Łuszczki E, Jarmakiewicz S, Sokal A, Polak E, et al. Nutritional behavior of pregnant women from the Podkarpacie province. *Eur J Clin Exp Med.* (2017):322–9. doi: 10.15584/ejcem.2017.4.4
17. Kobiołka A, Goraus M, Mêżyk I. Effect of pregnancy in to change eating habits women of childbearing age. *Zdr Dobrostan.* (2015) 2:187–205.
18. Elango R, Ball RO. Protein and amino acid requirements during pregnancy. *Adv Nutr.* (2016) 7:839S–44S. doi: 10.3945/an.115.011817
19. Trumbo P, Schlicker S, Yates A, Poos M. Food and Nutrition board of the institute of medicine, the national academies. dietary reference intakes for energy, carbohydrate, fiber, fat, fatty acids, cholesterol, protein and amino acids. *J Am Diet Assoc.* (2002) 102:1621–30.
20. Abd-Elmohdy Emara H. Effect of nutrition education package on pregnant women knowledge and healthy dietary practice. *IOSR J Nurs Health Sci.* (2019) 8:38–44.
21. Williams P. Nutritional composition of red meat. *Nutr Diet.* (2007) 64:S113–9. doi: 10.1111/j.1747-0080.2007.00197.x
22. Figueiredo AC, Gomes-Filho IS, Silva RB, Pereira PP, Da Mata FA, Lyrio AO, et al. Maternal anemia and low birth weight: a systematic review and meta-analysis. *Nutrients.* (2018) 10:601. doi: 10.3390/nu10050601
23. Caut C, Leach M, Steel A. Dietary guideline adherence during preconception and pregnancy: a systematic review. *Mater Child Nutr.* (2020) 16:e12916. doi: 10.1111/mcn.12916
24. Givens D. MILK symposium review: the importance of milk and dairy foods in the diets of infants, adolescents, pregnant women, adults, and the elderly. *J Dairy Sci.* (2020) 103:9681–99. doi: 10.3168/jds.2020-18296
25. Kobus-Cisowska J, Kmiecik D, Przeor M, Jêdrusek-Golięska A, Waszkowiak K, Żołna H. Assessment of the level of nutritional knowledge and diet of women during pregnancy. *Bromat Chem Toks.* (2016) 49:531–5.
26. Suliga E. Nutritional behaviours of pregnant women in rural and urban environments. *Ann Agric Environ Med.* (2015) 22: 513–17.
27. Lardon E, St-Laurent A, Babineau V, Descarreaux M, Ruchat S-M. Lumbopelvic pain, anxiety, physical activity and mode of conception: a prospective cohort study of pregnant women. *BMJ Open.* (2018) 8:e022508. doi: 10.1136/bmjopen-2018-022508
28. Fazzi C, Saunders DH, Linton K, Norman JE, Reynolds RM. Sedentary behaviours during pregnancy: a systematic review. *Int J Behav Nutr Phys Activity.* (2017) 14:1–13. doi: 10.1186/s12966-017-0485-z
29. Padmapriya N, Shen L, Soh S-E, Shen Z, Kwek K, Godfrey KM, et al. Physical activity and sedentary behavior patterns before and during pregnancy in a multi-ethnic sample of Asian women in Singapore. *Mater Child Health J.* (2015) 19:2523–35. doi: 10.1007/s10995-015-1773-3
30. WHO. *Global Recommendations on Physical Activity for Health: 18–64 Years Old*. (2011). Available online at: https://www.who.int/dietphysicalactivity/physical-activity-recommendations-18-64years.pdf
31. Cheikh Ismail L, Hashim M, Mohamad MN, Hassan H, Ajab A, Stojanovska L, et al. Dietary habits and lifestyle during coronavirus pandemic lockdown: experience from Lebanon. *Front Nutr.* (2021) 8:730425. doi: 10.3389/fnut.2021.730425
32. Hoteit M, Mortada H, Al-Jawaldeh A, Ibrahim C, Mansour R. COVID-19 home isolation and food consumption patterns: investigating the correlates of poor dietary diversity in Lebanon: a cross-sectional study [version 1; peer review: awaiting peer review]. *F1000Research.* (2022) 11:110. doi: 10.12688/f1000research.75761.1
33. Hoteit M, Mortada H, Al-Jawaldeh A, Mansour R, Yazbeck B, AlKhalaf M, et al. Dietary diversity in the eastern Mediterranean region before and during the COVID-19 pandemic: disparities, challenges and mitigation measures. *Front Nutr.* (2022) 9:813154. doi: 10.3389/fnut.2022.813154/abstract
34. McMillan JH, Schumacher S. *Research in Education: Evidence-Based Inquiry, MyEducationLab Series*. London: Pearson (2010).
35. Lim J (editor). *Considering the Impact of Self-regulation and Digital Literacy on Preserive Teachers' Attitudes toward Web 2.0 Personal Learning Environment (PLEs). E-Learn: World Conference on E-Learning in Corporate, Government, Healthcare, and Higher Education*. San Diego, CA: Association for the Advancement of Computing in Education (AACE) (2019).
36. Bou-Hamad I, Hoteit R, Harajli D. Health worries, life satisfaction, and social well-being concerns during the COVID-19 pandemic: insights from Lebanon. *PLoS One.* (2021) 16:e0254989. doi: 10.1371/journal.pone.0254989

Author Disclaimer: The views expressed in this article and they do not necessarily represent the views, decisions or policies of WHO, Saudi FDA or the other institutions with which the authors are affiliated.

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Nutrition

SYSTEMATIC REVIEW
published: 05 April 2022
doi: 10.3389/fnut.2022.821096

Long Term Weight Loss Diets and Obesity Indices: Results of a Network Meta-Analysis

Jana Jabbour[1,2†], Yasmin Rihawi[2†‡], Assem M. Khamis[3†‡], Layal Ghamlouche[2,4], Bayan Tabban[2], Gloria Safadi[5†], Nour Hammad[2,6†], Ruba Hadla[7†], Marwa Zeidan[8], Dana Andari[8,9], Riwa Nour Azar[2,10], Nadine Nasser[2,11] and Marlene Chakhtoura[12†]*

[1] Nutrition Department, School of Health Sciences, Modern University for Business and Sciences, Beirut, Lebanon, [2] Department of Clinical Nutrition, American University of Beirut Medical Center, Beirut, Lebanon, [3] York Medical School, University of Hull, York, United Kingdom, [4] Research & Programmes Department, Qualisus Consulting, Byblos, Lebanon, [5] Center for Research on Population and Health, Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon, [6] Duke Global Health Institute, Duke University, Durham, NC, United States, [7] Department of Health Management and Policy, Faculty of Health Sciences, American University of Beirut, Beirut, Lebanon, [8] Faculty of Medicine, American University of Beirut, Beirut, Lebanon, [9] Department of Nutrition and Dietetics, Faculty of Health Sciences, Beirut Arab University, Beirut, Lebanon, [10] The European School of Management and Technology, Berlin, Germany, [11] Access to Nutrition Initiative, Utrecht, Netherlands, [12] Calcium Metabolism and Osteoporosis Program, WHO Collaborating Center for Metabolic Bone Disorders, American University of Beirut Medical Center, Beirut, Lebanon

OPEN ACCESS

Edited by:
Reema Fayez Tayyem, Qatar University, Qatar

Reviewed by:
Naomi Kakoschke, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia
Maha Hoteit, Lebanese University, Lebanon

***Correspondence:**
Marlene Chakhtoura
mc39@aub.edu.lb

†ORCID:
Jana Jabbour
orcid.org/0000-0002-0576-1031
Yasmin Rihawi
orcid.org/0000-0002-4026-1868
Assem M. Khamis
orcid.org/0000-0002-5567-7065
Gloria Safadi
orcid.org/0000-0001-5110-5871
Nour Hammad
orcid.org/0000-0001-9578-7261
Ruba Hadla
orcid.org/0000-0002-3613-7848
Marlene Chakhtoura
orcid.org/0000-0003-0012-986X

‡*These authors have contributed equally to this work*

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *23 November 2021*
Accepted: *24 January 2022*
Published: *05 April 2022*

Citation:
Jabbour J, Rihawi Y, Khamis AM, Ghamlouche L, Tabban B, Safadi G, Hammad N, Hadla R, Zeidan M, Andari D, Azar RN, Nasser N and Chakhtoura M (2022) Long Term Weight Loss Diets and Obesity Indices: Results of a Network Meta-Analysis. Front. Nutr. 9:821096. doi: 10.3389/fnut.2022.821096

Background: Scientists have been investigating efficient interventions to prevent and manage obesity. This network meta-analysis (NMA) compared the effect of different diets [moderate macronutrients (MMs), low fat/high carbohydrate (LFHC), high fat/low carbohydrate (HFLC), and usual diet (UD)] on weight, body mass index (BMI), and waist circumference (WC) changes at ≥12 months.

Methods: We searched Medline, Embase, PubMed databases, and the Cochrane Library. We systematically assessed randomized controlled trials (RCTs) evaluating dietary interventions on adults (mean BMI ≥ 25 kg/m^2) receiving active dietary counseling for ≥12 months. We pooled the data using a random-effect NMA. We assessed the quality of the included RCTs using the Cochrane risk of bias (ROB) tool.

Results: We included 36 trials, 14 of which compared HFLC with MM diets. Compared with UD, all diets were associated with a significant weight loss (WL) at ≥12 months, HFLC [mean difference in kg (95% *CI*): −5.5 (−7.6; −3.4)], LFHC [−5.0 (−7.1; −2.9)] and MM [−4.7 (−6.8; −2.7)]. HFLC, compared with MM diet, was associated with a slightly higher WL (of −0.77 kg) and drop in BMI (of −0.36 kg/m^2), while no significant difference was detected in other dietary comparisons. WC was lower with all diets compared to UD, with no significant difference across specific diets. There was no significant interaction of the results with the pre-specified sub-groups. The ROB was moderate to high, mostly related to unclear allocation concealment, high dropout rate and unclear or lack of blinding of participants, providers, and outcome assessors.

Conclusion: Dietary interventions extending over ≥12 months are superior to UD in inducing weight, BMI and WC loss. HFLC might be associated with a slightly higher WL compared with MM diets.

Systematic Trial Registration: https://www.crd.york.ac.uk/prospero/display_record.php?RecordID=103116, PROSPERO (CRD42018103116).

Keywords: diet, obesity, Acceptable Macronutrient Distribution Ranges (AMDR), weight loss, waist circumference, body mass index (BMI)

INTRODUCTION

Obesity has almost increased three times in the last three decades to reach pandemic levels (1). Obesity is associated with a decreased lifetime expectancy of 5–20 years, depending on the severity and the presence of comorbidities (2–4). With more than half of the world population being overweight or obese, scientists are continuously exploring efficient interventions to prevent and manage this pandemic (5, 6).

Diet therapy remains one of the cornerstones of the multi-disciplinary approach to weight management. However, obesity treatment guidelines have variable recommendations regarding the most appropriate diet (**Supplementary Table S1**). While almost all agree on a reduced calorie meal plan, and a modification of macronutrient composition to enhance the dietary adherence and improve the metabolic profile, (7) (**Supplementary Table S1**), there is still no consensus yet on the most optimal macronutrient dietary pattern for weight management.

A network meta-analysis (NMA) is a meta-analysis (MA) technique that allows evaluation of at least three interventions in one analysis, using both direct and indirect comparisons (8). It is an "evidence synthesis method" gaining interest in the field of nutrition research (9). Two recent NMAs of randomized controlled trials (RCTs) assessed the short term (6–12 months) effect of different diets (10, 11). The first NMA included the following diet categories: lifestyle, exercise, attitudes, relationships, nutrition (LEARN), low carbohydrate, low fat, and moderate macronutrients (MMs) (10). The results (n = 7,286 participants) revealed that, compared with no diet, and as expected, any dietary intervention resulted in a significant weight loss (WL) at 6 months, of 5.1–8.7 kg (10). The WL response was attenuated at 12 months, with a weight reduction of 1–2 kg less compared with the 6-month follow up (10). The comparison of diets with different macronutrient composition between each other showed that a low carbohydrate diet was better than a MMs diet, at 6 and 12 months, with a small difference in mean WL of 1.9 and 1.5 kg, respectively, while none of the other comparisons reached significance (10). The more recent NMA (n = 21,942 participants) by Ge et al. included trials published until September 2018 and similarly showed that the low carbohydrate, low fat, and MM diets were superior to a usual diet (UD) at 6 months (WL of 4.6, 4.4, and 3.1 kg, respectively), with no significant difference comparing diets among each other's (11). WL decreased by 1.5 kg on average at 12 months compared with the 6-month assessment point (11). Several systematic reviews and meta-analyses (SR/MA) assessed the long term weight reducing effects of various diets beyond 12 months follow up (12–17). Two SR/MAs compared a low fat diet to any higher fat diet, including UD, and did not demonstrate any significant difference in the achieved weight at follow-up (15, 18). Two other SR/MAs compared a high protein/low or very low carbohydrate diet to other diets and showed a significant MD in WL of 0.4–0.9 kg, favoring the former diet (12, 14). One SR/MA compared Atkins, Weight Watchers diet, South Beach and Zone, and demonstrated a modest and comparable WL across all (13). The main limitations of the aforementioned SR/MAs assessing the long-term effects of dietary interventions stem from the inclusion of RCTs on patients with chronic diseases, such as diabetes mellitus (DM) and cancer, that might affect the WL response, the inclusion of RCTs with an active diet intervention extending over <1 year, or the lack of a systematic description and investigation of the effect of co-interventions, such as exercise and behavioral therapy.

Given the heavy burden of obesity, its chronic relapsing nature (19), and the lack of consensus on the most optimal diet composition, if any, for weight reduction, this SR/NMA aims at evaluating the association of long term dietary interventions, categorized using the Acceptable Macronutrient Distribution Ranges (AMDR), with changes in weight parameters. The AMDR, recommended by the Institute of Medicine (IOM), is widely used by clinicians and defines the ranges of macronutrient contribution to energy intake that have been linked to a lower risk of chronic diseases (20, 21).

METHODS

The protocol for this SR/NMA followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA), and was registered on PROSPERO (CRD42018103116) (22).

Eligibility Criteria

This section describes the Population, Intervention, Control, and Outcome (PICO) elements and details the eligibility criteria of this SR. We selected RCTs as we expected to have a complete summary of the evidence on the topic by gathering data from interventional studies. We included RCTs conducted in adults with overweight/obesity (mean body mass index (BMI) at baseline $\geq$ 25 kg/m^2) *(population)*, comparing an active dietary intervention of $\geq$12($\pm$1) months *(intervention)*, to another dietary regimen or UD *(control)*, and reporting on one or more outcomes of interest, change in weight, BMI, or waist circumference (WC), at $\geq$12 months follow-up *(outcome)*. We included only papers written in English. To assess the effect of dietary interventions in healthy individuals, we excluded trials where the majority of participants (>75%) were pregnant women, had chronic diseases (such as cancer, diabetes mellitus, advanced liver, or renal disease), or received medications inducing weight gain (such as anti-psychotic drugs), as these conditions are expected to affect the WL response. We excluded trials if the intensity of the intervention or the co-intervention differed between arms or in case a detailed description of the intervention (such as duration and macronutrient composition) was not provided in the trial or trial protocol publication. In addition, we excluded interventions consisting of a change in a single food item or that solely relied on the supplementation, as we aimed to assess the impact of comprehensive dietary changes. Exclusion criteria included RCTs assigning very-low-calorie diets (<800 Kcal/day) or meal replacement liquids (since such diets are not recommended as long term interventions), and RCTs where diets were assigned based on participants' genetic profiles (22).

Search Strategy

We conducted a systematic search in the following electronic databases Medline, Embase, PubMed, and the Cochrane Library, without time restriction and until December 2020. We used Medical Subject Heading (MeSH) terms and keywords relevant to the dietary intervention and overweight or obesity (as shown in **Supplementary Text S1**). Moreover, we manually searched the references of SRs on the topic to identify any potentially relevant studies that may have been missed. We contacted experts in the field and searched ClinicalTrials.gov for potentially completed and non-published trials.

Data Screening and Abstraction

We conducted the screening of citations and full texts, and data abstraction in duplicate and independently, using standardized forms, prepared a priori. At each step, we conducted a calibration exercise until discrepancy rate between reviewers got to <5%. The calibration exercise involved training and cross training of the researchers on the eligibility criteria and data abstraction, to make sure that the process was standardized. We prepared screening sheets for each step based on our research question. At all stages, we resolved disagreement between reviewers by discussion and through intervention from content experts (MC and JJ).

Risk of Bias (ROB) and Publication Bias Assessment in the Included RCTs

We assessed the risk of bias (ROB) of the included RCTs in duplicate and independently using the Cochrane ROB assessment tool (23). We assessed the risk of publication bias by visually checking the symmetry of the funnel plot of the included studies in the traditional meta-analyses for comparisons including ≥10 RCTs. In the funnel plot, for each trial, we plotted the effect by the inverse of its SE.

Statistical Considerations and Analyses

We presented the characteristics of the included RCTs as counts (percentages) and means (ranges or SD) for categorical and continuous variables, respectively. We used complete case analysis in the quantitative analysis. We categorized the dietary interventions of the included RCTs using the AMDR as defined by the IOM (20). MM diets referred to diets where all macronutrients were within the AMDR ranges: carbohydrate (45–65% of energy), protein (10–35% of energy), and fat (20–35% of energy). High fat/low carbohydrate (HFLC) diets had a total fat percentage that exceeded the AMDR range (>35% of energy) and/or carbohydrate percentage below the lower AMDR limit (≤45% of energy). Low fat/high carbohydrate (LFHC) diets had a total fat percentage below the lower AMDR limit (≤20% of energy) and/or carbohydrates percentage exceeding the upper AMDR limit (>65% of energy). UD were control diets where participants were asked not to change their dietary intake from their usual lifestyle.

We used Bayesian random-effects model to assess the pooled direct and the NMA estimates. We derived the latter using Markov chain Monte Carlo simulation techniques (24, 25). The outcome measures of interest were the change in weight (kg), the change in BMI (kg/m^2), and the change in WC (cm). When the change in the outcome measure was not reported, we used baseline and study end mean (SD) values of the outcome measure to calculate the mean difference (MD) of the change of this outcome. When the mean of the change was available but the SD was missing, we calculated the SD using the SE, 95% CI and/or *p*, when available, as suggested by the Cochrane Handbook (26). For the diets included in the NMA, we assessed the likelihood for every diet to be ranked first, second, etc. (27). We evaluated the statistical heterogeneity between studies for direct comparisons using I^2 statistic, defining moderate heterogeneity for I^2 of 40–70% and high for $I^2 > 70\%$.

For the traditional MA, we calculated the MD and 95% CI of continuous variables, when at least 2 RCTs were included in a given comparison, using a random-effects model. We used imputation methods when needed, as described above. We explored the reasons for moderate to high heterogeneity, by conducting sub-group analyses for the following variables, by outcome and by comparison, as applicable, when a given sub-group included at least 2 RCTs: gender (>75% of participants being men or women), baseline mean BMI (< 30 vs. ≥ 30 kg/m^2), age category (younger vs. older adults based on a cutoff point of 50 years, as a surrogate of menopausal status), intervention duration (12 months vs. 13–24 months), and the presence vs. the absence of concomitant exercise and/or behavioral prescription. We considered any explicit instruction on exercise, whether advised or supervised, as a physical activity (PA) co-intervention. Similarly, we considered any kind of behavioral support received, irrespective of the provider, as a behavioral co-intervention. We did not have data to explore the impact of compliance, dietary fiber content, and dietary restriction vs. *ad libitum* on the outcomes of interest. All the sub-group analyses were pre-specified in the protocol (22), with the exception of gender.

We used RStudio v1.4.1106 (Integrated Development for R. RStudio, PBC, Boston, MA) for the NMA and the league tables. We used Stata 17 to generate the network nodes (StataCorp. 2021. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC). We conducted the traditional meta-analysis, subgroup analyses, and funnel plots on Review Manager [(RevMan) (Computer program) Version 5.3. Copenhagen: The Nordic Cochrane Center, The Cochrane Collaboration, 2014].

RESULTS

The search strategy yielded 22,929 citations. After removal of duplicates, we screened 22,853 citations, 3,082 full text, and included 50 publications relevant to 36 trials (**Figure 1**). We identified 24 RCTs reporting on weight change (total n = 4,916 participants), 17 RCTs on BMI change (total n = 3,260 participants), and 15 RCTs on WC change (total n = 2,734 participants), and comparing diets with different macronutrient distribution between each other or to UD, at ≥12 months follow-up.

Characteristics of the Included RCTs

Supplementary Table S2 showcases the detailed study characteristics of each of the included RCTs. **Table 1** presents

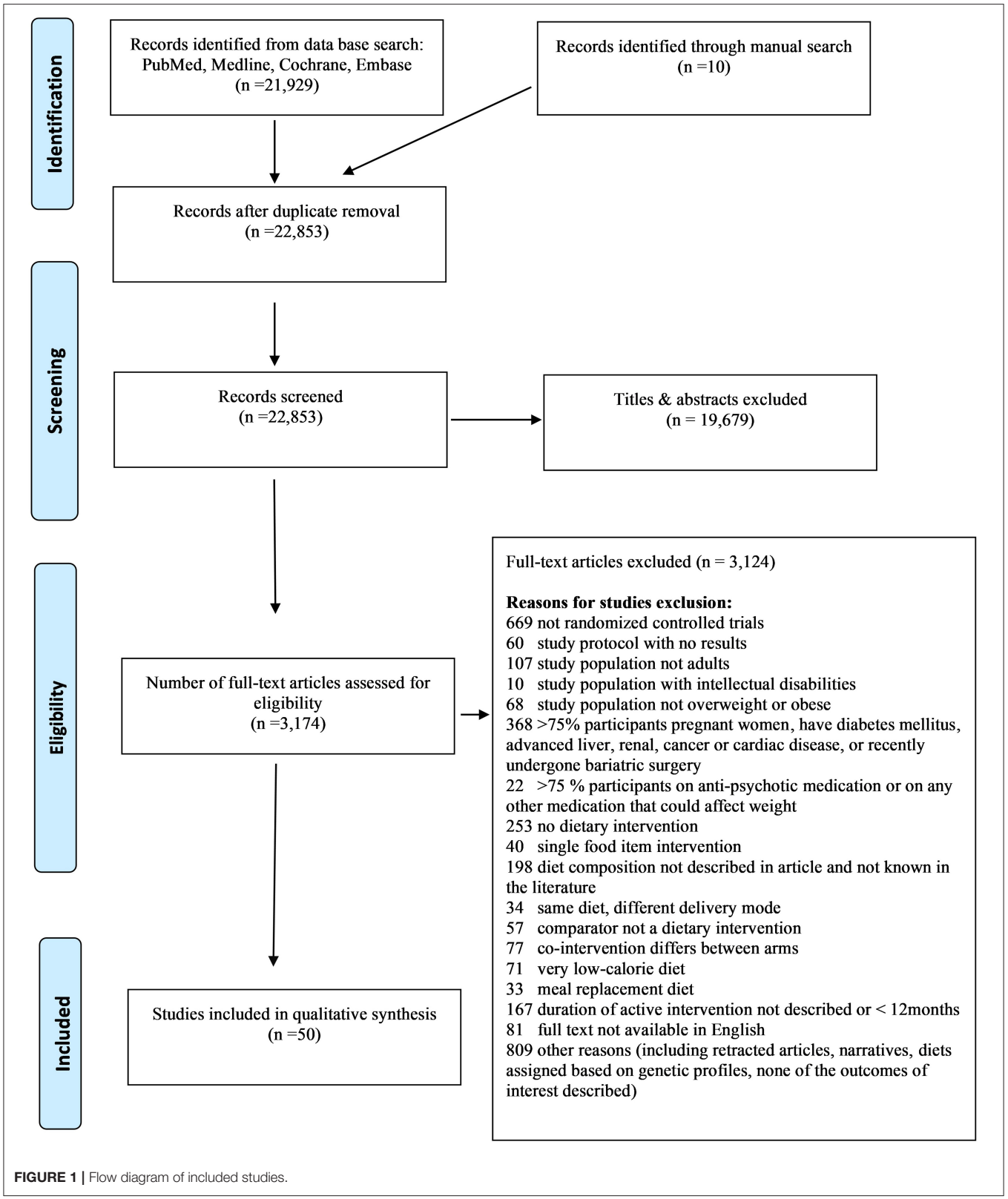


FIGURE 1 | Flow diagram of included studies.

a summary of the characteristics of the included RCTs. The comparison of MM to HFLC diets included the largest number of RCTs. The sample size of the RCTs ranged between 7 and 318 participants per arm and the duration of the active intervention spanned over 12–24 months. The range of mean age of participants was 22–67 years, and the range of mean BMI at baseline was 25.9–43.6 Kg/m^2. The majority of RCTs included both genders, and women represented >50% of the population, with the exception of 3 RCTs (28–30). Most of the trials were conducted in North America (44%) and Europe (28%). Furthermore, seventeen RCTs included participants with cardio-metabolic co-morbidities (e.g., coronary heart disease, hypertension, dyslipidemia, and metabolic syndrome) in <40% of the population. There were few exceptions where the majority of participants had metabolic syndrome (65–100% of the population) (31–35), hypertension (81% of the population) (33), and hyperinsulinemia (100% of the population) (36). The delivery of the dietary intervention was achieved in most of the trials through face-to-face individual and/or group assessment and education. Few trials incorporated a follow-up over the phone and/or *via* email (29, 37–41). Behavioral therapy and PA were co-interventions in 39 and 36% of the RCTs, respectively, and 8 RCTs had both co-interventions administered concomitantly (**Table 1**). Nine RCTs administered diets that have a similar macronutrient composition falling within the same AMDR classification, and therefore were not included in our quantitative analysis (35, 36, 41–47).

The compliance to the dietary intervention was assessed in about 50% of the trials using a variety of methods, the most common being food records (32, 40, 43, 48–50), followed by food frequency questionnaires and dietary recalls (32, 35, 51), urine urea nitrogen (41, 52, 53), and educational sessions' attendance (30, 32, 33, 54). The dropout rate was reported in most studies. It was <20% in 20 RCTs, and larger reaching 30–60% in 14 RCTs. The highest dropout rates were observed in one RCT with young female participants (18–25 years) (55) and other trials with participants following HFLC diets (41, 49, 55, 56). When the funding was described, the source consisted of national or international scientific organizations, with the exception of one trial funded by a private company (55).

Supplementary Table S3 features the ROB assessment of the included RCTs. Most studies (72%) had a "High" overall ROB. The high ROB was related to a poor description or lack of appropriate allocation concealment and blinding of participants/personnel and outcome assessors', high dropout rate, and incomplete outcome reporting. Seventeen RCTs have their protocols posted online. Among the other risks of bias, the imbalance in baseline characteristics was the most common limitation. We were able to assess the risk of publication bias only for the comparison of HFLC to MM, as it included more than 10 RCTs (**Supplementary Figures S1–S3**). The funnel plots revealed asymmetry in the publications reporting weight changes. No asymmetry was noted for RCTs describing BMI and WC changes.

TABLE 1 | Summary of the population and intervention characteristics of the included randomized controlled trials (RCTs).

Variable	Results
	Range of means
Age (years)	22–68
BMI (Kg/m^2)	26–44
	N* (%)
Gender	
Women only	7 (19)
Men only	4 (11)
Both	25 (69)
Continent	
Australia &New Zealand	7 (19)
Asia	3 (8)
Europe	10 (28)
North America	16 (44)
Diet categories comparisons	
MM vs. Usual diet	4 (11)
MM vs. LFHC	3 (8)
MM vs. HFLC	14 (39)
MM vs. MM	9 (25)
HFLC vs. HFLC	1 (3)
HFLC vs. LFHC	2 (5.5)
MM vs. LFHC vs. HFLC	2 (5.5)
LFHC vs. Usual diet	1 (3)
Study duration	
12 months	28 (78)
13–24 months	8 (22)
Mode of education¥	
Individual, face to face	19 (53)
Group, face to face	19 (53)
Mobile/email	6 (17)
Others	7 (19)
Behavioral co-intervention	14 (39)
Physical activity co-intervention	12 (33)

BMI, Body Mass Index; MM, Moderate Macronutrient; HFLC, High Fat Low Carbohydrate; LFHC, Low Fat High Carbohydrate.

**Percentages calculated out of the 36 included trials.*

¥*Percentages add up to more than 100% as there are trials that included several modes of education.*

Changes in Weight, BMI, and WC

We conducted an NMA for each of the outcomes of interest (**Figure 2**). The largest number of direct comparisons was between MM and HFLC diets for all outcome measures (**Figure 2**). All estimates were fed by direct and indirect comparisons, with the exception of the one derived from UD vs. HFLC diet for the weight, BMI, and WC changes, and the one derived from UD vs. LFHC diet for the WC change, that were only based on indirect comparisons.

We identified 24 RCTs reporting on the weight changes (total $n = 4{,}916$ participants) at ≥ 12 months of follow-up (28, 29, 31–34, 37–40, 49–51, 53–63). The NMA revealed that, compared with UD, all diets were associated with a significant and comparable WL, at 12 months and beyond (**Table 2**), HFLC diets [MD (95% *CI*): −5.5 (−7.6; −3.4)] kg, LFHC diets [−5.0 (−7.1; −2.9)] kg and the MM diets [−4.7 (−6.8; −2.7)] kg

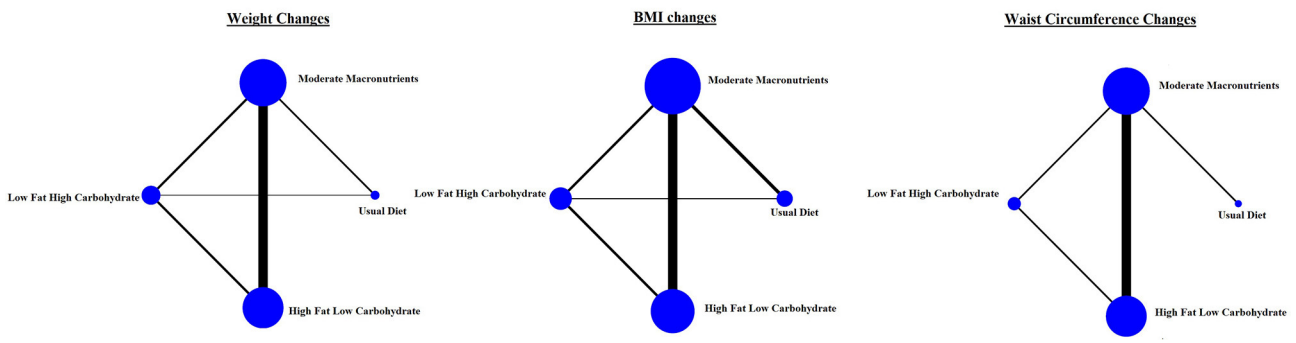


FIGURE 2 | Network plot of included studies.

TABLE 2 | League table of network meta-analysis results of weight changes (Kg) and BMI changes (Kg/m^2) at study end (≥ 12 months).

		BMI (Kg/m^2)		
Weight (Kg)	**Usual diet (W 0.09; BMI 0)***	−2.1 (−2.8:−1.4)	−1.8 (−2.5: −1.0)	−1.7 (−2.4:−1.1)
	−5.5 (−7.6: −3.4)	**High fat low carbohydrate diet (W 0.82; BMI 0.96) ***	0.30 (−0.18: 0.79)	0.36 (0.05: 0.67)
	−5.0 (−7.1:−2.9)	0.47 (−0.32:1.3)	**Low fat high carbohydrate diet (W 0.80; BMI 0.58)***	0.06 (−0.42:0.54)
	−4.7 (−6.8:−2.7)	0.77 (0.19:1.3)	0.77 (−0.38:1.9)	**Moderate macronutrient diet (W 0.29; BMI 0.47)***

BMI, body mass index; W, weight.
Values corresponding to weight changes are below or to the left of the diet categories.
Values corresponding to BMI changes are above and to the right of the diet categories.
**Numbers between parentheses refer to the probability of the diet being selected the best.*

TABLE 3 | League table of network meta-analysis results of waist circumference changes (cm) at study end (≥ 12 months).

Waist circumference (cm)	**Usual diet (0)***			
	−5.6 (−8.6:−2.6)	**High fat low carbohydrate diet (0.95)***		
	−5.2 (−8.4:−2.1)	0.36 (−0.85:1.6)	**Low fat high carbohydrate diet (0.58)***	
	−5.0 (−7.9:−2.1)	0.61 (−0.14:1.4)	0.25 (−0.97:1.5)	**Moderate macronutrient diet (0.47)***

**Numbers between parentheses refer to the probability of the diet being selected the best.*

(**Table 2**). When comparing dietary interventions between each other, the only significant difference was for the HFLC diets, associated with a higher WL compared with MM diets [MD (95% *CI*): −0.77 (−1.3; −0.19)] kg. The HFLC diet had the highest probability of being superior to all other diets (82%). The ROB of the included studies was moderate to high, mostly related to unclear allocation concealment and blinding, and high dropout rate of 20–60% (**Supplementary Figure S1**).

Moreover, 17 RCTs presented BMI changes (total $n = 3{,}260$ participants) at ≥ 12 months (29, 31, 34, 37–39, 49, 50, 54, 57–59, 61, 62, 64–66). The NMA on BMI change showed results similar to WL. There was a significant drop in BMI across all diets compared with UD, HFLC [−2.1 (−2.8; −1.4)] kg/m^2, LFHC [−1.8 (−2.5; −1.0)] kg/m^2, and the MM diets [−1.7 (−2.4; −1.1)] kg/m^2 (**Table 2**). When comparing dietary interventions between each other, the only significant difference was for the HFLC diets, associated with a significantly lower BMI compared with MM diets [MD (95% *CI*): −0.36 (−0.67; −0.05) kg/m^2]. The HFLC diets had the highest probability of being superior to all other diets (96%). The ROB of the included studies was moderate to high, mostly related to unclear sequence generation, allocation concealment and blinding, and incomplete data reporting, with a high dropout rate of 20–60% and other bias (**Supplementary Figure S2**).

We identified 15 RCTs reporting on WC change (total $n = 2{,}734$ participants) at ≥12 months (29, 31, 34, 37, 38, 49–51, 53–55, 57–59, 65). The results on WC changes echoed those of weight and BMI changes, with the HFLC associated with the highest changes [MD (95% *CI*): −5.6 cm (−8.6; −2.6)], followed by LFHC and MM diets, compared with UD. Yet, there was no significant difference in WC when diets were compared with each other (**Table 3**). The ROB of the included studies was moderate to high mostly related to unclear allocation concealment and blinding, and high dropout (**Supplementary Figure S3**).

Sub-group Analyses

We conducted subgroup analyses for the MM vs. LFHC comparison, as it had a moderate to high heterogeneity in the traditional MA for weight change (I^2 56%), BMI change (I^2 77%), and WC change (I^2 40%) (**Supplementary Table S4**). There was a larger drop in BMI with a longer intervention

duration of 12 months or more [MD −0.73 (−1.23; −0.27) kg/m^2], compared with a duration of 12 months only [MD −0.19 (−0.36; −0.02) kg/m^2], of borderline significance with a *p*-subgroup analysis 0.05. However, this finding was not reproduced for other outcome measures. Sub-group analysis by the type of co-intervention showed a trend for a larger difference in the mean change in WC in trials that administered both co-interventions (PA and behavioral therapy), *p*-subgroup analysis 0.05. We did not find any interaction by gender. We detected a consistent trend for a slightly larger effect in younger (age <50 years), compared with older (age ≥50 years) individuals, across various outcome measures. We could not assess the impact of baseline BMI given the narrow range of mean BMI (of 30–40 kg/m^2) in most studies.

Adverse Events

The adverse events were reported only in 6/36 trials (28, 33, 35, 52, 53, 57). Most adverse events were not related to the dietary interventions. Some diet related adverse events included increased urine micro-albumin to creatinine ratio in patients following high-protein diets (52) and hypoglycemia following an oral glucose tolerance test (57).

DISCUSSION

This NMA exclusively analyzes the long-term (≥ 12 months) effect of dietary interventions with active counseling, using the IOM macronutrient categorization brackets for diets categorization. The conduct of such an NMA is important given the wide utilization and reference of the AMDR (20). All diet categories (MM, LFHC, and HFLC), compared with UD, were associated with a significant WL of about 5 kg, a significant drop in BMI of 2 kg/m^2, and a significant drop in WC of 5 cm, at 12–24 months follow-up. Diets did not differ among each other, with the exception of the HFLC diet that was slightly better than MM diet, with a larger WL (of 0.8 kg) and BMI loss (0.4 kg/m^2). Since these differences in weight and BMI have a minimal clinical significance, our findings confirm that all diets have the same efficacy on weight management, and provide the evidence for obesity guidelines recommendations, not favoring a specific diet beyond the one that would optimize patient adherence and the adoption of healthy eating patterns (7, 67). Our conclusion contrasts with what diet advertisements claim to the public about the superiority of certain diets over others (68–70). Popular diets may be helpful as a jumpstart but do not affect long-term weight and WC changes (71).

Results of this NMA are aligned with those of two previous NMAs that assessed the effect of dietary interventions at 6–12 months follow-up (10, 11). Both NMAs showed that the different diet categories were superior to UD at 12 months, with a drop in weight (of 5–7 kg) and BMI of around 2 kg/m^2, similar to our findings. When comparing diets among each other, both NMAs showed a slightly higher effect of a low carbohydrate diet compared with the MM diet (10, 11), as demonstrated in our findings. Ge et al. showed a higher effect of a low-fat diet compared with an MM diet (11). While our NMA assessed the effect of dietary interventions of at least 12 months, in patients without chronic diseases potentially affecting WL, it confirmed the result of previous SR/MA on the topic, and hence showed comparable results, suggesting weight maintenance at a certain plateau with continuous dietary efforts beyond 12 months (72).

Our significant findings in one comparison only may be related to a higher power to detect significance given the larger number of included trials comparing HFLC to MM diets. The potential superiority of HFLC over an MM on weight and BMI changes may be explained by several reasons. A low-carbohydrate diet implies a higher protein intake and a reduced sugar consumption, and therefore more satiety (73). A HFLC diet may be associated with an higher secretion of the anorexigenic peptide YY hormone (74, 75), and a higher energy expenditure, compared with other diets (76). Furthermore, the carbohydrate-insulin model of obesity favors a low carbohydrate and a low glycemic index diet, allowing less fat deposition and higher energy expenditure, compared to a traditional low fat diet (77). However, this model has been criticized for being "too simplistic" (78), and further research is needed to explore the implication of this model in specific patient populations.

Aging is associated with a decrease in the total energy expenditure, and a change in various hormones that affect body composition and appetite (79). However, we did not detect a significant interaction by age, but a trend for a larger effect in younger individuals. Moreover, our subgroup analysis revealed a trend for better results in WC among recipients of PA and behavioral therapy interventions, compared with either one. Such findings highlight the importance of a multidisciplinary approach in weight management, such as diet, exercise, and psychologic support (80). Noteworthy, there was a wide heterogeneity in the intensity of delivery of the physical activity, consisting of education about healthy habits or supervised exercise sessions (29, 30, 34, 37, 44, 49, 51, 54, 55, 57, 59, 62). Similarly, the behavioral support consisted of counseling by behavioral therapists as well as support sessions provided by healthcare providers non-specialized in the behavioral field (34, 37, 39, 43, 44, 46, 50, 51, 53, 57, 59–62).

Strengths/Limitations

To our knowledge, this is the most comprehensive review on the long-term effect (≥ 12 months) of diets, assessing the WL response, in the general population with overweight/obesity. We have used a rigorous approach in the identification, data abstraction, and analysis of relevant RCTs. Our findings are based on RCTs mostly derived from Western populations and therefore might not be generalizable to non-Western countries. In addition, with the exception of few trials conducted exclusively in men, women constituted the majority of the participants, and therefore, we were not able to explore the gender effect on the response to dietary interventions. Our limitations stem from challenges identified in the included RCTs, most of which were of low quality, with a high ROB. We could not assess the impact of the quality of RCTs on the results given the paucity of high-quality trials. Although the International Committee of Medical Journal Editors (ICMJE) required, as of 2005, trials protocol registration for publication, and same did the World Health Organization as of 2006,

we identified several studies published after 2007, without an available published protocol. While blinding is an essential component in RCTs to reduce the risk of performance and detection bias, blinding of participants and dieticians to dietary interventions is very difficult, as previously recognized (81–83). There was a wide heterogeneity in the intensity and delivery mode of the dietary interventions, and this could have affected the WL response. Furthermore, compliance was assessed qualitatively in the majority of studies, implying the lack of accurate assessment of participants' adherence to dietary intervention. Few trials used quantitative methods and these included 24-h recall, self-reported food records, and food frequency questionnaires, and fewer ones chose urine urea nitrogen, urinary ketone levels, and respiratory quotient; the latter are preferred methods as they are subjected to less recall and social desirability biases. Due to the difference in the assessment methodology, there were no means of evaluating the relationship between adherence rate and changes in weight parameters. Finally, we noted an under-reporting of adverse events, as described previously (10, 11). Although various diet therapies are safe, limited data are available on their long-term effects (84).

CONCLUSION

Compared with the usual diet, all dietary interventions allow a sustained modest WL during the follow-up of 12 months and beyond. A HFLC diet seems to be slightly better than a MM diet, while all other comparisons between diets yield similar results. A major limitation of the findings stems from the lack of compliance/adherence data, the wide variability of the delivery of dietary interventions, and the low quality of RCTs. A formal and standardized delivery of diet therapy, a qualitative assessment of participants' adherence to diets, efforts to improve on blinding of participants and researchers, and to reduce the participants' attrition are essential in future trials. While our findings apply to the general population of patients with overweight/obesity, the long-term impact of dietary approaches on patients with chronic diseases is worth investigation in a separate systematic review of the literature.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

MC and JJ conceived, designed the study, coordinated data screening and abstraction, and wrote and reviewed the manuscript. MC, JJ, and AK analyzed and interpreted the data. DA, RA, RH, LG, NH, NN, GS, BT, YR, and MZ performed data screening. DA, RH, LG, NH, GS, BT, YR, and MZ performed data abstraction. YR and NH managed the data. All authors revised the article critically for important intellectual content, gave final approval of the version to be published, and agreed to be accountable for all aspects of the work. All authors contributed to the article and approved the submitted version.

ACKNOWLEDGMENTS

The authors would like to thank professionals who have supported this research project. Ms. Aida Farha and Ms. Layal Hneiny for their support in designing the search strategy and extracting the articles. Dr. Maria Armache for developing the search strategy. Ms. Noor Al Rubaye, Mr. Karim El Mokaddem, Ms. Nour El Ghawi, Ms. Sally El Sammak, Ms. Lara Haidous, Ms. Anna Maria Markarian, Ms. Nadine Omran, and Mr. Bassel Tfayli for their support in the abstract screening phase and data abstraction.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.821096/full#supplementary-material

REFERENCES

1. Blüher M. Obesity: global epidemiology and pathogenesis. *Nat Rev Endocrinol.* (2019) 15:288–98. doi: 10.1038/s41574-019-0176-8
2. Collaboration PS. Body-mass index and cause-specific mortality in 900 000 adults: collaborative analyses of 57 prospective studies. *Lancet.* (2009) 373:1083–96. doi: 10.1016/S0140-6736(09)60318-4
3. Fontaine KR, Redden DT, Wang C, Westfall AO, Allison DB. Years of life lost due to obesity. *JAMA.* (2003) 289:187–93. doi: 10.1001/jama.289.2.187
4. Berrington de Gonzalez A, Hartge P, Cerhan JR, Flint AJ, Hannan L, MacInnis RJ, et al. Body-mass index and mortality among 146 million white adults New England. *J Med.* (2010) 363:2211–9. doi: 10.1056/NEJMoa1000367
5. WHO. Obesity and overweight 2021 [updated June 9, 2021]. Available online at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed August 10, 2021).
6. Meldrum DR, Morris MA, Gambone JC. Obesity pandemic: causes, consequences, and solutions—but do we have the will? *Fertil Steril.* (2017) 107:833–9. doi: 10.1016/j.fertnstert.2017.02.104
7. Garber AJ, Abrahamson MJ, Barzilay JI, Blonde L, Bloomgarden ZT, Bush MA, et al. Consensus statement by the american association of clinical endocrinologists and american college of endocrinology on the comprehensive type 2 diabetes management algorithm – 2016 executive summary. *Endocr Pract.* (2016) 22:84–113. doi: 10.4158/EP151126.CS
8. Chaimani A, Caldwell DM, Li T, Higgins JP, Salanti G. Undertaking network meta-analyses. *Cochrane Handbook for Systematic Reviews of Interventions*. Bristol: The Cochrane Collaboration (2019). p. 285–320.
9. Schwingshackl L, Buyken A, Chaimani A. Network meta-analysis reaches nutrition research. *Eur. J. Nutr.* Springer (2019). 58:1–3.
10. Johnston BC, Kanters S, Bandayrel K, Wu P, Naji F, Siemieniuk RA, et al. Comparison of weight loss among named diet programs in overweight and obese adults: a meta-analysis. *JAMA.* (2014) 312:923–33. doi: 10.1001/jama.2014.10397
11. Ge L, Sadeghirad B, Ball GD, da Costa BR, Hitchcock CL, Svendrovski A, et al. Comparison of dietary macronutrient patterns of 14 popular named dietary programmes for weight and cardiovascular risk factor reduction in adults: systematic review and network meta-analysis of randomised trials. *BMJ.* (2020) 369:m696. doi: 10.1136/bmj.m696
12. Bueno NB, de Melo ISV, de Oliveira SL, da Rocha Ataide T. Very-low-carbohydrate ketogenic diet v. low-fat diet for long-term weight loss: a meta-analysis of randomised controlled trials. *Br J Nutr.* (2013) 110:1178–87. doi: 10.1017/S0007114513000548

13. Atallah R, Filion KB, Wakil SM, Genest J, Joseph L, Poirier P, et al. Long-term effects of 4 popular diets on weight loss and cardiovascular risk factors: a systematic review of randomized controlled trials. *Circ Cardiovasc Qual Outcomes.* (2014) 7:815–27. doi: 10.1161/CIRCOUTCOMES.113.000723
14. Clifton P, Condo D, Keogh J. Long term weight maintenance after advice to consume low carbohydrate, higher protein diets–a systematic review and meta analysis. *Nutr Metabol Cardiovasc Dis.* (2014) 24:224–35. doi: 10.1016/j.numecd.2013.11.006
15. Tobias DK, Chen M, Manson JE, Ludwig DS, Willett W, Hu FB. Effect of low-fat diet interventions versus other diet interventions on long-term weight change in adults: a systematic review and meta-analysis. *Lancet Diabetes Endocrinol.* (2015) 3:968–79. doi: 10.1016/S2213-8587(15)00367-8
16. Mancini JG, Filion KB, Atallah R, Eisenberg MJ. Systematic review of the Mediterranean diet for long-term weight loss. *Am J Med*. (2016) 129:407–15. e4. doi: 10.1016/j.amjmed.2015.11.028
17. Anton SD, Hida A, Heekin K, Sowalsky K, Karabetian C, Mutchie H, et al. Effects of popular diets without specific calorie targets on weight loss outcomes: systematic review of findings from clinical trials. *Nutrients.* (2017) 9:822. doi: 10.3390/nu9080822
18. Lu M, Wan Y, Yang B, Huggins CE, Li D. Effects of low-fat compared with high-fat diet on cardiometabolic indicators in people with overweight and obesity without overt metabolic disturbance: a systematic review and meta-analysis of randomised controlled trials. *Br J Nutr.* (2018) 119:96–108. doi: 10.1017/S0007114517002902
19. Bray G, Kim K, Wilding J, Federation WO. Obesity: a chronic relapsing progressive disease process. A position statement of the World Obesity Federation. *Obes Rev.* (2017) 18:715–23. doi: 10.1111/obr.12551
20. Medicine Io. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: The National Academies Press (2005). p. 1358.
21. Lee E, Choi J, Ahn A, Oh E, Kweon H, Cho D. Acceptable macronutrient distribution ranges and hypertension. *Clin Exp Hypertens.* (2015) 37:463–7. doi: 10.3109/10641963.2015.1013116
22. Chakhtoura M, Jabbour J, Armache A, Khamis A, Halperin F, Rihawi Y, et al. *Effect of different diets on weight and other outcomes in long term trials.* (2021). Available online at: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42018103116 (accessed November 1, 2021).
23. Higgins JPT, Altman DG, Gøtzsche PC, Jüni P, Moher D, Oxman AD, et al. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ.* (2011) 343:d5928. doi: 10.1136/bmj.d5928
24. Lumley T. Network meta-analysis for indirect treatment comparisons. *Stat Med.* (2002) 21:2313–24. doi: 10.1002/sim.1201
25. Ades A, Sculpher M, Sutton A, Abrams K, Cooper N, Welton N, et al. Bayesian methods for evidence synthesis in cost-effectiveness analysis. *Pharmacoeconomics.* (2006) 24:1–19. doi: 10.2165/00019053-200624010-00001
26. Higgins JP, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al. *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester, UK: John Wiley & Sons (2019).
27. Veroniki AA, Straus SE, Fyraridis A, Tricco AC. The rank-heat plot is a novel way to present the results from a network meta-analysis including multiple outcomes. *J Clin Epidemiol.* (2016) 76:193–9. doi: 10.1016/j.jclinepi.2016.02.016
28. Stern L, Iqbal N, Seshadri P, Chicano KL, Daily DA, McGrory J, et al. The effects of low-carbohydrate versus conventional weight loss diets in severely obese adults: one-year follow-up of a randomized trial. *Ann Intern Med.* (2004) 140:778–85. doi: 10.7326/0003-4819-140-10-200405180-00007
29. Shai I, Schwarzfuchs D, Henkin Y, Shahar DR, Witkow S, Greenberg I, et al. Weight loss with a low-carbohydrate, Mediterranean, or low-fat diet. *N Engl J Med.* (2008) 359:229–41. doi: 10.1056/NEJMoa0708681
30. Gepner Y, Shelef I, Schwarzfuchs D, Cohen N, Bril N, Rein M, et al. Intramyocellular triacylglycerol accumulation across weight loss strategies; Sub-study of the CENTRAL trial. *PLoS ONE.* (2017) 12:e0188431. doi: 10.1371/journal.pone.0188431
31. Rusu E, Jinga M, Enache G, Rusu F, Dragomir AD, Ancuta I, et al. Effects of lifestyle changes including specific dietary intervention and physical activity in the management of patients with chronic hepatitis C-a randomized trial. *Nutr J.* (2013) 12:1–12. doi: 10.1186/1475-2891-12-119
32. Klemsdal TO, Holme I, Nerland H, Pedersen TR, Tonstad S. Effects of a low glycemic load diet versus a low-fat diet in subjects with and without the metabolic syndrome. *Nutr Metabol Cardiovasc Dis.* (2010) 20:195–201. doi: 10.1016/j.numecd.2009.03.010
33. Salas-Salvadó J, Fernández-Ballart J, Ros E, Martinez-Gonzalez M-A, Fitó M, Estruch R, et al. Effect of a Mediterranean diet supplemented with nuts on metabolic syndrome status: one-year results of the PREDIMED randomized trial. *Arch Intern Med.* (2008) 168:2449–58. doi: 10.1001/archinte.168.22.2449
34. Pavić E, HadŽiabdić MO, Mucalo I, Martinis I, Romić Ž, BoŽikov V, et al. Effect of the Mediterranean diet in combination with exercise on metabolic syndrome parameters: 1-year randomized controlled trial. *Int J Vitamin Nutr Res.* (2019) 89:132–43. doi: 10.1024/0300-9831/a000462
35. Ma Y, Olendzki BC, Wang J, Persuitte GM, Li W, Fang H, et al. A randomized trial of single-versus multi-component dietary goals for metabolic syndrome. *Ann Intern Med.* (2015) 162:248. doi: 10.7326/M14-0611
36. Keogh JB, Brinkworth GD, Clifton PM. Effects of weight loss on a low-carbohydrate diet on flow-mediated dilatation, adhesion molecules and adiponectin. *Br J Nutr.* (2007) 98:852–9. doi: 10.1017/S0007114507747815
37. Dale KS, McAuley KA, Taylor RW, Williams SM, Farmer VL, Hansen P, et al. Determining optimal approaches for weight maintenance: a randomized controlled trial. *CMAJ.* (2009) 180:E39–46. doi: 10.1503/cmaj.080974
38. Frisch S, Zittermann A, Berthold HK, Götting C, Kuhn J, Kleesiek K, et al. A randomized controlled trial on the efficacy of carbohydrate-reduced or fat-reduced diets in patients attending a telemedically guided weight loss program. *Cardiovasc Diabetol.* (2009) 8:1–10. doi: 10.1186/1475-2840-8-36
39. Gardner CD, Kiazand A, Alhassan S, Kim S, Stafford RS, Balise RR, et al. Comparison of the Atkins, Zone, Ornish, and LEARN diets for change in weight and related risk factors among overweight premenopausal women: the A TO Z Weight Loss Study: a randomized trial. *JAMA.* (2007) 297:969–77. doi: 10.1001/jama.297.9.969
40. Brinkworth GD, Wycherley TP, Noakes M, Buckley JD, Clifton PM. Long-term effects of a very-low-carbohydrate weight-loss diet and an isocaloric low-fat diet on bone health in obese adults. *Nutrition.* (2016) 32:1033–6. doi: 10.1016/j.nut.2016.03.003
41. Jesudason D, Nordin BC, Keogh J, Clifton P. Comparison of 2 weight-loss diets of different protein content on bone health: a randomized trial. *Am J Clin Nutr.* (2013) 98:1343–52. doi: 10.3945/ajcn.113.058586
42. Marniemi J, Seppänen A, Hakala P. Long-term effects on lipid metabolism of weight reduction on lactovegetarian and mixed diet. *Int J Obes.* (1990) 14:113–25.
43. Due A, Toubro S, Skov A, Astrup A. Effect of normal-fat diets, either medium or high in protein, on body weight in overweight subjects: a randomised 1-year trial. *Int J Obes.* (2004) 28:1283–90. doi: 10.1038/sj.ijo.0802767
44. Ebbeling CB, Leidig MM, Sinclair KB, Seger-Shippee LG, Feldman HA, Ludwig DS. Effects of an ad libitum low-glycemic load diet on cardiovascular disease risk factors in obese young adults. *Am J Clin Nutr.* (2005) 81:976–82. doi: 10.1093/ajcn/81.5.976
45. Tanumihardjo SA, Valentine AR, Zhang Z, Whigham LD, Lai HJ, Atkinson RL. Strategies to increase vegetable or reduce energy and fat intake induce weight loss in adults. *Exp Biol Med.* (2009) 234:542–52. doi: 10.3181/0810-RM-293
46. Sukumar D, Ambia-Sobhan H, Zurfluh R, Schlussel Y, Stahl TJ, Gordon CL, et al. Areal and volumetric bone mineral density and geometry at two levels of protein intake during caloric restriction: a randomized, controlled trial. *J Bone Mineral Res.* (2011) 26:1339–48. doi: 10.1002/jbmr.318
47. Venn BJ, Perry T, Green TJ, Skeaff CM, Aitken W, Moore NJ, et al. The effect of increasing consumption of pulses and wholegrains in obese people: a randomized controlled trial. *J Am Coll Nutr.* (2010) 29:365–72. doi: 10.1080/07315724.2010.10719853
48. Azadbakht L, Mirmiran P, Esmaillzadeh A, Azizi F. Better dietary adherence and weight maintenance achieved by a long-term moderate-fat diet. *Br J Nutr.* (2007) 97:399–404. doi: 10.1017/S0007114507328602
49. Dansinger ML, Gleason JA, Griffith JL, Selker HP, Schaefer EJ. Comparison of the Atkins, Ornish, Weight Watchers, and Zone diets for weight loss and heart disease risk reduction: a randomized trial. *JAMA.* (2005) 293:43–53. doi: 10.1001/jama.293.1.43
50. Mellberg C, Sandberg S, Ryberg M, Eriksson M, Brage S, Larsson C, et al. Long-term effects of a Palaeolithic-type diet in obese postmenopausal women: a 2-year randomized trial. *Eur J Clin Nutr.* (2014) 68:350–7. doi: 10.1038/ejcn.2013.290
51. Foster-Schubert KE, Alfano CM, Duggan CR, Xiao L, Campbell KL, Kong A, et al. Effect of diet and exercise, alone or combined, on weight and body

composition in overweight-to-obese postmenopausal women. *Obesity.* (2012) 20:1628–38. doi: 10.1038/oby.2011.76
52. Sacks FM, Bray GA, Carey VJ, Smith SR, Ryan DH, Anton SD, et al. Comparison of weight-loss diets with different compositions of fat, protein, and carbohydrates. *N Engl J Med.* (2009) 360:859–73. doi: 10.1056/NEJMoa0804748
53. Bazzano LA, Hu T, Reynolds K, Yao L, Bunol C, Liu Y, et al. Effects of low-carbohydrate and low-fat diets: a randomized trial. *Ann Intern Med.* (2014) 161:309–18. doi: 10.7326/M14-0180
54. Santanasto A, Newman A, Strotmeyer E, Boudreau R, Goodpaster B, Glynn NW. Effects of changes in regional body composition on physical function in older adults: a pilot randomized controlled trial. *J Nutr Health Aging.* (2015) 19:913–21. doi: 10.1007/s12603-015-0523-y
55. Griffin H, Cheng H, O'Connor H, Rooney K, Petocz P, Steinbeck K. Higher protein diet for weight management in young overweight women: a 12-month randomized controlled trial. *Diabetes Obes Metabol.* (2013) 15:572–5. doi: 10.1111/dom.12056
56. Wycherley T, Brinkworth G, Clifton P, Noakes M. Comparison of the effects of 52 weeks weight loss with either a high-protein or high-carbohydrate diet on body composition and cardiometabolic risk factors in overweight and obese males. *Nutr Diabetes.* (2012) 2:e40-e. doi: 10.1038/nutd.2012.11
57. Gardner CD, Trepanowski JF, Del Gobbo LC, Hauser ME, Rigdon J, Ioannidis JP, et al. Effect of low-fat vs low-carbohydrate diet on 12-month weight loss in overweight adults and the association with genotype pattern or insulin secretion: the DIETFITS randomized clinical trial. *JAMA.* (2018) 319:667–79. doi: 10.1001/jama.2018.0245
58. Fernández AC, Casariego AV, Rodríguez IC. One-year effectiveness of two hypocaloric diets with different protein/carbohydrate ratios in weight loss and insulin resistance. *Nutr Hosp.* (2012) 27:2093–101. doi: 10.3305/nh.2012.27.6.6133
59. De Jonge L, Bray GA, Smith SR, Ryan DH, De Souza RJ, Loria CM, et al. Effect of diet composition and weight loss on resting energy expenditure in the POUNDS LOST study. *Obesity.* (2012) 20:2384–9. doi: 10.1038/oby.2012.127
60. Knopp RH, Walden CE, Retzlaff BM, McCann BS, Dowdy AA, Albers JJ, et al. Long-term cholesterol-lowering effects of 4 fat-restricted diets in hypercholesterolemic and combined hyperlipidemic men: the Dietary Alternatives Study. *JAMA.* (1997) 278:1509–15. doi: 10.1001/jama.1997.03550180059038
61. Pritchard JE, Nowson CA, Wark JD. A worksite program for overweight middle-aged men achieves lesser weight loss with exercise than with dietary change. *J Am Diet Assoc.* (1997) 97:37–42. doi: 10.1016/S0002-8223(97)00015-1
62. Wing RR, Venditti E, Jakicic JM, Polley BA, Lang W. Lifestyle intervention in overweight individuals with a family history of diabetes. *Diabetes Care.* (1998) 21:350–9. doi: 10.2337/diacare.21.3.350
63. Pereira MA, Swain J, Goldfine AB, Rifai N, Ludwig DS. Effects of a low–glycemic load diet on resting energy expenditure and heart disease risk factors during weight loss. *JAMA.* (2004) 292:2482–90. doi: 10.1001/jama.292.20.2482
64. Williams PT, Krauss RM, Stefanick ML, Vranizan KM, Wood PD. Effects of low-fat diet, calorie restriction, and running on lipoprotein subfraction concentrations in moderately overweight men. *Metabolism.* (1994) 43:655–63. doi: 10.1016/0026-0495(94)90210-0
65. Álvarez-Pérez J, Sánchez-Villegas A, Díaz-Benítez EM, Ruano-Rodríguez C, Corella D, Martínez-González MÁ, et al. Influence of a Mediterranean dietary pattern on body fat distribution: results of the PREDIMED–Canarias Intervention Randomized Trial. *J Am Coll Nutr.* (2016) 35:568–80. doi: 10.1080/07315724.2015.1102102
66. Brinkworth GD, Noakes M, Buckley JD, Keogh JB, Clifton PM. Long-term effects of a very-low-carbohydrate weight loss diet compared with an isocaloric low-fat diet after 12 mo. *Am J Clin Nutr.* (2009) 90:23–32. doi: 10.3945/ajcn.2008.27326
67. Garvey WT, Mechanick JI, Brett EM, Garber AJ, Hurley DL, Jastreboff AM, et al. American Association of Clinical Endocrinologists and American College of Endocrinology Comprehensive Clinical Practice Guidelines Formedical Care of Patients with Obesity. *Endocr Pract.* (2016) 22:1–203. doi: 10.4158/EP161365.GL
68. Eugene A. *Sugar Detox: Defeat Cravings and Restore Your Health*. Summertown, TN: Book Publishing Company (2016).
69. Grout P. *Jumpstart Your Metabolism: How to Lose Weight by Changing the Way You Breathe*. New York, NY: Simon and Schuster (2010).
70. Jauho M, Pääkkönen J, Isotalo V, Pöyry E, Laaksonen S-M. How do trendy diets emerge? An exploratory social media study on the low-carbohydrate diet in Finland. *Food Cult Soc.* (2021) 1–26. doi: 10.1080/15528014.2021.1971436
71. Freire R. Scientific evidence of diets for weight loss: different macronutrient composition, intermittent fasting, and popular diets. *Nutrition.* (2020) 69:110549. doi: 10.1016/j.nut.2019.07.001
72. Hall KD, Kahan S. Maintenance of lost weight and long-term management of obesity. *Med Clin.* (2018) 102:183–97. doi: 10.1016/j.mcna.2017.08.012
73. Seid H, Rosenbaum M. Low carbohydrate and low-fat diets: What we don't know and why we should know it. *Nutrients.* (2019) 11:2749. doi: 10.3390/nu11112749
74. Wolever TM, Chiasson JL, Josse RG, Leiter LA, Maheux P, Rabasa-Lhoret R, et al. Effects of changing the amount and source of dietary carbohydrates on symptoms and dietary satisfaction over a 1-year period in subjects with type 2 diabetes: Canadian Trial of Carbohydrates in Diabetes (CCD). *Can J Diabetes.* (2017) 41:164–76. doi: 10.1016/j.jcjd.2016.08.223
75. Hu T, Yao L, Reynolds K, Niu T, Li S, Whelton P, et al. The effects of a low-carbohydrate diet on appetite: A randomized controlled trial. *Nutr Metabol Cardiovasc Diseases.* (2016) 26:476–88. doi: 10.1016/j.numecd.2015.11.011
76. Ebbeling CB, Swain JF, Feldman HA, Wong WW, Hachey DL, Garcia-Lago E, et al. Effects of dietary composition on energy expenditure during weight-loss maintenance. *JAMA.* (2012) 307:2627–34. doi: 10.1001/jama.2012.6607
77. Ludwig DS, Aronne LJ, Astrup A, de Cabo R, Cantley LC, Friedman MI et al. The carbohydrate-insulin model: a physiological perspective on the obesity pandemic. *Am J Clin Nutr.* (2021) 114:1873–1885. doi: 10.1093/ajcn/nqab270
78. Hall D. A review of the carbohydrate–insulin model of obesity. *Eur J Clin Nutr.* (2018) 72:183. doi: 10.1038/ejcn.2017.156
79. Villareal DT, Apovian CM, Kushner RF, Klein S. Obesity in older adults: technical review and position statement of the American Society for Nutrition and NAASO, The Obesity Society. *Am J Clin Nutr.* (2005) 82:923–34. doi: 10.1093/ajcn/82.5.923
80. Seo D-C, Sa J, A. meta-analysis of psycho-behavioral obesity interventions among US multiethnic and minority adults. *Preven Med.* (2008) 47:573–82. doi: 10.1016/j.ypmed.2007.12.010
81. Staudacher HM, Irving PM, Lomer MC, Whelan K. The challenges of control groups, placebos and blinding in clinical trials of dietary interventions. *Proc Nutr Soc.* (2017) 76:203–12. doi: 10.1017/S0029665117000350
82. Mirmiran P, Bahadoran Z, Gaeini Z. Common Limitations and Challenges of Dietary Clinical Trials for Translation into Clinical Practices. *Int J Endocrinol Metab.* (2021) 19:e108170. doi: 10.5812/ijem.108170
83. Crichton GE, Howe PRC, Buckley JD, Coates AM, Murphy KJ, Bryan J. Long-term dietary intervention trials: critical issues and challenges. *Trials.* (2012) 13:111. doi: 10.1186/1745-6215-13-111
84. Koliaki C, Spinos T. Spinou, Brinia E, Mitsopoulou D, Katsilambros N. Defining the optimal dietary approach for safe, effective and sustainable weight loss in overweight and obese Adults. *Healthcare.* (2018) 6:73. doi: 10.3390/healthcare6030073

Conflict of Interest: LG is employed by Qualisus Consulting.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Nutrition

ORIGINAL RESEARCH
published: 10 May 2022
doi: 10.3389/fnut.2022.838937

Cluster Analysis and Classification Model of Nutritional Anemia Associated Risk Factors Among Palestinian Schoolchildren, 2014

Radwan Qasrawi[1,2]* *and Diala Abu Al-Halawa*[3]*

[1] Department of Computer Science, Al-Quds University, Jerusalem, Palestine, [2] Department of Computer Engineering, Istinye University, Istanbul, Turkey, [3] Medical Faculty, Al-Quds University, Jerusalem, Palestine

OPEN ACCESS

Edited by:
Juan Mielgo-Ayuso, University of Burgos, Spain

Reviewed by:
Majid Hajifaraji, National Nutrition and Food Technology Research Institute, Iran
Lovejeet Kaur, University of Delhi, India

***Correspondence:**
Radwan Qasrawi
radwan@staff.alquds.edu; radwan.qasrawi@istinye.edu.tr
Diala Abu Al-Halawa
halawadiala@gmail.com

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *18 December 2021*
Accepted: *21 March 2022*
Published: *10 May 2022*

Citation:
Qasrawi R and Abu Al-Halawa D (2022) Cluster Analysis and Classification Model of Nutritional Anemia Associated Risk Factors Among Palestinian Schoolchildren, 2014. Front. Nutr. 9:838937. doi: 10.3389/fnut.2022.838937

Nutritional inadequacy has been a major health problem worldwide. One of the many health problems that result from it is anemia. Anemia is considered a health concern among all ages, particularly children, as it has been associated with cognitive and developmental delays. Researchers have investigated the association between nutritional deficiencies and anemia through various methods. As novel analytical methods are needed to ascertain the association and reveal indirect ones, we aimed to classify nutritional anemia using the cluster analysis approach. In this study, we included 4,762 students aged between 10 and 17 years attending public and UNRWA schools in the West Bank. Students' 24-h food recall and blood sample data were collected for nutrient intake and hemoglobin analysis. The K-means cluster analysis was used to cluster the hemoglobin levels into two groups. Vitamin B12, folate, and iron intakes were used as the indicators of nutrient intake associated with anemia and were classified as per the Recommended Dietary Allowance (RDA) values. We applied the Classification and Regression Tree (CRT) model for studying the association between hemoglobin clusters and vitamin B12, folate, and iron intakes, sociodemographic variables, and health-related risk factors, accounting for grade and age. Results indicated that 46.4% of the students were classified into the low hemoglobin cluster, and 60.7, 72.5, and 30.3% of vitamin B12, folate, and iron intakes, respectively, were below RDA. The CRT analysis indicated that vitamin B12, iron, and folate intakes are important factors related to anemia in girls associated with age, locality, food consumption patterns, and physical activity levels, while iron and folate intakes were significant factors related to anemia in boys associated with the place of residence and the educational level of their mothers. The deployment of clustering and classification techniques for identifying the association between anemia and nutritional factors might facilitate the development of nutritional anemia prevention and intervention programs that will improve the health and wellbeing of schoolchildren.

Keywords: nutritional anemia, anemia classification, cluster analysis, classification model, Classification and Regression Tree, schoolchildren

INTRODUCTION

Anemia is a worldwide public health concern, with 24.8% of the global population suffering from anemia (1). It is associated with many diseases that affect all the age groups (1–3). The effects of the lack of oxygen are particularly troublesome in children, as that may affect their physical growth and cognitive development (4–8). There are many causes of this disease, with nutritional inadequacies being a primary factor contributing to anemia (9–11). Various studies have associated certain nutritional insufficiencies with this disease. Iron, vitamin B12, folic acid, vitamin A, and vitamin C are some nutrients that have been linked to its development (6, 11–16). The association between nutrient intake deficiencies and other health and cognitive development problems among schoolchildren has been investigated by several studies, indicating a strong correlation between nutrition and the health of children. Researchers have investigated the prevalence of nutrient deficiencies among medically documented patients with anemia, and it has become well known that iron deficiency is the most common cause of anemia (13, 17–19). Ensuring adequate nutrient intake requires dietary variety in food consumption, which could be lacking in children age group (20–25).

Other risk factors linked to the disease include children living conditions. Goswami et al. is one of the many researchers who found that the place of residence is a major factor associated with anemia, where rural children were more anemic than urban children (26). Other researchers have also established the linkage of parental educational level with this entity (26–28). It has become clear that, as many factors interact in the development of anemia, there is a need for an in-depth study of this complex interaction, one beyond prevalence and associations.

Investigators have used many statistical methods in discerning the interaction of sociodemographic and health-related risk factors resulting in anemia. Furthermore, data mining and machine learning techniques for clustering and classifications have been improved as effective tools in the clustering and classification of risk factors associated with the health of children (29, 30). The K-means, Decision Tree, Chi-square automatic interaction detection (CHAID), the K-Nearest Neighbors' algorithm (K-NN), and Classification and Regression Trees (CRT) clustering and classification models have been used by many research studies for predicting and identifying nutrition, lifestyle, and health diseases, such as obesity, diabetes, and anemia (31–34). In medical research, several ML clustering and classification, such as support vector machine, artificial neural network, and random forest techniques, are used for improving early detection and diagnosis of diseases (29, 30, 35–38). Particularly in anemia, M. Visser et al. have employed factor analysis for the determination of the nutrient pattern that is most associated with anemia, accounting for differences between provinces (14). On the other hand, Sow et al. employed machine learning algorithms in the identification of associated sociodemographic risk factors for anemia development (38). A study in China employed the CHAID decision tree analysis for the identification of infant anemia-related risk factors (31).

To the best of our knowledge, few studies have employed cluster analysis for the classification of hemoglobin levels among a certain population. The present study is a part of the national nutritional formative research among schoolchildren aimed at assessing children's health, nutrition, and mental health. The main aim of this study was to derive dietary patterns related to anemia in schoolchildren and to investigate the association between hemoglobin, vitamin B12, iron, and folate intakes with other sociodemographic variables, and health-related risk factors among Palestinian schoolchildren. We used the K-means and CRT machine learning techniques in identifying schoolchildren clusters based on hemoglobin data and finding the association patterns through the classification of the associated risk factors.

MATERIALS AND METHODS

Participants and Data Collection

This study utilizes data from the Health Behaviour in School-aged Children (HBSC) survey conducted by Al-Quds University and the Ministry of Health in the year 2013–2014, which aims to assess the nutritional, physical, and psychological health of Palestinian schoolchildren (34, 39, 40). The study sample included children aged 10–17 years who were enrolled in public and the United Nations Relief and Works Agency (UNRWA) for Palestinian refugee schools. A representative and clustered random sample of 5,000 students was selected from 100 schools in the West Bank and weighted for grade and age. Only the relevant variables and available data were used for this study; therefore, a final sample of 4,762 students was used for data analysis. Data collection included blood sampling, sociodemographic data, health-related practices, and 24-h dietary recalls. For hemoglobin acquisition, data were collected using the Hemoglobin (Hb) test using the HemoCue Hb 201+ analyzer. On-site 50 μl of non-fasting venous whole blood was collected for all subjects for complete blood count (CBC) analysis *via* nurses and doctors registered in the Ministry of Health on schools' grounds. The total Hb concentration was calculated to the nearest 0.1 g/dl. The anthropometric data were collected by the digital floor scale for measuring students' weights in kg and the portable stadiometer for measuring the height in cm. Prior to data collection, all parents or caregivers signed an informed consent form. The study received ethical approval from the Ministry of Education and Al-Quds University Institutional Review Board (IRB approval number: 05-Aug-2013-12/10).

Hematological Parameter

In this study, we acquired hemoglobin levels as an indicator of anemia. The use of hemoglobin as a single anemia parameter has been applied in various research studies (10, 38, 41). In this study, the K-means clustering method was used for identifying the hemoglobin groups (42). Using the K-means clustering method, two different hemoglobin clusters were identified. The first cluster includes the participants with average hemoglobin of <12 g/dl, the second cluster includes those ≥ 12 g/dl.

Health-Related Risk Factors

To measure nutrient intake, we used the 24-h food recall method. The tool gives a detailed insight into food consumption over a 24-h period (43–45). The food frequency scale was developed using the eight food items scale, which was categorized based on similarity in the nutrient profile (46). These categories were as follows: (1) vegetables; (2) fruits; (3) milk and other dairy products; (4) sweets and chocolate; (5) soft drinks; (7) beverages (juices and sugar); and (8) energy drinks. Response categories were (1) never, (2) 1–2 times a week, (3) 3–4 times a week, and (4) 5–7 times a week (almost daily). The food consumption quantities were identified using the recipes from the consumption weight book developed by ANAHRI (47). The food intake was entered and analyzed using Nutribase Professional V.9, the United States Department of Agriculture (USDA), and the Palestinian Food Recipes databases (47, 48). As studies have shown that there is an association between certain nutrients with anemia, we have chosen vitamin B12, iron, and folate as key nutrients for the analysis of and association with hemoglobin clusters. The nutrient values were analyzed and compared with the USDA Recommended Dietary Allowance (RDA) values according to the ages of participants (49).

As for health-related nutritional practices, we have used the food frequency questionnaire to classify the practices of students into (healthy and unhealthy) food consumption patterns. The indicated frequency of consumption was obtained over a week's duration (1) never, (2) 1–2 times a week, (3) 3–4 times a week, and (4) 5–7 times a week (almost daily).

The healthy group included participants who were in the top 2 quartiles (+50 percentile) of intake of fruits and vegetables (indicated as the indicators of a healthy diet by the WHO) (50) and milk and had indicated that they did not eat any unhealthy item. The unhealthy group included participants who had indicated that they did not eat any healthy nutritional items and were in the top 2 quartiles of the frequency of eating sweets, soft drinks, sugary juices, and energy drinks, respectively. The score for each variable was classified into yes and no values according to quartile classification.

Taking into consideration the numerous non-dietary risk factors that may be associated with anemia, we have included data regarding the general health status of the participants. Anthropometric measurements, such as height, weight, and neck circumference, were measured by school nurses, and the body mass index [BMI = weight/(height^2)] of each participant was calculated. The BMI was classified into 4 categories based on the WHO cutoff values for interpretation of BMI in 5–19-year-old children (51). Furthermore, the students were asked about their physical activity during the school days and excluding weekends. The following questions comprised the frequency of physical activities over a week duration: (1) In the last week, how many days were you physically active for more than 60 min? (2) In the last week, how many hours were you playing sports outside school? (3) In the last week, how many hours do you exercise per week? These responses were summed, and the final score was classified according to its quartiles into low (1st and 2nd quartiles), moderate (3rd quartile), and high physical activity (4th quartile), respectively. In addition, as leisure time activities were accounted for in the questionnaire, the respondents were asked about their screen behavior over school days in the past week. The questions included: (1) how many hours do you spend watching TV? (2) how many hours do you play video games? (3) how many hours do you spend using the internet? Again, the sum of these questions was used to generate a leisure time activity scale, and the quartiles were used to classify the outcome into low (1st and 2nd quartiles), moderate (3rd quartile), and high (4th quartile) leisure time activities. Moreover, students were asked about their smoking practices, and the responses were yes or no to smoking cigarettes and/or nargileh, respectively. Furthermore, as anemia could result from a multitude of chronic disease processes, we asked the students and their parents about any known chronic illnesses, in addition to checking the available school records on the chronic illnesses of students, and we ultimately excluded those students from this study.

Statistical Analysis

We employed descriptive statistics, the K-means clustering method, and the CRT technique (52). The statistical analysis was conducted using IBM Statistical Package for Social Science V21. The K-means clustering method is a type of statistical analysis that classifies the sample population into homogenous groups with different characteristics using a specific variable as the comparison criterion (42). The K-means clustering method defines the segments of a dataset and assigns each observation into a specific cluster, the algorithm identifies the smallest variation within each cluster. A non-hierarchical K-means clustering method was used to produce two hemoglobin clusters, with the random seed and 10 iterations to refine and optimize the classifications. The final clusters were selected based on interpretability and the percentage of participants in each cluster. The sociodemographic and nutrition variables were analyzed for these clusters. Chi-squared and univariate analysis tests were used to assess the differences between categorical data. Continuous data were assessed for normality and, if required, normalized with natural log transformation. Of the available decision tree models, we chose the CRT model for the identification of potential risk factors for childhood anemia, relating to each relevant nutrient of choice (vitamin B12, iron, and folate). Cases in each subgroup are further classified by the second most significant predictor. The analysis continues until the last significant risk factor is identified.

RESULTS

Demographics and Health-Related Risk Factors

The results of the demographic characteristics and health-related risk factors are depicted in **Table 1**. The study sample consists of 66.9% girls and 33.1% boys, 72.6% aged 10–13 years, and 27.4% aged 14–17 years. The students were mostly from urban habitats (42.8%), but 34.6% were from rural habitats and the rest were from refugee camps. When asked about their family income, almost 45% of the participants reported they had low family income compared with the minimum wages in the West Bank, and only 19.2% had high income, respectively. Additionally,

TABLE 1 | Demographic variables of the study sample ($n = 4,762$).

				Hemoglobin
		n	%	Mean ± SD
Gender	Boys	1,575	33.1	13.1 ± 1.35
	Girls	3,187	66.9**	12.9 ± 1.27
Age	10–13 years	3,455	72.6**	12.9 ± 1.23
	14–17 years	1,307	27.4	13.07 ± 1.47
Locality	Urban	2,037	42.8**	13.1 ± 1.26
	Rural	1,650	34.6	12.8 ± 1.29
	Camp	1,075	22.6	12.9 ± 1.38
Family income	L	2,122	44.6	12.9 ± 1.3
	M	1,724	36.2	13 ± 1.3
	H	916	19.2	13 ± 1.32
Father's education	≤Secondary	1,887	39.6	13 ± 1.3
	>Secondary	2,875	60.4	12.9 ± 1.31
Mother's education	≤Secondary	1,838	38.6	12.9 ± 1.3
	>Secondary	2,924	61.4	13 ± 1.31
BMI	Underweight	234	4.9	13 ± 1.29
	Normal	3,807	79.9	12.9 ± 1.42
	Overweight	480	10.1	12.8 ± 1.34
	Obese	241	5.1	12.9 ± 1.27
Healthy food consumption	No	2,019	42.4	13 ± 1.33
	Yes	2,743	57.6	13 ± 1.31
Unhealthy food consumption	No	1,506	31.6	13 ± 1.3
	Yes	3,256	68.4	13 ± 1.3
Smoking	No	3,977	83.5	13 ± 1.35
	Yes	785	16.5	12.9 ± 1.3
Physical activity	L	1,223	25.7	13 ± 1.29
	M	1,321	27.7	13 ± 1.32
	H	2,218	46.6	12.9 ± 1.31
Leisure time activity	L	1,245	26.1	13 ± 1.25
	M	1,281	26.9	13 ± 1.33
	H	2,236	47.0	13 ± 1.31

N, number of study samples; SD, standard deviation; L, low; M, Medium; H, high.
***$p < 0.001$.*

students were asked about the level of their parents' education. Over two-thirds reported that their parents have an education level of secondary school and above, 60.4% for fathers and 61.4% for mothers, respectively. The results of nutritional status assessment indicated that almost 80% were found to have normal BMI levels, while 5.1% exhibited obesity as per the BMI scale. Of the study participants, 50% reported healthy food consumption and 68% reported unhealthy food consumption. Most students reported medium or high levels of physical activity (74.3%), as well as leisure time activities (73.9%), respectively. Furthermore, about 16.5% of students were smoking cigarettes or nargileh.

Table 1 depicts the mean and standard deviation (SD) of hemoglobin values for each demographic variable category. There were statistically significant differences in hemoglobin values per age, gender, and locality (p *0*.000, 0.000, and 0.000, respectively). The mean hemoglobin values were higher in boys than girls (13.1 and 12.9, respectively), and in the older age group (13.07). Moreover, the mean hemoglobin was higher in urban than rural and camp residents (13.1, 12.8, and 12.9), respectively.

Overall Nutritional Profile

The macronutrient and micronutrients intake analysis of 24-h food recall data is reported in **Table 2**. All intakes differed significantly by age and gender ($p < 0.05$). The results indicated that the mean energy intake was higher in boys than girls across both age groups (2494.2, 2570.6) and (2101, 1936.7), respectively. In general, boys had a higher nutrient intake of carbohydrates, proteins, fat, cholesterol, vitamin B12, iron, and folate than girls.

Table 3 reports the percentage distribution of students' vitamin B12, iron, and folate intake according to the RDA as nutritional anemia indicators. All intakes differed significantly by age and gender ($p < 0.05$). Both boys and girls had vitamin B12 intake lower than the RDA across both age groups, with a higher percentage in girls (52.2 and 56.8% for boys, and 60.8 and 74% for girls, respectively). Iron intake was above the RDA for all boys (84.9 and 67.7%), and younger (10–13 years) girls (71.9%), respectively. However, 65.7% of older girls (14–17 years) had iron intake below RDA. Folate intake was below RDA for boys and girls across all age groups, with a lower intake for boys (61.1 and 77.6% for boys; 71.9 and 86.4% for girls), respectively.

K-Means Cluster Analysis of Hemoglobin

Table 4 shows the results of the K-means clustering of the hemoglobin values of the study participants. The clustering technique resulted in two distinct hemoglobin clusters, with statistically different average hemoglobin values of 11.85 and 13.9 g/dl ($p < 0.05$). The clusters were identified as low and high (46.4 and 53.6%) in reference to the WHO criteria for anemia definition, for both genders (1). There were significant differences in the distribution of children across hemoglobin clusters by age, gender, and locality. The high hemoglobin cluster included 915 boys and 1,636 girls. A higher percentage of students from both age groups were classified into the high hemoglobin cluster (52.2 and 57.2%). Furthermore, more students from urban and camps residences were classified into the high hemoglobin cluster (57.5 and 51.8%), while 50.8% of rural residents were in the low hemoglobin cluster.

Nutrition Profile per Hemoglobin Clusters

Table 5 shows the mean energy and main nutrients among the hemoglobin clusters. The mean energy, carbohydrates, vitamin B12, and fat are roughly equal among the low and high hemoglobin clusters (2,207.7, 2,208; 311.4, 311.5; 2.1, 2.2; and 76.3, 76.1). The high hemoglobin cluster had higher mean protein, iron, and folate intake (76.7, 17.8, and 263.6). These differences, however, were not found to be statistically significant across hemoglobin groups.

CRT Analysis of Anemia Related Risk Factors

The CRT classification technique has been used for classifying the hemoglobin clusters by schoolchildren's nutritional intake (vitamin B12, iron, and folate). **Table 6** shows the variables

TABLE 2 | Mean (± SD) nutrient intake per 24-h by age and gender.

	Age (years)			
	10–13		14–17	
	Boys	Girls	Boys	Girls
Energy (kcal)	2,494.2 ± 799**	2,101 ± 743.4	2,570.6 ± 859.4**	1,936.7 ± 731.3
Carbohydrates (g)	347.9 ± 120.1**	297.1 ± 105.9	362.9 ± 128.1**	276.3 ± 110.8
Protein (g)	88.8 ± 36.4**	72 ± 32.5	89.9 ± 38.4**	65.1 ± 30
Fat (g)	86.4 ± 36.8**	72.6 ± 32.9	88 ± 39.8**	66.6 ± 31
Cholesterol (mg)	256.2 ± 224.2**	197.1 ± 190.8	239.2 ± 224.7**	160.9 ± 154.3
VitB12 (mcg)	2.5 ± 2.7*	2 ± 2.3	2.7 ± 3*	1.7 ± 2
Iron (mg)	14.5 ± 6.8**	13.2 ± 6.9	14.1 ± 6.8**	11.7 ± 6.6
Folate (mcg)	298 ± 195.6**	250.9 ± 182	288.4 ± 181.8**	234.5 ± 171.5

SD, standard deviation; kcal, kilocalories; g, grams, mcg; micrograms; Vit, vitamin.
**p < 0.05.*
***p < 0.001.*

TABLE 3 | Nutrient intake levels according to the Recommended Dietary Allowance (RDA) per age and gender.

		Age (years)			
		10–13		14–17	
		Boys	Girls	Boys	Girls
		n (%)			
VitB12 (mcg)	<RDA	599 (52.5)	1,407 (60.8)**	246 (56.8)	647 (74)**
	≥RDA	543 (47.5)	906 (39.2)	187 (43.2)	227 (26)
Iron (mcg)	<RDA	172 (15.1)	556 (24)	140 (32.3)	574 (65.7)
	≥RDA	970 (84.9)**	1,757 (76)	293 (67.7)**	300 (34.3)
Folate (mcg)	<RDA	698 (61.1)	1,662 (71.9)**	336 (77.6)	755 (86.4)**
	≥RDA	444 (38.9)	651(28.1)	97 (22.4)	119 (13.6)

n, number of study sample; SD, standard deviation; mcg, micrograms; Vit, vitamin.
***p < 0.001.*

TABLE 4 | Distribution of study sample by hemoglobin clusters.

		Hemoglobin clusters	
		Low (<12g/dl)	High (≥12g/dl)
		n (row%)	
Total sample		2,211 (46.4)	2,551 (53.6)
Gender	Boys	660 (41.9)	915 (58.1)**
	Girls	1,551 (48.7)**	1,636 (51.3)
Age (years)	10–13	1,650 (47.8)**	1,802 (52.2)
	14–17	559 (42.8)	746 (57.2)**
Locality	Urban	865 (42.5)	1,172 (57.5)**
	Rural	828 (50.2)**	822 (49.8)
	Camp	518 (48.2)	557 (51.8)
		mean ± SD	
Hemoglobin level		11.85 ± 0.8	13.9 ± 0.8**

n, number of study sample; SD, standard deviation.
***p < 0.001.*

included in the CRT classification analysis. **Figures 1**–**3** show the CRT analysis. Each node contains three statistical values (category, %, *n*) in addition to node number, category stands for vitamin B12, iron, and folate intake, *n* stands for low and high hemoglobin clusters in this category, and % is the percentage of students in each cluster.

The CRT classification of hemoglobin in reference to vitamin B12 is shown in **Figure 1**, the classification tree includes a total of 39 nodes with 20 terminal nodes. In each category, the population of hemoglobin clusters differs significantly (all $p < 0.05$). The estimated error of risk in the model is 0.439, and the standard error (SE) is 0.007. The vitamin B12 intake was classified into below and above RDA values, the below RDA group was classified by locality, iron, gender, unhealthy food consumption, age, BMI, and physical activity, while the above RDA group was classified by gender, folate, age, iron, and locality. The below RDA node by locality was classified into two groups, urban group and camp and rural group, and the urban group was classified by iron intake (below and above RDA); the below group was classified by gender and unhealthy food consumption. Girls reported a higher percentage of low hemoglobin levels that were significant with unhealthy food consumption. The camp and rural group was further classified by gender. Boys were classified by age group, whereas girls were classified by BMI and physical activity. Other variables did not reach a significance of 0.05 and were not included in the model, such as father's and mother's education, healthy food consumption, and leisure time activity.

Figure 2 shows the hemoglobin clusters' classification per iron intake. The model includes a total of 39 nodes with 20 terminal nodes. In each category, the population of hemoglobin clusters differs significantly (all $p < 0.05$). The estimated error of risk in the model is 0.441, and the SE is 0.007.

The iron intake was classified into below and above RDA groups; the below group was classified by gender, locality, age

TABLE 5 | Mean (±SD) distribution of nutrient intake by hemoglobin clusters.

Nutrient (unit)	Hemoglobin clusters	
	Low (<12g/dl)	High (≥12g/dl)
Energy (kcal)	2,207.7 ± 784.9	2,208 ± 809.6
Carbohydrates (g)	311.4 ± 114.7	311.5 ± 117.7
Protein (g)	75.9 ± 34.2	76.7 ± 35.5
Fat (g)	76.3 ± 34.2	76.1 ± 35.8
VitB12 (mcg)	2.1 ± 2.4	2.2 ± 2.5
Iron (mg)	17.1 ± 13	17.8 ± 13.5
Folate (mcg)	261.4 ± 188.9	263.6 ± 181.6

SD, standard deviation; kcal, kilocalories; g, grams; mcg, micrograms; Vit, vitamin.

TABLE 6 | Classification tree variables' description.

Variable name	Description	Values
Gender	Gender	Boys, girls
Age	Age	Age (10–17 years)
FAS	Economic status	Low, medium, high
FatherEdu	Father education	≤Secondary, >Secondary
MotherEdu	Mother education	≤Secondary,>Secondary
HealthConsump	Healthy food consumption	Low, moderate, high
UnhealthyConsump	Unhealthy food consumption	Low, moderate, high
BMI	Body mass index	Underweight, normal, overweight, or obese
Smoking	Tobacco risk	Yes, no
PA	Physical activity	Low, moderate, high
Calories	Energy in kilocalories	Mean
Carbs_g	Carbohydrates in grams	Mean
Protein_g	Protein in grams	Mean
Fatg	Fat in grams	Mean
Vitb12rda	Vitamin B12 intake per recommended dietary allowance (RDA)	Below RDA, above RDA
FolatemcgRDA	Folate intake per recommended dietary allowance (RDA)	Below RDA, above RDA
Ironmgrda	Iron intake per recommended dietary allowance (RDA)	Below RDA, above RDA

group, unhealthy food consumption, BMI, physical activity, and family income. The above group was classified by locality, gender, folate intake, age group, physical activity, BMI, and mother education. The below RDA group was further classified by gender; the boys' group were associated with age, while the girls' group were further classified by locality, in which the urban residents group was associated with unhealthy food consumption, whereas those who had high unhealthy food consumption were classified by their family income. However, camp and rural residents were classified by their BMI level, and those who are overweight or obese were further classified by their physical activity. Those who have normal BMI or are underweight were classified by family income.

On the other hand, the above RDA group was classified first by locality (camp and rural residents and urban residents). Among the camp and rural residents group, the hemoglobin level was affected by folate intake. In the left branch, those who had low folate intake were classified by gender and then by age. In students who had high folate intake, physical activity was a significant factor, split into low, medium, and high levels, which were classified by the BMI level. In the latter group, those in the urban residence group were classified by gender, and boys were classified by age, and younger students (10–13-year-old) were further classified by the education level of their mothers, respectively.

Figure 3 demonstrates the hemoglobin clusters' classification per folate intake. The model includes a total of 35 nodes with 18 terminal nodes. In each category, the population of hemoglobin clusters differs significantly (all $p < 0.05$). The estimated error of risk in the model is 0.441, and the SE is 0.007.

The folate intake was classified into below and above RDA values, the below RDA group was classified by locality, age group, physical activity, family income, and mother's education. The above RDA group was classified by locality, gender, age group, vitamin B12 intake, iron intake, and mother's education. Both folate intakes above and below RDA values were first classified by locality. On the left branch of the tree, the camp and rural residents were classified per age. Older students (14–17 years) were further classified by gender; boys were classified by their residence in camp and rural areas. Younger students (10–13 years) were classified by physical activity; those who had either low or high levels of physical activity were further classified by their vitamin B12 intake. Residents of the urban were first categorized by gender. Boys were classified by their age, where the education of a mother was a significant factor in younger boys. On the other hand, girls were first classified per their vitamin B12 intake; those who had vitamin B12 intake below RDA were further classified according to their iron intake. On the right branch of the tree, those who had higher folate intake and lived in camps or rural areas were classified based on their physical activity levels. Those who had either low or medium levels were affected by their family income. Furthermore, those with low family income were classified by the education level of their mothers. Those who lived in urban residences were only classified by their age.

DISCUSSION

Anemia remains a major health concern among schoolchildren (6). Almost half of the sample were found to have mean hemoglobin levels below the WHO cutoff value for anemia (1). The results of the present study indicate that there is an interlinked association between nutritional intake and sociodemographic factors in the development of the disease, which is consistent with other studies (11, 18, 41). The sole deficiency of certain nutrients is rarely found as a single nutritional anemia associated factor. The CRT analysis partitioned the sample's hemoglobin clustered groups into homogeneous subgroups, taking vitamin B12, iron, and folate

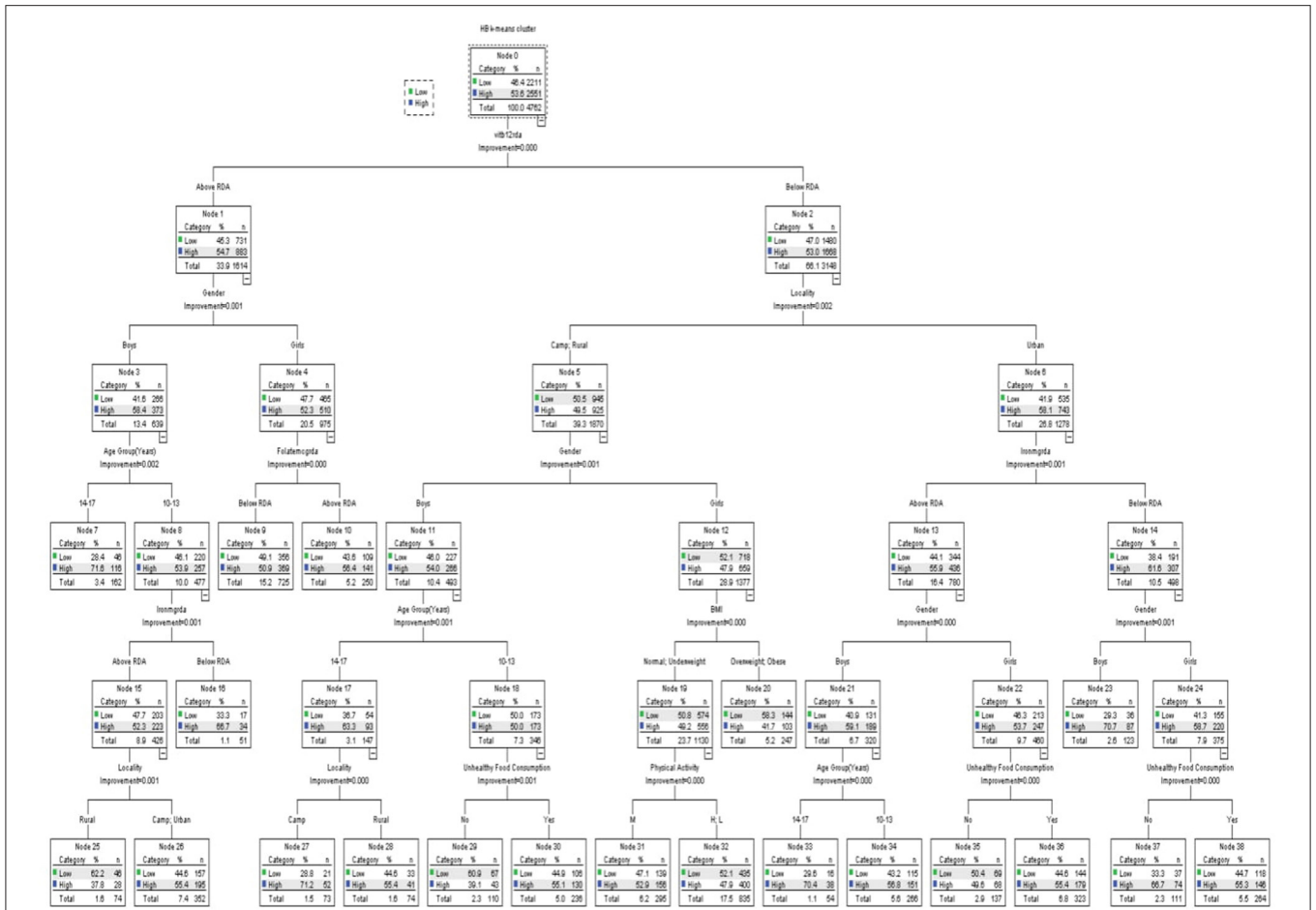


FIGURE 1 | Classification and regression decision tree (CRT) analysis of anemia-associated risk factors as per vitamin B12 intake.

intakes as key splitting variables. The results indicate that two-thirds of hemoglobin clusters were found to have a vitamin B12 intake below the RDA level and were significantly associated with the place of residence factor. This result is consistent with studies that associate living place and anemia among children (26, 41, 53). Interestingly, our results indicate that weight and physical activity are significant anemia-related factors in girls living in camps and rural areas. Whereas, in urban areas, iron intake and unhealthy food consumption were found to be significant anemia-related factors, which could be explained by the differences in lifestyle and eating habits between these residences. Furthermore, girls in camps and rural areas spend more indoor time than those in urban areas, which might lead to limited access to physical activities and higher obesity rates furthermore, this finding is consistent with other studies which indicated that obesity is associated with vitamin B12 deficiency and iron deficiency, therefore possible nutritional anemia (54–57). The coexistence of these nutrients' deficiencies has been observed in other studies. Ahmed et al. have demonstrated the prevalence of coexisting vitamin B12 and iron deficiencies among adolescent girls, albeit in rural rather than urban areas as found in our study (58). In boys, however, we have observed that the anemia differs significantly across the urban and non-urban areas by age, where younger boys have the higher rates of anemia. This finding is inconsistent across studies. Research carried out in Ethiopia, for example, has found that anemia levels are lower in 10–13-year-old boys than older adolescents (59); however, other studies have demonstrated that anemia is higher among early adolescent years (10–13 years) compared with the late adolescent period (60). Another study in Nepal concluded that the anemia level in older boys and girls (15–19 years) is higher than the anemia level in younger children (61).

Even those who have an adequate vitamin B12 intake can still be affected by other variables. It seems that, in this group, iron intake is a significant factor in young boys, while the hemoglobin levels of girls might be more affected by folate intake. This emphasizes the need for a holistic approach to nutrient intake enhancement when developing policies to prevent nutritional anemia.

On the other hand, when we classified the anemic status with iron intake, it seems that lower iron intake is higher in girls. Furthermore, anemia in girls residing in urban areas is associated with food consumption and family income, whereas in camps and rural areas, it seems that obesity and lower physical activity correspond with the higher rates of anemia. In boys, age again is a major factor whatever their iron intake may be. Of note,

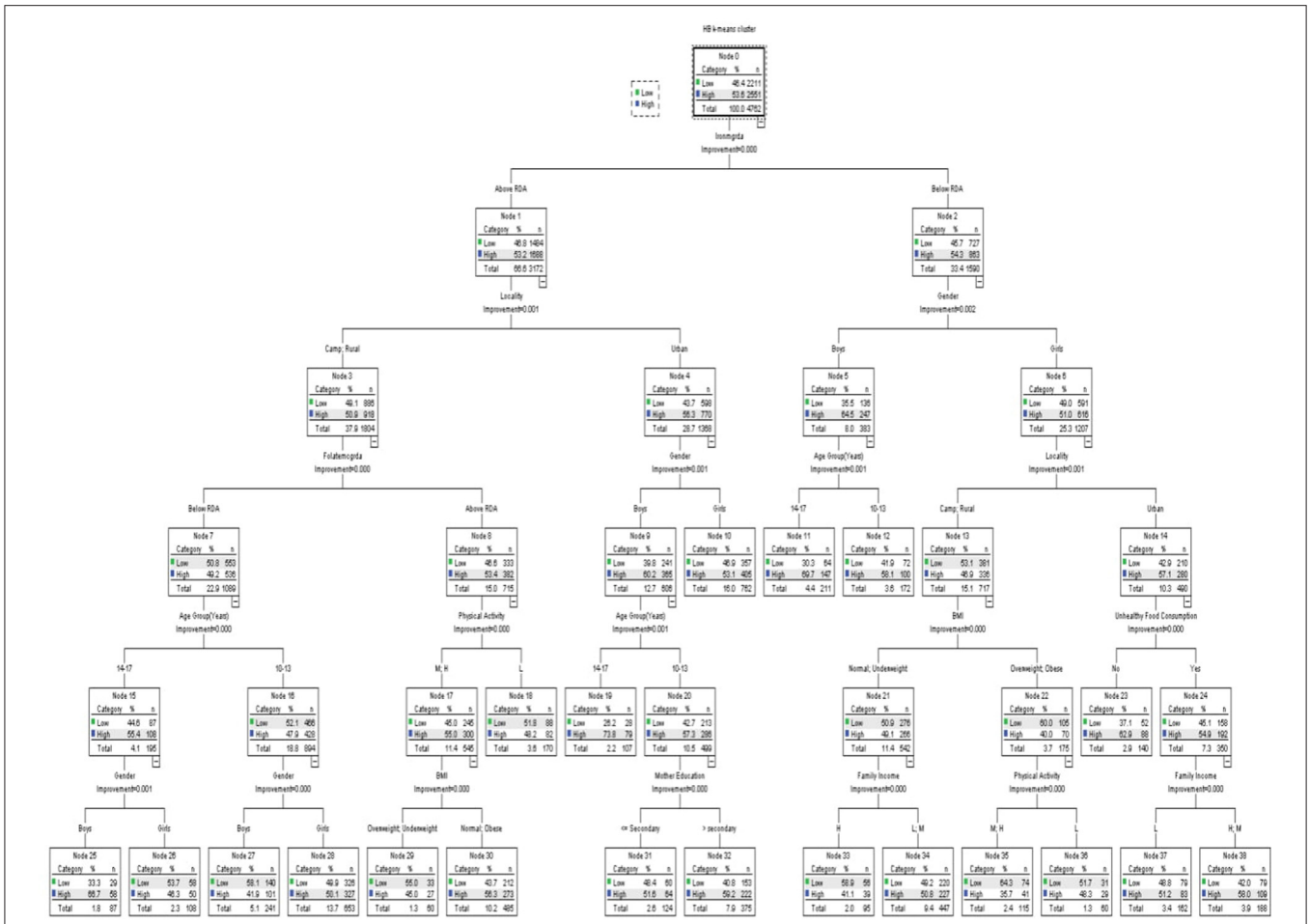


FIGURE 2 | Classification and regression decision tree (CRT) analysis of anemia-associated risk factors as per iron intake.

folate intake seems to affect both boys and girls in non-urban areas with adequate iron intake; however, it is more significant in younger boys and older girls, respectively. This result coincides with the literature, which has found that average folate intake in girls differs by age (15) and between boys and girls, especially in 13–15-year-old children (62).

When we classified hemoglobin clusters by folate intake, there were differences by locality across all levels of folate intake. Younger children living in camps and rural areas who had a lower intake of folate are affected by lower physical activity and lower vitamin B12 intake. However, the hemoglobin levels of older children in the same conditions are affected by age and gender, where anemia is higher among girls. This may indicate that focusing on the folate levels of girls in camps and rural areas might significantly affect their anemic status. On examining urbanite children with folate intake lower than the RDA, vitamin B12 and iron intake are important factors, however, young boys are particularly affected by the education of their mothers. Unexpectedly, in this group,the hemoglobin level is higher in boys whose mothers have a lower education. This could be explained by the fact that mothers with lower education are most likely housewives and spend more time with their children and family, which might contribute to the better care of children's health and nutrition. This finding needs further investigation, as the educational status of mothers is found to be positively correlated with the lower odds of anemia across children in numerous studies (26, 63, 64).

The K-means and CRT clustering and classification techniques showed a different pattern of nutritional deficiencies in reference to the hemoglobin results of schoolchildren. The classification by vitamin B12 is associated with locality, iron, gender, unhealthy food consumption, age, BMI, and physical activity. The classification by iron intake is associated with gender, locality, age group, unhealthy food consumption, BMI, physical activity, and family income. The classification by folate intake is associated with locality, age, gender, physical activity, vitamin B12, locality, mother's education, and iron intake.

The findings of this study have considerable implications for researchers and policymakers to reduce the prevalence of nutritional anemia. This study supports the implementation of data mining and machine learning techniques in developing AI solutions for the development of patient-specific anemia prevention and intervention programs. As indicated, there are several sociodemographic gaps that have to be taken

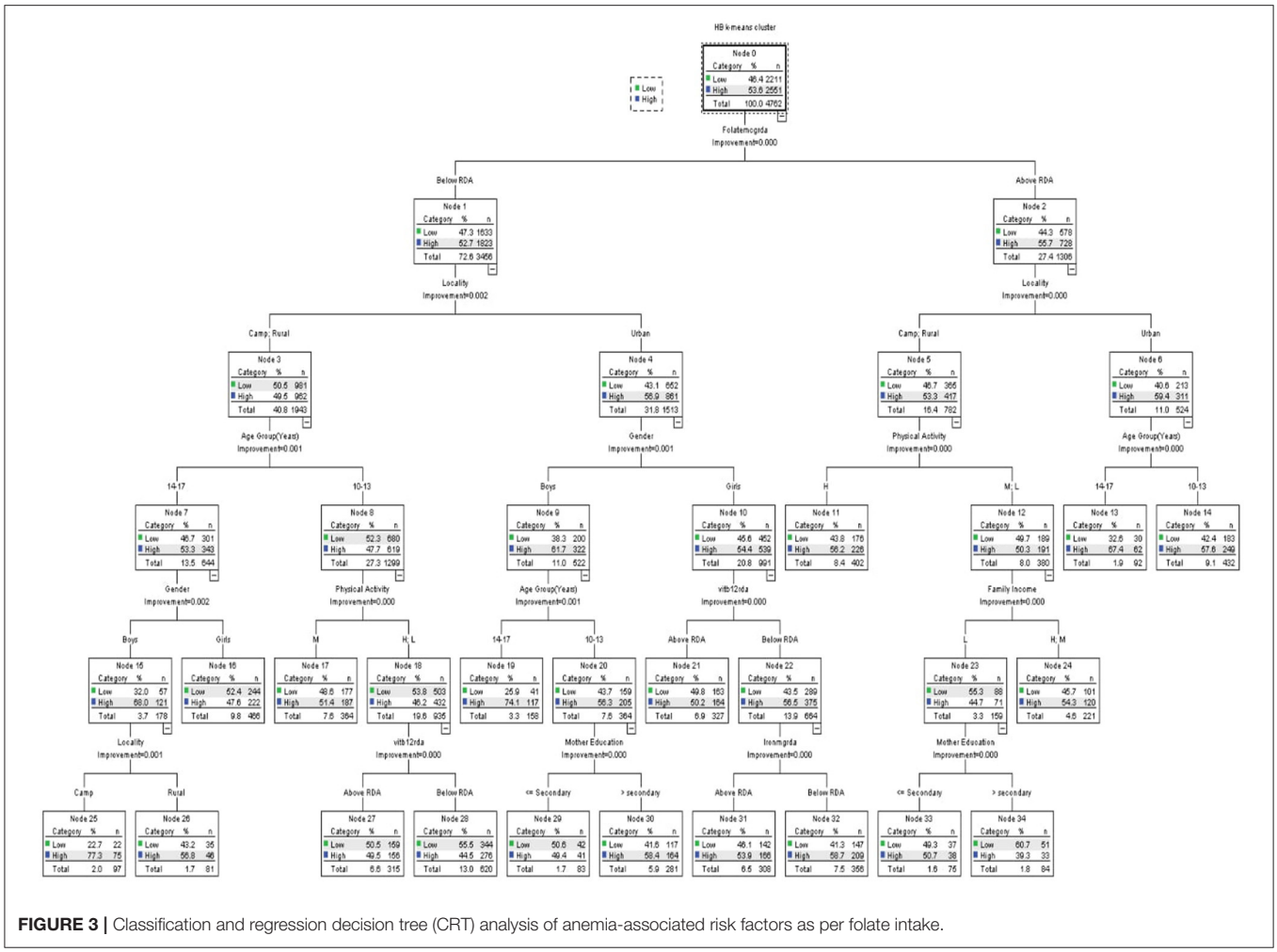


FIGURE 3 | Classification and regression decision tree (CRT) analysis of anemia-associated risk factors as per folate intake.

into consideration when designing interventional strategies to improve nutritional deficiencies. Overall, it seems that it is rather important to address the vitamin B12, iron, and folate intake in girls, while accounting for age, locality, food consumption patterns, and physical activity levels, and focus on iron and folate intake in young boys with consideration to the place of residence. However, there are some limitations to our study, namely, the use of a single 24-h recall interview, and the nutrient was calculated from food intake rather than blood biomarkers. Furthermore, the study sample only included the schoolchildren age group and did not include the younger age groups (<10 years). Hopefully, the findings of this study might aid policymakers in signifying the population groups requiring priority attention, what strategy to choose, and where to allocate public resources, to customize intervention plans based on the most significant factors involved in nutritional anemia occurrence.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Ministry of Education and Al-Quds University Institutional Review Board (IRB). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

RQ and DA: conceptualization, methodology, data curation, formal analysis, validation, writing—original draft preparation, and review and editing. All authors contributed to the article and approved the submitted version.

FUNDING

The work included in this study is part of the wider project Determinants of Cognitive Development in Deprived Environments: evidence from the West Bank funded by the German Research Foundation (DFG) under Grant Number JU 2769/2.

ACKNOWLEDGMENTS

We wish to thank the Ministry of Education and Al-Quds University, Palestine for its permission to perform the study, all children and their parents for their patience, as well as all field workers, Ziad Abdeen and Sameh Al Halaq for their contributions, and we are also grateful to Mohammad Remawi and Suzan Tutah for their support in data collection.

REFERENCES

1. de Benoist Bruno, World Health Organization, Centers for Disease Control and Prevention (U.S.). *Worldwide Prevalence of Anaemia 1993-2005 of : WHO Global Database of Anaemia*. Geneva: World Health Organization (2008). p. 40.
2. Llanos MJ. Significance of anaemia in the different stages of life/Significado de la anemia en las diferentes etapas de la Vida. *Enfermería Glob.* (2016) 15:419–30. Available online at: https://scielo.isciii.es/scielo.php?pid=S1695-61412016000300015&script=sci_arttext&tlng=en
3. Kassebaum NJ, Jasrasaria R, Naghavi M, Wulf SK, Johns N, Lozano R, et al. A systematic analysis of global anemia burden from 1990 to 2010. *Blood.* (1990) 123:615–24. doi: 10.1182/blood-2013-06-508325
4. Yadav D, Chandra J. Iron deficiency: beyond anemia. *Indian J Pediatr*. (2011). 78:65–72. doi: 10.1007/s12098-010-0129-7
5. Mattiello V, Schmugge M, Hengartner H. von der Weid N, Renella R. Diagnosis and management of iron deficiency in children with or without anemia: consensus recommendations of the SPOG pediatric hematology working group. *Eur J Pediatr*. (2020) 179:527–45. doi: 10.1007/s00431-020-03597-5
6. Allali S, Brousse V, Sacri AS, Chalumeau M, de Montalembert M. Anemia in children: prevalence, causes, diagnostic work-up, and long-term consequences. *Expert Rev Hematol.* (2017) 10:1023–8. doi: 10.1080/17474086.2017.1354696
7. Krämer M, Kumar S, Vollmer S. *Anemia, Diet, and Cognitive Development: Impact of Health Information on Diet Quality and Child Nutrition in Rural India*. (2021). www.iza.org (accessed January 04, 2022).
8. Janus J, Moerschel SK. Evaluation of anemia in children. *Am Fam Physician.* (2010) 81:1462–71.
9. Stiller CK, Golembiewski SKE, Golembiewski M, Mondal S, Biesalski HK, Scherbaum V. Prevalence of undernutrition and anemia among santal adivasi children, Birbhum District, West Bengal, India. *Int J Environ Res Public Health.* (2020) 17:342. doi: 10.3390/ijerph17010342
10. Jinghuan J, Hu Y, Li M, Chen J, Mao D, Li W, et al. Prevalence of anemia in chinese children and adolescents and its associated factors. *Int J Environ Res Public Health.* (2019) 16:1416. doi: 10.3390/ijerph16081416
11. André HP, Sperandio N, Siqueira RL de, Franceschini S. do CC, Priore SE. Food and nutrition insecurity indicators associated with iron deficiency anemia in Brazilian children: A systematic review. *Cien Saude Colet.* (2018) 23:1159–67. doi: 10.1590/1413-81232018234.16012016
12. Gupta PM, Perrine CG, Mei Z, Scanlon KS. Iron, anemia, and Iron deficiency anemia among young children in the United States. *Nutrients.* (2016) 8:330. doi: 10.3390/nu8060330
13. Cappellini MD, Musallam KM, Taher AT. Iron deficiency anaemia revisited. *J Intern Med.* (2020) 287:153–70. doi: 10.1111/joim.13004
14. Visser M, van Zyl T, Hanekom SM, Baumgartner J, van der Hoeven M, Taljaard-Krugell C, et al. Nutrient patterns and their relation to anemia and iron status in 5- to 12-y-old children in South Africa. *Nutrition.* (2019) 62:194–200. doi: 10.1016/j.nut.2019.01.016
15. Bhardwaj A, Kumar D, Raina SK, Bansal P, Bhushan S, Chander V. Rapid assessment for coexistence of vitamin B12 and iron deficiency anemia among adolescent males and females in northern himalayan state of India. *Anemia.* (2013) 2013:959605. doi: 10.1155/2013/959605
16. Sharourou ASA, Hassan MA, Teclebrhan MB. Anemia : Its Prevalence, Causes and Management. *Egypt J Hosp Med.* (2018) 70:1877–9. doi: 10.12816/0044770
17. Stelle I, Kalea AZ, Pereira DIA. *Symposium 1: Competition and Bioavailability of Dietary Components: Iron Deficiency Anaemia: Experiences and Challenges. Proceedings of the Nutrition Society*. Cambridge: Cambridge University Press (2019). p. 19–26.
18. Hussein NA, Ouda MM. Life style risk factors of Iron deficiency anemia among adolescents' girls. *IJND.* (2018) 8:18–28. doi: 10.15520/ijnd.v8i10.2326
19. Stoltzfus RJ. Iron deficiency: global prevalence and consequences. *Food Nutr Bull.* (2003) 24:S99–S103. doi: 10.1177/15648265030244S106
20. Lioret S, Touvier M, Lafay L, Volatier J-L, Maire B. Dietary and physical activity patterns in french children are related to overweight and socioeconomic status. *J Nutr.* (2018) 138:101–7. doi: 10.1093/jn/138.1.101
21. Wirfält AKE, Jeffery RW. Using cluster analysis to examine dietary patterns: Nutrient intakes, gender, and weight status differ across food pattern clusters. *J Am Diet Assoc.* (1997) 97:272–9. doi: 10.1016/S0002-8223(97)00071-0
22. Hosseini SH, Papanikolaou Y, Islam N, Rashmi P, Shamloo A, Vatanparast H. Consumption patterns of grain-based foods among adults in Canada: evidence from Canadian community health survey-nutrition 2015. *Nutrients.* (2019) 11:784. doi: 10.3390/nu11040784
23. Niermann CYN, Spengler S, Gubbels JS. Physical activity, screen time, and dietary intake in families: a cluster-analysis with mother-father-child triads. *Front Public Health.* (2018) 6:1–12. doi: 10.3389/fpubh.2018.00276
24. Gubbels JS, van Assema P, Kremers SPJ. Physical activity, sedentary behavior, and dietary patterns among children. *Curr Nutr Rep.* (2013) 2:105–12. doi: 10.1007/s13668-013-0042-6
25. Pérez-Rodrigo C, Gil Á, González-Gross M, Ortega RM, Serra-Majem L, Varela-Moreiras G, et al. Clustering of dietary patterns, lifestyles, and overweight among Spanish children and adolescents in the ANIBES study. *Nutrients.* (2015) 8:1–17. doi: 10.3390/nu8010011
26. Goswmai S, Das KK. Socio-economic and demographic determinants of childhood anemia. *J Pediatr.* (2015) 91:471–7. doi: 10.1016/j.jped.2014.09.009
27. Kumar A, Goyal A, Verma N, Mahesh A. Study of anemia among adolescent school girls and young adults. *Int J Adv Med.* (2018) 5:877. doi: 10.18203/2349-3933.ijam20182753
28. Asmare B, Taddele M, Berihun S, Wagnew F. Nutritional status and correlation with academic performance among primary school children, northwest Ethiopia. *BMC Res Notes.* (2018) 11:1–6. doi: 10.1186/s13104-018-3909-1
29. Qasrawi R, VicunaPolo S, Al-Halawa DA, Hallaq S, Abdeen Z. Predicting school children academic performance using machine learning techniques. *Adv Sci Technol Eng Syst J.* (2021) 6:8–15. doi: 10.25046/aj060502
30. Qasrawi R, Abdeen Z, Taweel H, Younis MA, Al-Halawa DA. Data mining techniques in identifying factors associated with schoolchildren science and arts academic achievement. *Proceedings - 2020 International Conference on Promising Electronic Technologies, ICPET 2020*. Piscataway, NJ: Institute of Electrical and Electronics Engineers Inc. (2020). p. 78–83.
31. Ye F, Chen ZH, Chen J, Liu F, Zhang Y, Fan QY, et al. Chi-squared automatic interaction detection decision tree analysis of risk factors for infant anemia in Beijing, China. *Chin Med J.* (2016) 129:1193–9. doi: 10.4103/0366-6999.181955
32. Meena K, Tayal DK, Gupta V, Fatima A. Using classification techniques for statistical analysis of Anemia. *Artif Intell Med.* (2019) 94:138–52. doi: 10.1016/j.artmed.2019.02.005
33. Kilicarslan S, Celik M, Sahin S. Hybrid models based on genetic algorithm and deep learning algorithms for nutritional Anemia disease classification. *Biomed Signal Process Control.* (2021) 63:102231. doi: 10.1016/j.bspc.2020.102231
34. Qasrawi R. Cluster analysis for food group consumption patterns in a national sample of Palestinian schoolchildren: evidence from HBSC Survey 2013-2014. *Al-Quds J Acad Res.* (2021) 01:33–52. doi: 10.47874/2021p7
35. Khan JR, Chowdhury S, Islam H, Raheem E. Machine learning algorithms to predict the childhood anemia in Bangladesh. *J Data Sci.* (2021) 17:195–218. doi: 10.6339/JDS.201901_17(1).0009
36. Gunčar G, Kukar M, Notar M, Brvar M, Cernelč P, Notar M. Application of machine learning for hematological diagnosis. *Sci Rep.* (2018) 8:411. doi: 10.1038/s41598-017-18564-8

37. Chaves LO, Domingos ALG, Fernanades DL, Cerqueira FB, Siqueira-batista R, Bressan J. Applicability of machine learning techniques in food intake assessment: A systematic review. *Crit Rev Food Sci Nutr.* (2021) 1–18. doi: 10.1080/10408398.2021.1956425. [Epub ahead of print].
38. Sow B, Mukhtar H, Ahmad HF, Suguri H. Assessing the relative importance of social determinants of health in malaria and anemia classification based on machine learning techniques. *Inform Health Soc Care.* (2020) 45:229–41. doi: 10.1080/17538157.2019.1582056
39. Roberts C, Currie C, Samdal O, Currie D, Smith R, Maes L. Measuring the health and health behaviours of adolescents through cross-national survey research: recent developments in the health behaviour in school-aged children (HBSC) study. *J Public Health.* (2007) 15:179–86. doi: 10.1007/s10389-007-0100-x
40. Qasrawi R. Links between nutrition, life style habits and academic acheivment in Palestinian schoolchildren: A cross-sectional study. *Al-Quds J Acad Res.* (2021) 01:90–102. doi: 10.47874/2021p6
41. Mohammed SH, Habtewold TD, Muhammad F, Esmaillzadeh A. The contribution of dietary and non-dietary factors to socioeconomic inequality in childhood anemia in Ethiopia: a regression-based decomposition analysis. *BMC Res Notes.* (2019) 12:646. doi: 10.1186/s13104-019-4691-4
42. Khanmohammadi S, Adibeig N, Shanehbandy S. An improved overlapping k-means clustering method for medical applications. *Expert Syst Appl.* (2017) 67:12–8. doi: 10.1016/j.eswa.2016.09.025
43. Foster E, Bradley J. Methodological considerations and future insights for 24-hour dietary recall assessment in children. *Nutrition Research.* (2018) 51:1–11. doi: 10.1016/j.nutres.2017.11.001
44. Bailey RL. Overview of dietary assessment methods for measuring intakes of foods, beverages, and dietary supplements in research studies. *Curr Opin Biotechnol.* (2021) 70:91–6. doi: 10.1016/j.copbio.2021.02.007
45. Gibson RS, Ferguson EL. An Interactive 24-Hour Recall for Assessing the Adequacy of Iron and Zinc Intakes in Developing Countries. International Food Policy Research Institute (IFPRI); International Center for Tropical Agriculture (CIAT) (2008).
46. Frank GC, Nicklas TA, Webber LS, Major C, Miller JF, Berenson GS, et al. Food frequency questionnaire for adolescents: defining eating patterns. *J Am Diet Assoc.* (1992) 92:313–8. doi: 10.1016/S0002-8223(21)00617-9
47. Abdeen Z, Qasrawi R. *Palestinian Food: The First Palestinian National Nutrition Survey (FPNNS2000).* Jerusalem: VDM Publishng House (2010).
48. Lee RD. Nutribase nutrition manager. *J Acad Nutr Diet.* (1997) 97:219.
49. of Medicine I. *Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids*. Washington, DC: The National Academies Press (2005).
50. World Health Organization, Regional Office for the Eastern Mediterranean. *Healthy Diet*. Cairo: World Health Organization (2019).
51. World Health Organization. *World Health Organization Reference Curves*. (2015). Available online at: https://www.who.int/tools/growth-reference-data-for-5to19-years/indicators/bmi-for-age (accessed February 22, 2022).
52. Morgan J. *Classification and Regression Tree Analysis*. (2014). Available online at: https://www.bu.edu/sph/files/2014/05/MorganCART.pdf (accessed December 17, 2021).
53. Policy H, Children FOR. *Growing Up Unequal : Gender and Socioeconomic Differences in Young People's Health and Well-Being*. (2014). Available online at: https://apps.who.int/iris/handle/10665/326320 (accessed December 17, 2021).
54. Zhao L, Zhang X, Shen Y, Fang X, Wang Y, Wang F. Obesity and iron deficiency: a quantitative meta-analysis. *Obesity Reviews.* (2015) 16:1081–93. doi: 10.1111/obr.12323
55. Ho M, Halim JH, Gow ML, El-Haddad N, Baur LA, Cowell CT, et al. Vitamin B12 in obese adolescents with clinical features of insulin resistance. *Nutrients.* (2014) 6:5611–8. doi: 10.3390/nu6125611
56. Pinhas-Hamiel O, Doron-Panush N, Reichman B. Obese children and adolescents a risk group for low vitamin B 12 concentration. *Arch Pediatr Adolesc Med.* (2006) 160:933–6. doi: 10.1001/archpedi.160.9.933
57. Alshwaiyat N, Ahmad A, Wan Hassan WMR, Al-jamal H. Association between obesity and iron deficiency (Review). *Exp Ther Med.* (2021) 22:1268. doi: 10.3892/etm.2021.10703
58. Ahmed F, Khan MR, Banu CP, Qazi MR, Akhtaruzzaman M. The coexistence of other micronutrient deficiencies in anaemic adolescent schoolgirls in rural Bangladesh. *Eur J Clin Nutr.* (2008) 62:365–72. doi: 10.1038/sj.ejcn.1602697
59. Zeleke MB, Shaka MF, Anbesse AT, Tesfaye SH. Anemia and its determinants among male and female adolescents in southern ethiopia: a comparative cross-sectional study. *Anemia.* (2020) 2020:3906129. doi: 10.1155/2020/3906129
60. Shaka MF, Wondimagegne YA. Anemia, a moderate public health concern among adolescents in South Ethiopia. *PLoS ONE.* (2018) 13:e0191467. doi: 10.1371/journal.pone.0191467
61. Chalise B, Aryal KK, Mehta RK, Dhimal M, Sapkota F, Mehata S, et al. Prevalence and correlates of anemia among adolescents in Nepal: findings from a nationally representative cross-sectional survey. *PLoS ONE.* (2018) 13:e0208878. doi: 10.1371/journal.pone.0208878
62. Jani R, Salian N, Udipi S, Lohia N, Haas J, Boy E. Folate status and intake of tribal Indian adolescents aged 10 to 17 year. *Food Nutr Bull.* (2015) 36:14–23. doi: 10.1177/156482651503600102
63. Choi HJ, Lee HJ, Jang HB, Park JY, Kang JH, Park KH, et al. Effects of maternal education on diet, anemia, and iron deficiency in Korean school-aged children. *BMC Public Health.* (2011) 11:870. doi: 10.1186/1471-2458-11-870
64. Al-Shookri A, Al-Shukaily L, Hassan F, Al-Sheraji S, Al-Tobi S. Effect of mothers nutritional knowledge and attitudes on Omani children's dietary intake. *Oman Med J.* (2011) 26:253–7. doi: 10.5001/omj.2011.61

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

frontiers | Frontiers in Nutrition

ORIGINAL RESEARCH
published: 18 May 2022
doi: 10.3389/fnut.2022.902103

Parents' Modeling During the COVID-19 Pandemic: Influences on Family Members' Diet Quality and Satisfaction With-Food-Related Life in Dual-Earner Parents With Adolescent Children

Berta Schnettler[1,2,3,4], Edgardo Miranda-Zapata[5,6], Ligia Orellana[3], Mahia Saracostti[7], Héctor Poblete[3], Germán Lobos[8], Cristian Adasme-Berríos[9], María Lapo[4], Katherine Beroiza[3] and Klaus G. Grunert[10,11]*

[1] Facultad de Ciencias Agropecuarias y Forestales, Universidad de La Frontera, Temuco, Chile, [2] Scientific and Technological Bioresource Nucleus (BIOREN-UFRO), Universidad de La Frontera, Temuco, Chile, [3] Centro de Excelencia en Psicología Económica y del Consumo, Núcleo de Ciencias Sociales, Universidad de La Frontera, Temuco, Chile, [4] Universidad Católica de Santiago de Guayaquil, Guayaquil, Ecuador, [5] Facultad de Educación, Centro de Investigación Escolar y Desarrollo (Cied-UCT), Universidad Católica de Temuco, Temuco, Chile, [6] Universidad Autónoma de Chile, Temuco, Chile, [7] Escuela de Trabajo Social, Universidad de Valparaíso, Valparaíso, Chile, [8] Facultad de Economía y Negocios, Universidad de Talca, Talca, Chile, [9] Departamento de Economía y Administración, Universidad Católica del Maule, Talca, Chile, [10] MAPP Centre, Aarhus University, Aarhus, Denmark, [11] University of Vaasa, Vaasa, Finland

Reciprocal family influences in the food domain have been little explored, particularly during the COVID-19 pandemic. To fill in this gap, this study explored actor and partner effects between parents' food modeling and parents' and their adolescent children's diet quality and satisfaction with food-related life (SWFoL); and the mediating role of diet quality between modeling and SWFoL. This study used a cross-sectional design. A sample of 430 different-sex dual-earner parents and one adolescent child were recruited in Rancagua, Chile, between March and June 2020. Parents answered the modeling dimension of the Comprehensive Feeding Practices Questionnaire. Parents and adolescents answered the Adapted Healthy Eating Index (AHEI) and the SWFoL Scale. Analyses were conducted using the Actor-Partner Interdependence Model and structural equation modeling. Results showed that one parent's modeling enhanced diet quality for themselves, their partner, and the adolescents. Parents' modeling was associated with their own SWFoL, directly and *via* their own diet quality. There were positive associations between mothers' modeling and adolescents' SWFoL; between mothers' diet quality and fathers' SWFoL; and between mothers' modeling and fathers' SWFoL *via* the fathers' diet quality. Parents' modeling can improve the three family members' diet quality, while mothers' modeling and diet quality showed to improve fathers' and adolescents' SWFoL.

Keywords: food parenting practices, modeling, diet quality, satisfaction with food-related life, dual-earner couples, adolescents

OPEN ACCESS

Edited by:
Maha Hoteit,
Lebanese University, Lebanon

Reviewed by:
Reem Hoteit,
American University of Beirut, Lebanon
Jana Jabbour,
Modern University for Business and Science, Lebanon

****Correspondence:***
Berta Schnettler
berta.schnettler@ufrontera.cl

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *22 March 2022*
Accepted: *02 May 2022*
Published: *18 May 2022*

Citation:
Schnettler B, Miranda-Zapata E, Orellana L, Saracostti M, Poblete H, Lobos G, Adasme-Berríos C, Lapo M, Beroiza K and Grunert KG (2022) Parents' Modeling During the COVID-19 Pandemic: Influences on Family Members' Diet Quality and Satisfaction With-Food-Related Life in Dual-Earner Parents With Adolescent Children. Front. Nutr. 9:902103. doi: 10.3389/fnut.2022.902103

INTRODUCTION

Parents use an array of techniques or behaviors to influence what, when or how much their children eat. These techniques are known as food parenting practices (FPP) and they can be used by parents to promote healthy eating and prevent overweight and obesity in their children (1, 2). Parents remain responsible for feeding their children during adolescence (3, 4), but in this life stage adolescents seek autonomy in all life spheres, including the decisions regarding what and when to eat (5, 6). Adolescents change their dietary behaviors, engaging more with peers and eating outside the home (7, 8), and thus they decrease their involvement in family meals and possibly increase their consumption of convenience foods. These changes in adolescents' eating habits have been found to contribute to a decline in diet quality and to an increased weight gain risk for adolescents (7, 9).

The COVID-19 pandemic has brought on changes in how parents apply FPP. Lockdown measures to reduce the risk of contagion enforced changes in behavioral patterns, including diet and eating habits (10, 11). Studies show that families get together more frequently for meals during the pandemic (12–15), which has entailed changes in how parents of young children exert FPP (11, 14). Nevertheless, there are scarce studies into FPP during the pandemic and their use on adolescents (11). Therefore, this study focuses on the effects of parents' modeling of healthy food choices on their adolescent children. Modeling is one of the multiple FPP in which parents can engage in Jennings et al. (16), and it plays a vital role in shaping children's food preferences (3, 5, 17). Using modeling to promote healthy eating involves an active demonstration from parents to children (6, 18). Parents thus become a point of reference on eating behaviors and can influence children's long-term food choices and eating habits (19). The literature has reported positive relationships between parents' modeling of healthy food choices and diet outcomes in adolescents (5, 9, 10, 20–24). These studies, however, have focused on samples from developed countries (23, 25, 26), and on mother-child dyads (17, 23, 25–29). Father-child dyads have been less explored in terms of FPP. Evidence to date suggests that fathers are becoming more involved in childcare tasks such as feeding, partly due to the increase of dual-earner families (15, 19, 28, 30, 31), and more markedly due to changes in work-home dynamics in response to the COVID-19 pandemic (13, 32).

Another gap in knowledge relates to the influence of parents' FPP and family dietary behaviors. FPP may reflect parents' eating habits (25, 29, 33–35), but it is not clear whether and how parents' dietary behaviors are linked to the FPP exerted on adolescents (29). Most of the literature has also assumed a unidirectional relationship between FPP and children's dietary behaviors, omitting the exploration of reciprocal influences between parents and children (25, 35–37). Addressing the reciprocity between parents and children's eating behaviors can help identify children's eating and weight development processes (25). This knowledge can inform overweight prevention and intervention programs, particularly in contexts such as Chile, where 60% of children, and three out of four adults, are overweight or obese (38).

In samples of adolescents and adults, FPP aimed to implement healthy eating habits have been linked to higher levels of emotional wellbeing and satisfaction in the food domain (4, 39–43). The latter construct, known as satisfaction with food-related life [SWFoL, (44)], defines a person's overall cognitive assessment of their food and eating habits, covering from meal planning, shopping and meal preparation, consumption, and disposal. To the best of the authors' knowledge, SWFoL has not been explored in its relationships with parental modeling and diet quality at a family level. This exploration becomes relevant, particularly in dual-earner parents, because high job demands have been associated with lower diet quality, not only for the worker but also for their families, given that personal resources such as time and energy are invested in workplace responsibilities instead of on food-related tasks [e.g., (20, 45, 46)].

Against this background, this study examined the influence of both parents' modeling on their own diet quality and SWFoL, and on their adolescent children's diet quality and SWFoL. This study was conducted in different-sex dual-earner parents with adolescent children in a Latin American country during the COVID-19 pandemic. Data was analyzed using the Actor-Partner Interdependence Model [APIM, (47)] (**Figure 1**). Therefore, the aims of this study were to explore the actor and partner effects between the parents' modeling and mothers', fathers', and adolescents' diet quality and SWFoL; and to explore whether diet quality have a mediating role between both parents' modeling and the three family members' SWFoL.

Relationships Between Parental Modeling, Diet Quality and Satisfaction With Food-Related Life

Studies regarding the impact of parental modeling on adolescent children's outcomes are scarce (23), but previous findings have shown links between modeling of healthy food choices and children's healthy dietary intake (16, 23). Moreover, it has been reported that parents' food intake strongly predicts that of their children (26). For instance, studies in the European Union and the United States have shown that parental modeling of healthy food choices is positively associated with dietary outcomes in adolescents such as healthier diet (24, 48), greater intake of fruits and vegetables (8, 21, 27, 48, 49), and fewer consumption of sugar-sweetened beverages and palatable snack foods (5, 22, 27, 49).

Nevertheless, FPP may not only be related to children's eating habits, but to the eating habits of other family members (20). Evidence from the United States and European countries indicate a high correlation between parents' and adolescents' dietary behaviors (33, 34), while parents' FPP are consistent not only with their adolescent children's dietary behavior, but their own diet (29). In different-sex couples, the literature also shows that spouses can influence one another on their eating behaviors (50). Findings in this line show that women are more influenced by their male partner than vice versa, and this distinction has been explained by women's traditional gender socialization regarding a higher sensitivity toward their partners than men (51, 52). Nevertheless, men's eating behaviors can also be influenced by

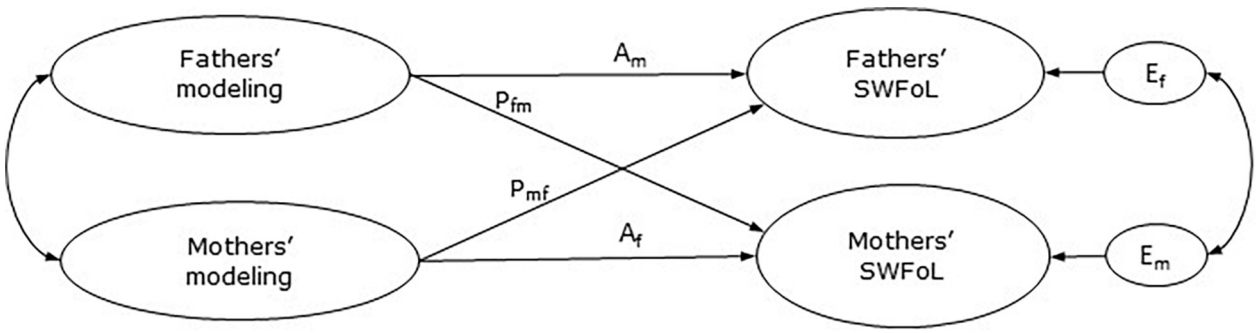


FIGURE 1 | Basic actor-partner interdependence model of modeling and satisfaction with food-related life (SWFoL). A_m, actor effect of father's modeling on his own SWFoL; A_f, actor effect of mother's modeling on her own SWFoL; P_{fm}, partner effect of father's modeling on mother's SWFoL; P_{mf}, partner effect of mothers' modeling on fathers' SWFoL; E_f and E_m, residual errors on SWFoL for the father and mother, respectively.

their female partners (53). On this basis, we propose that parents' modeling can influence not only their adolescent children's diet quality, but also their own and their partner's, in the following hypotheses:

H1. Parents' modeling of healthy food choices is positively associated with their own diet quality (actor effects).

H2. Modeling of healthy food choices of one parent is positively associated with the diet quality of (a) the other parent and (b) of the adolescent (partner effects).

Healthier eating habits have been positively associated with higher levels of SWFoL in individual-level research in adults [e.g., (36, 39, 40, 54–57)] and adolescents (39, 57, 58). At the same time, findings show that eating behaviors and SWFoL are correlated among family members (28, 29, 34, 36), and that parents' SWFoL is linked to healthy eating behaviors in the family (36, 59). Therefore, it can be expected that parental modeling and associated dietary outcomes are linked to both adolescents' and parents' SWFoL, as proposed in the following hypotheses:

H3. Diet quality is positively associated with satisfaction with food-related life for (a) fathers, (b) mothers, and (c) adolescents (actor effects).

H4. Diet quality of one parent is positively associated with satisfaction with food-related life of (a) the other parent, and (b) the adolescent (partner effects).

H5. Diet quality of adolescents is positively associated with their parents' satisfaction with food-related life (partner effects).

Outcomes of different FPP on adolescents' and their parents' wellbeing have been scarcely studied, but research to date shows that structure-related and autonomy supporting FPP can benefit both parents' and children's wellbeing (9, 41). This beneficial relationship is thought to occur because these FPP are based on a supportive parental approach to healthy eating that also accounts for the child's emotional and psychological needs (2, 25). Studies on monitoring and SWFoL and life satisfaction [i.e., the individual's assessment of their overall life conditions or specific domains, (60)] also support these findings. Some studies have found that maternal monitoring of child snacking behavior is linked to both mothers' and adolescents' SWFoL (39, 41). Other studies have reported that structured meals, a healthy food-home environment, and lack of pressure to eat increase emotional wellbeing and life satisfaction in adolescent's and their parents (40, 43), and these relations continue during the COVID-19 pandemic in young adults (12). Therefore, we propose that modeling has a beneficial influence on parents' and adolescents' SWFoL, with crossover effects of modeling and SWFoL between both parents:

H6. Modeling of healthy food choices is positively associated with satisfaction with food-related life for each parent (actor effects).

H7. Modeling of healthy food choices of one parent is positively associated with satisfaction with food-related life of (a) the other parent, and (b) of the adolescent (partner effects).

Figure 2 displays the conceptual model including the first seven hypotheses. The effects proposed in H6 and H7 imply that modeling of healthy food choices could lead to more SWFoL independently of the effect of the modeling on diet quality. To the best of our knowledge, there are no published studies exploring the mediating role of diet quality between FPP and SWFoL. Previous studies suggest mechanisms supporting positive relationships between parental modeling and healthy dietary intake in parents (29, 33, 34) and children (8, 21, 27, 48, 49); between healthier eating habits and higher levels of SWFoL in samples of adults [e.g., (39, 50–57)] and adolescents (39, 57, 58); and between parents' SWFoL and their family members' healthy eating behaviors (36, 59, 61). On this base, we posed the last hypothesis of this study:

H8. Diet quality has a mediating role between both parents' modeling of healthy food choices and satisfaction with food-related life for the three family members (actor and partner effects).

One last consideration for this proposal derives from the Latin American context in which this study is conducted. In

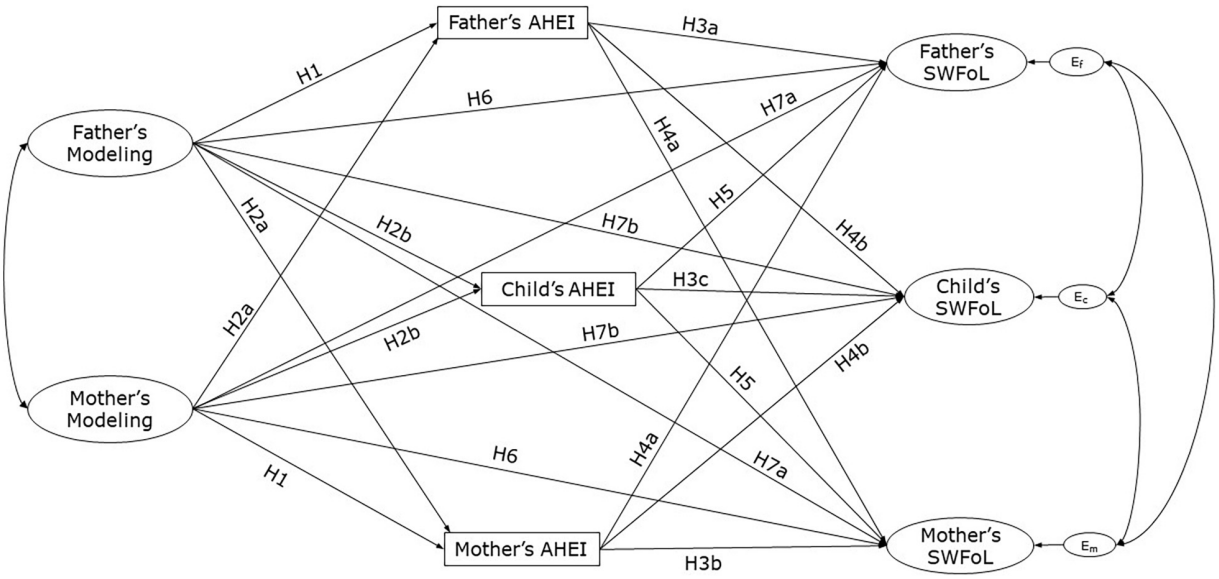


FIGURE 2 | Conceptual model of the proposed actor and partner effects of both parent's modeling on the three family members' diet quality (measured by the Adapted Healthy Eating Index, AHEI) and Satisfaction with Food-related Life (SWFoL) in dual-earner parents with adolescent children. Ef, Ec, and Em, residual errors on SWFoL for the fathers, mothers and their adolescent children, respectively. The indirect effects of AHEI (H8) were not shown in the conceptual path diagram to avoid cluttering the figure.

this cultural context, fathers tend to engage less in FPP than mothers, because the latter are traditionally tasked with food purchase and meal preparation (20, 28, 33, 34, 40). However, other research with Latino families suggests that fathers can also improve their children's eating behaviors by exerting FPP, buying and preparing foods, and participating in mealtimes (27, 34, 62). Another study reported gender differences in FPP and established the differential roles that mothers and fathers play in the development of their children's eating habits (28). Thus, we expect that the proposed associations between parental modeling, diet quality and SWFoL may show different patterns based on the parent's gender.

MATERIALS AND METHODS

Sample and Procedure

This study used a cross-sectional design. The sample was composed of 430 dual-earner families including mother, father (married or cohabiting) and one adolescent child ages 10–16 (**Table 1**). This study is part of a wider research on the relations between work, family, and food-related life in Chilean families. Sample size was determined considering 10 participants for each item of each scale used in this project. Families were recruited using non-probability sampling in Rancagua, Chile. Potential participants were contacted *via* seven schools that serve diverse socioeconomic backgrounds in the city. School principals signed authorization letters to conduct the research with students from fifth grade of primary level (minimum age of 10 years) to the first grade of secondary level (maximum age of 16 years). Parents of students in these grades received information from trained interviewers about the study's objectives, the structure of the questionnaire, and the guarantees of anonymity and confidentiality of the responses.

Families who agreed to participate in the study provided one e-mail address to receive the links to three surveys, one for each family member, between March and July 2020. Trained interviewers maintained contact with the families by phone, to answer questions about the study and to monitor the responses to the questionnaire. The COVID-19 pandemic was declared by mid-March 2020 in Chile, and the city of Rancagua was on mandatory lockdown during June and July 2020. However, most workers in the country, particularly women, began to work from home at the start of the pandemic (32).

For mothers and fathers, the first page of the questionnaire showed the informed consent form, while for adolescents it showed an informed assent form. The three family members were asked to click a box to confirm their agreement to participate before starting the questionnaire. All responses were recorded in the QuestionPro platform (QuestionPro Inc.) in separate databases for each family member. When the three family members submitted their responses, the family received a bank transfer for 15 USD as retribution for their participation.

A pilot test for this study was conducted with fifty families in Temuco, Chile. The recruitment method and data collection procedure were the same as the ones declared above. Results of this pilot test were satisfactory, with no changes required to the method nor the questionnaire. This study has been approved by The Ethics Committee of the Universidad de La Frontera.

Measures

The following scale was answered only by mothers and fathers:

TABLE 1 | Sample characteristics (n = 430).

Characteristic	Total sample	*P*-value[a]
Age [Mean (*SD*)][a]		
Mother	39.5 (6.6)	<0.001
Father	42.3 (7.8)	
Adolescent	13.0 (2.0)	
Adolescents' gender [%, (*n*)]		
Male	46.3 (199)	
Female	53.7 (231)	
Number of family members [Mean (*SD*)]	4.3 (1.0)	
Number of children [Mean (*SD*)]	2.2 (0.8)	
Socioeconomic status [%, (*n*)]		
High	3.7 (57)	
Middle	83.0 (357)	
Low	3.7 (16)	
Number of days/week families ate together [Mean (*SD*)]		
Breakfast	3.5 (2.7)	
Lunch	4.9 (2.4)	
Supper	6.0 (1.9)	
Dinner	2.2 (3.1)	
Number of days/week families eat different types of foods [Mean (*SD*)]		
Homemade foods	6.4 (1.3)	
Buy ready-to eat food	0.4 (1.2)	
Order food at home	0.6 (0.7)	
Eat at restaurants	0.2 (0.5)	
Eat at fast-food outlets	0.3 (0.6)	
Number of hours per day spent cooking during the week [Mean (*SD*)][b]		
Mother	2.6 (1.3)	<0.001
Father	1.2 (1.3)	
Another person	0.9 (1.5)	
Number of hours per day spent cooking on the weekend [Mean (*SD*)][b]		
Mother	3.1 (1.6)	<0.001
Father	1.7 (1.4)	
Another person	0.7 (1.2)	
Type of employment [%, (*n*)][c]		<0.001
Woman employee	62.8 (270)	
Woman self-employed	37.2 (160)	
Man employee	75.3 (324)	
Man self-employed	24.7 (106)	
Working hours [%, (*n*)][c]		
Woman working 45 h per week	44.0 (189)	<0.001
Woman less than 45 h per week	56.0 (241)	
Man working 45 h per week	67.2 (289)	
Man working less than 45 h per week	32.8 (141)	

[a] *Independent sample t-test.*
[b] *Analysis of variance.*
[c] *P-value corresponds to the (bilateral) asymptotic significance obtained in Pearson's Chi-square Test.*

Modeling of Healthy Food Choices

Four items were adapted from the modeling factor of the *Comprehensive Feeding Practices Questionnaire* (CFPQ). The CFPQ (18) is a 12-factor questionnaire that measures 12 FPP, including the modeling dimension. Mothers and fathers answered the validated adapted version of the modeling factor (6) for adolescents' parents, which measures that "parents actively demonstrate healthy eating for the child" (i.e., 1. "I model healthy eating for my child by eating healthy myself," 2. "I try to eat healthy foods in front of my child, even if they are not my favorite," 3. "I try to show enthusiasm about healthy foods," 4. "I show my child how much I enjoy eating healthy foods"). Melbye and Hansen (63) reported a Cronbach's alpha of 0.66 for the modeling dimension of the adapted CFPQ in a sample of parents of adolescents in Norway. In this study, the Spanish adapted version of this measure was used (64). Participants answered to each item using a 5-point Likert scale (1: disagree, 5: agree). Modeling scores were obtained by summing the scores from the four items, with higher scores representing higher modeling in parents.

The three family members answered the following instruments:

Adapted Healthy Eating Index

This instrument measures diet quality and is an adaption of the US-HEI (65) into Spanish developed by Norte and Ortiz (66). Participants are asked to report the frequency of consumption of nine food groups: 1. Cereal and derivatives; 2. Vegetables; 3. Fruit; 4. Milk and dairy products; 5. Meats; 6. Legumes; 7. Sausages and cold meats; 8. Sweets, 9. Soft drinks with sugar. The frequency for each food group is converted to a score from 0 to 10, as proposed by Norte and Ortiz (66) following the degree of compliance with food daily and weekly recommendations. For the first nine variables, respondents indicated their consumption frequency of the target food. Each variable received a score, ranging from 0 to 10, according to the degree of compliance with dietary recommendations [criteria is available in reference (66)]. The last variable, relating to diet variety, is constructed using the consumption frequency of the nine target foods: two points were received if the respondent complied with each of the daily recommendations and one point was received if he/she complied with each of the weekly recommendations. The overall Adapted Healthy Eating Index (AHEI) score was calculated by adding the scores obtained in each of the variables. The maximum possible score is of 100 points. Scores above 80 points indicate a "healthy" diet; scores between 51 and 80 points suggest that the diet "requires changes"; and scores below 50 points indicate "unhealthy" diets (65).

Satisfaction With Food-Related Life

The SWFoL (44) is a one-dimension, five-item scale that measures an individual's overall assessment of their food and eating habits (e.g., "Food and meals are very positive elements in your life"). The Spanish version of the SWFoL was used (67), which has been validated and it has shown good internal consistency in samples of adults, adolescents and dual-earner parents in Chile [e.g., (4, 15, 32, 36, 39–41, 57, 61)]. Respondents indicate their degree of agreement with each statement using a 6-point Likert scale (1: completely disagree; 6: completely agree). SWFoL scores are obtained by summing the scores from the five items, and higher scores indicate higher SWFoL.

The three family members reported their age; adolescents reported their gender. Parents answered questions about their type of employment, the number of working hours per week and their monthly income. Mothers reported the number of family members, the number of children, the number of days per week that all family members eat together (breakfast, lunch, supper, and dinner); the number of days per week that they consumed homemade food, buy ready-to-eat food, order food at home, or eat at restaurants or fast-food outlets; and the number of hours per day that they, their male partner and other person spent cooking during the week and on weekends. They were asked their own approximate weight and height as well as from the fathers and the children to determine body mass index (BMI) in kg/m^2. The family socioeconomic status (SES) was determined based on the total household income and its size. The definition of SES in Chile considers two variables: total household income and household size. Total household income is the fundamental variable for socioeconomic segmentation, due to its predictive power on access to goods and services, and because the inverse relationship is much weaker: access to goods and services is not a good predictor of income. The size of the household exerts a restriction on purchasing power: When an additional member is added to the household without increasing income, basic expenses increase albeit in a sub-proportionate way considering economies of scale. The combination of ranges of the household monthly income and the number of family members in a matrix determines the SES (68).

Data Analysis

Descriptive analyses were conducted using the Statistical Package for Social Sciences (SPSS) version 23.0 (IBM Corp. Released 2015. IBM SPSS Statistics for Windows, Armonk, NY: IBM Corp). The actor-partner interdependence model (APIM) with distinguishable dyads was tested using structural equation modeling (SEM) (47) with Mplus 8.4. In this study, actor effects are those outcomes predicted by the individuals' own characteristics, while partner effects are outcomes from one member of the dyad predicted by the characteristics of the other member. Members of a dyad are both an actor and a partner in the analysis. In this study, dyads are composed of mother-father, and parent-adolescent. The actor and partner effects tested were modeling from mothers and fathers, and the three family members' diet quality and SWFoL.

In the APIM, other effects were controlled for. First, the influence of modeling from one parent to the other was controlled for by specifying a correlation between this variable reported by each parent. Other sources of interdependence between individuals were controlled for following guidelines by Kenny et al. (47), by specifying correlations between the residual errors of the dependent variable (SWFoL) of the three family members. Other effects that were controlled for were those of family SES, number of children, parents' and adolescents' age, both parents' number of working hours and type of employment, and family supper times per week. These variables with direct effects on the dependent variables of the three family members (diet quality and SWFoL) were thus incorporated in the model.

To conduct the SEM, structural model parameters were estimated using weighted least square mean and variance adjusted (WLSMV). Because the items were on an ordinal scale, the polychoric correlation matrix was used. A good model fit of the data was determined with the following values: when values are above 0.95 for the Tucker-Lewis index (TLI) and the comparative fit index (CFI); and when values are below 0.06 for the root mean square error of approximation [RMSEA, (69)]. Lastly, to test the mediating role of diet quality, a SEM through a bias-corrected (BC) bootstrap confidence interval using 1,000 samples (70) was conducted. A mediating role is found when BC confidence intervals do not include zero.

RESULTS

Sample Description

Table 1 shows the sociodemographic characteristics of the sample composed by 430 mother-father-adolescent families. The average age for mothers was 39.5 years old, for fathers 42.3 years, and for adolescents 13.0 years. The difference between mothers' and fathers' age was significant ($p < 0.001$). In the adolescent subsample, 53.7% were female. On average, families had four members and two children, and most families belonged to a middle SES.

Reports about frequency of family meals showed that families got together for breakfast, lunch, and supper more than 3 days per week, and homemade food was consumed frequently. The main responsibility for food decision-making and purchases in the household was most often shared by both parents, followed by mothers having main responsibility. Mothers spent significantly more hours per day cooking during the week and on weekends, compared to fathers and other persons ($p < 0.001$), and fathers spent more hours in this same activity than other persons. "Other persons" referred most frequently to grandmothers, adult children, and domestic service. Most mothers and fathers were employees as opposed to independent workers. A greater proportion of fathers, compared to mothers, worked full time (45 h per week in Chile, $p < 0.001$) and were employees ($p < 0.001$).

In terms of body mass index, following the norms of the World Health Organization (WHO), 28.4% of mothers had a body mass index in the normal range (BMI: 18.5–24.9), 44.2% were overweight (BMI: 25.0–29.9) and 27.9% were obese (BMI $\geq$ 30). In fathers, 16.3% had a body mass index in the normal range, 57.0% were overweight, and 26.7% were obese. For adolescents, the guidelines used are those from the WHO (71) and the Technical Norm of Nutritional Evaluation of children from 5 to 19 years old of the Ministry of Health of Chile (72). According to these guidelines, 0.5% of adolescents in this sample had a body mass index that denote thinness (≤ -1 to -1.9 *SD*), 27.9% were in the normal range ($+0.9$ to -0.9 *SD*), 44.2% were overweight ($\geq +1$ to $+ 1.9$ *SD*), and 27.4% obese ($\geq + 2$ *SD*).

Table 2 shows the average score and the correlations for both parents' modeling, diet quality (measured by the AHEI) and SWFoL. All of the correlations were significant and in the expected directions. Mothers scored significantly higher than

TABLE 2 | Descriptive statistics and correlations for both parent's modeling and the three family members' diet quality (measured by the Adapted Healthy Eating Index, AHEI) and Satisfaction with Food-related Life (SWFoL) in dual-earner parents with adolescent children (n = 430).

	M (*SD*)	Correlations							
		1	2	3	4	5	6	7	8
1. Mother's modeling	16.32 (3.20)	–	0.328***	0.392***	0.210***	0.236***	0.267***	0.193***	0.199***
2. Father's modeling	15.25 (2.91)		1	0.208***	0.311***	0.152***	0.129**	0.358***	0.177***
3. Mother's AHEI	65.07 (12.52)			1	0.500***	0.593***	0.309***	0.124**	0.220***
4. Father's AHEI	60.89 (14.10)				1	0.508***	0.146**	0.303***	0.125**
5. Adolescent's AHEI	64.78 (14.36)					1	0.124**	0.189***	0.164**
6. Mother's SWFoL	22.13 (4.52)						1	0.303***	0.298***
7. Father's SWFoL	23.13 (4.30)							1	0.351***
8. Adolescent's SWFoL	23.94 (4.35)								1

$^{**}p < 0.01$, $^{***}p < 0.001$.

fathers in modeling (t = 4.421, $p < 0.001$). Fathers scored significantly lower than mothers and their adolescent children in the AHEI (F = 12.524, $p \geq 0.001$), whereas mothers and adolescents did not differ from one another. However, according to the cut-off point proposed by Kennedy et al. (65), the three family members had AHEI average scores indicating that their diet "requires changes." Adolescents scored significantly higher than their mothers and fathers in the SWFoL (F = 18.321 $p < 0.001$), while fathers scored significantly higher than mothers.

Actor-Partner Interdependence Model Results: Testing Actor-Partner Hypotheses

In this study, the standardized factor loadings of the modeling factor ranged from0.732 to 0.933 for mothers and from 0.818 to 0.909 for fathers, all statistically significant ($p < 0.001$). The Average Variance Extracted (AVE) values were higher than 0.50 (AVE mothers = 0.71, fathers = 0.76). The modeling factor showed good internal reliability, as the Omega coefficient was 0.91 for mothers and 0.93 for fathers. The standardized factor loadings of the SWFoL scale were all statistically significant ($p < 0.001$), and ranged from 0.681 to 0.930 for mothers, from 0.597 to 0.931 for fathers, and from 0.655 to 0.847 for adolescents. The AVE values were higher than 0.50 (AVE mothers = 0.63, fathers = 0.63, adolescents = 0.58). The SWFoL scale showed good internal reliability, as the Omega coefficient was 0.89 for mothers, 0.89 for fathers, and 0.87 for adolescents.

The results from the estimation of the structural model are shown in **Figure 3**. The model that assessed the APIM associations between the mothers' and fathers' modeling and the three family members' AHEI and SWFoL had a good fit with the data (CFI = 0.983; TLI = 0.978; RMSEA = 0.036). A significant correlation (covariance) was found between modeling of both parents (r = 0.397, $p < 0.001$). Significant correlations were also found between the residual errors of mothers' and fathers' SWFoL (r = 0.377, $p < 0.001$), between mothers' and adolescents' SWFoL (r = 0.293, $p < 0.001$), as well as between fathers' and adolescents' SWFoL (r = 0.359, $p < 0.001$).

H1 tested actor effects, stating that parents' modeling of healthy food choices is positively associated with their own diet quality. The path coefficients (standardized) indicate that fathers' (γ = 0.307, $p < 0.001$) and mothers' (γ = 0.382, $p < 0.001$) modeling was positively associated with their own AHEI. These findings supported H1 for both parents.

H2 tested partner effects, stating that modeling of healthy food choices of one parent is positively associated with the diet quality of the other parent (H2a) and of the adolescent (H2b). Results showed that fathers' modeling was positively associated with mothers' AHEI (γ = 0.086, p = 0.044), and that mothers' modeling was positively associated with fathers' AHEI (γ = 0.122, p = 0.010). Likewise, fathers' (γ = 0.143, p = 0.003) and mothers' (γ = 0.242, $p < 0.001$) modeling was positively associated with adolescents' AHEI. These findings supported H2a and H2b.

H3 tested actor effects for the three family members, that is, diet quality is positively associated with SWFoL for fathers (H3a), mothers (H3b), and adolescents (H3c). The results indicate that fathers' (γ = 0.220 p = 0.018) and mothers' (γ = 0.262, p = 0.001) AHEI was positively associated with their own SWFoL. By contrast, adolescents' AHEI was not significantly associated with their own SWFoL (γ = 0.062, p = 0.297). These findings supported H3 for both parents (H3a and H3b) but not for adolescents (H3c).

H4 tested partner effects, stating that the diet quality of one parent is positively associated with the SWFoL of the other parent (H4a) and of the adolescent (H4b). Fathers' AHEI was not significantly associated with mothers' SWFoL (γ = −0.001, p = 0.990), nor with their adolescent children's SWFoL (γ = −0.017, p = 0.768). The mother's AHEI was positively associated with the father's (γ = 0.127, p = 0.049), but not with their adolescent children's (γ = 0.130, p = 0.051) SWFoL. These findings partially supported H4a, while they did not support H4b.

H5 stated that adolescents' diet quality is positively associated with their parents' satisfaction with food-related life. The adolescents' diet quality was not significantly associated with the fathers' SWFoL (γ = 0.054, p = 0.326), but it was positively associated with their mothers' SWFoL (γ = 0.127, p = 0.040), and thus H5 was partially supported.

H6 stated that modeling of healthy food choices is positively associated with satisfaction with food-related life for each parent. This relationship can be direct and/or mediated by diet quality. As shown in **Figure 3**, the path coefficients indicate that fathers'

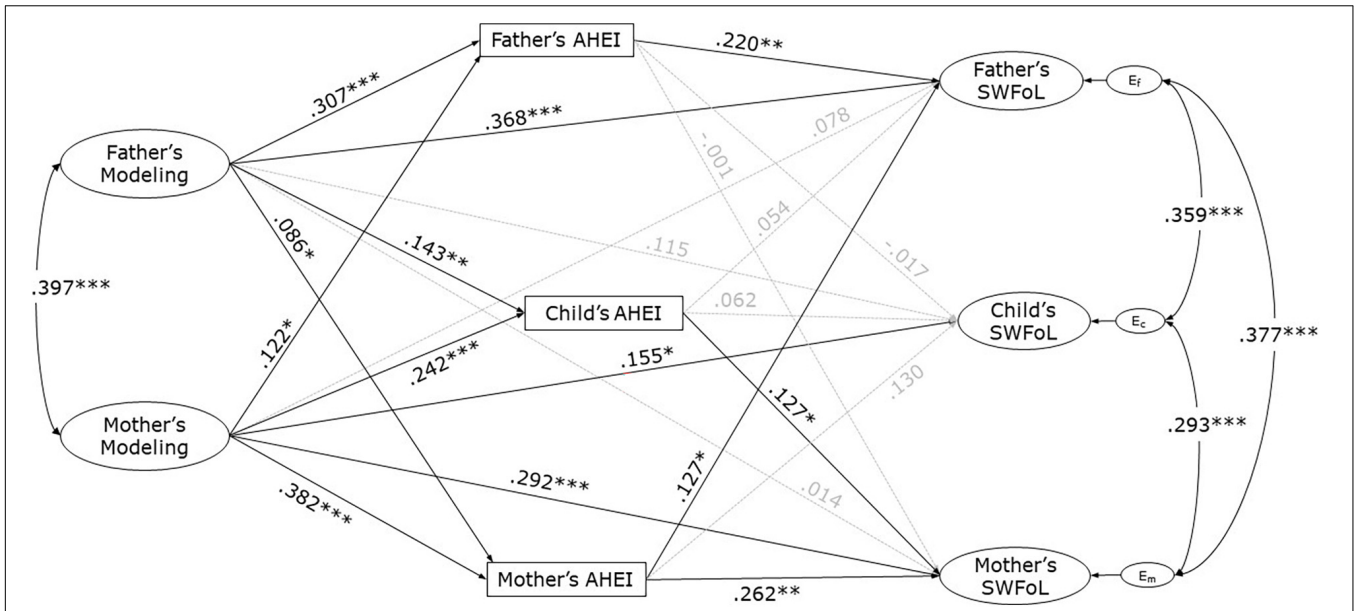


FIGURE 3 | Actor-partner interdependence model of the effect of both parents' modeling on the three family members' diet quality (measured by the Adapted Healthy Eating Index, AHEI) and Satisfaction with Food-related Life (SWFoL) in dual-earner parents with adolescent children. E_f, E_c and E_m, residual errors on SWFoL for fathers, mothers and their adolescent children, respectively. $^*p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. The control for the effects of family SES, number of children, parents' and adolescents' age, both parents' number of working hours and type of employment, and times per week in which the family members had supper together on the dependent variables of the three family members (AHEI and SWFoL) were not shown in the path diagram to avoid cluttering the figure.

($\gamma = 0.368$, $p < 0.001$) and mothers' ($\gamma = 0.292$, $p < 0.001$) modeling was directly and positively associated with their own SWFoL. These findings supported H6 for both parents even when not taking the possible mediation effect into account.

H7 examined partner effects, stating that modeling of healthy food choices of one parent is positively associated with the SWFoL of the other parent (H7a) and of the adolescent (H7b). There was no significant direct link between fathers' modeling and mothers' SWFoL ($\gamma = 0.014$, $p = 0.798$). Likewise, there was no significant direct link between mothers' modeling and fathers' SWFoL ($\gamma = 0.078$, $p = 0.193$). While fathers' modeling ($\gamma = 0.115$, $p = 0.064$) was not directly associated with the adolescents' SWFoL, mothers' modeling was positively and directly associated with the adolescents' SWFoL ($\gamma = 0.155$, $p = 0.015$). Before establishing a conclusion about H7, however, indirect effects must be explored in which the relationship between modeling and SWFoL is mediated by diet quality (H8).

Most of the control variables did not affect the model significantly (see **Supplementary Information**). The family SES positively affected the mothers' ($\gamma = 0.170$, $p < 0.01$) and the adolescents' ($\gamma = 0.128$, $p < 0.05$) AHEI as well as the mothers' SWFoL ($\gamma = 0.134$, $p < 0.01$). Namely, those mothers belonging to the high SES had a higher score on the AHEI and experienced higher levels of SWFoL than those of lower SES, while adolescents belonging to the high SES had a higher score on the AHEI than those of lower SES. The mothers' type of employment positively affected her own ($\gamma = 0.116$, $p < 0.05$) and their adolescent children's AHEI ($\gamma = 0.118$, $p < 0.05$), meaning that self-employed mothers and their adolescent children had higher AHEI scores than employed mothers and their adolescent children. The number of family supper times per week positively affected the adolescents' AHEI ($\gamma = 0.106$, $p < 0.05$) and the fathers' SWFoL ($\gamma = 0.110$, $p < 0.05$).

Testing Mediating Roles of Diet Quality

The last hypothesis of this study proposed the mediating role of the three family members' diet quality between both parents' modeling of healthy food choices and the three family members' satisfaction with food related life (H8). The role of the mother's diet quality (i.e., AHEI score) as a mediator in the relationship between her own modeling and SWFoL was supported by a significant indirect effect obtained with the bootstrapping confidence interval procedure (standardized indirect effect = 0.062, 95% CI = 0.028, 0.097), as the confidence intervals did not include zero (**Table 3**). Similarly, the role of the father's diet quality as a mediator in the relationship between his own modeling and SWFoL was supported by a significant indirect effect (standardized indirect effect = 0.034, 95% CI = 0.016, 0.053). In addition, the role of the father's diet quality as a mediator in the relationship between the mother's modeling and the father's SWFoL was supported by a significant indirect effect (standardized indirect effect = 0.016, 95% CI = 0.001, 0.031). No other indirect effects of diet quality were found, as the confidence intervals did include zero (**Table 3**).

As we find neither direct nor indirect effects of parents' modeling on the partners SWFoL, H7a is not supported. H7b is supported only for mothers. In addition, we find that the effect of parents' modeling on their own SWFoL is partly mediated by their diet quality. These findings partially support the mediating role of diet quality between parents' modeling and their own

TABLE 3 | Bias-corrected confidence intervals of specific mediation effects of the three family members' diet quality (measured by the Adapted Healthy Eating Index, AHEI).

Specific indirect effects	Estimate	Lower 2.5%	Upper 2.5%	*P*-value
Mothers' modeling → Mothers' AHEI → Mothers' SWFoL	0.062	0.028	0.097	<0.001**
Mothers' modeling → Fathers' AHEI → Mothers' SWFoL	0.000	−0.008	0.008	0.990
Mothers' modeling → Adolescents' AHEI → Mothers' SWFoL	0.019	−0.002	0.040	0.073
Fathers' modeling → Mothers' AHEI → Mothers' SWFoL	0.012	−0.001	0.025	0.073
Fathers' modeling → Fathers' AHEI → Mothers' SWFoL	0.000	−0.017	0.017	0.990
Fathers' modeling → Adolescents' AHEI → Mothers' SWFoL	0.009	−0.001	0.020	0.079
Mothers' modeling → Mothers' AHEI → Fathers' SWFoL	0.030	−0.001	0.060	0.054
Mothers' modeling → Fathers' AHEI → Fathers' SWFoL	0.016	0.001	0.031	0.031*
Mothers' modeling → Adolescents' AHEI → Fathers' SWFoL	0.008	−0.008	0.024	0.331
Fathers' modeling → Mothers' AHEI → Fathers' SWFoL	0.006	−0.002	0.013	0.161
Fathers' modeling → Fathers' AHEI → Fathers' SWFoL	0.034	0.016	0.053	<0.001***
Fathers' modeling → Adolescents' AHEI → Fathers' SWFoL	0.004	−0.005	0.012	0.362
Mothers' modeling → Mothers' AHEI → Adolescents' SWFoL	0.033	−0.001	0.066	0.059
Mothers' modeling → Fathers' AHEI → Adolescents' SWFoL	−0.001	−0.010	−0.008	0.769
Mothers' modeling → Adolescents' AHEI → Adolescents' SWFoL	0.010	−0.009	0.028	0.298
Fathers' modeling → Mothers' AHEI → Adolescents' SWFoL	0.006	−0.005	0.015	0.165
Fathers' modeling → Fathers' AHEI → Adolescents' SWFoL	−0.003	−0.022	0.016	0.769
Fathers' modeling → Adolescents' AHEI → Adolescents' SWFoL	0.005	−0.005	0.015	0.327

SWFoL, Satisfaction with food-related life.
$^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

SWFoL, while they did not support the mediating role of the adolescent's diet quality.

DISCUSSION

Focusing on different-sex dual-earner parents with adolescent children, this study tested the actor and partner effects between parents' modeling and the three family members' diet quality and SWFoL; and whether diet quality has a mediating role between both parents' modeling and the three family members' SWFoL. Using the APIM approach, our results showed that both mothers' and fathers' modeling can enhance their own and their adolescents' diet quality, whereas one parent's modeling also improves the other parent's diet quality, regardless of the parents' gender. Modeling and higher diet quality are directly associated with higher SWFoL in both parents. However, different patterns emerged in the direct and indirect links between modeling, diet quality and SWFoL according to the parent's gender. Findings are discussed in detail below by examining actor and partner effects, and the mediating role of diet quality.

Actor Effects

A positive relationship was found between each parent's modeling of healthy food choices and their own diet quality (H1). These results provide support to the findings reported by Fleary and Ettiene (29) showing that parents' FPP are indicative of their own dietary behavior, focusing on fruit and vegetable consumption in a sample of parent-adolescent dyads in the US. Our results expand on this knowledge by showing that parental modeling is another structured FPP that is indicative of parents' dietary behavior. It should be noted, however, that these results are framed within the first months of the COVID-19 pandemic. The frequency of family meals reported in this study was higher than the one observed in studies conducted in Chile before the pandemic (36, 39), while the frequency of homemade meals was high. Therefore, the positive relationship between both parents' modeling and their own diet may be related to the higher frequency of family meals during lockdown, which have been associated with healthier eating behaviors in different countries (11, 12, 14).

The second hypothesis testing actor effects stated that diet quality is positively associated with SWFoL for fathers (H3a) mothers (H3b), and adolescents (H3c). This hypothesis was supported for mothers and fathers, supporting previous studies showing that healthier eating habits are positively associated with higher levels of SWFoL in adult samples [e.g., (36, 39, 54–57)]. However, the lack of association between adolescents' healthier diet and SWFoL contradicts previous studies in adolescent samples from different countries (39, 57, 58). Possible explanations to this latter finding may be related to shifting food preferences during the adolescence, or to changes due to the pandemic. The search for independence in adolescents also occurs in the food domain, as they increasingly choose what to eat and where, when and with whom (5, 6, 9). Research has also shown that adolescents prioritize hedonic food consumption over a healthy and nutritious consumption, and that they associate eating unhealthy/tastier food with higher SWFoL (59). Moreover, during the pandemic, adolescents have remained closer to their parents and away from their peers (73), so their diet might have depended more on what they are served (i.e., healthier food) rather than on what they want (i.e., enjoyable food).

Lastly, actor effects showed that modeling of healthy food choices is positively associated with SWFoL, for mothers and

fathers (H6). Hence, part of this effect is observed because modeling is reflective of parents' own eating behaviors, and these eating behaviors, in turn, result in higher levels of SWFoL (36, 39, 54–57). The direct, unmediated effect of both parents' modeling on their own SWFoL may be related to the possibility of improving their children's diet quality and wellbeing (2, 25). Overall, these findings are notable because they indicate that another structured FPP (i.e., parental modeling) directly and positively influences parents' SWFoL. This result contributes to knowledge regarding FPP and their potential link to higher levels of SWFoL in parents (4, 39, 41–43).

Our results also show that both mothers' and fathers' SWFoL is positively influenced by exerting a positive FPP. The association for fathers was of medium strength, while the same association in mothers was of low strength. Although further research is needed regarding the association between fathers' FPP and their own SWFoL, it is feasible that this result may be reflecting a higher concern of fathers in engaging in healthy eating behaviors during the pandemic, as it has been reported in different countries (13, 32). However, it is also possible that fathers' modeling increased during the pandemic in keeping with a higher frequency of family meals in comparison to the pre-pandemic period (36, 39). A higher frequency of family meals has been also associated with healthier diets (11, 12, 14) and with higher emotional wellbeing during the pandemic in young adults from the US (12). Thus, future research is needed to corroborate if the medium strength association between fathers' modeling and their own SWFoL remains beyond the pandemic or whether it is a consequence of the pandemic.

Partner Effects

The first hypothesis testing partner effects stated that modeling of healthy food choices of one parent is positively associated with the diet quality of the other parent (H2a) and of the adolescent (H2b). Hypothesis 2a was supported for both parents, as mothers' modeling positively influenced the fathers' diet quality, and vice versa. These results show that modeling exerted by one parent to enhance children's diet quality also positively influences the other parent's diet quality, regardless of the parent's gender (50, 53). However, our results contradict previous studies reporting that women are more influenced by their partner than men (51, 52), as the association between mothers' modeling and the fathers' diet quality was of similar strength in comparison with the association between fathers' modeling and the mothers' diet quality. Therefore, both parents' modeling is important to enhance the diet quality of both members of the couple.

Mothers' and fathers' modeling was also positively related to their adolescent children's diet quality (H2b). This result supports previous studies reporting that modeling is associated with an improvement in the adolescents' diet quality, a higher consumption of healthy foods, and with lower consumption of unhealthy foods, mainly in samples of mother-adolescent dyads in developed countries (8, 22, 24, 48, 49). Our results also provide support to the scarce evidence showing that fathers' modeling is related to positive dietary outcomes in adolescents (27, 34). Furthermore, the positive association between both parents' modeling and their adolescent children's diet quality also provides support to the findings reported by Jaeger et al. (21), who found that both parents reported similar levels of modeling to promote healthier eating habits (fruit and vegetable consumption) in their adolescent children. Thus, although research have highlighted the important role that mothers play in explaining their children's food intake (20, 28, 33, 34, 41), our results support that both parents have a role in modeling healthy food-related behaviors among youth (27). The fathers' modeling influence on their adolescent children's diet quality may indicate an increased involvement of fathers in their children's eating habits (19, 28, 30, 31), linked to societal changes in terms of gender roles, or it may be associated with the pandemic. The latter option, an increase in the fathers' involvement in food-related tasks, has been consistently reported in the early stages of this health crisis (13, 32). Therefore, as it was previously posed, future research should assess if the positive association between fathers' modeling and diet quality remains after the pandemic.

Actor effects were of medium strength (i.e., the influence of each parent's modeling on their own diet quality), while partner effects were of low strength (i.e., the influence of one parent's modeling on the other parent's diet quality, as well as the influence of each parent's modeling on their adolescent children's diet quality). Although previous research using the APIM approach to study reciprocal influences among members of a dyad or between family members have reported similar results (32, 74), this finding is notable considering that FPP are used by parents to influence their children's eating habits. By contrast, our results suggest that parent's modeling have a stronger influence on their own diet quality than on their adolescent children's diet quality.

The second hypothesis testing partner effects posed that diet quality of one parent is positively associated with SWFoL of the other parent (H4a) and of the adolescents (H4b). Hypothesis 4a was partially supported, as the mothers' diet quality positively influenced the fathers' SWFoL, but not vice versa, while hypothesis 4b was not supported. A possible explanation for this result may be related to the lower AHEI scores (indicating diet quality) in fathers. Although all three family members had AHEI scores in the range that their diet quality "requires changes," fathers' diet quality is the worst among the three family members under study. Therefore, it can be hypothesized that the improvement of the fathers' diet quality associated with their own modeling is not enough to positively influence the mothers' SWFoL, while a similar explanation may be true in the opposite direction, meaning that mothers' diet quality positively influences fathers' SWFoL because mothers have a higher diet quality than fathers. Regarding hypothesis 4a, the lack of significant associations between both parents' diet quality and their adolescent children's SWFoL is probably associated with their increased autonomy in food choices during adolescence (5, 6, 9). However, as the adolescent children's SWFoL was also not influenced by their own diet quality (actor effects), the probability of the existence of partner effects is almost inexistent (74).

Hypothesis 5 also tested partner effects but in the opposite direction, stating that diet quality of adolescents is positively associated with their parents' SWFoL. This hypothesis was

supported only for mothers. The results suggest that traditional gender-based demands and expectations remain, particularly in the Latin American context, where feeding children is still predominantly female labor even if mothers and other female caretakers have paid employment (20, 28, 33, 34, 41). It thus may be the case for these women that if they can perform as well at work than as in food-related tasks, including the promotion of healthy eating habits in their adolescent children, their self-confidence may be reinforced, positively influencing their SWFoL (75).

Hypothesis 7 stated that modeling of healthy food choices of one parent is positively associated with the SWFoL of the other parent (H7a) and of the adolescent (H7b). Whereas hypothesis 7a was not supported for mothers and fathers, hypothesis 7b was partially supported. Only the mothers' modeling was related to their adolescent children's SWFoL, and this relationship was not mediated by the adolescent's quality of diet. Previous evidence on crossover effects involving SWFoL is mixed, with lack of significant partner effects in some studies (75), others reporting at least an asymmetrical partner effect [from women to men, (61)], and symmetrical partner effects [from women to men, and from men to women, (76)] in dual-earner couples. Therefore, it is possible to suggest that crossover relationships involving SWFoL are associated with the variables under study, as it has been reported by Yucel and Latshaw (77) regarding crossover effects in the work-family interface among couples. Nevertheless, it is also possible that the relationship between both parents' modeling and SWFoL may occur by underlying mechanisms, as discussed below.

Regarding the positive crossover association between mothers' modeling and their adolescent children's SWFoL, one possible explanation for these results may be associated with the different socialization practices and social roles for women and men. The positive association between mothers' modeling and adolescents' SWFoL may be due to adolescents' perception that their mothers are fulfilling their gender role, while the lack of relationship between fathers' modeling and their adolescent children's SWFoL may be reflecting that adolescents do not value the fathers' modeling, because this task is not associated with the traditional men's role within the family in the Latin American culture (4). Overall, our results show that FPP may not only positively influence the SWFoL of the parent who exert the FPP (39–41), but also that of their adolescent children through crossover.

Testing Mediating Roles of Diet Quality

The last hypothesis of this study (H8) tested the mediating role of the three family members' diet quality between both parents' modeling of healthy food choices and the three family members' satisfaction with food related life (actor and partner effects). This hypothesis was partially supported for parents' diet quality, and not supported for the adolescents' diet quality. Diet quality shows an intra-individual mediating role between modeling and SWFoL in mothers and fathers. These findings show that modeling and SWFoL were also indirectly associated *via* diet quality regardless of the parent's gender.

In addition, mothers' modeling was indirectly associated with fathers' SWFoL *via* fathers' diet quality. This result underscores the important role that mothers have in modeling healthy eating behaviors in their family, positively influencing -directly or indirectly- their own, the fathers', and their adolescent children's diet quality and SWFoL. Although further research is needed to explain the lack of an inter-individual mediating role of mothers' diet quality, this null finding may be related to the weak relationship between fathers' modeling and mothers' diet quality. A similar explanation may stand for the lack of a mediating role for the adolescents' diet quality.

Limitations

This study is not without limitations. The first limitation is the cross-sectional design of this study, which does not allow to indicate causal relationships between the variables. A second limitation relates to the sample. Families were self-selected, and although they were representative of the Chilean population in terms of socioeconomic status (68), these families had more family members than the average Chilean family (78). Moreover, data were self-reported, and participants might have answered the questionnaires thinking about expectations regarding modeling practices, eating habits, and their overall food-related life. Another limitation pertains to the AHEI measure, which has been shown to be useful to evaluate diet quality, but it does not include all possible food groups nor the quantity consumed for each. Regarding the overall method, the design of this study predated the pandemic, and the questionnaire was not able to capture conditions specific to this ongoing event, such as the transition from commuting to working from home, or commuting during lockdown. Lastly, this study did not account for other FPP, the adolescent's perception of parental modeling, nor restrictions related to the COVID-19 pandemic. Longitudinal designs, probabilistic sampling, and cross-cultural comparisons are needed in future studies to further explore the relationships seen in this study. In addition, research must include the perception of both parents and adolescents regarding FPP, and the family-level assessment of diverse FPP, such as other structured ones, and those included in the coercive control and autonomy support or promotion classification by Vaughn et al. (2).

CONCLUSION AND IMPLICATIONS

Despite these limitations, this is the first study that analyses actor and partner effects for the relationships between both parents' modeling and the three family members' diet quality and SWFoL in different-sex dual-earner parents with adolescent children. Results showed that one parent's modeling enhanced their own, their adolescent children's and the other parent's diet quality, regardless of the parent's gender. Both parents' modeling was associated with their own SWFoL, directly and indirectly *via* their own diet quality. However, different gender patterns emerged among parents regarding one parent's modeling and diet quality influence on the other parent's and their adolescent children's SWFoL. Only mothers' modeling was positively associated with their adolescent children's SWFoL; mothers' diet quality was positively associated with fathers' SWFoL; and mothers'

modeling was indirectly related to the father SWFoL, *via* the fathers' diet quality.

These results have research implications. Research is needed based on possible reciprocal relationships between parents' FPP and family members' outcomes to assess the influence that parents' FPP have on their own and their children' diet quality and wellbeing. In addition, as FPP are also exerted by parents to prevent overweight and obesity in their children (1), future studies should also assess the influence that different FPP have on parents' and children's nutritional status at a family level. Furthermore, as different patterns emerged according to the parent's gender, future research should corroborate if these differences are associated with the COVID-19 pandemic or whether they may persist post-pandemic. In addition, future research should explore possible moderators of the associations found in this study. For instance, the frequency of family meals, the family SES, and the mothers' type of employment, due as control variables significantly affect diet quality or SWFoL.

Our results also entail practical implications. As the three family members have diets that require changes to be considered healthy, interventions should be targeted at a family level. For instance, both parents should be encouraged to have a healthy diet to be a model for their partner's and adolescent children's eating habits, and should be encouraged to use other positive FPP. Interventions and policies that foster motivation, knowledge, and access to resources to establish healthy diets is particularly relevant in dual-earner families with adolescent children, because workers' high job demands can entail lower diet quality for the worker and their families (20, 45, 46), and because adolescents' diet quality tends to decrease during this stage of life (7, 9). Furthermore, unhealthy diet has been associated with modern health-related issues such as obesity, diabetes, and cardiovascular disease, as well as with lower work performance in workers (79). Therefore, our findings also underscore the need for policymakers and organizations to promote healthy eating habits in working parents, with emphasis on working fathers.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Scientific Committee of the Universidad de La Frontera. Written informed consent to participate in this study was provided by the participants' legal guardian/ next of kin.

AUTHOR CONTRIBUTIONS

BS conceptualized the study. EM-Z conducted the analysis. EM-Z and HP handled the databases. KB collected data. MS, GL, CA-B, and ML provided support throughout data collection and manuscript preparation. BS and LO wrote the first draft and the final version of the manuscript. KG provided support for manuscript preparation. All authors reviewed and approved the final version of the manuscript.

FUNDING

This study was funded by FONDECYT Project no. 1190017.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.902103/full#supplementary-material

REFERENCES

1. Vaughn AE, Tabak RG, Bryant MJ, Ward DS. Measuring parent food practices: a systematic review of existing measures and examination of instruments. *Int J Behav Nutr Phys Act.* (2013) 10:1–27. doi: 10.1186/1479-5868-10-61
2. Vaughn AE, Ward DS, Fisher JO, Faith MS, Hughes SO, Kremers SP, et al. Fundamental constructs in food parenting practices: a content map to guide future research. *Nutr Rev.* (2016) 74:98–117. doi: 10.1093/nutrit/nuv061
3. Piccoli ÂB, Neiva-Silva L, Mosmann CP, Musher-Eizenman D, Pellanda LC. Adolescents' perception of parental feeding practices: adaptation and validation of the comprehensive feeding practices questionnaire for Brazilian adolescents-the CFPQ-teen. *PLoS One.* (2017) 12:e0187041. doi: 10.1371/journal.pone.0187041
4. Schnettler B, Rojas J, Grunert KG, Lobos G, Miranda-Zapata E, Lapo M, et al. Family and food variables that influence life satisfaction of mother-father-adolescent triads in a South American country. *Curr Psychol.* (2021) 40:3747–64. doi: 10.1007/s12144-019-00328-4
5. Loth KA, MacLehose RF, Larson N, Berge JM, Neumark-Sztainer D. Food availability, modeling and restriction: how are these different aspects of the family eating environment related to adolescent dietary intake? *Appetite.* (2016) 96:80–6. doi: 10.1016/j.appet.2015.08.026
6. Melbye EL, Øgaard T, Øverby NC. Validation of the comprehensive feeding practices questionnaire with parents of 10-to-12-year-olds. *BMC Med Res Methodol.* (2011) 11:113. doi: 10.1186/1471-2288-11-113
7. Balantekin KN, Anzman-Frasca S, Francis LA, Ventura AK, Fisher JO, Johnson SL. Positive parenting approaches and their association with child eating and weight: a narrative review from infancy to adolescence. *Pediatr Obes.* (2020) 15:e12722. doi: 10.1111/ijpo.12722
8. Lopez NV, Schembre S, Belcher BR, O'Connor S, Maher JP, Arbel R, et al. Parenting styles, food-related parenting practices, and children's healthy eating: a mediation analysis to examine relationships between parenting and child diet. *Appetite.* (2018) 128:205–13. doi: 10.1016/j.appet.2018.06.021
9. Gunther C, Reicks M, Banna J, Suzuki A, Topham G, Richards R, et al. Food parenting practices that influence early adolescents' food choices during independent eating occasions. *J Nutr Educ Behav.* (2019) 51:993–1002. doi: 10.1016/j.jneb.2019.05.597
10. Brizi A, Biraglia A. "Do I have enough food?" How need for cognitive closure and gender impact stockpiling and food waste during the COVID-19 pandemic: a cross-national study in India and the United States of America. *Pers Individ Differ.* (2021) 168:110396. doi: 10.1016/j.paid.2020.110396
11. Philippe K, Chabanet C, Issanchou S, Monnery-Patris S. Child eating behaviors, parental feeding practices and food shopping motivations during

the COVID-19 lockdown in France: (how) did they change? *Appetite.* (2021) 161:105132. doi: 10.1016/j.appet.2021.105132
12. Berge JM, Hazzard VM, Larson N, Hahn SL, Emery RL, Neumark-Sztainer D. Are there protective associations between family/shared meal routines during COVID-19 and dietary health and emotional well-being in diverse young adults? *Prev Med Rep.* (2021) 24:101575. doi: 10.1016/j.pmedr.2021.101575
13. Grunert KG, De Bauw M, Dean M, Lähteenmäki L, Maison D, Pennanen K, et al. No lockdown in the kitchen: how the COVID-19 pandemic has affected food-related behaviours. *Food Res Int.* (2021) 150:110752. doi: 10.1016/j.foodres.2021.110752
14. Jansen E, Thapaliya G, Aghababian A, Sadler J, Smith K, Carnell S. Parental stress, food parenting practices and child snack intake during the COVID-19 pandemic. *Appetite.* (2021) 161:105119. doi: 10.1016/j.appet.2021
15. Schnettler B, Miranda-Zapata E, Orellana L, Grunert KG, Poblete H, Lobos G, et al. Work-to-family enrichment and atmosphere of family meals influence satisfaction with food-related life: an actor-partner interdependence approach in dual-earner parents with adolescent children. *Food Qual Prefer.* (2022) 97:104471. doi: 10.1016/j.foodqual.2021.104471
16. Jennings KM, Loth KA, Tate AD, Miner MH, Berge JM. Application of latent profile analysis to define subgroups of parenting styles and food parenting practices. *Appetite.* (2019) 139:8–18. doi: 10.1016/j.appet.2019.04.001
17. Patel C, Karasouli E, Shuttlewood E, Meyer C. Food parenting practices among parents with overweight and obesity: a systematic review. *Nutrients.* (2018) 10:1966. doi: 10.3390/nu10121966
18. Musher-Eizenman D, Holub S. Comprehensive feeding practices questionnaire: validation of a new measure of parental feeding practices. *J Pediatr Psychol.* (2007) 32:960–72. doi: 10.1093/jpepsy/jsm037
19. Rahill S, Kennedy A, Kearney J. A review of the influence of fathers on children's eating behaviours and dietary intake. *Appetite.* (2020) 147:104540. doi: 10.1016/j.appet.2019.104540
20. Garrido-Fernández A, García-Padilla FM, Sánchez-Ramos JL, Gómez-Salgado J, Sosa-Cordobés E. The family as an actor in high school students' eating habits: a qualitative research study. *Foods.* (2020) 9:419. doi: 10.3390/foods9040419
21. Jaeger MM, Vieth G, Rothman AJ, Simpson JA. Parents' use of intentional modeling and social control to influence their adolescent's health behavior: findings from the FLASHE study. *J Soc Pers Relationsh.* (2021) 38:2722–41. doi: 10.1177/02654075211020136
22. Thomson JL, Hennessy E, Landry AS, Goodman MH. Patterns of food parenting practices regarding junk food and sugary drinks among parent-child dyads. *Nutr J.* (2020) 19:91. doi: 10.1186/s12937-020-00610-3
23. Yee AZ, Lwin MO, Ho SS. The influence of parental practices on child promotive and preventive food consumption behaviors: a systematic review and meta-analysis. *Int J Behav Nutr Phys Act.* (2017) 14:1–14. doi: 10.1186/s12966-017-0501-3
24. Zarychta K, Mullan B, Luszczynska A. It doesn't matter what they say, it matters how they behave: parental influences and changes in body mass among overweight and obese adolescents. *Appetite.* (2016) 96:47–55. doi: 10.1016/j.appet.2015.08.040
25. Beckers D, Karssen LT, Vink JM, Burk WJ, Larsen JK. Food parenting practices and children's weight outcomes: a systematic review of prospective studies. *Appetite.* (2021) 158:105010. doi: 10.1016/j.appet.2020.105010
26. Blaine RE, Kachurak A, Davison KK, Klabunde R, Fisher JO. Food parenting and child snacking: a systematic review. *Int J Behav Nutr Phys Act.* (2017) 14:146. doi: 10.1186/s12966-017-0593-9
27. Baltaci A, Alvarez de Davila S, Reyes Peralta AO, Laska MN, Larson N, Hurtado GA, et al. Adolescent-reported Latino fathers' food parenting practices and family meal frequency are associated with better adolescent dietary intake. *Int J Environ Res Public Health.* (2021) 18:8226. doi: 10.3390/ijerph18158226
28. De-Jongh O, Tugault-Lafleur CN, O'Connor TM, Hughes SO, Mâsse LC. Are fathers' and mothers' food parenting practices differentially associated with children's eating behaviors? *Appetite.* (2021) 166:105434. doi: 10.1016/j.appet.2021.105434
29. Fleary SA, Ettienne R. The relationship between food parenting practices, parental diet and their adolescents' diet. *Appetite.* (2019) 135:79–85. doi: 10.1016/j.appet.2019.01.008
30. Litchford A, Roskos MRS, Wengreen H. Influence of fathers on the feeding practices and behaviors of children: a systematic review. *Appetite.* (2020) 147:104558. doi: 10.1016/j.appet.2019.104558
31. Sharif MZ, Alcalá HE, Albert SL, Fischer H. Deconstructing family meals: do family structure, gender and employment status influence the odds of having a family meal? *Appetite.* (2017) 114:187–93. doi: 10.1016/j.appet.2017.03.032
32. Schnettler B, Orellana L, Miranda-Zapata E, Saracostti M, Poblete H, Lobos G, et al. Diet quality during the COVID-19 pandemic: effects of workplace support for families and work-to-family enrichment in dual-earner parents with adolescent children. *Appetite.* (2022) 169:105853. doi: 10.1016/j.appet.2021.105823
33. van den Broek N, Larsen J, Verhagen M, Burk WJ, Vink JM. Is adolescents' food intake associated with exposure to the food intake of their mothers and best friends? *Nutrients.* (2020) 12:786. doi: 10.3390/nu12030786
34. Zhang Y, Reyes Peralta A, Arellano Roldan Brazys P, Hurtado GA, Larson N, Reicks M. Development of a survey to assess Latino fathers' parenting practices regarding energy balance–related behaviors of early adolescents. *Health Educ Behav.* (2020) 47:123–33. doi: 10.1177/1090198119878769
35. Verjans-Janssen S, Van Kann D, Kremers S, Vos S, Jansen M, Gerards S. A cross-sectional study on the relationship between the family nutrition climate and children's nutrition behavior. *Nutrients.* (2019) 11:2344. doi: 10.3390/nu11102344
36. Schnettler B, Lobos G, Miranda-Zapata E, Denegri M, Ares G, Hueche C. Diet quality, satisfaction with life, family life and food-related life across families: a cross-sectional pilot study with mother-father-adolescent triads. *Int J Environ Res Public Health.* (2017) 14:1313. doi: 10.3390/ijerph14111313
37. Kerr ME, Bowen M. *Family Evaluation*. New York, NY: Norton (1988).
38. Ministerio de Salud de Chile. *Encuesta Nacional de Consumo Alimentario*. (2021). Available online at: https://www.minsal.cl/sites/default/files/ENCA.pdf (accessed July 14, 2021).
39. Schnettler B, Grunert KG, Lobos G, Miranda-Zapata E, Denegri M, Hueche C. Maternal food-related practices, quality of diet, and well-being: profiles of Chilean mother-adolescent dyads. *J Nutr Educ Behav.* (2018) 50:776–87. doi: 10.1016/j.jneb.2018.03.003
40. Schnettler B, Grunert KG, Lobos G, Miranda-Zapata E, Denegri M, Ares G, et al. A latent class analysis of family eating habits in families with adolescents. *Appetite.* (2018) 129:37–48. doi: 10.1016/j.appet.2018.06.035
41. Schnettler B, Grunert KG, Lobos G, Miranda-Zapata E, Denegri M, Hueche C. Exploring relationships between family food behaviour and well-being in single-headed and dual-headed households with adolescent children. *Curr Psychol.* (2021) 40:585–600. doi: 10.1007/s12144-018-9974-8
42. Utter J, Denny S, Lucassen M, Dyson B. Adolescent cooking abilities and behaviors: associations with nutrition and emotional well-being. *J Nutr Educ Behav.* (2016) 48:35–41. doi: 10.1016/j.jneb.2015.08.016
43. Utter J, Denny S, Farrant B, Cribb S. Feasibility of a family meal intervention to address nutrition, emotional wellbeing, and food insecurity of families with adolescents. *J Nutr Educ Behav.* (2019) 51:885–92. doi: 10.1016/j.jneb.2019.03.015
44. Grunert KG, Dean M, Raats MM, Nielsen NA, Lumbers M. A measure of satisfaction with food-related life. *Appetite.* (2007) 49:486–93. doi: 10.1016/j.appet.2007.03.010
45. Djupegot IL, Nenseth CB, Bere E, Bjørnarå HBT, Helland SH, Øverby NC, et al. The association between time scarcity, sociodemographic correlates and consumption of ultra-processed foods among parents in Norway: a cross-sectional study. *BMC Public Health.* (2017) 17:447. doi: 10.1186/s12889-017-4408-3
46. Takeda W, Melby MK, Ishikawa Y. Who eats with family and how often? Household members and work styles influence frequency of family meals in urban Japan. *Appetite.* (2018) 125:160–71. doi: 10.1016/j.appet.2016.04.034
47. Kenny DA, Kashy DA, Cook WL. *Dyadic Data Analysis*. New York, NY: Guilford press (2006).
48. Loth KA, Friend S, Horning ML, Neumark-Sztainer D, Fulkerson JA. Directive and non-directive food-related parenting practices: associations between an expanded conceptualization of food-related parenting practices and child dietary intake and weight outcomes. *Appetite.* (2016) 107:188–95. doi: 10.1016/j.appet.2016.07.036
49. Ma Z, Hample D. Modeling parental influence on teenagers' food consumption: an analysis using the family life, activity, sun, health, and eating

(FLASHE) survey. *J Nutr Educ Behav*. (2018) 50:1005–14. doi: 10.1016/j.jneb.2018.07.005
50. Côté M, Gagnon-Girouard MP, Sabourin S, Bégin C. Emotion suppression and food intake in the context of a couple discussion: a dyadic analysis. *Appetite*. (2018) 120:109–14. doi: 10.1016/j.appet.2017.08.029
51. Schnettler B, Miranda-Zapata E, Orellana L, Bech-Larsen T, Grunert KG. The effects of actor-partner's meal production focus on satisfaction with food related life in cohabiting couples. *Food Qual Prefer*. (2020) 84:103949. doi: 10.1016/j.foodqual.2020.103949
52. van Vleet M, Helgeson V, Korytkowski M, Seltman H, Hausmann L. Communally coping with diabetes: an observational investigation using the actor-partner interdependence model. *J Fam Psychol*. (2018) 32:654–63. doi: 10.1037/fam0000414
53. Cornelius T, Desrosiers A, Kershaw T. Spread of health behaviors in young couples: how relationship power shapes relational influence. *Soc Sci Med*. (2016) 165:46–55. doi: 10.1016/j.socscimed.2016.07.030
54. Ismael D, Ploeger A. The potential influence of organic food consumption and intention-behavior gap on consumers' subjective wellbeing. *Foods*. (2020) 9:650. doi: 10.3390/foods9050650
55. Liu R, Grunert KG. Satisfaction with food-related life and beliefs about food health, safety, freshness and taste among the elderly in China: a segmentation analysis. *Food Qual Prefer*. (2019) 79:103775. doi: 10.1016/j.foodqual.2019.103775
56. Oliveira L, Poínhos R, de Almeida MDV. Food-related quality of life among older adults living in community: a multi-factorial approach. *Clin Nutr ESPEN*. (2021) 44:224–9. doi: 10.1016/j.clnesp.2021.06.013
57. Schnettler B, Grunert KG, Lobos G, Miranda-Zapata E, Denegri M, Lapo M, et al. Maternal well-being, food involvement and quality of diet: profiles of single mother-adolescent dyads. *Child Youth Serv Rev*. (2019) 96:336–45. doi: 10.1016/j.childyouth.2018.11.020
58. Vaqué-Crusellas C, González M, Casas F. Does satisfaction with food matter? testing the personal well-being index-school children (PWI-SC) with an additional item on satisfaction with food on a sample of 10 to 12-year-olds. *Child Ind Res*. (2015) 8:961–73. doi: 10.1007/s12187-015-9301-y
59. Schnettler B, Hueche C, Andrades J, Ares G, Miranda H, Orellana L, et al. How is satisfaction with food-related life conceptualized? A comparison between parents and their adolescent children in dual-headed households. *Food Qual Prefer*. (2020) 86:104021. doi: 10.1016/j.foodqual.2020.104021
60. Diener ED, Emmons RA, Larsen RJ, Griffin S. The satisfaction with life scale. *J Pers Assess*. (1985) 49:71–5. doi: 10.1207/s15327752jpa4901_13
61. Schnettler B, Miranda-Zapata E, Grunert KG, Lobos G, Lapo M, Hueche C. Satisfaction with food-related life and life satisfaction: a triadic analysis in dual-earner parents families. *Cad Saude Publica*. (2020) 36:e00090619. doi: 10.1590/0102-311X00090619
62. O'Connor T, Perez O, Garcia IC, Gallagher M. Engaging Latino fathers in children's eating and other obesityrelated behaviors: a review. *Curr Nutr Rep*. (2018) 7:29–38. doi: 10.1007/s13668-018-0225-2
63. Melbye EL, Hansen H. Promotion and prevention focused feeding strategies: exploring the effects on healthy and unhealthy child eating. *Biomed Res Int*. (2015) 2015:306306. doi: 10.1155/2015/306306
64. Schnettler B, Denegri M, Miranda-Zapata E, Saracostti M. *Fondecyt Project 1190017 "Interrelaciones Trabajo-Familia-Alimentación y Satisfacción Vital en Familias Nucleares con dos Ingresos Parentales e Hijos Adolescentes, en Tres Regiones de Chile: Un Estudio Transversal y Longitudinal*. Santiago: Conicyt (2018).
65. Kennedy ET, Ohls J, Carlson S, Fleming K. The healthy eating index: design and applications. *J Am Diet Assoc*. (1995) 95:1103–8. doi: 10.1016/S0002-8223(95)00300-2
66. Norte AI, Ortiz R. Calidad de la dieta española según el índice de alimentación saludable. *Nutr Hosp*. (2011) 26:330–6. doi: 10.3305/nh.2011.26.2.4630
67. Schnettler B, Miranda H, Sepúlveda J, Denegri M, Mora M, Lobos G, et al. Psychometric properties of the satisfaction with food-related life scale: application in southern Chile. *J Nutr Educ Behav*. (2013) 45:443–9. doi: 10.1016/j.jneb.2012.08.003
68. Asociación de Investigadores de Mercado. *Cómo Clasificar los Grupos Socioeconómicos en Chile*. (2016). Available online at: http://www.iab.cl/wp-content/uploads/2015/12/Presentaci%C3%B3n-final-AIM.pdf (accessed May 23, 2018).
69. Hu LT, Bentler PM. Cutoff criteria for fit indexes in covariance structure analysis: conventional criteria versus new alternatives. *Struct Equ Model*. (1999) 6:1–55. doi: 10.1080/10705519909540118
70. Lau RS, Cheung GW. Estimating and comparing specific mediation effects in complex latent variable models. *Organ Res Methods*. (2012) 15:3–16. doi: 10.1177/1094428110391673
71. World Health Organization [WHO]. *Child Growth and Development*. (2007). Available online at: http://www.who.int/childgrowth/en/ (accessed May 26, 2016).
72. Ministerio de Salud de Chile. *Patrones de Crecimiento Para la Evaluación Nutricional de Niños, Niñas y Adolescentes, Desde el Nacimiento Hasta los 19 Años de Edad*. (2018). Available online at: http://www.bibliotecaminsal.cl/wp/wp-content/uploads/2018/03/2018.03.16-Patrones-de-crecimiento-para-la-evaluaci%C3%B3n-nutricional-de-ni%C3%B1os-ni%C3%B1as-y-adolescentes-2018.pdf (accessed May 26, 2021).
73. Magson N, Freeman J, Rapee R, Richardson C, Oar E, Fardouly J. Risk and protective factors for prospective changes in adolescent mental health during the COVID-19 pandemic. *J Youth Adolesc*. (2020) 50:44–57. doi: 10.1007/s10964-020-01332-9
74. Garcia RL, Kenny DA, Ledermann T. Moderation in the actor–partner interdependence model. *Pers Relationsh*. (2015) 22:8–29. doi: 10.1111/pere.12060
75. Schnettler B, Miranda-Zapata E, Orellana L, Poblete H, Lobos G, Lapo M, et al. Domain satisfaction and overall life satisfaction: testing the spillover-crossover model in Chilean dual-earner couples. *Int J Environ Res Public Health*. (2020) 17:7554. doi: 10.3390/ijerph17207554
76. Schnettler B, Miranda-Zapata E, Grunert KG, Lobos G, Lapo M, Hueche C. Testing the spillover-crossover model between work-life balance and satisfaction in different domains of life in dual-earner households. *Appl Res Qual Life*. (2021) 16:1475–501. doi: 10.1007/s11482-020-09828-z
77. Yucel D, Latshaw BA. Spillover and crossover effects of work-family conflict among married and cohabiting couples. *Soc Ment Health*. (2020) 10:35–60. doi: 10.1177/2156869318813006
78. Instituto Nacional de Estadísticas. *Censo de Población y Vivienda 2017*. (2018). Available online at: http://www.censo2017.cl/ (accessed August 5, 2019).
79. Liu Y, Song Y, Koopmann J, Wang M, Chang CHD, Shi J. Eating your feelings? Testing a model of employees' work-related stressors, sleep quality, and unhealthy eating. *J Appl Psychol*. (2017) 102:1237. doi: 10.1037/apl0000209

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Nutrition

ORIGINAL RESEARCH
published: 23 May 2022
doi: 10.3389/fnut.2022.893963

Comparative Study Regarding the Adherence to the Mediterranean Diet Among Older Adults Living in Lebanon and Syria

Joanne Karam[1], *Carole Serhan*[2], *Eman Swaidan*[1] *and Mireille Serhan*[3]*

[1] Department of Nutrition and Dietetics, Modern University for Business and Science, Beirut, Lebanon, [2] Department of Business Management and Administration, University of Balamand, Beirut, Lebanon, [3] Department of Nutritional Sciences, Faculty of Health Sciences, University of Balamand, Beirut, Lebanon

The Mediterranean diet (MedDiet) has been associated with many health benefits. Poor adherence to MedDiet has been found among Lebanese adults, while in Syria, little is known about the adherence to MedDiet. A quantitative research approach was used, and data were collected through convenience sampling. The structure of the survey included the socio-economic and demographic data and the validated 14-point MedDiet assessment tool. The target population included 367 Lebanese and Syrian adults respectively residing in Lebanon and Syria. Descriptive statistics were used to explore the characteristics of the sample population. Adequate adherence MedDiet was determined if the Med-Diet score $\geq$ 9. Significant differences among the variables and the adherence to the MedDiet were examined using the chi-square test. Approximately 47.42% of participants reported adherence to MedDiet higher than 9, with a mean of 7.98. Lebanese participants, men, and those who are aged between 64 and 67, had higher adherence than Syrian participants, women, and other age groups, respectively. Lebanese participants (7.82 $\pm$ 2.32) had slightly higher adherence than Syrian participants (7.31 $\pm$ 2.04). Wine, *sofrito*, vegetables, and olive oil were mostly consumed by participants, with differences in consumption between the Lebanese and Syrian adults. The statistical analysis performed using the chi-square test showed no statistical difference ($P>.05$) between Lebanese and Syrian participants regarding their consumption of 160 red meat, butter/margarine, and sugary drinks. Future studies in the aged population are required to explore furthermore the adherence to MedDiet in Lebanon and Syria and its impact on health.

Keywords: MedDiet, dietary habits, older adults, Lebanon, Syria

OPEN ACCESS

Edited by:
Maha Hoteit,
Lebanese University, Lebanon

Reviewed by:
Yonna Sacre,
Holy Spirit University of Kaslik, Lebanon
Sophie Julien,
Holy Spirit University of Kaslik, Lebanon

***Correspondence:**
Mireille Serhan
mireille.serhan@balamand.edu.lb

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

Received: *11 March 2022*
Accepted: *19 April 2022*
Published: *23 May 2022*

Citation:
Karam J, Serhan C, Swaidan E and Serhan M (2022) Comparative Study Regarding the Adherence to the Mediterranean Diet Among Older Adults Living in Lebanon and Syria. Front. Nutr. 9:893963. doi: 10.3389/fnut.2022.893963

INTRODUCTION

The Mediterranean Diet (MedDiet) represents a healthy dietary pattern in the context of healthy lifestyle habits. Epidemiological studies have shown that a higher degree of adherence to the MedDiet pattern is associated with reduced mortality concerning deaths due to cancer (1). Better control of diabetes through a protective role on glycemic control and a reduction in cardiovascular risk are also favored by the adoption of this dietary pattern (2). Moreover, MedDiet is significantly associated with less overweight and more weight loss (3).

In addition to its well-documented beneficial effects on health, MedDiet is considered a key component for healthy aging and might contribute to the onset of frailty at late stages of life (4). In older adults, the adherence to MedDiet moderates the association between multimorbidity and depressive symptoms (5). Greater adherence to a MedDiet was associated with better lower extremity physical performance in older adults with type 2 diabetes mellitus (T2DM) (6). Coelho-Júnior et al. (7) have investigated the association between adherence to MedDiet and physical performance and cognitive function in older adults (7). Results of the aforementioned study revealed that high adherence to MedDiet reduced the risk of global cognitive decline in non-demented older adults. Many observational studies led to the assumption that MedDiet could be a healthy eating pattern against cognitive and physical impairment in older adults (8–10).

Over the past few years, there has been a great effort to study the adherence to this Mediterranean-style diet, among the adult and older adult population in several Mediterranean and Gulf countries. In Spain, the influence of adherence to the MedDiet and its components on early vascular aging has been widely investigated (11). In Greece, adherence to the MedDiet is associated with higher levels of successful aging (12). In Italy, higher adherence scores were observed in females compared to males, and in elderly people compared to young people (13). Adherence to the MedDiet among the Cypriot adult population was associated with male sex, age >45 y, being married, being physically active, and being resident of rural regions (14). In Turkey, adherence to the MedDiet in hospitalized Turkish older adults and its association with hospital clinical outcomes was assessed (15). Moreover, in Gulf countries, the adherence to the MedDiet among adult participants from Saudi Arabia, Oman, and Kuwait was low (16).

In Lebanon, few studies were found to assess the compliance with the MedDiet (17–19). Poor adherence to MedDiet has been found among the Lebanese adult University students (20) and the adult population during the COVID-19 outbreak and the economic crisis (21). Other studies assessed the adherence to MedDiet in adolescents (22, 23) and among youth (24). However, in Syria, little is known about the adherence to MedDiet. (25) have evaluated the lifestyle factors, along with biomarkers related to cardiovascular risk factors in a group of university female students. The average adherence to the Mediterranean dietary pattern was low (25). Another study has assessed the Mediterranean adequacy index in young Syrians (26).

To our knowledge, no previous studies have focused on the compliance with the MedDiet among older adults in Lebanon and Syria and no previous study has compared the adherence to the MedDiet among the aforementioned countries. It is crucial to mention that adherence to the MedDiet might be useful for developing strategies for improving diet quality and setting governmental preventive health policies for the aged population. Therefore, the present study aimed to assess the adherence to the MedDiet among older adults from two Mediterranean countries (Lebanon and Syria) using a validated 14-item questionnaire.

MATERIALS AND METHODS

Sampling Method

To overcome the practical difficulty of accessing participants from different geographical locations, a quantitative research approach was applied based on the distribution of an online survey throughout different social media platforms *via* networking. The target population of this research study included older Lebanese adults (45 and above) residing in Lebanon, and older Syrian adults (45 and above) residing in Syria. Lebanese and Syrian participants aged below 45 years old were not eligible to participate in the study, since they do not fit our age recommendations. A convenience sampling technique was used in this research.

Population and Sample Size Calculation

The sample size was 367 participants from both countries (185 Lebanese vs. 183 Syrian). The sample size of 367 was considered enough, considering the target population of both the older Lebanese and Syrian adults, and through the determination with the sample size software, G*Power, version 3.1.3; margin of error of 5% confidence level of 95% (27). Data collection took place between July 2021 and December 2021.

Ethical Considerations

This study received approval from the ethical committee of the Modern University of Business and Science (*approval reference MU-20210222-21, February 24th, 2021*). Older adult respondents provided written informed consent before filling out the questionnaire, and their confidentiality was protected. The collected data were solely used for scientific and research purposes.

Study Tool

An online survey, created using Google Forms, was distributed. The structure of the survey included (1) the socio-economic and demographic data; (2) the validated Mediterranean Diet Assessment Tool. The validated Mediterranean diet (Med-diet) tool contained 14 items (1-point criteria for each item) to assess the participant's adherence to the diet, developed by the Prevención con Dieta Mediterránea (PREDIMED) consortium (28, 29). The score of adherence was calculated by summing the points of the 14 questions ("Yes" answer was one point, "No" was zero point; the results ranged between 0 and 14). The overall score of < 9 points represented participants with low adherence, while the overall score of ≥ 9 points was used to identify participants with high adherence. This questionnaire has been adapted to and validated for the Spanish population (30) and then adapted in an English version to be implemented in other populations (31). The English version of the questionnaire was subsequently translated into Arabic. The latter is the native language of the participants. The questionnaire was piloted with 30 respondents (15 Lebanese vs. 15 Syrian) to determine the extent of their understanding of sentences and the time taken to answer questions. To determine the internal consistency of the survey questionnaire, a Cronbach's alpha coefficient reliability analysis was performed. This method shows an indication of the average correlation between all the items of the research questionnaire on the Likert scale, in this

TABLE 1 | Mean adherence to mediterranean diet.

Variables		*N*	%	Mean (SD)
Total		367	100.0	7.98 (2.11)
Age (grouped data)	45-63	320	87.2	7.48 (2.18)
	64-67	19	5.2	8.01 (2.27)
	≥68	28	7.6	7.57 (2.35)
Gender	Men	129	35.1	8.53 (2.47)
	Women	238	64.9	7.34 (2.29)
Nationality	Lebanese	185	50.4	7.82 (2.32)
	Syrian	183	49.6	7.31 (2.04)

case. The Cronbach's alpha coefficient for the questionnaire was measured to be 0.960. The findings generated from the pilot study were not considered in the final data analysis.

Data Analysis

Data were processed and analyzed by the SPSS statistical software, Windows Version 23.0 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics including means of scores and standard deviations were used, to meet the study objectives. Frequencies were computed to examine the demographic and behavioral characteristics of the sample population. To determine their high adherence to Med-Diet, the Med-Diet score of ≥9 is used. A non-parametric test (chi-square) was employed to analyze the significant difference among the variables of gender, age, nationality, and adherence to the Mediterranean diet.

RESULTS

Mean adherence to Mediterranean Diet among the participants is shown in **Table 1**. Among the 367 participants, the mean MedDiet adherence score was 7.98 (± SD 2.11). Those who are aged between 64 and 67 had a higher mean (8.01 ± 2.27) than other age groups, followed by those aged 45 to 63 (7.48 ± 2.18). Men (8.53 ± 2.47) had a higher adherence compared to women (7.34 ± 2.29). Lebanese participants (7.82 ± 2.32) had slightly higher adherence than Syrian participants (7.31 ± 2.04).

Table 2 shows the adequacy of adherence to the Mediterranean Diet according to different variables. About 47.42% of participants reported higher adherence to MedDiet than the adequate adherence score (≥ 9), while 52.58% of the participants had an adherence score lower than 9. Those who are aged between 45 and 63, as well as older than 68, showed similar adequacy of adherence (48.44% and 48.43%, respectively), higher than other age groups (64–67: 31.58%). Men (48.07%) and women (47.06%) reported similar adherence adequacy. Lebanese participants (49.73%) displayed higher adequacy of adherence than Syrian participants (45.06%). Specifically, Lebanese participants residing in Mount Lebanon (52.95%) and the North province (47.06) had lower adherence adequacy than other areas (64.29%). Results, however, were not significant ($p > 0.05$)

Table 3 shows the stratification of adherence to Mediterranean Diet items. Most of the Lebanese and Syrian participants (78.74%) used olive oil as the main added fat, and 62.94% abided by the recommended quantity (four tablespoons or more). Vegetables (79.56%) were consumed by the participants according to MedDiet more than fruits (40.05%); 93.46% of the sample consumed wine, and 75.20% of the consumed legumes, according to the recommendations. Only 7.35% of the participants referred to an adequate intake of fish or shellfish. About 58.85% of the participants consumed commercial sweets <3 times/week, and 41.14% consumed the recommended portions of nuts per week. Additionally, chicken, turkey, or rabbit was preferred by more than half of the participants (58.58%) instead of beef, pork, hamburgers, or sausages. Consumption of *sofrito*, which is a sauce made with olive oil, onion, garlic, and tomato, was also very common among participants (83.92%).

Lebanese participants consumed more olive oil (84.86%), fruits (53.51%), legumes (80%), and fish products (12.43%) than Syrian participants according to the MedDiet recommendations (**Table 3**). Lebanese participants also showed more tendency toward nuts (47.56%) and *sofrito* (86.48%) consumption. However, more Syrian participants consumed the recommended daily quantity of olive oil (65.93%), preferred chicken over meat (59.34%), and consumed more vegetables (82.41%), wine (97.80%), and processed desserts (60.43%) than Lebanese participants. The statistical analysis performed using the chi-square test showed no statistical difference ($P > .05$) between Lebanese and Syrian participants regarding their consumption of red meat, butter/margarine, and sugary drinks (Q5, Q6, and Q7).

DISCUSSION

The mean adherence to the MedDiet in our study (7.98) was similar to the adherence in Spain (8.6), among Lebanese adults (8) and university students (7.96), but higher than that in the UK (5.47) and Korea (6.2). Little is known about the adherence to MedDiet in Syria. Less than half of the participants (47.42%) had an adequate score of adherence to MedDiet (≥9). This can be explained by the economic crisis hitting Lebanon and Syria, which led to a major increase in prices of traditional and healthy foods, forcing citizens to shift toward less expensive products and generally higher in calories, thus, less adhering to the MedDiet (32).

Those who are aged 64 to 67 had a higher mean (8.01) than other age groups, similar to earlier studies, where being older was related to higher adherence; this result suggests that MedDiet is rooted in cultural heritage and food traditions, maintained by older generations (13, 32, 33). Younger generations are, on the other hand, shifting toward unhealthier food patterns due to the widespread of non-Mediterranean food groups and Western diets (32, 33). However, the population above 68 showed a decrease in adherence (7.57), which may be the result of the age-related chemosensory changes and health problems, as deterioration in taste and smell senses and salivary function was observed in 60–70 years adults, leading to problems in flavor perception and consumption of unhealthy food as the last form of pleasure (34).

TABLE 2 | Adequacy of adherence to MedDiet according to different variables.

Variables		Score <9		Score ≥9		*p**	Crude OR
		N	%	*N*	%		95% CI
Total		193	52.58	174	47.42		
Age	45–63	165	51.56	155	48.44	0.25	0.60
	64–67	13	68.42	6	31.58		(0.56–0.64)
	≥68	15	53.57	13	48.43		
Gender	Men	67	51.93	62	48.07	0.28	0.68
	Women	126	52.94	112	47.06		(0.65–0.70)
Nationality	Lebanese	93	50.27	92	49.73	0.15	0.82
	Syrian	100	54.94	82	45.06		(0.72–0.91)
Province in Lebanon	Mount Lebanon	16	47.05	18	52.95	0.68	1.02
	North	72	52.94	65	47.06		(1)
	Others	5	35.71	9	64.29		

OR, odds ratio; MedDiet, Mediterranean Diet; CI, confidence interval.
**Evaluated by chi-square test.*

TABLE 3 | Stratification of adherence to MedDiet items.

Med-Diet Survey	All				Lebanese				Syrian				*p**
	N	%	*N*	%	*N*	%	*N*	%	*N*	%	*N*	%	
	Yes		No		Yes		No		Yes		No		
Q1:Olive oil for cooking	289	78.74	78	21.26	157	84.86	28	15.14	132	72.52	50	27.48	0.04
Q2:Quantity of olive oil per day	231	62.94	136	37.06	111	60.00	74	40.00	120	65.93	62	34.07	0.02
Q3:Vegetables portion per day	292	79.56	75	20.44	142	76.75	43	23.25	150	82.41	32	17.59	0.03
Q4:Fruits portion per day	147	40.05	220	59.95	99	53.51	86	46.49	48	26.37	134	73.63	0.01
Q5:Red meat per day	266	72.47	101	27.53	120	64.86	65	35.14	146	80.21	36	19.79	0.18
Q6:Butter/ margarine portion per day	266	72.47	101	27.53	118	63.78	67	36.22	148	81.31	34	18.69	0.09
Q7:Sugary drinks portion per day	280	76.29	87	23.71	121	65.40	64	34.60	159	87.36	23	12.64	0.29
Q8:Wine portion per week	343	93.46	24	6.540	165	89.18	20	10.82	178	97.80	4	2,20	0.02
Q9:Legumes portion per week	276	75.20	91	24.80	148	80.00	37	20.00	128	70.32	54	29.68	0.03
Q10:Fish and fish products portion per Week	27	7.35	340	92.65	23	12.43	162	87.57	4	2.19	178	97.81	0.02
Q11:Processed deserts portion per week	216	58.85	151	41.15	106	57.29	79	42.71	110	60.43	72	39.57	0.03
Q12:Nuts portion per week	151	41.14	216	58.86	88	47.56	97	52.44	63	34.61	119	65.39	0.01
Q13:Consumption of chicken preferably over meat	215	58.58	152	41.42	107	57.83	78	42.17	108	59.34	74	40.66	0.05
Q14:Cooking vegetables, pasta, rice with olive oil, onion, garlic and tomato per week (*sofrito*)	308	83.92	59	16.08	160	86.48	25	13.52	148	81.31	34	18.69	0.01

**Lebanese vs. Syrian by chi-square test; MedDiet, Mediterranean diet.*

Differences in adherence were also seen among genders, where men had higher adherence than women This result is complementary to other studies, where females showed a lower adherence than males, among under 30-year-old Lebanese adults (35) and young Syrian people (26). This difference can be explained by the focus of women on body image, which leads to reducing calorie intake and healthy eating (36). The economic crisis also forced women to decrease their consumption of expensive products for the sake of their families (37), leading to a greater adherence among men, as higher adherence to MedDiet was associated with higher dietary costs, compared to lower costs for unhealthy foods (38).

Lebanese participants had slightly higher adherence than Syrian participants opposite to results obtained in 2004–2011, where Syria displayed a higher adherence than Lebanon (39). The current result can, thus, be explained by the increased food insecurity in Syria, which reached 55% of the population after the

protracted economic crisis and war, compared to 34% among the Lebanese population, in late 2020 (40, 41).

Most of the participants used olive oil as the main added fat, mainly among Lebanese participants This high consumption of olive oil in the two countries is based on its wide production, as it forms a dominant agro-industrial product (42). Although this consumption was much higher in Syria than in Lebanon back in 2016 (43), the Syrian war caused a sharp fall in the olive oil sector, affecting Syrian nutritive intake (44).

According to MedDiet, the participants consumed vegetables more than fruits The number of fruits consumed was dominant among the Lebanese participants, while more Syrian participants consumed vegetables. Fruits became unaffordable upon the reduction of agriculture due to the Syrian war (44). The coronavirus disease 2019 (COVID-19) pandemic has also affected the transportation and production of fruits and vegetables in Lebanon, changing the food patterns of consumers involuntarily (45).

Roughly 93.46% of the sample consumed wine, according to the MedDiet recommendations, Syrian participants might have also consumed alcohol as a coping strategy to the war situation, as psychological stress might cause increased consumption of wine, although more evidence is needed on the impact of the crisis on alcohol drinking. However, only 7.35% of the participants referred to an adequate intake of fish, which was higher in Lebanon. This result confirms the outcome of earlier studies showing a low consumption of fish products among the Lebanese adult population (35, 46). Around 41.14% of participants also consumed nuts, as consumers tended to reduce their consumption of fish and nuts due to their unaffordable prices (37).

On the other hand, 75.20% consumed legumes, mainly among Lebanese participants. As a result of the COVID-19 lockdowns in Lebanon, dietary diversity was declined, and cooking practices increasingly relied on grains, pasta, and legumes due to their low prices and high stocking (45). Also, Syrian adults traditionally consume pulses as their main source of energy, mostly among low-income populations (26).

About 58.85% consumed commercial sweets, and Syrian participants showed more inclination toward processed desserts consumption This increased consumption was another consequence of the COVID-19 pandemic, mainly among food insecure consumers who suffer from mental problems and anxiety (45).

Additionally, chicken was preferred by more than half of the participants over meat, primarily among the Syrian population This result is similar to other studies showing that Syrian populations are having a higher tendency toward protein intake, which is mainly chicken (26). Consumption of *sofrito* was also quite common among participants Cooking using *sofrito* is very usual among Mediterranean people as it is a typical Mediterranean sauce, strongly associated with a reduced risk of CVD (46).

Consequently, this study showed that although MedDiet is traditionally prevailing in Lebanon and Syria, some of its components might be affected by the economic crisis. The association between income and adherence has been recently studied among Lebanese adults during the COVID-19 outbreak and the current economic crisis; participants with average to high income had higher adherence mean compared to other participants with lower salaries (21).

However, more comprehensive research is needed to better investigate the food patterns and MedDiet adherence of adults, mainly among the Syrian population.

Strengths and Limitations

Mediterranean Diet has been assessed in Lebanon among the Lebanese young population. No previous studies have focused on the compliance with the MedDiet among older adults in Lebanon and Syria and no previous study has compared the adherence to the MedDiet among the aforementioned countries. Findings from this study might be useful for developing strategies for improving diet quality and setting governmental preventive health policies in the aged population. Moreover, our study includes several limitations that need to be acknowledged. First, the MedDiet assessment tool was conducted using a 14-question questionnaire validated among the Spanish population not among Lebanese and Syrian adults; however, the questionnaire was adapted to an English version used in other samples of young adults. Second, data were self-reported through an online survey, which might affect the accuracy of the results. Finally, this is a cross-sectional study, and, therefore, we acknowledge that we are not able to draw causal conclusions but only observations.

CONCLUSION

Around 47.42% of participants reported adherence to MedDiet higher than 9, with a mean of 7.98. Lebanese participants, men, and those who are aged between 64 and 67 had higher adherence than Syrian participants, women, and other age groups, respectively. Wine, *sofrito*, vegetables, and olive oil were mostly consumed by participants, with differences in consumption between the Lebanese and Syrian adults. However, the lack of studies in Syria emphasizes the need for further research on the dietary habits among its population. Awareness and policies must be also spread at national levels to improve the public adherence to MedDiet amid the crisis, thus, ensuring better health outcomes and economic sustainability.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Modern University of Business and Science Ethics Committee (approval reference MU-20210222-21, February 24th, 2021). The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MS and JK designed the study, wrote the protocol, conducted literature searches, and provided summaries of previous research studies. ES collected data. CS conducted the statistical analysis. All authors wrote the first draft of the manuscript, read, and agreed to the published version of the manuscript.

REFERENCES

1. Capurso C, Vendemiale G. The mediterranean diet reduces the risk and mortality of the prostate cancer: a narrative review. *Front Nutr.* (2017) 4:38. doi: 10.3389/fnut.2017.00038
2. Sleiman D, Al-Badri MR, Azar ST. Effect of Mediterranean diet in diabetes control and cardiovascular risk modification: a systematic review. *Front Public Health.* (2015) 3:69. doi: 10.3389/fpubh.2015.00069
3. D'innocenzo S, Biagi C, Lanari M. Obesity and the Mediterranean diet: a review of evidence of the role and sustainability of the Mediterranean diet. *Nutrients MDPI AG.* (2019) 11:1306. doi: 10.3390/nu11061306
4. Rahi B, Ajana S, Tabue-Teguo M, Dartigues JF, Peres K, Feart C. High adherence to a Mediterranean diet and lower risk of frailty among French older adults community-dwellers: results from the three-city-bordeaux study. *Clin Nutr*. (2018) 37:1293–8. doi: 10.1016/j.clnu.2017.05.020
5. Vicinanza R, Bersani FS, D'Ottavio E, Murphy M, Bernardini S, Crisciotti F, et al. Adherence to mediterranean diet moderates the association between multimorbidity and depressive symptoms in older adults. *Arch Gerontol Geriatr.* (2020) 1:88. doi: 10.1016/j.archger.2020.104022
6. McClure R, Villani A. Greater adherence to a Mediterranean diet is associated with better gait speed in older adults with type 2 diabetes mellitus. Clin Nutr ESPEN. (2019) 32:33–9. doi: 10.1016/j.clnesp.2019.05.009
7. Coelho-Júnior HJ, Trichopoulou A, Panza F. Cross-sectional and longitudinal associations between adherence to Mediterranean diet with physical performance and cognitive function in older adults: a systematic review and meta-analysis. *Ageing Res Rev.* (2021) 70:101395. doi: 10.1016/j.arr.2021.101395
8. Scarmeas N, Stern Y, Tang MX, Mayeux R, Luchsinger JA. Mediterranean diet and risk for Alzheimer's disease. *Ann. Neurol.* (2006) 59:912–21, 10.1002/ana.20854 doi: 10.1002/ana.20854
9. Trichopoulou A, Bamia C, Trichopoulos D. Anatomy of health effects of Mediterranean diet: Greek EPIC prospective cohort study. *BMJ.* (2009) 339:26–28. doi: 10.1136/bmj.b2337
10. Zbeida M, Goldsmith R, Shimony T, Yardi H, Naggan L, Shahar DR. Mediterranean diet and functional indicators among older adults in non-Mediterranean and Mediterranean countries. *J Nutr Heal Aging.* (2014)18:411–8, 10.1007/s12603-014-0003-9 doi: 10.1007/s12603-014-0003-9
11. Sánchez MG, Sánchez LG, Patino-Alonso MC, Alonso-Domínguez R, Sánchez-Aguadero N, Lugones-Sánchez C, et al. Adherence to the Mediterranean diet in Spanish population and its relationship with early vascular aging according to sex and age: EVA study. *Nutrients*. (2020) 12:1025. doi: 10.3390/nu12041025
12. Papadimitriou A, Foscolou A, Itsiopoulos C, Thodis A, Kouris-Blazos A, Brazionis L, et al. Adherence to the Mediterranean Diet and successful aging in Greeks living in Greece and abroad: the epidemiological Mediterranean Islands Study (MEDIS). *Nutr Health.* (2022). doi: 10.1177/02601060211072363. [Epub ahead of print].
13. Dinu M, Pagliai G, Giangrandi I, Colombini B, Toniolo L, Gensini G, et al. Adherence to the Mediterranean diet among Italian adults: results from the web-based Medi-Lite questionnaire. *Int J Food Sci Nutr*. (2020) 72:271–79. doi: 10.1080/09637486.2020.1793306
14. Kyprianidou M, Christophi CA, Giannakou K. Quarantine during COVID-19 outbreak: adherence to the Mediterranean diet among the Cypriot population. *Nutrition.* (2021) 1:90. doi: 10.1016/j.nut.2021.111313
15. Ergul F, Sackan F, Koc A, Guney I, Kizilarslanoglu MC. Adherence to the Mediterranean diet in Turkish hospitalized older adults and its association with hospital clinical outcomes. *Arch Gerontol Geriatr.* (2022) 99:104602. doi: 10.1016/j.archger.2021.104602
16. Shatwan IM, Alhinai EA, Alawadhi B, Surendran S, Aljefree NM, Almoraie NM. High adherence to the mediterranean diet is associated with a reduced risk of obesity among adults in gulf countries. *Nutrients*. (2021) 13:1–11. doi: 10.3390/nu13030995
17. El Hajj J, Julien S. Factors associated with adherence to the Mediterranean Diet and dietary habits among university students in Lebanon. *J Nut Metab.* (2021) 2021:6688462. doi: 10.1155/2021/6688462
18. Naja F, Itani L, Hamade R, Chamieh MC, Hwalla N. Mediterranean diet and its environmental footprints amid nutrition transition: the case of Lebanon," *Sustainability (Switzerland)*. (2019) 11:1–18. doi: 10.3390/su11236690
19. El Khoury CN. & Julien S. Inverse association between the mediterranean diet and COVID-19 risk in Lebanon: a case-control study. *Front Nutr.* (2021) 8:707359. doi: 10.3389/fnut.2021.707359
20. Karam J, Bibiloni MDM, Serhan M, Tur JA. Adherence to mediterranean diet among lebanese university students. *Nutrients.* (2021) 13:1264. doi: 10.3390/nu13041264
21. Karam J, Ghach W, Bouteen C, Makary MJ, Riman M, Serhan, M. Adherence 646 to Mediterranean diet among adults during the COVID-19 outbreak and 647 the economic crisis in Lebanon. *Nutrition Food Sci.* doi: 10.1108/NFS-10-2021-0325. [Epub ahead of print].
22. Hayek J, de Vries H, Tueni M, Lahoud N, Winkens B, Schneider F. Increased adherence to the mediterranean diet and higher efficacy beliefs are associated with better academic achievement: a longitudinal study of high school adolescents in lebanon. *Int J Environ Res Public Health.* (2021) 18:6928. doi: 10.3390/ijerph18136928
23. Mounayar R, Jreij R, Hachem J, Abboud F, Tueni M. Breakfast intake and factors associated with adherence to the Mediterranean diet among Lebanese high school adolescents," *J Nutr Metabolism.* (2019) 2019:2714286. doi: 10.1155/2019/2714286
24. Naja F, Hasan H, Khadem SH, Buanq MA, Al-Mulla HK, Aljassmi AK, et al. Adherence to the Mediterranean diet and its association with sleep quality and chronotype among youth: a cross-sectional study. *Front Nutr.* (2022) 19:8. doi: 10.3389/fnut.2021.805955
25. Dehneh N, Rajab M, Zarzour W, Jouma M. Profile of healthy female students in Syria: Investigation on anthropometric, lifestyle, and dietary characteristics, along with hematological and plasma biochemical parameters. *Cogent Med.* (2016) 3:1. doi: 10.1080/2331205X.2016.1180741
26. Atasi M. Mediterranean adequacy index in young people in Syria. *Asian J Pharmaceutical Res Health Care.* (2016) 8:112–21. doi: 10.18311/ajprhc/2016/4595
27. Hemming K, Girling AJ, Sitch AJ, Marsh J, Lilford RJ. Sample size calculations for cluster randomized controlled trials with a fixed number of clusters. *BMC Med Res Methodol.* (2011) 11:102, doi: 10.1186/1471-2288-11-102
28. Martínez-González MA, García-Arellano A, Toledo E, Salas-Salvadó J, Buil-Cosiales P, Corella D, et al. A 14-item Mediterranean Diet assessment tool and obesity indexes among high-risk. the PREDIMED trial. *PLoS ONE.* (2012) 7:e43134. doi: 10.1371/journal.pone.0043134
29. Bouzas C, Bibiloni MDM, Julibert A, Ruiz-Canela M, Salas-Salvadó J, Corella D, et al. Adherence to the Mediterranean lifestyle and desired bodyweight loss in a Mediterranean adult population with overweight: a PREDIMED-Plus study. *Nutrients.* (2020) 12:2114. doi: 10.3390/nu12072114
30. Schröder H, Fitó M, Estruch R, Martínez-González MA, Corella D, Salas-Salvadó J, et al. A Short screener is valid for assessing mediterranean diet adherence among older spanish men and women. *J Nutr*. (2011) 141:1140–5. doi: 10.3945/jn.110.135566
31. Papadaki A, Johnson L, Toumpakari Z, England C, Rai M, Toms S, et al. Validation of the English version of the 14-item mediterranean diet adherence screener of the PREDIMED study, in people at high cardiovascular risk in the UK. *Nutrients.* (2018) 10:20138. doi: 10.3390/nu10020138
32. Marventano S, Godos J, Platania A, Galvano F, Mistretta A, Grosso G. Mediterranean diet adherence in the Mediterranean healthy eating, aging

and lifestyle (MEAL) study cohort. *Int J Food Sci Nutr*. (2018) 69:100–7. doi: 10.1080/09637486.2017.1332170
33. Buscemi S. What are the determinants of adherence to the mediterranean diet? *Int J Food Sci Nutr*. (2021) 72:143–4. doi: 10.1080/09637486.2021.1889995
34. Spence C, Youssef J. Aging and the (Chemical) senses: implications for food behaviour amongst elderly consumers. *Foods*. (2021) 10:168. doi: 10.3390/foods10010168
35. Farhat AG, Jaalouk D, Francis S. Adherence to the Mediterranean diet in a Lebanese sample. *Nutr Food Sci*. (2016) 46:272–81. doi: 10.1108/NFS-09-2015-0108
36. Musaiger AO, Kalam F. Dietary habits and lifestyle among adolescents in Damascus, Syria. *Ann Agric Environ Med*. (2014) 21:416–9. doi: 10.5604/1232-1966.1108616
37. Pan W-H, Hsieh Y-T, Wahlqvist ML. Gender-specific roles and needs in food-health security. *Asia Pac J Clin Nutr*. (2009) 18:642-6
38. Tong TYN, Imamura F, Monsivais P, Brage S, Griffin SJ, Wareham NJ, et al. Dietary cost associated with adherence to the Mediterranean diet, and its variation by socio-economic factors in the UK Fenland Study. *British J Nutr*. (2018) 119:685–94. doi: 10.1017/S0007114517003993
39. Vilarnau C, Stracker DM, Funtikov A, da Silva R, Estruch R, Bach-Faig A. Worldwide adherence to Mediterranean Diet between 1960 and 2011. *Eur J Clin Nutr*. (2019) 72:83–91. doi: 10.1038/s41430-018-0313-9
40. WFP. WFP-0000136870. *WFP Syria Country Brief*. (2021). Available online at: www.wfp.org/countries/Syria.
41. Idal, *Investment Development Authority in Lebanon, Olive Oil Industry in Lebanon 2017 Factsheet 2 Sector: Overview Main Geographical Features Olive Oil Production Olive Oil Mills*. p. 1–14.
42. Statista Research Department. *Value of Olive Oil Consumption in the Middle East and North Africa in 2016 by Country*. (2022).
43. Alolabi H, Alchallah MO, Mohsen F, Marrawi M, Alour Z. *Social and psychosocial factors affecting eating habits Among University Students in Syria: A Cross-Sectional Study*. (2021). doi: 10.21203/rs.3.rs-559421/v1
44. Hoteit M, Mortada H, Al-Jawaldeh A, Ibrahim C, Mansour R. COVID-19 home isolation and food consumption patterns: investigating the correlates of poor dietary diversity in Lebanon: a cross-sectional study. *F1000Res*. (2022) 11:110. doi: 10.12688/f1000research.75761.1
45. Vallverdú-Queralt A, Alvarenga JFR de, Estruch R, Lamuela-Raventos RM. Bioactive compounds present in the Mediterranean sofrito. *Food Chem*. (2013) 141:3365–72. doi: 10.1016/j.foodchem.2013.06.032
46. de Goeij MCM, Suhrcke M, Toffolutti V, van de Mheen D, Schoenmakers TM, Kunst AE. How economic crises affect alcohol consumption and alcohol-related health problems: a realist systematic review. *Soc Sci Med*. (2015) 131:131–46. doi: 10.1016/j.socscimed.2015.02.025

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Sustainable Food Systems

SYSTEMATIC REVIEW
published: 30 May 2022
doi: 10.3389/fsufs.2022.882939

Systematic Review: Heat Treatments on Phenolic Content, Antioxidant Activity, and Sensory Quality of Malaysian Mushroom: Oyster (*Pleurotus* spp.) and Black Jelly (*Auricularia* spp.)

Inshirah Izham[1], *Farhat Avin*[2] *and Siva Raseetha*[1]*

[1] Faculty of Applied Sciences, Universiti Teknologi MARA, Shah Alam, Malaysia, [2] Department of Agricultural and Environmental Sciences, Tennessee State University, McMinnville, OR, United States

Pleurotus spp. and *Auricularia* spp. are popular species consumed by the Malaysian community. Recently, due to increased awareness, both mushrooms are also being consumed for their bioactive compounds, ergothioneine, and antioxidant properties and has been used since earlier ages as therapeutic remedies. The bioactive compounds such as phenol, flavonoid and ergothioneine found in both *Pleurotus* and *Auricularia* mushrooms were explored. Differences in heat treatments (microwave, hot air drying, and solar drying) and cooking methods may affect the content of bioactive compounds and their properties. Similarly, sensory acceptance by consumers may be affected too. Antioxidant properties using DPPH (1,1-diphenyl-2-picryl-hydrazyl) radical and FRAP (ferric reducing antioxidant power) assay of both raw and heat-treated mushrooms are included. Microwave drying retained color characteristics and bioactive compounds in both mushrooms. To add value to this review, a survey on the consumption pattern of *Pleurotus* and *Auricularia* species among Malaysians has been conducted online and concluded that *Pleurotus* species is the most considered species compared to *Auricularia* mushroom and almost half of the respondents were not aware that heat may deplete nutritional contents in mushroom despite agreeing both gave beneficial health in diets.

Keywords: black jelly mushroom, oyster mushroom, bioactive compound, heat, antioxidant

OPEN ACCESS

Edited by:
Maha Hoteit,
Faculty of Public Health, Lebanese University, Lebanon

Reviewed by:
Temel Kan Bakır,
Kastamonu University, Turkey
Mohamad Koubar,
Lebanese University, Lebanon

***Correspondence:**
Siva Raseetha
raseetha@uitm.edu.my

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Sustainable Food Systems

Received: *24 February 2022*
Accepted: *08 April 2022*
Published: *30 May 2022*

Citation:
Izham I, Avin F and Raseetha S (2022) Systematic Review: Heat Treatments on Phenolic Content, Antioxidant Activity, and Sensory Quality of Malaysian Mushroom: Oyster (Pleurotus spp.) and Black Jelly (Auricularia spp.). Front. Sustain. Food Syst. 6:882939. doi: 10.3389/fsufs.2022.882939

INTRODUCTION

Generally, *Pleurotus* spp. such as pearl oyster, gray oyster, pink oyster, and *Auricularia* spp., like jelly ear and black jelly mushrooms, are well-known among consumers. In addition to being low in calories, salt, fat, and cholesterol, *Pleurotus* spp. is also high in nutrients and vitamins, protein, carbohydrates, and fiber. *Auricularia* mushrooms are used in traditional Chinese medicine. Due to their bioactive ingredients, mushroom extracts have been recognized as antioxidants, anticarcinogenic, and anti-inflammatory by food and biochemical experts since 3500 BC. One of the mushrooms' bioactive compounds, ergothioneine, protects cells

from oxidative stress caused by reactive nitrogen forms like nitric oxide. Furthermore, ergothioneine depletion in cells may cause DNA damage and protein and lipid oxidation (Paul and Snyder, 2010). Due to this reason, many food industries have used mushroom extracts in health care products and as added functional ingredients in food products. Heating treatments are used to extract or prepare foods for human consumption. Due to its thermolabile qualities, heating affects the residual nutrients and bioactive substances in food. Thermal processing is commonly used to extend food shelf life. As a result, heat-processed foods are regarded to be less healthful than fresh foods. Thermally processed foods, notably fruits and vegetables, have higher biological activity than non-thermally processed meals, according to recent studies (Kim et al., 2000; Dewanto et al., 2002).

In Malaysia, a few studies have shown that heat treatments on mushrooms affect phenolic chemicals, ergothioneine content, and antioxidant activity. This research benefits Malaysia's future food development, whereas nutritional imbalance has also occurred, particularly in poorer nations where animal protein is scarce and expensive, necessitating the development of an alternative protein source. Mushrooms are recognized as a vegetarian meat substitute since they are rich in nutrients.

SELECTION OF ARTICLES

The articles for this systematic review were chosen from two databases (Scopus and Google Scholar). The literature review took place between March 2021 and February 2022. The terms "heat treatment" OR "auricula" AND "pleurotus" OR "bioactive compound" were used in the search (Article title, Abstracts, Keywords). Additionally, the term "mushroom" was entered specifically in the [Search within results] section. A database search identified around 1,503 publications, and an extra 50 articles found in ScienceDirect, as displayed in **Supplementary Figure 1**.

LOCAL SURVEY ON OYSTER MUSHROOM AND BLACK JELLY MUSHROOM CONSUMPTION

An online local survey on oyster mushroom and black jelly mushroom was conducted. This survey contained two parts; Part A being a survey on Oyster mushroom consumption and Part B being a survey on Black jelly mushroom consumption. Both sections have to answer by respondents. This survey tested the respondents' general knowledge on oyster and black jelly mushrooms, including the benefits of both mushrooms, availability of both mushrooms on the market, mushroom price, and preferable dishes using the mushrooms. The type of questionnaire may vary, such as multiple-choice, open-ended, close-ended, Likert-scale, and dichotomous questions.

BACKGROUND OF RESPONDENTS

A local survey has been conducted in order to study the consumption of random Malaysians of Oyster mushroom and Black Jelly Mushroom. A total of 52 respondents have answered this survey, aged 21–60 years old. This survey has been answered by 88.5% (46) women and 11.5% (6) men, ages ranging mostly from 21 to 30 years old (61.5%), followed by 41 to 50 years old (21.2%) and 51 to 60 years old (11.5%).

OVERVIEW OF SELECTED MUSHROOM BIOLOGICAL ACTIVITIES AND CONSUMPTION PATTERN

Oyster and Black Jelly Mushroom: *Pleurotus* spp. and *Auricularia* spp.

Origin

Pleurotus species belong to a small group of higher fungi known as Basidiomycetes, which are categorized by fruit bodies with an eccentric stalk attached to the pileus, which opens up like an oyster shell during morphogenesis. *Pleurotus* is a genus of cultivated mushrooms with a wide range of species and there are over 30 species of *Pleurotus* mushroom, which have been found in wide parts of the world. The evolutionary relationship between *Pleurotus* species is still ambiguous, and several taxonomic issues remain unresolved. The earliest cultivation of oyster mushroom (*Pleurotus* species) has been recorded in Germany by Flank in 1917 (Adebayo and Oloke, 2017). *Pleurotus* species can grow in temperate and tropical zones but are more prevalent in the subtropical regions (Rajarathnam et al., 1987).

Wood ear, black jelly, tree ear, or ear fungus are local names for some *Auricularia* species. This mushroom species originated from China (Packialakshmi et al., 2017). Zhang et al. (2015) reported the cultivation of *Auricularia* mushroom started 1400 years ago in China. One *Auricularia* species it is believed existed 2000 years ago in China was *Auricularia heimuer,* it is reported in the Chinese medicinal book, "Shennong's Compendium of Materia Medica" (Sekara et al., 2015). In the Red Dragon country, a popular *Auricularia* mushroom is called "he i mù e'r" or in English "Juda's ear" and scientists may refer to this as *Auricularia auricula-judae*. *Auricularia auricula-judae, Auricularia fuscosuccinea,* and *Auricularia polytricha are* all from under the same genus called *Auricularia.* All saprophytic fungi with gelatinous, ear-to-shell-shaped fruiting bodies belong under the same genus.

Growth, Life Cycle, and Classification of Mushroom Species

Pleurotus ostreatus, Pleurotus sajor-caju, Pleurotus djamor and similar species can grow in habitats with a temperature of 15–31°C. In their natural habitat, *Pleurotus* spp. grow on broad-leaf hardwoods in the spring and fall, especially cottonwoods, oaks, alders, maples, aspens, ash, beech, birch, elm, willows, and poplars. *Pleurotus* spp. can thrive in a wide spectrum of natural lignocellulosic materials like cereal straws, all hardwoods, on wood by-products (sawdust, paper, pulp sludge), banana

pseudostems, corn cobs, cotton waste, cotton boll locules, forest woods, sugarcane bagasse, coffee residues (coffee grounds, hulls, stalks, and leaves), banana fronds, cottonseed hulls, agave waste, soy pulp, and many more (Rajarathnam et al., 1987; Adebayo and Oloke, 2017). *Pleurotus* spp. undergoes two phases in their life cycle, which are vegetative growth and reproductive growth. Environmental factors that is suitable for *Pleurotus* spp.'s fruiting bodies formation is temperature of 10–21°C, 85–90% relative humidity, CO_2 concentration of below 1,000 ppm and light exposed to 1,000–1,500 lux. Many types of *Pleurotus* spp. have been cultivated by local farmers for domestic market (refer **Supplementary Table 1**). Additionally, some types of *Pleurotus* spp. are also being imported to meet the consumer demand. As such, very few edible oyster mushrooms were cultivated in Malaysia and some of them were even no longer seen in Malaysia any more (Samsudin and Abdullah, 2019). Those species are, *P. citrinopleatus*, *P. cyctidious, P. eryngii, P. flabellatus, P. pulmonarius*, and *P. tuber-regium* (Samsudin and Abdullah, 2019). **Supplementary Table 2** shows a list of *Pleurotus* spp. that are still available and being cultivated in Malaysia. Mat-Amin et al. (2014), stated in Malaysia, only abalone (*Pleurotus cystidiosus*), gray oyster (*Pleurotus sajor-caju*), white oyster (*Pleurotus florida*), and red oyster (*Pleurotus flabellatus)* are suitable to cultivate in Malaysia's climate and be successfully cultivated commercially. In general, oyster mushrooms are grown in the lowland parts of Malaysia.

Auricularia spp. mostly found in tropical, subtropical, and temperate regions, hence it is widely available worldwide. *Auricularia* spp. can be found scattered and in clusters on dead or dying tree branches, main trunk, decaying logs and others suitable (Packialakshmi et al., 2015). Also, this mushroom can adapt in monsoon season, hence it is producing large overlapping bunch due to its high humidity presence and the production of the basidiomes can be enormous. When growing conditions are favorable, the life cycle of *Auricularia* spp. begins with germination of haploid basidiospores and matures into short-lived haploid mycelia. The cycle ended with ballistospory, the mechanism by which mature basidiospores are expelled from the sterigmata (by removing surface tension). Finally, the wind disperses the spores after they fall below the cap. *Auricularia* spp. recorded found in Malaysia was *A. auricula judae, A. fuscosuccinea* and *A. polytricha* (refer **Supplementary Table 3** for vernacular name and common name for *Auricularia* spp.). "Cendawan telinga kera" is often found grow wildly on logs and tree trunks. Locals identified them as firmer texture and dark brown color. While "cendawan gelememeh" often identified as in bigger size, thinner and tougher than "cendawan telinga kera". If the locals spot the reddish-purple color *Auricularia* spp. and founded wet, then it should be "cendawan bibir". **Supplementary Figure 2** shows the picture of *Auricularia auricular-judae* and *Auricularia* polytricha. Mostly, *Auricularia* spp. recorded in Malaysia was found in Sarawak (Abdullah and Rusea, 2009).

Toxicity Studies on Mushrooms

Mushrooms are generally known as alternative remedies to medical drugs, either as a source of functional food or for drug development. Unfortunately, few studies have been reported to support the continued medicinal use of these remedies due to a lack of scientific research on their safety and efficiency. Acute and subacute toxicity testing on animals has been conducted to determine the toxicity assessment of ethanolic extract of the mushroom, according to Organization for Economic Cooperation and Development OECD guidelines (Deepalakshmi and Mirunalini, 2014). The acute toxicity test resulted in the maximal dosage level of 5,000 mg/kg body weight (Sprague Dawley rats) of orally administered *P. ostreatus* for 72 h; no mortality or major changes in the general behavior of rats were found. While, subacute toxicity resulted from 250 to 1,000 mg/kg doses of hepatic marker enzymes, none of the animals showed significant changes including in food and drink intake. In fact, no significant changes were recorded in vital organs like the liver, and this indicated that *P. ostreatus* had a high margin of safety due to the non-existence of toxicological effects recorded. Concern may arise from consumers as ergothioneine is usually consumed for its antioxidant properties, hence many studies investigated its mutagenic and toxicologic potential. In human and mammalian tissues, the concentration of ergothioneine was found to be 1–2 mM, implying that ergothioneine could act as a non-toxic antioxidant *in vivo* (Aruoma, 1999). While living organisms need trace amounts of certain elements such as iron, cobalt, copper, manganese, chrome, and zinc, excessive amounts of these elements are toxic to them (Erel, 2004, 2005). Mercury and arsenic are trace elements found in cultivated mushrooms, ranging from 0.01 to 0.17 mg/kg (Lelamurni and Razak, 2013). According to a report of the Joint Food and Agriculture Organization of the United Nations (FAO)/World Health Organization (WHO) Expert Committee on Food Additives, the provisional tolerable weekly intake (PTWI) of arsenic is 15 μg/kg body weight (equivalent to 2.1 μg/kg body weight per day), while PTWI for mercury is 4 μg/kg body weight. Mercury and arsenic levels were 10 and 170 g/kg dry weight, respectively, in the cultivated *A. polytricha*. The maximum PTWI for mercury for a 60 kg individual is 240 g, according to calculations. If a 60 kg individual ate 50 g of dried *A. polytricha* per day, their daily mercury intake would be 30 g, and their weekly mercury intake would be 210 g (Lelamurni and Razak, 2013). The highest PTWI for arsenic in a 60 kg human is 900 g. This person's daily arsenic consumption would be 510 g and weekly arsenic intake would be 3570 g if they consumed the same volume of *A. polytricha* on a daily basis (Lelamurni and Razak, 2013). This is even higher than the PTWI for arsenic. Therefore, a daily intake of 50 g dry weight of *A. polytricha* by a 60 kg individual may be considered potentially dangerous (Lelamurni and Razak, 2013). Based on these figures, the healthy daily intake of cultivated *A. polytricha* using the same fruiting substrate formulation as in this study must be less than 10 g dry weight (Lelamurni and Razak, 2013). *Auricularia polytricha* contains high amounts of a molecular toxin named auritoxin (Kim, 1993). Auritoxin had a polysaccharide content of 93.9% and a protein content of 6.8%. Mice were given median lethal doses of auritoxin of 56.4, 157.2, and 454.6 mg/kg. Convulsions occurred within 30 min of the injection, coma or sleeping occurred within an hour, and tremors, lacrimation, respiratory swelling, congestion,

and death occurred within 24 h (Kim, 1993). The spleen was observed to be significantly swollen among the different organs of the mouse. The addition of auritoxin to human platelets prevented aggregation (Kim, 1993). The toxin inhibited the function of malic dehydrogenase *in vitro*. Other studies have shown consumption of 12 g *Auricularia auricula judae* in a day, does not give harmful effects on health, but helped abdominal obese women improve their blood LDL cholesterol, triglyceride, and bone density (Han et al., 2012).

Isolated Compounds and Antioxidant Properties of Oyster and Black Jelly Mushroom

Phenolics Compounds

Bioactive compounds in *Pleurotus* spp. such as phenolics, lipid, glycoproteins, peptides, and polysaccharides can be found in crude extracts, mycelia, and basidioma of *Pleurotus* spp (Corrêa et al., 2016). Patel et al. (2012) affirm that bioactive compounds in the *Pleurotus* mushroom has potential for therapeutic purposes in the future. Interestingly, bioactive compounds in the mycelium and fruiting bodies of oyster mushrooms were found to have immunostimulatory, anti-neoplastic, anti-diabetic, anti-atherosclerotic, anti-inflammatory, antibacterial, and anti-oxidative properties (Golak-Siwulska et al., 2018). Of the low molecular weight bioactive compounds, polyphenol is the most popular compound under research because of its anti-oxidative effects (Palacios et al., 2011; Muszyńska et al., 2013; Piska et al., 2017). Phenolics compounds have been known for their function of stabilizeing lipid oxidation, hence it is able to prevent oxidation damage and protect the human body (Gülçin et al., 2003; Ren et al., 2014). Phenolics and flavonoids have been found in *Pleurotus ostreatus* fruiting bodies and weighing 708 mg 100 g-1 D.M and 170 mg 100 g-1 D.M. Besides that, phenolics in mushrooms are reported to have anti-microbial activity and this may benefit further applications in the pharmacological industry as a natural source (Adebayo and Oloke, 2017). Researchclaims if ethanol solvents are used to extract phenolic content in *P. ostreatus*, the antioxidant activities would be 94.54%, higher than methanolic extract (Thillaimaharani et al., 2013). Phenolic compounds do not only exist in *P. ostreatus*, but are also found in, *P. djamor* (Acharya et al., 2017), *P. florida* (Thillaimaharani et al., 2013), and *P. gigantues* (synonyms: *Lentinus giganteus* and *Panus giganteus*) (Yun et al., 2020). Fruiting bodies of *P. giganteus* were found to have phenolic compounds (caffeic acid and cinnamic acid) and triterpenoids (Thillaimaharani et al., 2013). Triterpenoids were discovered to have a range of pharmacological functions, including anti-inflammatory, anti-diabetic and anti-cancer, and immune function control (Xu et al., 2018). Phan et al. (2014) emphasized the phenolics content in mushrooms had positively associated with antioxidant activity (free radical scavenging, ferric reducing power, and lipid peroxidation inhibition). Phenolic compounds in *P. djamor* also been recorded, which is 7.845 μg gallic acid/ mg dry extract (Acharya et al., 2017). The most common derivatives of phenolic compounds were found in *Pleurouts* spp. was benzoic acid and benzoic acid derivatives. In *P. djamor*'s extract, protocatechuic acid, gallic acid, vanillic acid and syringic acid from benzoic derivatives were found, while from cinnamic derivatives, caffeic acid and ferulic acid obtained (Alves et al., 2013). *Pleurotus florida* has been recorded to have high phenolic content which is 6.25 mg gallic acid/of dry extract extracted using ethanol solvents (Thillaimaharani et al., 2013). Interestingly, ethanol extract of *P. djamor* exhibited excellent antibacterial and antifungal activities against human bacterial pathogen and non-pathogens such as *E. coli* and *S. typhi* and pathogenic fungi such as *T. rubrum, E. floccosum*, and *M. gypseum*, compared to methanol extract and chloroform (Thillaimaharani et al., 2013).

Since extracts' antioxidation capacities are also related to their levels of phenolic and flavonoid material, there has been a lot of literature interest in bioactive compounds in *Auricularia* species. Wong et al. (2013) reported, *A. polytricha* from a local Malaysian food store had the strongest radical scavenging and metal chelating activities compared to mushrooms obtained locally—*H. tessulatus, P. eryngii, P. florida,* and *F. velutipes*. The author also reported the total phenolic content highest in *A. polytricha* (6.03 mg GAE/g dry matter) compared to *Pleurotus* spp.. Also, both *P. florida* and *A. polytricha* extracts reported had moderate antimicrobial activity. Total phenol contents has been reported in *A. auricula judae* (Packialakshmi et al., 2017), which are 10.25 mg of ferulic acid equivalent/ g and 8.94 g of catechol equivalent/g (Packialakshmi et al., 2015), both studies were used dried *Auricularia auricula-judae* originating from China. According to Bandara et al. (2019), inflammation is a natural response to a compromised immune system, and many Auricularia species, including *A. polytricha*, possess anti-inflammatory qualities due to the presence of phenolic compounds. Fresh fruit bodies of *Auricularia auricula-judae* grown in Malaysia were found in an earlier 2000s study to have 56.84 mg of gallic acid equivalents/g of extract (Kho et al., 2009).

Flavonoids

High flavonoid presence in *Pleurotus* spp. mushroom extracts may well account for the significant antioxidant activities recorded in the literature (Patel et al., 2012). Moreover, antimicrobial activity in flavonoids against *S. aureus* and *E. coli* has been reported (Elisashvili, 2012). Previously, Jaworska et al. (2015) reported that flavonoid content in *P. ostreatus* weighed 70 mg 100 g-1 dry matter. *P. djamor* of flavonoid acts as reducing agents, free radical scavengers, metal chelators, deactivators of singlet oxygen, good antioxidants, and have antimicrobial properties (Sudha et al., 2016). Phan (2015) reported the flavonoids in wild *P. giganteus* were 2.09% higher than in commercial strains. The studies conducted by Prabu and Kumuthakalavalli (2016) concluded that *P. florida* has significant antioxidant and antimicrobial properties due to its bioactive secondary metabolites and phenols (Adebayo and Oloke, 2017).

Flavonoids are the most abundant and extensively distributed class of plant phenolics, and they are extremely potent antioxidants. According to Ng and Rosman (2019), of the *Pleurotus* and *Auricularia* species studied, *P. sajor-caju* had the greatest flavonoid concentration, followed by *A. polytricha*. Furthermore, flavonoids, particularly catechin, quercetin, and chrysin, were the most abundant phenolic components in

Pleurotus spp. This is consistent with the current finding that *Pleurotus sajor-caju* (gray oyster) had the highest flavonoid content of the five mushrooms tested [*Agaricus bisporus* (white button), *Auricularia polytricha* (black jelly), *Flammulina velutipes* (enokitake), *Lentinula edodes* (shiitake), and *Pleurotus sajor-caju* (gray oyster)]. *P. sajor-caju,* which had the highest flavonoid content, also had the strongest anti-amylase and anti-aglucosidase activity, whereas *A. polytricha* had the least amount of activity. The TFC in *Auricularia* spp. was enhanced by steaming and pressure cooking. *L. polytricha* and *L. polytricha* edodes by 119 percent and 117 percent, respectively, although all cooked *P. sajor-caju* extracts showed a considerable loss of total flavonoid content. When compared to the WPC, cooking had a smaller effect on the total flavonoid content in mushroom extracts. *In vitro* digestion also resulted in the greatest increase in total flavonoid content (3,097%) and water phenolic content (281%) in pressure-cooked *A. polytricha* extract. Wong et al. (2013) reported the total flavonoid contents highest in *A. polytricha*, 6.95 mg QE/g dry matter compared to *Pleurotus* spp.. Total flavonoid contents has been reported in *A. auricula judae* (Packialakshmi et al., 2017) as 5.36 mg of quercetin equivalents/g, and 3.49 mg of rutin equivalents/g (Packialakshmi et al., 2015). Another study shows that cultivated *A. auricula* has a lower amount of total flavonoid content, which is only 0.86 mg of catechin equivalents/100 g, the mushroom tested was from a local market in Thailand (Srikram and Supapvanich, 2016).

Ergothioneine

In humans, a high concentration of ergothioneine exists in the bone marrow, liver, kidneys, and the lens of the eye/cornea. Even though ergothioneine is most commonly found in human tissues, its deficiency of it does not cause any harmful effect on human health, therefore it is not considered an essential dietary component for human consumption (Cheah and Halliwell, 2012). However, a thiol-containing amino acid, ergothioneine has been discovered to have an essential source in mushrooms, as well as its antioxidant properties. Another benefit of ergothioneine is that it protects cells from oxidative stress caused by reactive nitrogen forms such as nitric oxide. Dubost et al. (2007) found the highest ergothioneine content in oyster mushrooms compared to button, portabella, and shiitake mushrooms and other vegetables, such as spinach and broccoli. This shows oyster mushroom is a great source of ergothioneine. To the extent of readings, species recorded to have high ergothioneine were only reported in *P. ostreatus* (Ey et al., 2007), *P. cornucopiae, P. eryngii* (Duy Bao and Ohshima, 2013). Authors reported that the ergothioneine is mostly extracted from mushroom fruiting body and mushroom mycelia (Duy Bao and Ohshima, 2013). Ergothioneine in *Pleurotus* spp. is also functional to prevent and treat atherosclerosis via the reduction of oxidative stress (Abidin et al., 2017). Paul and Snyder (2010) reported in the review, that deficiency of ergothioneine in cells could lead to DNA damage and protein and lipid oxidation induced by oxidative stress.

Ergothioneine commonly exists in mushroom species such as in *Pleurotus* genus mushroom, *Boletus edulis, Agrocybe aegerita,* and many more (Lee et al., 2009; Chen et al., 2012; Kalaras et al., 2017). It is mainly found in the fruiting bodies and mycelia of the mushroom. This compound is also famous for its antioxidant properties and other beneficial content. Lo et al. (2012) reported the highest ergothioneine was in fruiting bodies and mycelia of *Volvariella volvacea* (537.27 mg/kg), *Boletus edulis* (258.03 mg/kg), *Pleurotus ferulae* (250.23 mg/kg), and *P. salmoneostramineus* (222.08 mg/kg). While, ergothioneine in *Auricularia* spp, such as *A. fuscosuccinea* and *A. polytricha,* was only 21.4 mg/kg and 1.4 mg/kg dry weight. In fact, the *Pleurotus* spp. has better content of ergothioneine than *Auricularia* spp., ranging from 26.2 to 250.2 mg/kg and 1.4 to 21.4 mg/kg dry weight. Although many studies reported ergothioneine popular content in fungi mushroom, there are some that were not detected in fruiting bodies and mycelia, for example *Inonotus obliquus* and *Termitomyces albuminosus* (Genghof, 1970; Lo et al., 2012).

DPPH (1,1-diphenyl-2-picryl-hydrazyl) Free Radical Assay

Lam and Okello (2015) in the study of the effect of different blanching methods on antioxidant properties of oyster mushrooms discovered that raw *P. ostreatus* gave 14.46 μmol TEAC/g of DPPH radical scavenging ability (extraction by methanol). Between commonly cultivated oyster species, the fruiting body of king trumpet or king oyster (91.84%) has higher DPPH percentages compared to the fruiting body of pink oyster (87.15%), white oyster (83.82%), Indian oyster (78.79%), and pearl oyster (61.98%) mushroom (Krakowska et al., 2020). While compared to *Auricularia* species, *Pleurotus* species has lower percentages of scavenging ability either by methanolic or aqueous extraction method (Oke and Aslim, 2011). In previous research, Corrêa et al. (2016) investigated and compared the hydrophilic and lipophilic compounds, as well as the antioxidant, anti-inflammatory, and antimicrobial activities of *P. ostreatoroseus* fruiting bodies and submerged culture mycelia (by ethanolic extraction). Five free sugars, four organic acids, four phenolic compounds, and two tocopherols were discovered in the bioactive formulations. In brain homogenates, the fruiting body-based formulation showed stronger reducing power, DPPH scavenging activity, also higher anti-inflammatory, and antibacterial effects than the mycelium-based preparation.

A study conducted by Wong et al. (2013) showed that at different mushroom extract concentrations (from 4,000, 2,000, 1,000, 500, 200, 100, 50 μg/ml) *A. polytricha* has the highest DPPH scavenging activity, compared to *P. eryngii* and *P. florida*. *A. polytricha*'s high antioxidation capacity was demonstrated by its low EC50 values (which <50 mg dry matter/ml) (Wong et al., 2013). Additionally, EC50 values are shown, which represent the concentration of extract necessary to scavenge 50% of DPPH radicals (Wong et al., 2013). The *A. polytricha* were obtained in Kampar, Malaysia, at a local food store. In another study conducted by Kho et al. (2009), all extracts of *Auricularia auricula-judae* (freeze-dried, oven-dried, and mycelium) have a significant scavenging action on DPPH radicals, however, fresh fruit body extract could not be dissolved in methanol, which could be due to the high fiber content of fresh fruit bodies. As a result, the DPPH radical scavenging effect of this extract could

not be evaluated. In fact, the butylated hydroxyanisole (BHA) was used for related concentrations as the positive control as it dissolved in methanol. From the findings, *A. auricula judae* values gave incomparable percentage of scavenging activity on DPPH free radicals. Differ from He et al. (2012), in the study *A. auricula* recorded the EC50 values of scavenging action on DPPH radicals was 1.62 mg/mL, vitamin C was used as standard antioxidant and positive control.

FRAP (Ferric Reducing Antioxidant Power) Assay

Kibar (2021) in the study conducted the FRAP analysis on the *P. ostreatus* mushroom before applying the different drying methods and cold storage treatments. From the FRAP analysis, it was found that the antioxidant activity of the FRAP assay was 68.53 (μmol g^{-1}TE). Contrary, from the findings of Lam and Okello (2015), the FRAP values of 11.21 μmol/g were found in raw *P. ostreatus*. Despite employing the same assays, comparing antioxidant activity to previously published data is difficult due to a lack of uniformity in techniques and data interpretation. The FRAP values of Kanagasabapathy et al. (2011) on ethanol aqueous extract of *P. sajor-caju* (26.29 μmol/g) and Zeng et al. (2012) (13 μmol/g extract) are likewise comparable. Mushroom antioxidant activity was shown to be substantially linked with total polyphenol content. The total polyphenol content and antioxidant assays (FRAP) were shown to have substantial positive relationships in this investigation. This shows that the differences in antioxidant capabilities observed in the methanol: water extracts were attributed mostly to the overall polyphenol concentration of the extracts. Despite this, some research has found no link between polyphenol concentration and antioxidant activity in certain vegetables (Ismail et al., 2004). *P. ostreatus*, in conclusion, is an excellent source of beta-glucan, dietary polyphenols, and antioxidants.

Since most of *Auricularia* spp. had an extensive amount of phenolic and valuable polysaccharide which exert antioxidant properties, many studies have been conducted locally (Kho et al., 2009; Mahfuzatunajla, 2012) and internationally (Packialakshmi et al., 2015, 2017; Srikram and Supapvanich, 2016) to examine their ability to scavenge free radicals by single electron transfer. In 2009, FRAP assay of grown local fresh fruit bodies of *Auricularia auricula judae* was found to have 56.84 μmol of $FeSO_4 \bullet 7H_20$ equivalents/g of extract (Kho et al., 2009). The author concludes, the significant positive correlation between FRAP value and total phenolic content indicates that phenolics contribute to *A. auricula-judae*'s antioxidant activity. These findings shed light on some of the uses of *Auricula auricula-judae* in folk medicine and add to the body of knowledge regarding the plant's medicinal properties. Mahfuzatunajla (2012) conducted a FRAP assay of locally grown mushrooms and discovered the highest antioxidant activity in *Auricularia auricula-judae* with the lowest IC_{50}, which is 52.7 μg/ mL. Total antioxidant capacity of the mushroom from Srikram and Supapvanich (2016) exhibited in the range of 0.86 mmol of Trolox equivalents/100 g of dry weight, among lowest from *L. squarrosulus, P. sajor-caju, V. vovacea*, and *L. polychrous*. *Auricula auricula*'s ferric reducing power was observed to be dependent on the concentration. At 4 mg/mL, *A. auricula* had a reducing power of 0.403 nm, the results indicate that *A. auricula* has a greater potential for hydrogen donation, implying that it possesses significant reducing power (Packialakshmi et al., 2017). Nattoh et al. (2016) examined reducing power assay on four different parts of the body of *Pleurotus djamor*, those being spawn mycelia phase, early young fruiting body, young fruiting body, and mature fruiting body. Results showed the ethanolic extract of young fruit body yield at 5 mg/ mL concentration had the highest (11.491) reducing power activity, higher than water extract of young fruit body of *P. djamor* (10.077). The bioactive compounds and both DPPH and FRAP assay of *Pleurotus* spp. and *Auricularia* spp. from studies can be simplified in this below **Supplementary Table 4**.

Heat Treatments on Isolated Compounds and Its Bioactivity of *Pleurotus* spp. and *Auricularia* spp.

Pre-treatments Before Drying

Pre-treatment methods are frequently used prior to various drying processes to avoid color changes, inhibit enzyme activity, reduce the number of microorganisms, enhance flavor retention, and improve the overall stability of mushrooms. Blanching, soaking in potassium metabisulphite (Brennan et al., 1999), and citric acid (Brennan et al., 2000) are all traditional pretreatment methods, but various means including whey fermentation, curd fermentation, and others have been reported. As for blanching, they are typically blanched at 95–98°C in water or antioxidative-containing aquatic solutions. This treatment might last from 20 s and 15 min. Blanching is the first procedure after washing and is mostly applied with chemical treatments such as sodium metabisulfite, citric acid, brine made from table salt, and sodium-calcium salt of versenic acid ($CaNa_2EDTA$). Blanching in only water and with added chemical treatments may give a different result for the mushroom. As an example, 15 min of water-only blanching mushrooms could reduce the darkening of the pilei induced by enzyme activity; due to the complete inactivation of peroxidase (Bernaś et al., 2006). Another study also found that blanching without chemical treatment could prevent the phenolic content losses (Mutukwa et al., 2019). A study conducted by Walde et al. (2006) on the effect of the drying rate of different pre-treatments reported soaking with fermented whey and blanching followed with curd can decrease the drying time of oyster mushrooms compared to control, only blanching, only whey, only curd, and blanching followed with whey treatment. Those blanching treatments involve a temperature of 90°C. The addition of citric acid and using a brine consisting of table salt and sodium-calcium salt of versenic acid could improve the color and texture of sterilized mushrooms while also increasing their microbiological resilience (Bernaś et al., 2006). According to Nöfer et al. (2018), prolonged drying time and high temperatures may degrade the mushroom aroma. According to Hassan and Medany (2014), pre-treatment of *P. ostreatus* and *P. eryngii* with 0.1% sodium metabisulfite at room temperature improved mushroom color and microbiological characteristics, while also retaining its nutrients. The highest rehydration ratio

was found in the untreated mushrooms. Additionally, soaking mushrooms in 0.1% NaCl or 0.1% citric acid for 10 min at room temperature produced acceptable results, though they were not as good as those treated with sodium metabisulfite. Hassan and Medany (2014) found out blanching as a pre-treatment is ineffective for enhancing the quality of dried mushrooms. Not just them, Argyropoulos et al. (2011b) in the research concluded that blanching can cause undesired color and texture of mushrooms (hardens), while also inhibiting enzyme activity and reducing microbial populations.

Solar Drying

Natural sun-drying is still widely utilized in many cultures due to its low-investment, simple operation, and energy-savings. Direct solar drying includes spreading out the mushroom to be dried in a thin layer on large outside free open surfaces and leaving it until it reaches the necessary moisture content. During the day, the mushroom must be flipped over to allow stored moisture to escape. The drying surface is usually concrete with polyethylene nets, although sensitive food is placed on perforated trays. Obviously, the drying rate is low. The crops must be left outdoors for 10–30 days, depending on their type and the local weather (Belessiotis and Delyannis, 2011). Moreover, the open sun drying procedure can also cause significant loss and quality degradation due to pollution, insufficient drying, microbial development, and other factors. Therefore, technology has been developed, such as solar drying, to alleviate these limitations, in which the mushrooms are maintained in a UV irradiation chamber equipped with UVB lamps for drying. One study reported that there is a benefit of exposing mushrooms to a UVB light, which is the greater generation of vitamin D2, especially when it is sliced and followed by freeze-drying (Nölle et al., 2017). The study was conducted by exposing the samples on both sides and irradiating for 20 min at room temperature until a dose of 1.5 J/cm^2 (2.54 mW/cm^2) was reached independently of slicing or drying (Nölle et al., 2017). Solar dryers are rather basic equipment. They range from relatively rudimentary ones used in small, desert, or remote communities to more complex industrial systems. Forced convection cabinet solar dryer type is recommended as it assists in keeping constant conditions inside the drying chamber, such as temperature and air velocity, increases the drying rate, and decreases the moisture rate (Bhavsar and Patel, 2021). Moreover, the efficiency of natural solar dryer and forced convection solar dryers was determined to be 19.27 and 35.60%, respectively. Reyes et al. (2013) in the study, dehydrated mushrooms using a hybrid solar dryer that had a three-square-meter solar panel and electrical resistances. As to the results, solar energy succeed in conserving between 3.5 and 12.5% of total energy. Mishra et al. (2016) studied the antioxidant properties and mineral composition of oyster mushrooms in relation to the different drying processes used. Solar dried oyster mushrooms were discovered to be extremely rich in a variety of antioxidants and minerals, compared to sun-dried oyster mushrooms.

Hot Air Drying

The simplest and most extensively used type of drier is hot air drying. This method is frequently used to dry wild mushroom species such as *Craterellus cornucopioides*, *Boletus edulis*, *Morchella* spp., *Cantharellus cibarius*, and *Lentinula edodes*. Typically, mushrooms are placed on a tray and pushed into a cabinet or tunnel dryer for hot air drying. When heated to a temperature of 50–70°C (Argyropoulos et al., 2011a) and combined with air convection, the hot wind evaporates the moisture contained within the mushroom, fulfilling the aim of drying. High temperatures and rapid air convection are favorable for mushroom drying in terms of drying speed alone. However, if the water on the surface of the mushroom flows too quickly, the internal water does not have enough time to reach the surface, and the surface might become overheated. As this process develops, the moisture content of the mushroom falls, the drying rate consumes more energy, and dramatically slows, making drying more difficult. Inadequate hot air drying of mushrooms can result in distinctive color changes and structural deformations (Kotwaliwale et al., 2007). Inah et al. (2021) studied the effect of oven-hot air drying on the sensory attributes of the *A. auricula judae*. The results showed the optimal process variables for treating mushrooms are 110 minutes of hot air drying with a temperature of 75°C. The greatest desirability index 0.648. (64.8%) was achieved.

Microwave-Vacuum Drying Technique

In the initial days of drying, hot-air drying is undeniably practical. As days go by, the dehydration became impractical in the food industry, as hot-air-dried mushrooms will lose color and shape and the process takes substantially longer and consumes significantly more energy. Microwave drying has been used to solve these issues, either alone or in combination with hot air drying. Microwave drying is faster than conventional drying due to less heat loss, volumetric heating, easy automatic control, and lower equipment footprint. Microwave drying may considerably reduce drying time and improve product quality. Microwave-assisted or accelerated drying technologies have been extensively studied (Zhang et al., 2006). Microwave-assisted drying is ideal for heat-sensitive items like mushrooms. Microwave energy has the ability to increase product quality, but the inappropriate application might cause irreversible changes in dried vegetable quality. Also, for mass transfer control, the microwave energy is pulsed to enhance drying efficiency because continuous heating does not accelerate moisture removal. Microwave drying mushrooms at reduced power density with warm air has increased moisture diffusivity, rehydration, and flavor retention. According to Askari et al. (2009), unlike other agricultural goods, microwave treatment can degrade the quality of mushrooms. Therefore, vacuum and microwave drying have been combined to increase dried mushroom quality. Also, due to high initial and ongoing expenses, microwave-vacuum processing has lately been utilized in conjunction with hot-air drying. It can be used after pre-drying with hot air to remove moisture when the drying rate slows. The material is dry on the surface and damp in the center. Microwave energy can selectively heat the interior of products, causing a high steam pressure. The dry surface acts as a barrier, preventing rapid pressure release, resulting in puffed produce. Vacuum, on the other hand, allows rapid mass transport at low temperatures, speeding up the

final drying cycle. When working with temperature sensitive materials like mushrooms, combining drying procedures may be required to produce high-quality dried products. Das et al. also discovered a method to rapidly dry mushrooms using microwaves and convective hot air, achieving commercial quality in only 72 min (Das and Arora, 2018). Argyropoulos et al. discovered that combining hot air and microwave vacuum drying produced good quality mushrooms with less color change, soft texture, and a high rehydration rate. Combined drying can make mushroom structure airy and crunchy, allowing for innovative snack development (Argyropoulos et al., 2011a).

Effects of heat treatments on isolated compounds and antioxidant activities of *Pleurotus* spp. and *Auricularia* spp.

Analysis of Phenolic Compounds Content

Singhal et al. (2020) explain in their study that the phenolic content increased during the first hour of drying using a tray/cabinet drier and then declined with time. Also, two phytochemical kinetic models were used. Since the capacity of drying equipment to preserve nutrients at low cost is still being studied, a kinetics analysis of nutritional characteristics is necessary. This helps understand how food molecules degrade throughout processing (Sarpong et al., 2018). For free radical scavenging activity (percent inhibition) and phenolic content degradation, a first-order kinetic model could be predicted better than a second-order model using statistical parameters. Additionally, the D value of phytochemicals is being examined. The figures indicated the time (hr.) required to reduce the phytochemical content by 90% at each temperature (60, 65, and 70°C). Ascorbic acid, which has the greatest D values, degraded the fastest during heat treatment, followed by total flavonoids and total phenolics. The total phenolic content of dried *Pleurotus sajor-caju* samples was assessed by Mishra et al. Sun dried sample had 31.4 mg GAE/g dry weight, which was greater than hot air dried sample (28.7 mg GAE/g dry weight) (Mishra et al., 2016). Phenolic molecules could be utilized to assess antioxidant capability. The antioxidant activity of mushrooms is linked to their phenolic component concentration. A study conducted by Mutukwa (2014) concluded that among the chemical pre-treatments, vinegar and potassium bisulfite produced the highest total phenolic chemicals. The drying process had no effect on total phenolic content. The interaction of the blanching method with chemical pre-treatment on total phenolic compound content was significant. The vinegar and potassium bisulfite treated samples with no blanching had 8.31 mg/g GAE and 8.4 mg/g GAE of phenolic, respectively (Mutukwa, 2014). Water blanched samples with a chemical preparation had smaller total phenolic content than water blanched samples with no chemical pre-treatment. Unblanched samples had greater total phenolic content than blanched samples among those that received a chemical pre-treatment. This could be explained by the fact that potassium bisulfite is a reducing agent, and so the increased total phenolic content reported in potassium bisulfite-treated samples could be a result of this molecule. Polyphenols were found in white vinegar, but no flavonoids, therefore the vinegar treatment may have enhanced the total phenolic content of the sample (Lopez et al., 2005). Furthermore, leaching may be the cause of the decreased total phenolic compounds in the blanched samples. Blanching may have facilitated the loss of phenolic chemicals. This may include the release of bound phenolic compounds and/or disruption of phenolic compound and cell wall structure, facilitating phenolic compound leaching out after blanching.

The investigation showed that different processing processes did influence *A. auricula-judae* total phenolic content (Kho et al., 2009). Oven-dried *A. auricula-judae* fruit bodies had 2.75 times more total phenolics than fresh fruit bodies. The amounts of total phenolic contents in freeze-dried tomatoes increased 2.6% to 5.9% compared to the fresh ones, and the total phenolic contents in oven-dried tomatoes increased 13% to 29% compared to the fresh ones. This may be due to the drying process releasing phenolic chemicals from the matrix. Processing may speed up the release of bound phenolic compounds by breaking down cellular components. The high temperature of the oven-drying procedure may denature oxidative and hydrolytic enzymes that could damage phenolic compounds in *A. auricula-judae*. This may have increased the antioxidant capacity of *A. auricula-judae* by reducing phenolic acid loss. The freeze-dried *A. auricula-judae* fruit bodies had 3.54 times the total phenolic content of the oven-dried fruit bodies. This may be related to greater overall phenolic extraction efficiency. During freeze-drying, ice crystals form within the fruit bodies' matrix. Ice crystals can cause more cell rupturing, allowing for improved solvent access and extraction. The cooking process reduced the water-soluble phenolic content (WPC) of all mushroom extracts by 29% to 85% (Ng and Rosman, 2019). With the loss of WPC in all cooked mushroom extracts, especially *F. velutipes* and *L. edodes*, came a loss of FRAP values, indicating WPC contributes to their antioxidant activity. This trend was absent in *A. bisporus, A. polytricha,* and *P. sajor-caju* (Ng and Rosman, 2019), perhaps due to the existence of heat-resistant antioxidant substances other than phenolics such as b-glucan and amino acid, ergothioneine (Soler-Rivas et al., 2009) and heat-stable component (superoxidase dismutase and quinone oxidoreductase). After conducting *in vitro* digestion (simulates human gastrointestinal digestion to assess phenolic content digesting stability on the reducing power, and radical scavenging capabilities in digested mushroom products), Ng and Rosman (2019) found the pressure-cooked *A. polytricha* extract had the largest increase in WPC (281%). In the digested microwaved samples, WPC increased significantly for *A. polytricha* (156%) and *L. edodes* (116%) but decreased significantly for *A. bisporus* (-48%) and *P. sajor-caju* (-60%).

Analysis of Flavonoid Content

Singhal et al. (2020) studied the effect of heat on flavonoids in mushrooms (microwave blanched for 30 s, then osmotic dehydration in 15% sodium chloride solution for 10 min). The study concluded that as temperature and time increased, the flavonoid content decreased. Flavonoids lose much more at 70°C than at 60°C. In apricots, Madrau et al. (2009) found that 75°C results in a greater loss of flavonoids than 55°C. The bigger the enthalpy change, the more heat-sensitive the chemical (Karaaslan et al., 2014). Hence, ascorbic acid and flavonoids are more heat-sensitive than total phenolics. Furthermore, positive

enthalpy change values indicate that the breakdown of flavonoids and ascorbic acid constituted an endothermic reaction. A similar result was reported by Sarpong et al. (2018). The total flavonoids in oyster mushroom with different blanching methods (control, water, and steam) and different chemical treatments (no chemical, with potassium bisulfite, lemon juice, and vinegar) was assessed by Mutukwa (2014). The water-blanched samples had the highest total flavonoids, while the un-blanched samples had the lowest. The drying method had no impact on total flavonoid content. Total flavonoid content was affected by the blanching procedure with chemical pre-treatment. Blanching and soaking in different pre-treatments increased overall flavonoid concentration. The unblanched samples showed the lowest total flavonoid concentration, except for those treated with potassium bisulfite. While the blanched samples exhibited higher flavonoid concentration than the unblanched samples. Water blanching yielded more total flavonoids than steam blanching. Heat may increase flavonoid availability, resulting in increased flavonoid content in blanched samples. A 15-min heat treatment at 100°C increased free flavonoids while decreasing bound flavonoids, according to Choi et al. (2006). These alterations may be due to heat disrupting the cell wall and leading to the release of bound flavonoids. Given that blanching mushrooms and soaking them in chemicals both cause nutrient leaching, these findings suggest that polyphenols in the flavonoid class are less susceptible. Blanching and chemical pre-treatments reduce polyphenol oxidase activity. Therefore, combining both treatments should help maintain polyphenols, which contribute to greater total flavonoids. It is also possible that the chemical pre-treatments affected the total flavonoid content directly. This may have aided in the total flavonoid concentration detected in lemon juice treated samples (Gattuso et al., 2007). The amount of flavonoids in *Pleurotus ostreatus* dried fruit extracts resulted in the following order: microwave, freeze-drying, hot air drying, and sun-drying (Piskov et al., 2020). Despite the expexctations of Piskov et al. that low-oxygen and low-temperature freeze-drying would limit flavonoid losses, the microwave drying sample extracts had the highest flavonoid content. Toor and Savage (2006) explained that this result could be because the permeability of microwave radiation damages the cellular components of tissue, hence increasing the accessibility of flavonoids for extraction. Microwave drying also preserves more flavonoids than hot air drying due to its rapid heating. Sun-dried samples had the lowest flavonoid levels, this is most likely related to drying time and consequently oxidation processes, as shown by Oprica et al. (2019) in their studies of dehydrogenation in plants. True retention of minerals, vitamins, and bioactive compounds in mushrooms has been studied by Lee et al. (2019) while undergoing steaming, blanching, microwaving, boiling, and roasting. Alpha-glucan shows higher values in all cooking methods except for raw, while total flavonoid shows higher values in the microwave and roasting method other than that the values decreased. Also, Ng and Rosman (2019) claimed the flavonoid content was improved by 119% and 117% in *A. polytricha* after steaming and pressure cooking, respectively, while there was a considerable loss of flavonoid content in all cooked *P. sajor-caju* extracts. When compared to the phenolic content, cooking had a smaller effect on the flavonoid in mushroom extracts. Total flavonoid content (3,097%) of pressure-cooked *A. polytricha* extract increased the most after *in vitro* digestion.

Determination of Ergothioneine Content

There was a statistically significant difference in the amount of ergothioneine present in no blanching, water blanching, and steam blanching of oyster mushrooms (Mutukwa, 2014). The highest concentrations of ergothioneine were found in the unblanched samples, followed by the steam blanched samples, and the lowest concentrations were found in the water blanched samples. This loss was most likely caused by leaching. Nguyen et al. (2012) steamed, boiled, and microwaved *Flammulina velutipes* mushrooms for 2–5 min and discovered that all of these treatments reduced the amount of ergothioneine in the mushrooms, with the boiled mushrooms showing the greatest reduction in this component. According to their findings, heat degradation was not considered, and the reduction was attributable to leaching instead. Increased ergothioneine yield was seen as the microwave-convective drying temperature was raised up to 70°C, after which the yield began to decline progressively as the drying temperature was raised even higher (Bhattacharya et al., 2013). Microwave-convective heating enables the temperature of the product to rise dramatically, resulting in a flux that aids in the quick evaporation of water vapor from the product. True retention of minerals, vitamins, and bioactive compounds in mushrooms has been studied by Lee et al. (2019) while undergoing steaming, blanching, microwaving, boiling, and roasting. The ergothioneine concentration of mushrooms was significantly reduced by all of the cooking methods. Boiling induced the greatest loss of ergothioneine in the shiitake mushrooms when compared to the other cooking procedures. Lee et al. (2019) came to the conclusion that microwaving and roasting were preferable to other cooking methods in terms of retaining functional compounds such as ergothioneine, polyphenols, and flavonoids while boiling resulted in the greatest reduction in the amount of functional compounds present in mushrooms.

Analysis of Heat on Antioxidant Activities

Piskov et al. (2020) studied the effects of different drying methods (microwave, hot air, and solar drying) on the maximum antioxidant properties (ferric reducing ability, reducing power activity, antiradical scavenging activity, total antioxidant capacity, the activity of inhibiting lipid oxidation) and ACE-inhibiting activity. From the study, electrochemical analysis revealed that hot air-dried oyster mushrooms possessed a high overall antioxidant capacity. The remaining mushroom extracts were accepted in the following order: freeze-drying > sun-drying > microwave drying. Contrary to expectations, microwave drying extracts with the highest antioxidant activity measured using spectrophotometric methods (Reducing Power Activity, ABTS, and FRAP assays) had the lowest total antioxidant activity evaluated using the electrochemical approach. Study shows *P. sajor-caju* treated with sun dry has high FRAP values than solar dry and hot air treatments, while DPPH assay has

shown higher values in solar dry compared to sun dry and hot air (Mishra et al., 2016). Lam and Okello (2015) observed FRAP antioxidant activity of blanched treatment of *P. ostreatus* is reduced compared to raw/fresh mushroom. Tan et al. (2015) examined the DPPH free radical scavenging assay of mushrooms cooked in boiling, microwave, and pressure cooking compared to the uncooked sample. The antioxidant activity of *Pleurotus pulmonarius* increased by 151% when boiling for 5 min compared to uncooked samples (16.56 ± 0.18%). The antioxidant activity of *Pleurotus citrinopileatus, P. flabellatus*, and *P. floridanus* was not affected by boiling. *Pleurotus cystidiotus* and *P. eryngii* had reduced antioxidant activity (relative percentage 12 and 77%) than raw samples. Lee et al. (2007) found that hot water extracts of *P. citrinopileatus* (heated at reflux for 1 h) scavenged 20.7–2.3 % at 20 mg/ml. After 5 min of boiling, *P. citrinopileatus* had 18.8% scavenging ability at 5 mg/ml. To compare the DPPH free radical scavenging activity of boiled (100°C, 1 h) *Agaricus bisporus* (button mushroom) to uncooked (15.6–65.8%), Jagadish et al. (2009) found that the boiled (100°C, 1 h) *Agaricus bisporus* decreased by 8.3–53.1%. The increased boiling time may have reduced the scavenging ability of bioactive chemicals in mushrooms. The antioxidant activity of *P. floridanus, P. flabellatus,* and *P. pulmonarius* (0.46; 4.60 and 6.72, respectively) increased significantly after microwave heating (1.45, 6.50, and 14.43 correspondingly). However, *P. citrinopileatus, P. cystidiosus,* and *P. eryngii* demonstrated lower antioxidant activity than the uncooked sample, with relative percentages of 44, 65, and 70%. Kettawan et al. (2011) reported that the texture, color, and form of each mushroom variety may alter antioxidant activity. *P. cystidiosus* and *P. eryngii* had thick, meaty, solid, and hard features where the microwave heat may not have entered the mushroom tissue or broken the cell wall to free the antioxidant compounds. However, Hayat et al. (2009) observed that microwave treatment could speed up the release of phenolic chemicals from orange peels by thermally destroying the cell wall and subcellular compartments. Microwave cooking retained more phenolic acids in Boletus mushrooms than pressure cooking, steaming, boiling, or frying, according to Sun et al. (2014). When compared to all other processed and uncooked mushrooms, *P. floridanus* had the highest scavenging ability (>200%). The increase in antioxidant activity may be attributed to the fiber complexes being released during pressure cooking (low moisture level and high temperature). The DPPH radical scavenging activities of *P. flabellatus* and *P. pulmonarius* increased by 10.01 and 10.02, respectively. *P. citrinopileatus* and *P. eryngii* demonstrated 50 and 67% decreased scavenging ability by pressure cooking compared to raw samples. Choi et al. (2006) found that increasing heating time and temperature will greatly influence *Lentinula edodes*' DPPH radical scavenging activity. *P. pulmonarius, P. floridanus,* and *P. flabellatus* have thinner and softer tissue than *P. eryngii* and *P. cystidiosus*. Thus, high-pressure cooking may liberate phenolic chemicals more easily from mushroom tissues. Thermal reactions may also produce greater antioxidants. Furthermore, it was discovered that cooking ordinary beans (*Phaseolus vulgaris*) for longer periods of time increased their free radical scavenging activity (Rocha-Guzmán et al., 2007). An antioxidant assay, FRAP, and DPPH method showed, that the steamed *A. polytricha* mushroom showed the highest antioxidant activities compared to boiling, microwaving, and stir-frying the mushrooms (Shamaruddin et al., 2021). The antioxidant activity of cooked *Auricularia polytricha* has been investigated by Ng and Rosman (2019). It is found out that boiling *A. polytricha* would be the best option for cooking to achieve best antioxidant values, while for *P. sajor caju* preferably by pressure cooking. Interestingly, cooked *A. polytricha* and *P. sajor caju* showed decreasing value in water soluble phenolic content, however that doesn't affect the FRAP values, in fact the FRAP values of boiled and steamed *A. polytricha* and *P. sajor caju* was increased. This can be explained by the presence of non-phenol molecules such as b-glucan and amino acid, ergothioneine, which are heat-resistant anti-oxidants (Soler-Rivas et al., 2009). Moreover, steaming and pressure cooking are believed to improve the total flavonoid content in *A. polytricha* (not in *P. sajor caju*), therefore the FRAP values increased. The study conducted using autoclave and the temperature arrangement mimicked the domestic cooking styles, which are 95°C (steam), 100°C (boiling), and 121°C (pressure cooking). Kho et al. (2009) in their study found that because of the high fiber content in fresh fruit bodies of *A. auricula-judae* obtained from a local farm at Tanjung Sepat, Selangor, Malaysia, the extract of fresh fruit bodies could not be dissolved in methanol. As a result, the DPPH radical scavenging effect of this extract could not be calculated. Therefore, the EC50 value of BHA, was employed as a positive control, and the results was 12.05 μg/mL. The extracts of freeze-dried fruit bodies of *A. auricula-judae* had the lowest EC50 value of 2.02 mg/mL. BHA is a pure or concentrated synthetic phenolic antioxidant. It can scavenge reactive oxygen species like DPPH free radicals by giving them labile hydrogen and leaving behind an oxidized phenolic ion that is stabilized by the resonance of the benzene ring. This could explain why BHA had a stronger free radical scavenging activity than *A. auricula-judae* extracts. It was found that 1 mg/mL air-dried and oven-dried ear mushrooms grown in Taiwan with an EC50 value of 91 μg/mL showed a 100 percent scavenging effect (Mau et al., 2001). It is possible that the variation in species and growing environment accounts for the significantly high free radical scavenging potency of ear mushrooms grown in Malaysia. When compared to the EC50 value (2.02 mg/mL) exhibited by freeze-dried fruit bodies of *Auricula judae*, fresh fruit bodies of *Phenillus linteus*, a wild fungus, had a low EC50 value of 22.1 g/mL (Song et al., 2003). The scavenging capabilities of freeze-dried Grifola and Morchella mycelia with EC50 values of 4 to 5 mg/mL, on the other hand, were lower than those of *A. auricula-judae* (Mau et al., 2004). At a concentration of 4 mg/mL, methanol extracts of *A. auricula-judae* freeze-dried and oven-dried fruit bodies had DPPH radical scavenging effects of 94.77 and 74.04%, respectively, in the current study. When compared to the processed (freeze-dried and oven-dried) *A. auricula-judae*, processed tomatoes are thought to have only marginally higher DPPH radical scavenging activity. It is possible that the microwave, pulsed electric field, and ultrasonic treatments alter the antioxidant activity of Auricularia polysaccharides, but not their main chemical structures. The microwave-derived Auricularia polysaccharides

had reduced molecular weight, higher glucose content, and improved antioxidant activities, indicating that molecular weight may be a key factor determining antioxidant activities (Miao et al., 2020).

Consumer Preferences on Heat-Treated Oyster and Black Jelly Mushroom: *Pleurotus* spp. and *Auricularia* spp.

Sensory Analysis of Pleurotus spp. and Auricularia spp.

Studies conducted by Aishah and Rosli (2013) stated that the taste and features of *Pleurotus sajor-caju* remain the same when dried. Çelen et al. (2010) stated at 50°C heat treatment of mushrooms risked their taste and protein. The texture, color, or shape of each mushroom variety can influence the reduction of antioxidant activities. *Pleurotus cystidiosus* and *Pleurotus eryngii* have thick, meaty, strong, and firm characteristics, suggesting that the microwave heat did not reach the mushroom tissue or disrupt the cell wall, allowing the antioxidant compounds to be freed. Mutukwa (2014) in his experiment on the effect of drying treatment on the sensory quality of oyster mushrooms, found that oyster mushrooms in the oven method gave lower yellow and browning color ratings than solar-dried oyster mushrooms in terms of appearance. White colors decreased with an increase in the intensity of yellow and brown. Maillard browning may be the product of the higher brown and yellow color ratings of solar drying. Overall acceptability was still recorded as highest for oven and sundried oyster mushrooms. L*, a*, and b* values after heat treatments for oyster and black jelly mushroom were recorded in **Supplementary Table 5**.

Hot-air drying at 40, 50, 60, 70, and 80°C has been applied to *Auricularia auricula-judae,* results show as temperature increases to the 70°C the appearance is denoted as good in shape and resilience (Choi et al., 2014). Resilience reduction and low moisture content of tissue were observed at 80°C. In terms of chromaticity, as the temperature increases, the *L, *a, and *b values also increase, while the hardness may vary for each temperature. One study was conducted by Chen et al. (2020) on the effect of different drying temperatures on the color of the *Auricularia cornea,* the milky-white mushroom, and the light yellow ventral surface. A major index for selecting the drying technique is the changes in the color of edible fungi during drying. The color of the dry fruiting bodies and the rehydrated fruiting bodies influences sales price significantly. The selection of an appropriate drying temperature is therefore especially important. Results show as the temperature of drier increases from 35, 45, 55, and 65°C, the L* (lightness and darkness), a* (red and green), and b* (yellow and blue) values of the dry fruiting bodies showed random changes. At 35 and 65°C the ΔE values of the mushroom are lower than the other temperature, the color is exactly as that of the mushrooms in sun-drying treatments (Chen et al., 2020). While, at 65°C the *L and *a values of the fruiting body of *A. cornea* indicates the highest brightness and lowest redness which can be said the mushroom was in good color. When compared to *A. bisporus* dried thoroughly with conventional hot air, combining hot-air and microwave-vacuum drying resulted in a dried product of greater quality (Argyropoulos et al., 2011a). Furthermore, using the combined process, dried mushrooms with a puffed structure and crispy texture were created, which might be deemed relevant attributes for making a snack-type product. A study was conducted by Shamaruddin et al. (2021) on the effect of sensory quality of the different domestic cooking of black jelly mushroom. The authors concluded that it is normal that *Auricularia* spp. regains a darker color when exposed to heat, especially during boiling due to the Maillard reaction. Moreover, the firmness of the black jelly mushroom getting decreases when exposed to high temperature compared to raw mushroom. This is because of as high temperature penetrated the mushroom, cells will shrink and reduce intercellular space which later causes tighter hyphae organization within tissue (Zivanovic and Buescher, 2004). Also, the heterogeneous structure of black jelly mushroom will gave varying results during texture analysis. Heating indeed alters mushroom tissue, causing membranes to denature and permeability to rise, resulting in water loss and softening of the cells, hereto changing the structure. Because the mushroom cell wall is made up of glucan and chitin and does not provide the same support as a plant cell wall, the effect of cooking treatment is more visible in mushrooms than in vegetables. In addition, hydrolysis in macrostructures of mushroom cells resulting in additional tissue relaxation. Overall, between heat treatments there is no significant difference in terms of overall acceptability such in appearances, texture, color, flavor. Only that chemical treatments were found the least for overall acceptability.

Trends in Oyster and Black Jelly Mushroom Consumption

Based on the 52 respondents (refer to **Supplementary Figure 3**), most of them had eaten oyster mushroom (82.7%), while for others it depended on the dish cooked before consumption, and only a few among the 52 respondents did not ever consume oyster mushrooms (3.8%). This finding corresponds with the previous study which found out that the gray oyster mushroom was the most preferable among consumers in Malaysia, and one of the most valuable crops that will be commercially farmed by the Malaysian government (Mohd Tarmizi et al., 2013). The 82.7% mostly included white oyster mushroom and gray oyster mushroom in their meals, since most of them claimed oyster mushroom is delicious and has been influenced by their family. Soup (78%) and frying (68%) are the most favored cooking styles for mushroom dishes, respondents claimed such styles give the most flavorful taste to the mushrooms and suit the texture of the mushrooms. Mohd Tarmizi et al. (2013) found mushrooms had also been included in Malay cuisine as floss (serunding), in curry dishes, and as satay.

Generally, the questions asked in the Black jelly section were similar to the questions asked in the oyster mushroom section. However, contrary to our expectation, the actual respondents that had black jelly mushrooms or wood ear mushroom (40.3%) were much lower than and not even close to the amount who had oyster mushrooms. Almost half of the respondents voted they never ate black jelly mushroom and wood ear mushroom

(46.2%) (refer **Supplementary Figure 4**). The Department of Agriculture of Malaysia listed that among 17 types of mushroom, the cultivation of black jelly mushroom was only 1.17% compared to oyster mushroom at 90.89% (Rosmiza et al., 2016). This shows demand for black jelly mushroom is still very low, hence more local farmers go for oyster mushrooms instead. Interestingly, respondents who had eaten black jelly mushroom because of its supposed benefits afterwards considered it delicious, while family influences were the lowest contributor to self-consumption.

Availability of the Oyster Mushroom and Black Jelly Mushroom in the Local Community

According to the respondents, most of them had never seen pink oyster mushroom, hence they had never tried it. This is understandable since pink oyster mushroom is almost never seen in the local market (**Supplementary Figure 3**). According torespondents, only white oyster and gray oyster mushroom are commonly found in the supermarket. Moreover, the high number of people consuming oyster mushroom may because of the moderate price offered at the supermarket, neither expensive nor cheap but still affordable for regular consumption. Since most supermarkets in Malaysia mixed imported vegetables and local vegetables, respondents had no idea the origin of the mushroom (54%), while 46% of respondents claimed the mushroom was locally farmed.

In terms of the mushroom availability, black jelly mushroom was easier to find (89.3%) in the market compared to wood ear mushroom (14.3%), according to respondents. Moreover, respondents mentioned that besides the market, online platforms were also among the best options to get black jelly mushrooms. However, the price available in supermarkets was considered somewhat expensive-to-average for the 28 respondents who consume black jelly mushroom. It can be seen, even though the price is considered a bit expensive, people still consume black jelly mushroom, therefore it can be said price is not the sole influence the consumer for vegetable intake. One study showed that during fruit season, the prices were lower than other fruits, and they were sold in abundance even by the roadside (FAMA, 2010), yet those same findings showed that consumption of low-cost seasonal fruits did not rise. Thus, the price was not the sole determinant of seasonal fruit consumption choices. Similarly, another study comparing consumers from several Asian countries found that price is not a significant influence on Malaysian food choices (Prescott et al., 2002).

Nutritional Value of Oyster Mushroom and Black Jelly Mushroom

On the nutritional side of oyster mushrooms, 54% of the 50 respondents who consume oyster mushroom and 2 respondents who did not agreed that the style of cooking may decrease the nutrients, while another 42% disagree with that. It can be concluded that the knowledge of depletion of nutrients by higher temperature is not familiar enough. This can be seen in the results survey, even though washing has no relation to the depletion of nutrients, 8% of respondents still thought washing caused nutrients to decrease in mushrooms. However, 84% of respondents agreed depletion of mushroom nutrients could be caused by high temperature during cooking, style of cooking, and UV radiation; the least expected to cause low nutrients in mushrooms was storage in a refrigerator or freezer (see **Supplementary Figure 3**). Benefits of oyster mushroom also were asked in this survey, some respondents agreed the oyster mushroom is of high nutritional and health-promoting value (35%), good antioxidant properties from bioactive compounds (phenolic content) (22%), and is a good source of protein (21%).

In terms of nutrients of black jelly mushroom, respondents agreed this mushroom contained high nutritional and pharmacological value and good antioxidant properties from bioactive compounds (phenolic content). Furthermore, decrease in nutritional value may be caused by high temperature during cooking, style of cooking, UV radiation, and storage in refrigerator or freezer, according to respondents.

Intake of Oyster Mushroom and Black Jelly Mushroom Consumption

On the other hand, the amount of oyster mushroom intake was mostly not conscious by the respondents who consume this mushroom (54%), and only 46% of them were aware of their intake of this mushroom, therefore it can be seen that both types of respondent probably never thought of food poisoning as really being caused by oyster mushroom (56%) or had actually known about this mushroom causing poisoning (44%). Since only gray and white oyster mushroom are consumed by people in any great quantities, it still considered safe, as most literature recorded no toxicity or poisoning cases reported from oyster species (Deepalakshmi and Mirunalini, 2014; Sharma and Gautam, 2015). Interestingly, respondents who never consume black jelly mushroom (18 people), were conscious about the toxicity of those mushrooms, rather than respondents who had eaten this mushroom (11 people).

CONCLUSION AND RECOMMENDATION

It can be concluded that microwave drying have a lot of benefits as heat treatment to contained bioactive compound and the quality of oyster and black jelly mushroom, followed by freeze-drying and oven drying. Blanching mushrooms only retained flavonoids only but no other valuable components, therefore instead of blanching, using pre-chemical treatments alone could enhance the extraction of phenol in the mushroom, especially potassium bisulfite and vinegar. Ergothioneine yielded greater after microwave treatments. Phenol and flavonoid were not the only compounds that can be seen as indicators of high antioxidant values, this review analysis found antioxidant properties may be enhanced by other valuable compounds such as beta-glucans. Therefore, the microwave is seen to have a better chance to retain these compounds. Apart from that, boiling the mushroom has become a good option for domestic cooking to retain bioactive compounds, even if not as much as microwave treatment for industry purposes, it can be practical for domestic use in retaining healthy nutrition in cooked meals. Based on the observation conducted, many still have not realized that temperature and style of cooking could impact the nutritional values of these mushrooms, hence it

is a huge loss if these beneficial contents cannot be retained in meals. This analysis did not compare the bioavailability of bioactive chemicals released from mushroom extracts and absorbed through the digestive system. More research using an *in vivo* model is needed to offer a more extensive nutritional bioavailability profile across diverse mushroom species. Knowledge about how heat treatments and *in vitro* digestion influence bioavailability in mushrooms would be beneficial to both consumers and food manufacturers for future production and invention.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

II conducted the research as well as the writing of the article. SR gave input on drafting the review article. FA gave constructive comments to improve the article. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supports by the Grant Scheme: 600-RMC/GPK 5/3 (229/2020) from Universiti Teknologi MARA.

ACKNOWLEDGMENTS

The authors would like to thank the Grant Scheme: 600-RMC/GPK 5/3 (229/2020) from Universiti Teknologi MARA. The authors would like to thank the facilities and technical assistance from lab staff from Universiti Teknologi MARA.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.882939/full#supplementary-material

REFERENCES

Abdullah, F., and Rusea, G. (2009). Documentation of inherited knowledge on wild edible fungi from Malaysia. *Blumea J. Plant Taxon. Plant Geogr.* 54, 35–38. doi: 10.3767/000651909X475996

Abidin, M. H. Z., Abdullah, N., and Abidin, N. Z. (2017). Therapeutic properties of Pleurotus species (oyster mushrooms) for atherosclerosis: a review. *Int. J. Food Prop.* 20, 1251–1261. doi: 10.1080/10942912.2016.1210162

Acharya, K., Khatua, S., and Ray, S. (2017). Quality assessment and antioxidant study of *Pleurotus djamor* (Rumph. ex Fr.) *Boedijn* 7, 105–110. doi: 10.7324/JAPS.2017.70614

Adebayo, E., and Oloke, J. K. (2017). Oyster mushroom (pleurotus species); a natural functional food. *J. Microbiol. Biotechnol. Food Sci.* 7, 254–264. doi: 10.15414/jmbfs.2017/18.7.3.254-264

Aishah, M. S., and Rosli, W. I. W. (2013). Effect of different drying techniques on the nutritional values of oyster mushroom (*Pleurotus sajor-caju*). *Sains Malaysiana* 42, 937–941.

Alves, M. J., Ferreira, I. C. F. R. F. R., Froufe, H. J. C. C., Abreu, R. M. V. V., Martins, A., and Pintado, M. (2013). Antimicrobial activity of phenolic compounds identified in wild mushrooms, SAR analysis and docking studies. *J. Appl. Microbiol.* 115, 346–357. doi: 10.1111/jam.12196

Argyropoulos, D., Heindl, A., and Müller, J. (2011a). Assessment of convection, hot-air combined with microwave-vacuum and freeze-drying methods for mushrooms with regard to product quality. *Int. J. Food Sci. Technol.* 46, 333–342. doi: 10.1111/j.1365-2621.2010.02500.x

Argyropoulos, D., Khan, M. T., and Müller, J. (2011b). Effect of air temperature and pre-treatment on color changes and texture of dried Boletus edulis mushroom. *Dry. Technol.* 29, 1890–1900. doi: 10.1080/07373937.2011.594194

Aruoma, O. I. (1999). Free radicals, antioxidants and international nutrition. *Asia Pacific J. Clin. Nutr.* 8, 53–63. doi: 10.1046/j.1440-6047.1999.00036.x

Askari, G. R., Emam-Djomeh, Z., and Mousavi, S. M. (2009). An investigation of the effects of drying methods and conditions on drying characteristics and quality attributes of agricultural products during hot air and hot air/microwave-assisted dehydration. *Dry. Technol.* 27, 831–841. doi: 10.1080/07373930902988106

Bandara, A. R., Rapior, S., Mortimer, P. E., Kakumyan, P., Hyde, D., Xu, J. (2019). A review of the polysaccharide, protein and selected nutrient content of Auricularia, and their potential pharmacological value. *Mycosphere* 10, 579–607. doi: 10.5943/mycosphere/10/1/10

Belessiotis, V., and Delyannis, E. (2011). Solar drying. *Sol. Energy* 85, 1665–1691. doi: 10.1016/j.solener.2009.10.001

Bernaś, E., Jaworska, G., and Kmiecik, W. (2006). Storage and processing of edible mushrooms. *Acta Sci. Pol. Technol. Aliment.* 5, 5–23.

Bhattacharya, M., Srivastav, P. P., and Mishra, H. N. (2013). Effect of microwave-convective drying on antioxidant activity and color of oyster mushroom (*Pleurotus ostreatus*). *Am. Soc. Agric. Biol. Eng. Annu. Int. Meet.* 5, 3854–3866. doi: 10.13031/aim.20131619707

Bhavsar, H. P., and Patel, C. M. (2021). Performance investigation of natural and forced convection cabinet solar dryer for ginger drying. *Mater. Today Proc.* 47, 6128–6133. doi: 10.1016/j.matpr.2021.05.050

Brennan, M., Le Port, G., and Gormley, R. (2000). Post-harvest treatment with citric acid or hydrogen peroxide to extend the shelf life of fresh sliced mushrooms. *LWT Food Sci. Technol.* 33, 285–289. doi: 10.1006/fstl.2000.0657

Brennan, M., Le Port, G., Pulvirenti, A., and Gormley, R. (1999). The effect of sodium metabisulphite on the whiteness and keeping quality of sliced mushrooms. *LWT Food Sci. Technol.* 32, 460–463. doi: 10.1006/fstl.1999.0575

Cai, M., Lin, Y., Luo, Y., Liang, H., and Sun, P. (2015). Extraction, antimicrobial, and antioxidant activities of crude polysaccharides from the wood ear medicinal mushroom *Auricularia auricula-judae* (Higher Basidiomycetes). *Int. J. Med. Mushrooms* 17, 591–600. doi: 10.1615/IntJMedMushrooms.v17.i6.90

Çelen, S., Kahveci, K., and Akyol, U., Haksever, A. (2010). Drying behavior of cultured mushrooms. *J. Food Process. Preserv.* 34, 27–42. doi: 10.1111/j.1745-4549.2008.00300.x

Cheah, I. K., and Halliwell, B. (2012). Ergothioneine; antioxidant potential, physiological function and role in disease. *Biochim. Biophys. Acta* 1822, 784–793. doi: 10.1016/j.bbadis.2011.09.017

Chen, S.-Y., Ho, K.-J., Hsieh, Y.-J., Wang, L.-T., and Mau, J.-L. (2012). Contents of lovastatin, γ-aminobutyric acid and ergothioneine in mushroom fruiting bodies and mycelia. *LWT* 47, 274–278. doi: 10.1016/j.lwt.2012.01.019

Chen, Y., Lv, Z., Liu, Z., Li, X., Li, C., Sossah, F. L., et al. (2020). Effect of different drying temperatures on the rehydration of the fruiting bodies of Yu Muer (*Auricularia cornea*) and screening of browning inhibitors. *Food Sci. Nutr.* 8, 6037–6046. doi: 10.1002/fsn3.1891

Choi, S. R., Yu, Y. J., Ahn, M. S., Song, E. J., Seo, S. Y., Choi, M. K., et al. (2014). Quality characteristics by various drying methods in ear mushroom (*Auricularia auricula-judae* Quel.). *Korean J. Med. Crop Sci.* 22, 497–503. doi: 10.7783/KJMCS.2014.22.6.497

Choi, Y., Lee, S. M., Chun, J., Lee, H. B., and Lee, J. (2006). Influence of heat treatment on the antioxidant activities and polyphenolic compounds of Shiitake (*Lentinus edodes*) mushroom. *Food Chem.* 99, 381–387. doi: 10.1016/j.foodchem.2005.08.004

Corr?a, R. C. G., Brugnari, T., Bracht, A., Peralta, R. M., and Ferreira, I. C. F. R. (2016). Biotechnological, nutritional and therapeutic uses of Pleurotus spp. (Oyster mushroom) related with its chemical composition: a review on the past decade findings. *Trends Food Sci. Technol.* 50, 103–117. doi: 10.1016/j.tifs.2016.01.012

Das, I., and Arora, A. (2018). Alternate microwave and convective hot air application for rapid mushroom drying. *J. Food Eng.* 223, 208–219. doi: 10.1016/j.jfoodeng.2017.10.018

Deepalakshmi, K., and Mirunalini, S. (2014). Toxicological assessment of *Pleurotus ostreatus* in Sprague Dawley rats. *Int. J. Nutr. Pharmacol. Neurol. Dis.* 4, 139. doi: 10.4103/2231-0738.132665

Dewanto, V., Wu, X., Adom, K. K., and Liu, R. H. (2002). Thermal processing enhances the nutritional value of tomatoes by increasing total antioxidant activity. *J. Agri Food Chem.* 50, 3010–3014. doi: 10.1021/jf0115589

Dubost, N. J., Ou, B., and Beelman, R. B. (2007). Quantification of polyphenols and ergothioneine in cultivated mushrooms and correlation to total antioxidant capacity. *Food Chem.* 105, 727–735. doi: 10.1016/j.foodchem.2007.01.030

Duy Bao, H. N., and Ohshima, T. (2013). "Strategies to minimize oxidative deterioration in aquatic food products: application of natural antioxidants from edible mushrooms," in *Lipid Oxidation: Challenges in Food Systems*, eds A. Logan, U. Nienaber, and X. Pan (Urbana, IL: AOCS Press), 345–380. doi: 10.1016/B978-0-9830791-6-3.50014-X

Elisashvili, V. I. (2012). Submerged cultivation of medicinal mushrooms: bioprocesses and products. *Int. J. Med. Mushrooms.* 14, 211–239. doi: 10.1615/IntJMedMushr.v14.i3.10

Erel, O. (2004). A novel automated direct measurement method for total antioxidant capacity using a new generation, more stable ABTS radical cation. *Clin. Biochem.* 37, 277–285. doi: 10.1016/j.clinbiochem.2003.11.015

Erel, O. (2005). A new automated colorimetric method for measuring total oxidant status. *Clin. Biochem.* 38, 1103–1111. doi: 10.1016/j.clinbiochem.2005.08.008

Ey, J., Schömig, E., and Taubert, D. (2007). Dietary sources and antioxidant effects of ergothioneine. *J. Agric. Food Chem.* 55, 6466–6474. doi: 10.1021/jf071328f

FAMA (2010). *Kalendar Buah-Buahan Bermusim 2010*. Malaysia. FAMA, Kementerian Pertanian Malaysia, Kuala Lumpur.

Gattuso, G., Barreca, D., Gargiulli, C., Leuzzi, U., and Caristi, C. (2007). Flavonoid composition of citrus juices. *Molecules* 12, 1641–1673. doi: 10.3390/12081641

Genghof, D. S. (1970). Biosynthesis of ergothioneine and hercynine by fungi and Actinomycetales. *J. Bacteriol.* 103, 475–478. doi: 10.1128/jb.103.2.475-478.1970

Golak-Siwulska, I., Kałuzewicz, A., Spizewski, T., Siwulski, M., and Sobieralski, K. (2018). Bioactive compounds and medicinal properties of Oyster mushrooms (*Pleurotus* sp.). *Folia Hortic.* 30, 191–201. doi: 10.2478/fhort-2018-0012

Gülçin, I., Büyükokuroglu, M. E., Oktay, M., and Küfrevioglu, Ö. I. (2003). Antioxidant and analgesic activities of turpentine of *Pinus nigra Arn.* subsp. *pallsiana* (Lamb.) *Holmboe. J. Ethnopharmacol.* 86, 51–58. doi: 10.1016/S0378-8741(03)00036-9

Han, J.-S., Kim, J.-K., and Kim, A.-J. (2012). The effects of *Auricularia auricula-judae* on blood lipids profile and bone density of middle aged abdominal obese women. *Korean J. Food Nutr. Vol* 25, 1075–1080. doi: 10.9799/ksfan.2012.25.4.1075

Hassan, F. R., and Medany, G. M. (2014). Effect of pretreatments and drying temperatures on the quality of dried pleurotus mushroom spp. *Egypt. J. Agric. Res.* 92, 1009–1023. doi: 10.21608/ejar.2014.156436

Hayat, K., Hussain, S., Abbas, S., Farooq, U., Ding, B., Xia, S., et al. (2009). Optimized microwave-assisted extraction of phenolic acids from citrus mandarin peels and evaluation of antioxidant activity *in vitro*. *Sep. Purif. Technol.* 70, 63–70. doi: 10.1016/j.seppur.2009.08.012

He, J.-Z., Ru, Q.-M., Dong, D.-D., and Sun, P.-L. (2012). Chemical characteristics and antioxidant properties of crude water soluble polysaccharides from four common edible mushrooms. *Molecules* 17, 4373–4387. doi: 10.3390/molecules,17044373

Inah, G., Udota, H., Effiong, B. N., and Eden, E. V. (2021). Optimization of pre-treatment (blanching) and drying on the sensory attributes of tree ear mushroom *Auricularia auricula-judae* (AAJ). *Eur. J. Soc. Sci.* 61, 96–113.

Ismail, A., Marjan, Z., and Foong, C. (2004). Total antioxidant activity and phenolic content in selected vegetables. *Food Chem.* 87, 581–586. doi: 10.1016/j.foodchem.2004.01.010

Jagadish, L. K., Krishnan, V. V., Shenbhagaraman, R., and Kaviyarasan, V. (2009). Comparitive study on the antioxidant, anticancer and antimicrobial property of *Agaricus bisporus* (JE Lange) Imbach before and after boiling. *Afr. J. Biotechnol.* 8, 654–661.

Jaworska, G., Pogoń, K., Bernaś, E., and Duda-Chodak, A. (2015). Nutraceuticals and antioxidant activity of prepared for consumption commercial mushrooms *Agaricus bisporus* and *Pleurotus ostreatus*. *J. Food Qual.* 38, 111–122. doi: 10.1111/jfq.12132

Kalaras, M. D., Richie, J. P., Calcagnotto, A., and Beelman, R. B. (2017). Mushrooms: a rich source of the antioxidants ergothioneine and glutathione. *Food Chem.* 233, 429–433. doi: 10.1016/j.foodchem.2017.04.109

Kanagasabapathy, G., Malek, S. N. A., Kuppusamy, U. R., and Vikineswary, S. (2011). Chemical composition and antioxidant properties of extracts of fresh fruiting bodies of *Pleurotus sajor-caju* (Fr.) Singer. *J. Agric. Food Chem.* 59, 2618–2626. doi: 10.1021/jf104133g

Karaaslan, M., Yilmaz, F. M., Cesur, Ö., Vardin, H., Ikinci, A., and Dalgi,ç, A. C. (2014). Drying kinetics and thermal degradation of phenolic compounds and anthocyanins in pomegranate arils dried under vacuum conditions. *Int. J. Food Sci. Technol.* 49, 595–605. doi: 10.1111/ijfs.12342

Kettawan, A., Chanlekha, K., Kongkachuichai, R., and Charoensiri, R. (2011). Effects of cooking on antioxidant activities and polyphenol content of edible mushrooms commonly consumed in Thailand. *Pakistan J. Nutr.* 10, 1094–1103. doi: 10.3923/pjn.2011.1094.1103

Kho, Y. S., Vikineswary, S., Abdullah, N., Kuppusamy, U. R., and Oh, H. I. (2009). Antioxidant capacity of fresh and processed fruit bodies and mycelium of *Auricularia auricula-judae* (Fr.) Quél. *J. Med. Food* 12, 167–174. doi: 10.1089/jmf.2007.0568

Kibar, B. (2021). Influence of different drying methods and cold storage treatments on the postharvest quality and nutritional properties of *P. ostreatus* mushroom. *Turkish J. Agric. For.* 45, 565–579. doi: 10.3906/tar-2102-76

Kim, H. W. (1993). Toxic components of *Auricularia polytricha*. *Arch. Pharm. Res.* 16, 36–42. doi: 10.1007/BF02974126

Kim, W. Y., Kim, J. M., Han, S. B., Lee, S. K., Kim, N. D., Park, M. K., et al. (2000). Steaming of ginseng at high temperature enhances biological activity. *J. Nat. Prod.* 63, 1702–1704. doi: 10.1021/np990152b

Klomklung, N., Karunarathna, S. C., Chukeatirote, E., and Hyde, K. D. (2012). Domestication of wild strain of Pleurotus giganteus. *Sydowia* 64, 39–53.

Kotwaliwale, N., Bakane, P., and Verma, A. (2007). Changes in textural and optical properties of oyster mushroom during hot air drying. *J. Food Eng.* 78, 1207–1211. doi: 10.1016/j.jfoodeng.2005.12.033

Krakowska, A., Zieba, P., Włodarczyk, A., Kała, K., Sułkowska-Ziaja, K., Bernaś, E., et al. (2020). Selected edible medicinal mushrooms from Pleurotus genus as an answer for human civilization diseases. *Food Chem.* 327. doi: 10.1016/j.foodchem.2020.127084

Lam, Y. S., and Okello, E. J. (2015). Determination of lovastatin, β-glucan, total polyphenols, and antioxidant activity in raw and processed oyster culinary-medicinal mushroom, *Pleurotus ostreatus* (Higher Basidiomycetes). *Int. J. Med. Mushrooms* 17, 117–128. doi: 10.1615/IntJMedMushrooms.v17.i2.30

Lee, K., Lee, H., Choi, Y., Kim, Y., Jeong, H. S., and Lee, J. (2019). Effect of different cooking methods on the true retention of vitamins, minerals, and bioactive compounds in shiitake mushrooms (*Lentinula edodes*). *Food Sci. Technol. Res.* 25, 115–122. doi: 10.3136/fstr.25.115

Lee, W. Y., Park, E.-J., Ahn, J. K., and Ka, K.-H. (2009). Ergothioneine contents in fruiting bodies and their enhancement in mycelial cultures by the addition of methionine. *Mycobiology* 37, 43–47. doi: 10.4489/MYCO.2009.37.1.043

Lee, Y. L., Huang, G. W., Liang, Z. C., and Mau, J. L. (2007). Antioxidant properties of three extracts from *Pleurotus citrinopileatus*. *LWT Food Sci. Technol.* 40, 823–833. doi: 10.1016/j.lwt.2006.04.002

Lelamurni, D., and Razak, A. (2013). *Cultivation of Auricularia polytricha mont. sacc (Black Jelly Mushroom) Using Oil Palm Wastes* Kuala Lumpur: University of Malaya.

Lo, Y. C., Lin, S. Y., Ulziijargal, E., Chen, S. Y., Chien, R. C., Tzou, Y. J., et al. (2012). Comparative study of contents of several bioactive components in fruiting bodies and mycelia of culinary-medicinal mushrooms. *Int. J. Med. Mushrooms* 14, 357–363. doi: 10.1615/IntJMedMushr.v14.i4.30

Lopez, F., Pescador, P., Güell, C., Morales, M. L., García-Parrilla, M. C., and Troncoso, A. M. (2005). Industrial vinegar clarification by cross-flow microfiltration: effect on colour and polyphenol content. *J. Food Eng.* 68, 133–136. doi: 10.1016/j.jfoodeng.2004.05.021

Madrau, M. A., Piscopo, A., Sanguinetti, A. M., Del Caro, A., Poiana, M., Romeo, F. V., et al. (2009). Effect of drying temperature on polyphenolic content and antioxidant activity of apricots. *Eur. food Res. Technol.* 228, 441–448. doi: 10.1007/s00217-008-0951-6

Mahalakshmi, A., Suresh, M., and Rajendran, S. (2019). Cultivation of oyster mushroom *(Pleurotus florida)* in various seasons on paddy straw. *Res. J. Life Sci.* 5, 79–86. doi: 10.26479/2019.0506.07

Mahfuzatunajla, H. (2012). *Biological activities of methanolic extract of selected local mushrooms* (M. Sc. thesis). University Putra Malaysia, Selangor, Malaysia.

Martínez-Soto, G., Ocanña-Camacho, R., and Paredes-López, O. (2001). Effect of pretreatment and drying on the quality of oyster mushrooms (*Pleurotus ostreatus*). *Dry. Technol.* 19, 661–672. doi: 10.1081/DRT-100103942

Mat-Amin, M. Z., Harun, A., and Abdul-Wahab, M. A. M. (2014). Status and potential of mushroom industry in Malaysia. *Econ. Technol. Manag. Rev.* 9, 103–111.

Mau, J.-L., Chang, C.-N., Huang, S.-J., and Chen, C.-C. (2004). Antioxidant properties of methanolic extracts from *Grifola frondosa*, *Morchella esculenta* and Termitomyces albuminosus mycelia. *Food Chem.* 87, 111–118. doi: 10.1016/j.foodchem.2003.10.026

Mau, J.-L., Chao, G.-R., and Wu, K.-T. (2001). Antioxidant properties of methanolic extracts from several ear mushrooms. *J. Agric. Food Chem.* 49, 5461–5467. doi: 10.1021/jf010637h

Miao, J., Regenstein, J. M., Qiu, J., Zhang, J., Zhang, X., Li, H., et al. (2020). Isolation, structural characterization and bioactivities of polysaccharides and its derivatives from Auricularia-A review. *Int. J. Biol. Macromol.* 150, 102–113. doi: 10.1016/j.ijbiomac.2020.02.054

Mishra, K. K., Pal, R. S., Mishra, P. K., and Bhatt, J. C. (2016). Antioxidant activities and mineral composition of oyster mushroom (*Pleurotus sajor-caju*) as influenced by different drying methods. *Asian J. Chem.* 28, 2025–2030. doi: 10.14233/ajchem.2016.19873

Mohd Tarmizi, H., Rahim, H., and Rozhan Abu, D. (2013). Understanding the mushroom industry and its marketing strategies for fresh produce in Malaysia. *Econ. Technol. Manag. Rev.* 8, 27–37.

Muszyńska, B., Sułkowska-Ziaja, K., and Ekiert, H. (2013). Phenolic acids in selected edible basidiomycota species: *Armillariamellea, Boletus badius, Boletus edulis, Cantharellus cibarius, Lactarius* deliciosus and Pleurotus ostreatus. *Acta Sci. Pol. Hortorum Cultus* 12, 107–116.

Mutukwa, I. (2014). Drying and pretreatments affect the nutritional and sensory quality of Oyster mushrooms. *North Dakota State Univ. Grad. Sch.* 1–137.

Mutukwa, I. B., Hall, C. A., Cihacek, L., and Lee, C. W. (2019). Evaluation of drying method and pretreatment effects on the nutritional and antioxidant properties of oyster mushroom (*Pleurotus ostreatus*). *J. Food Process. Preserv.* 43, 1–9. doi: 10.1111/jfpp.13910

Nattoh, G., Musieba, F., Gatebe, E., and Mathara, J. (2016). Towards profiling differential distribution of bioactive molecules across four phenologies in *Pleurotus djamor* R22. *Asian Pacific J. Trop. Dis.* 6, 472–480. doi: 10.1016/S2222-1808(16)61071-X

Ng, Z. X., and Rosman, N. F. (2019). *In vitro* digestion and domestic cooking improved the total antioxidant activity and carbohydrate-digestive enzymes inhibitory potential of selected edible mushrooms. *J. Food Sci. Technol.* 56, 865–877. doi: 10.1007/s13197-018-3547-6

Nguyen, T. H., Nagasaka, R., and Ohshima, T. (2012). Effects of extraction solvents, cooking procedures and storage conditions on the contents of ergothioneine and phenolic compounds and antioxidative capacity of the cultivated mushroom *Flammulina velutipes*. *Int. J. food Sci. Technol.* 47, 1193–1205. doi: 10.1111/j.1365-2621.2012.02959.x

Nöfer, J., Lech, K., Figiel, A., Szumny, A., and Carbonell-Barrachina, ?. A. (2018). The influence of drying method on volatile composition and sensory profile of Boletus edulis. *J. Food Qual.* 2018, 1–11. doi: 10.1155/2018/2158482

Nölle, N., Argyropoulos, D., Ambacher, S., Müller, J., and Biesalski, H. K. (2017). Vitamin D2 enrichment in mushrooms by natural or artificial UV-light during drying. *LWT Food Sci. Technol.* 85, 400–404. doi: 10.1016/j.lwt.2016.11.072

Oke, F., and Aslim, B. (2011). Protective effect of two edible mushrooms against oxidative cell damage and their phenolic composition. *Food Chem.* 128, 613–619. doi: 10.1016/j.foodchem.2011.03.036

Oprica, L., Antohe, R. G., Verdes, A., and Grigore, M. N. (2019). Effect of freeze-drying and oven-drying methods on flavonoids content in two romanian grape varieties. *Rev. Chim.* 70, 491–494. doi: 10.37358/RC.19.2.6941

Packialakshmi, B., Sudha, G., and Charumathy, M. (2015). Total phenol, flavonoid and antioxidant properties of *Auricularia auricula-judae*. *Int. J. Pharm. Pharm. Sci.* 7, 233–237.

Packialakshmi, B., Sudha, G., and Charumathy, M. (2017). Studies on phytochemical compounds and antioxidant potential of *Auricularia auricula-judae*. *Artic. Int. J. Pharm. Sci. Res.* 8, 3508–3515. doi: 10.13040/IJPSR.0975-8232.8(8).3508-15

Pak, S. J., Chen, F., Ma, L., Hu, X., and Ji, J. (2021). Functional perspective of black fungi (*Auricularia auricula*): Major bioactive components, health benefits and potential mechanisms. *Trends Food Sci. Technol.* 114, 245–261. doi: 10.1016/j.tifs.2021.05.013

Palacios, I., Lozano, M., Moro, C., D'arrigo, M., Rostagno, M. A., Martínez, J. A., et al. (2011). Antioxidant properties of phenolic compounds occurring in edible mushrooms. *Food Chem.* 128, 674–678. doi: 10.1016/j.foodchem.2011.03.085

Patel, Y., Naraian, R., and Singh, V. K. (2012). Medicinal properties of pleurotus species (oyster mushroom): a review. *World J. Fungal Plant Biol.* 3, 1–12. doi: 10.5829/idosi.wjfpb.2012.3.1.303

Paul, B. D., and Snyder, S. H. (2010). The unusual amino acid L-ergothioneine is a physiologic cytoprotectant. *Cell Death Differ.* 17, 1134–1140. doi: 10.1038/cdd.2009.163

Phan, C.-W., Wong, W.-L., David, P., Naidu, M., and Sabaratnam, V. (2012). *Pleurotus giganteus* (Berk.) Karunarathna and KD Hyde: Nutritional value and *in vitro* neurite outgrowth activity in rat pheochromocytoma cells. *BMC Complement. Altern. Med.* 12, 102. doi: 10.1186/1472-6882-12-102

Phan, C. W. (2015). Neurite outgrowth stimulatory activity of an edible mushroom Pleurotus Giganteus in differentiating neuroblastoma-2a cells/Phan *Chia Wei* (Ph.D. thesis). University of Malaya, Kuala Lumpur, Malaysia.

Phan, C. -W., David, P., Tan, Y. -S., Naidu, M., Wong, K. -H., Kuppusamy, U. R., et al. (2014). Intrastrain comparison of the chemical composition and antioxidant activity of an edible mushroom, Pleurotus giganteus, and its potent neuritogenic properties. *Sci. World J.* 2014, 1–10 doi: 10.1155/2014/378651

Piska, K. T., Sułkowska-Ziaja, K., and Muszyńska, B. (2017). Edible mushroom Pleurotus ostreatus (oyster mushroom)-its dietary significance and biological activity. *Acta Sci. Pol. Hortorum Cultus* 16, 151–161.

Piskov, S., Timchenko, L., Grimm, W. D., Rzhepakovsky, I., Avanesyan, S., Sizonenko, M., et al. (2020). Effects of various drying methods on some physico-chemical properties and the antioxidant profile and ACE inhibition activity of oyster mushrooms (*Pleurotus ostreatus*). *Foods* 9, 160. doi: 10.3390/foods9020160

Prabu, M., and Kumuthakalavalli, R. (2016). Antioxidant activity of oyster mushroom (*Pleurotus florida* [Mont.] singer) and milky mushroom (Calocybe indica P and C). *Int. J. Curr. Pharm. Rev. Res.* 8, 48–51.

Prescott, J., Young, O., O'neill, L., Yau, N. J. N., and Stevens, R. (2002). Motives for food choice: a comparison of consumers from Japan, Taiwan, Malaysia and New Zealand. *Food Qual. Prefer.* 13, 489–495. doi: 10.1016/S0950-3293(02)00010-1

Rajarathnam, S., Bano, Z., and Miles, P. G. (1987). Pleurotus mushrooms. Part I A. Morphology, life cycle, taxonomy, breeding, and cultivation. *Crit. Rev. Food Sci. Nutr.* 26, 157–223. doi: 10.1080/10408398709527465

Ramsaha, S., Neergheen-Bhujun, V. S., Verma, S., Kumar, A., Bharty, R. K., Chaudhary, A. K., et al. (2016). Modulation of hepatocarcinogenesis in N-methyl-N-nitrosourea treated Balb/c mice by mushroom extracts. *Food Funct.* 7, 594–609. doi: 10.1039/C5FO00870K

Ren, L., Hemar, Y., Perera, C. O., Lewis, G., Krissansen, G. W., and Buchanan, P. K. (2014). Antibacterial and antioxidant activities of aqueous extracts of eight edible mushrooms. *Bioact. Carbohydrates Diet. Fibre* 3, 41–51. doi: 10.1016/j.bcdf.2014.01.003

Reyes, A., Mahn, A., Cubillos, F., and Huenulaf, P. (2013). Mushroom dehydration in a hybrid-solar dryer. *Energy Convers. Manag.* 70, 31–39. doi: 10.1016/j.enconman.2013.01.032

Rocha-Guzmán, N. E., González-Laredo, R. F., Ibarra-Pérez, F. J., Nava-Berumen, C. A., and Gallegos-Infante, J.-A. (2007). Effect of pressure cooking on the antioxidant activity of extracts from three common bean (*Phaseolus vulgaris* L.) cultivars. *Food Chem*. 100, 31–35. doi: 10.1016/j.foodchem.2005.09.005

Rosmiza, M. Z., Davies, W. P., Aznie Cr, R., Jabil, M. J., Mazdi, M., Aznie, R. C., et al. (2016). Prospects for increasing commercial mushroom production in Malaysia: challenges and opportunities. *Mediterr. J. Soc. Sci*. 7, 406–415. doi: 10.5901/mjss.2016.v7n1s1p406

Rout, M. K., Mohapatra, K. B., Mohanty, P., Chandan, S. S., Kendra, K. V., Pathology, P., et al. (2015). Studies on effect of incubation temperature and light intensity on mycelial growth of oyster species. *J. Crop Weed* 11, 44–46.

Samsudin, N. I. P., and Abdullah, N. (2019). Edible mushrooms from Malaysia; A literature review on their nutritional and medicinal properties. *Int. Food Res. J*. 26, 11–31. Available online at: http://www.ifrj.upm.edu.my/26%20(01)%202019/(2).pdf

Sarpong, F., Yu, X., Zhou, C., Amenorfe, L. P., Bai, J., Wu, B., et al. (2018). The kinetics and thermodynamics study of bioactive compounds and antioxidant degradation of dried banana (*Musa* ssp.) slices using controlled humidity convective air drying. *J. Food Meas. Charact*. 12, 1935–1946. doi: 10.1007/s11694-018-9809-1

Sekara, A., Kalisz, A., Grabowska, A., and Siwulski, M. (2015). Auricularia spp.-mushrooms as Novel Food and therapeutic agents-A review. *Sydowia* 67, 1–10. doi: 10.12905/0380.sydowia67-2015-001

Shamaruddin, N., Tan, E. T. T., Shin, T. Y., Razali, R. M., and Siva, R. (2021). Comparison of cooking methods on physicochemical and sensory properties of the Black Jelly Mushroom, *Auricularia polytricha* (Heterobasidiomycetes). *Int. J. Med. Mushrooms* 23, 41–49. doi: 10.1615/IntJMedMushrooms.2021038812

Sharma, S. K., and Gautam, N. (2015). Chemical, bioactive, and antioxidant potential of twenty wild culinary mushroom species. *Biomed. Res. Int*. 2015, 1–12. doi: 10.1155/2015/346508

Singhal, S., Rasane, P., Kaur, S., Singh, J., and Gupta, N. (2020). Thermal degradation kinetics of bioactive compounds in button mushroom (Agaricus bisporus) during tray drying process. *J. Food Process Eng*. 43, e13555. doi: 10.1111/jfpe.13555

Soler-Rivas, C., Ramírez-Anguiano, A. C., Reglero, G., and Santoyo, S. (2009). Effect of cooking, *in vitro* digestion and Caco-2 cells absorption on the radical scavenging activities of edible mushrooms. *Int. J. food Sci. Technol*. 44, 2189–2197. doi: 10.1111/j.1365-2621.2009.02059.x

Song, Y. S., Kim, S.-H., Sa, J.-H., Jin, C., Lim, C.-J., and Park, E.-H. (2003). Anti-angiogenic, antioxidant and xanthine oxidase inhibition activities of the mushroom *Phellinus linteus*. *J. Ethnopharmacol*. 88, 113–116. doi: 10.1016/S0378-8741(03)00178-8

Srikram, A., and Supapvanich, S. (2016). Proximate compositions and bioactive compounds of edible wild and cultivated mushrooms from Northeast Thailand. *Agric. Nat. Resour*. 50, 432–436. doi: 10.1016/j.anres.2016.08.001

Stamets, P. (2011). *Growing Gourmet and Medicinal Mushrooms*. Berekely, CA: Ten Speed Press. p. 223–257.

Su, D., Lv, W., Wang, Y., Wang, L., and Li, D. (2020). Influence of microwave hot-air flow rolling dry-blanching on microstructure, water migration and quality of *Pleurotus eryngii* during hot-air drying. *Food Control* 114, 107228. doi: 10.1016/j.foodcont.2020.107228

Sudha, G., Janardhanan, A., Moorthy, A., Chinnasamy, M., Gunasekaran, S., Thimmaraju, A., et al. (2016). Comparative study on the antioxidant activity of methanolic and aqueous extracts from the fruiting bodies of an edible mushroom *Pleurotus djamor*. *Food Sci. Biotechnol*. 25, 371–377. doi: 10.1007/s10068-016-0052-4

Sun, L., Bai, X., and Zhuang, Y. (2014). Effect of different cooking methods on total phenolic contents and antioxidant activities of four Boletus mushrooms. *J. Food Sci. Technol*. 51, 3362–3368. doi: 10.1007/s13197-012-0827-4

Tan, Y. S., Baskaran, A., Nallathamby, N., Chua, K. H., Kuppusamy, U. R., and Sabaratnam, V. (2015). Influence of customized cooking methods on the phenolic contents and antioxidant activities of selected species of oyster mushrooms (*Pleurotus* spp.). *J. Food Sci. Technol*. 52, 3058–3064. doi: 10.1007/s13197-014-1332-8

Teoh, H. L., Ahmad, I. S., Johari, N. M. K., Aminudin, N., and Abdullah, N. (2018). Antioxidant properties and yield of wood ear mushroom, *Auricularia polytricha* (Agaricomycetes), cultivated on rubberwood sawdust. *Int. J. Med. Mushrooms* 20, 369–380. doi: 10.1615/IntJMedMushrooms.2018025986

Thillaimaharani, K. A., Sharmila, K., Thangaraju, P., Karthick, M., and Kalaiselvam, M. (2013). Studies on antimicrobial and antioxidant properties of oyster mushroom Pleurotus florida. *Int. J. Pharm. Sci. Res*. 4, 1540–1545. doi: 10.13040/IJPSR.0975-8232.4(4).1540-45

Toor, R. K., and Savage, G. P. (2006). Effect of semi-drying on the antioxidant components of tomatoes. *Food Chem*. 94, 90–97. doi: 10.1016/j.foodchem.2004.10.054

Walde, S. G., Velu, V., Jyothirmayi, T., and Math, R. G. (2006). Effects of pretreatments and drying methods on dehydration of mushroom. *J. Food Eng*. 74, 108–115. doi: 10.1016/j.jfoodeng.2005.02.008

Wong, F. C., Chai, T. T., Tan, S. L., and Yong, A. L. (2013). Evaluation of bioactivities and phenolic content of selected edible mushrooms in Malaysia. *Trop. J. Pharm. Res*. 12, 1011–1016. doi: 10.4314/tjpr.v12i6.21

Xu, F., Huang, X., Wu, H., and Wang, X. (2018). Beneficial health effects of lupenone triterpene: a review. *Biomed. Pharmacother*. 103, 198–203. doi: 10.1016/j.biopha.2018.04.019

Yun, H. K., Boon, C. S., Shin, T. Y., and Sabaratnam, V. (2020). Breeding and evaluation of *Pleurotus giganteus* (Berk.) Karunarathna and K.D. Hyde hybrids via intraspecific mating. *Sains Malaysiana* 49, 1223–1236. doi: 10.17576/jsm-2020-4906-02

Zeng, X., Suwandi, J., Fuller, J., Doronila, A., and Ng, K. (2012). Antioxidant capacity and mineral contents of edible wild Australian mushrooms. *Food Sci. Technol. Int*. 18, 367–379. doi: 10.1177/1082013211427993

Zhang, J., Chen, Q., Huang, C., Gao, W., and Qu, J. (2015). History, current situation and trend of edible mushroom industry development. *Mycosystema* 34, 524–540. doi: 10.13346/j.mycosystema.150076

Zhang, M., Tang, J., Mujumdar, A. S., and Wang, S. (2006). Trends in microwave-related drying of fruits and vegetables. *Trends Food Sci. Technol*. 17, 524–534. doi: 10.1016/j.tifs.2006.04.011

Zivanovic, S., and Buescher, R. (2004). Changes in mushroom texture and cell wall composition affected by thermal processing. *J. Food Sci*. 69, SNQ44–SNQ49. doi: 10.1111/j.1365-2621.2004.tb17885.x

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Sustainable Food Systems

PERSPECTIVE
published: 23 June 2022
doi: 10.3389/fsufs.2022.924396

Perspectives of Meat Eaters on the Consumption of Cultured Beef (*in vitro* Production) From the Eastern Cape of South Africa

Bamidele Andrew Falowo[1], *Yiseyon Sunday Hosu*[2,3] *and Emrobowansan Monday Idamokoro*[2,3]*

[1] *Department of Animal Science, Adekunle Ajasin University, Akungba-Akoko, Nigeria,* [2] *Small-Scale Agribusiness and Rural Non-farm Enterprise, Niche Area, Walter Sisulu University, Mthatha, South Africa,* [3] *Faculty of Commerce and Administration, Department of Economics and Business Sciences, Walter Sisulu University, Mthatha, South Africa*

The creation and growing popularity of cultured meat has raised mixed reactions among consumers about its originality, acceptability, edibility, and nutritional quality across the world. The perception and reaction of consumers to novel meat are influenced by a variety of factors, such as geographical location, media coverage, educational status, culture, and religion. Therefore, this study was designed to examine the perceptions of consumers on the consumption of natural vs. cultured beef in the Eastern Cape Province, South Africa. A total of 255 respondents were interviewed using structured questionnaires, and the data were analyzed using descriptive statistics and X^2 tests. Interviewees included representatives from University (educated), urban (literate), and rural (semi-literate) communities. The results revealed the majority (63%) of the respondents had not heard about the concept of cultured beef production, of which 27% of them were men and 36% were women. More than half (53%) of the respondents indicated their willingness to eat cultured beef if offered to them after explaining the concept and process of making cultured beef to them. Among all factors that were analyzed, the participant level of education was found to significantly influence their willingness to eat cultured beef when available commercially. It is therefore concluded that the majority of consumers in this study supported the concept of cultured meat as an alternative way to complement conventional meat production and would be willing to eat it when provided.

Keywords: meat eaters, perceptions, cultured beef, meat production, meat

OPEN ACCESS

Edited by:
Reema Fayez Tayyem, Qatar University, Qatar

Reviewed by:
Hiba Al-Sayyed, Petra University, Jordan
Mohammed O. Ibrahim, Mutah University, Jordan
Sabika Allehdan, The University of Jordan, Jordan

***Correspondence:**
Emrobowansan Monday Idamokoro
midamokoro@wsu.ac.za;
mondayidamokoro@gmail.com

Specialty section:
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Sustainable Food Systems

Received: *20 April 2022*
Accepted: *19 May 2022*
Published: *23 June 2022*

Citation:
Falowo BA, Hosu YS and Idamokoro EM (2022) Perspectives of Meat Eaters on the Consumption of Cultured Beef (in vitro Production) From the Eastern Cape of South Africa. Front. Sustain. Food Syst. 6:924396. doi: 10.3389/fsufs.2022.924396

INTRODUCTION

The geometric rise in meat consumption across the world over the past few years has been phenomenal. Presently, worldwide average meat consumption is estimated at 42.9 kg per capita, with industrial countries consuming about 76.1 kg, two times the quantity in developing countries (33.6 kg) (FAO, 2014; WWF Report, 2016). However, it has been indicated that the consumption of meat and meat products will double by 2050, and beef consumption will increase by 200% in developing countries (FAO, 2011; Chriki and Hocquette, 2020). This increase could be attributed to several reasons, including (a) the processing of meat into ready-to-eat products (such as, sausage,

polonies, and patties), (b) the application of innovative technologies to increase production and improve qualities, such as tenderness, leanness (fat content), palatability, freshness, shelf life, and safety, (c) awareness on its inherent essential micronutrients, such as iron, zinc, calcium, vitamin A, vitamin B1, and other bioactive compounds (Datar and Betti, 2010). Beyond this, the shift toward high meat consumption has been attributed to an increase in income and the human population, which has been forecast to reach 9 billion in 2050 (Nellemann et al., 2009; Alexandratos and Bruinsma, 2012; OECD-FAO, 2021). As the world becomes more developed and prosperous, the global consumption of meat (such as, beef) will continue to rise enormously in the coming decades (van der Weele and Tramper, 2014; OECD-FAO, 2021).

As a consequence, satisfying the demand for meat without an alternative means of meat production will be a great challenge (Post, 2012; Goodwin and Shoulders, 2013). Innovation and productivity improvements alone in conventional beef production may not be enough to mitigate these challenges. Any further attempt to engender intensive (mass-scale) meat production may cause more harmful effects on the environment, public health, and the global economy (Smil, 2014). Similarly, commitment to vegetarianism or a meatless diet (meatless Monday) will not fundamentally affect future demand for meat (Smil, 2014). Therefore, the production of alternative meat sources, such as cultured meat among others is seen as a hopeful option to complement conventional beef production (Tuomisto, 2010; Zaraska, 2013; Chriki and Hocquette, 2020). *In vitro* meat, also known as "cultured or clean meat" is meat produced without slaughtering the animal from embryonic stem cells or adult stem cells (Post, 2012; Post et al., 2020; Newton and Blaustein-Rejto, 2021). Given the appropriate technology has been fully developed, cultured meat could be seen as an option to diminish the increasing problems associated with meat production, such as greenhouse emissions, animal welfare (suffering caused by intensive farming), the mass slaughter of animals, and health claims (Chiles, 2013; Hocquette et al., 2015; Newton and Blaustein-Rejto, 2021).

Moreover, the creation of cultured meat has raised mixed reactions among consumers about its originality, edibility, and nutritional quality. However, it is worth noting that the world's first cultured beef burger was launched on 5 August 2013 for sensory evaluation in London (Riverside TV studios) in front of a live audience and was streamed internationally for an interested individual to gain familiarity with the technology (Zaraska, 2013; O'Riordan et al., 2017). Yet some consumers are skeptical about the suitability of the meat. Verbeke et al. (2015) in a survey study conducted in Belgium, Portugal, and the United Kingdom revealed that most participants were disgusted when they first heard about the cultured meat, while others thought it was ridiculous and completely unnatural. In the United States, Wilks and Phillips (2017) revealed in an online survey study that one-third of the respondents showed a willingness to eat cultured meat regularly or as a replacement for farmed meat when provided. In another study involving an analysis of 34 United States and European Union newspapers, Goodwin and Shoulders (2013) found a statement indicating that if cultured meat feels and tastes similar to meat, people will buy it. Laestadius and Caldwell (2015) observed the comment of consumers in an online newspaper survey and found that the majority described cultured meat as an unnatural and unappealing food. However, in Africa, limited or no information is available on the knowledge and reaction of consumers to cultured meat.

Presently, cultured meat is yet to be commercially available. However, some researchers are convinced and optimistic that its production will reduce the meat industry's environmental footprint, while others have criticized its potential or advantages (Hocquette et al., 2015; Newton and Blaustein-Rejto, 2021). It is expected that factors, such as media information, culture, religious belief, public involvement, affluence, age, level of education, health-related issues, and trust in science and technology could influence the perception and reaction of consumers to food products (Chiles, 2013; Fayemi and Muchenje, 2014; Font-i-Furnols and Guerrero, 2014; Verbeke et al., 2015). To some extent, craving for originality, nutritional quality, and healthiness can also determine consumer perceptions and acceptance of cultured meat (Guerrero et al., 2013).

Therefore, the objective of this study was to investigate the perceptions of meat consumers regarding the potential and willingness to eat cultured beef (*in vitro* meat production) in the Eastern Cape Province, South Africa.

MATERIALS AND METHODS

Study Site and Sampling

The study was conducted in the Eastern Cape Province of South Africa. The Eastern Cape is the second largest province in the country covering approximately 169,580 km^2 (13.9%) of the total land area of South Africa. The province is located on the east coast of South Africa with an average population of 6.62 million people constituting about 12.5% of the country's population. The province is largely dominated by blacks, of whom 78% are Xhosa-speaking. The Eastern Cape is regarded as the home of livestock, having the highest number of beef cattle production in the country (DAFF, 2013). The chosen municipalities in the province for this study include Nkonkobe (Alice and Dimbaza), Buffalo city (Mdantsane and KingWilliams town), and Alfred-Nzo (Mount Frere and Mount Ayliff). According to their geographical location, the three municipalities were further stratified into three groups to include University (Alice), urban (Mdantsane and KingWilliams town), and rural (Dimbaza, Mount Frere, and Mount Ayliff) communities. The stratification of the municipalities in this study supports the widely-held view that consumer perception varies according to geographical location (Dindyal and Dindyal, 2003). The total population of the people living in the study area selected for this study is < 2 million. With the use of the Raosoft calculator, and the confidence level set at 95% (with the confidence interval at 5%), the total expected sample size is 384 participants.

Data Collection

The data used in the present study were obtained from 255 respondents. This was so because of some constraints, such as scarce resources, the inability of respondents to properly

answer the questionnaires, and the lack of willingness of some respondents to partake in the study. Of the 255 respondents, 101 participants were selected from the university community, 66 from the urban community, and 88 from the rural community. Meanwhile, the larger the population of a given area does not necessarily increase the sample size of the area (Krejcie and Morgan, 1970). A snowball sampling technique was used to collect the data. We aimed to get representation from a wide variety of perspectives, and interviewees were selected from universities (those that have unlimited access to information, especially through social media, such as the internet), urban (those that are literate) and rural (those that are semi-literate) communities. Questionnaires (with closed-ended questions) were administered through personal contact in the respondent's residence. Those respondents that do not fill their questionnaire properly and completely from all the categories were also excluded from the analysis. The respondents provided information on demographic characteristics (such as, age group, gender, and education), perception on the consumption of beef, possible reasons of not eating beef, and knowledge and willingness to eat cultured meat (*in vitro* production), if provided. Some of the questions asked about the consumption of beef include (i) do you eat meat from cattle, (ii) how often do you eat meat from cattle, (iii) what are the factors influencing the choice/purchase of beef, and (iv) possible reasons why you do not eat beef. While questions asked on knowledge and willingness to eat cultured meat include (i) have you heard about or aware of the production of *in vitro* meat, (ii) do you agree that the production of *in vitro* meat/beef is important for enhancing food security, (iii) will you like to eat *in vitro* meat/beef if provided, and if no, give a reason. Before data collection, a group of experienced field workers that could effectively communicate with the respondents in vernacular (Xhosa) and English Language were recruited to administer the questionnaires. Each member of the group was trained on how to administer the questionnaire correctly and also describe the cultured meat for easy understanding of the respondent. The primary term used to describe the "cultured meat" includes meat grown in the laboratory from the adult cells of an animal.

Statistical Analysis

Data were analyzed using the Frequency procedure (PROC FREQ) and the chi-square procedures (PROC CHISQ) of the Statistical Analysis System (SAS, version 1.9.3 of 2007). PROC FREQ was computed based on the age groups, gender classes, tribes, locations, and levels of education of the respondents. PROC CHISQ was used to determine the association between demographic characteristics of the respondents and their perceptions of the production and consumption of *in vitro* cultured beef.

RESULTS AND DISCUSSION

Consumer Distribution and Socio-Demographic Characteristics

Results on participant's distribution according to locations showed that the university community had the highest proportion of respondents (39.6%), followed by urban (34.5%) and rural (25.9%) dwellers, respectively (**Table 1**). Regarding the socio-demographic characteristics of the respondents, 47.5% were men and 52.5% were women. Nearly 50% of the respondents were aged between 18 and 30 years, while other respondents were within the age categories of 18 years or below (3.5%), 31–40 years (16.5%), and 41 years or above (31.8%). The majority of the respondents (85.1%) were Xhosa-speaking people while the rest were non-Xhosa. More than half of the respondents (58.1%) had obtained tertiary education, while 27.8 and 5.5% had only primary and secondary education respectively. Only 8.6% of the respondents had no formal school education (other).

TABLE 1 | Demographic characteristics of the respondents ($n = 255$).

Variable	Group	Value	Proportion (%)
Gender	Male	121	47.5
	Female	134	52.5
Age	<18	9	3.5
	18–30	123	48.2
	31–40	42	16.5
	>40	81	31.8
Education	Primary	14	5.5
	Secondary	71	27.8
	Tertiary	148	58.1
	Others	22	8.6
Tribe	Xhosa	217	85.1
	Non-Xhosa	38	14.9
Location	University	101	39.6
	Urban	66	25.9
	Rural	88	34.5

Consumers' Perceptions of Beef Quality and Consumption in Eastern Cape Province

The results of the deposition of respondents to beef consumption are shown on **Figure 1**. The majority of the respondents (89%) were beef eaters while 11% do not eat beef based on various reasons. Of the 89% of respondents that were beef consumers, 44.5% were men and women. In addition, out of the non-beef consumers, 1% claimed to be vegetarians, 5% linked their decision to an allergic reaction, and the remaining 5% attributed their reason to cultural beliefs and personal preferences. A similar result on beef consumption among consumers has been reported in Ghana, Tanzania, and Nigeria (Nandonde et al., 2013; Osei-Asare and Eghan, 2014; Okoronkwo et al., 2020). Preference for beef could be attributed to its role as the first-choice meat for social, religious, and cultural functions in the Eastern Cape and other parts of Africa. This preference for beef is not limited to a province in South Africa but has been reported as the highest consumed meat type in Africa (Guerrero et al., 2013; FAOSTAT, 2014). On the other hand, our results further agree with the findings of Smil (2014), who reported that < 4% of Western society populations are vegetarians (non-meat eaters).

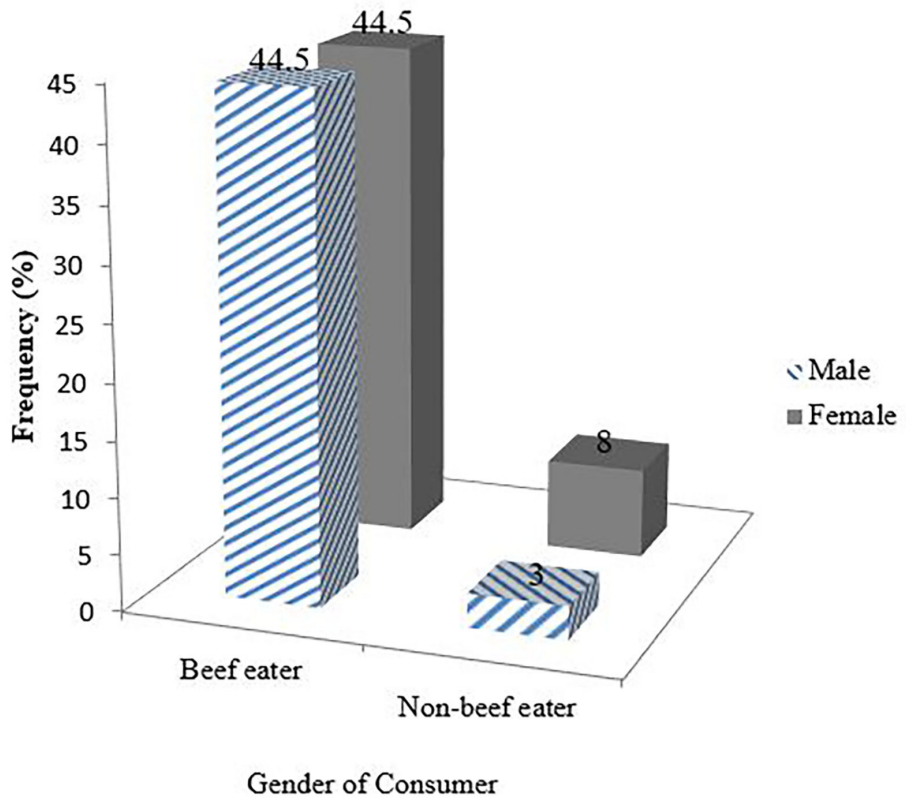


FIGURE 1 | Effect of gender on consumption of conventional beef in the Eastern Cape province of South Africa.

The proportion of participants that indicated allergic reactions after eating beef in this study is in line with the reports of Sampson (2004) and Hong and Vogel (2010), who found that food allergies, such as meat, only affect < 4% of the adult population in the United States. However, different symptoms, such as itching, skin rash, headache, coughing, and throat swelling were reported by the respondents as a consequence of allergic reactions after eating beef and other red meat products. Saleh et al. (2012) reported that allergic reactions are caused by the presence of alpha-gal (oligosaccharide) in beef and other red meat. Following the consumption of beef, the alpha-gal activates T helper 2 (Th2) and causes induction of interleukins, leading to the formation of IgE antibodies by B cells and this, in turn, culminates in mast cell activation, eosinophilia, and hypersensitivity reactions in predisposed individuals. In contrast, Alexander and Cushing (2011) and reported that the association of beef consumption to health risks may be confounded or modified by other dietary factors (such as, high intake of refined sugars and alcohol, or low intake of fruits and vegetables) and/or behavioral factors (low physical activity and smoking) rather than the consumption of beef and other red meat. Conversely, there has been no concrete/conclusive evidence that moderate consumption of beef has negative health effects on consumers (Van Wezemae et al., 2010; Wyness et al., 2011). The result on factors influencing the purchase of beef clearly showed that freshness/color and price were the most quality dictators when purchasing beef market (**Figure 2**). Very few consumers purchase beef in relation to its source or fat content. The results from the present study agree with those obtained by Robbins et al. (2003), McCarthy and Henson (2004), Jocumsen (2005), and Predanocyová et al. (2019), who found freshness, color, and price as most important factors dictating the purchase of meat in shop and butcheries.

Consumers' Perception Toward Their Knowledge of Cultured "*in vitro*" Beef Production

As presented in **Table 2**, the result revealed that 63% of the respondents (26.7% male and 36.1% female) have not heard about the idea of cultured beef production ($p < 0.05$). Most respondents living in the university community were found to be more conversant with the idea of cultured beef than those from urban and rural areas ($p < 0.01$). These could be attributed to a number of factors, such as inadequate media publicity and access to current information on innovative products. Although, Goodwin and Shoulders (2013) reported that consumer awareness and information/media coverage on cultured meat are still in their infancy. Therefore, a proactive communication scheme for the production of *in vitro* cultured beef would be necessary to create more awareness on the importance for future benefits. This in turn could allow the agricultural industry to have greater

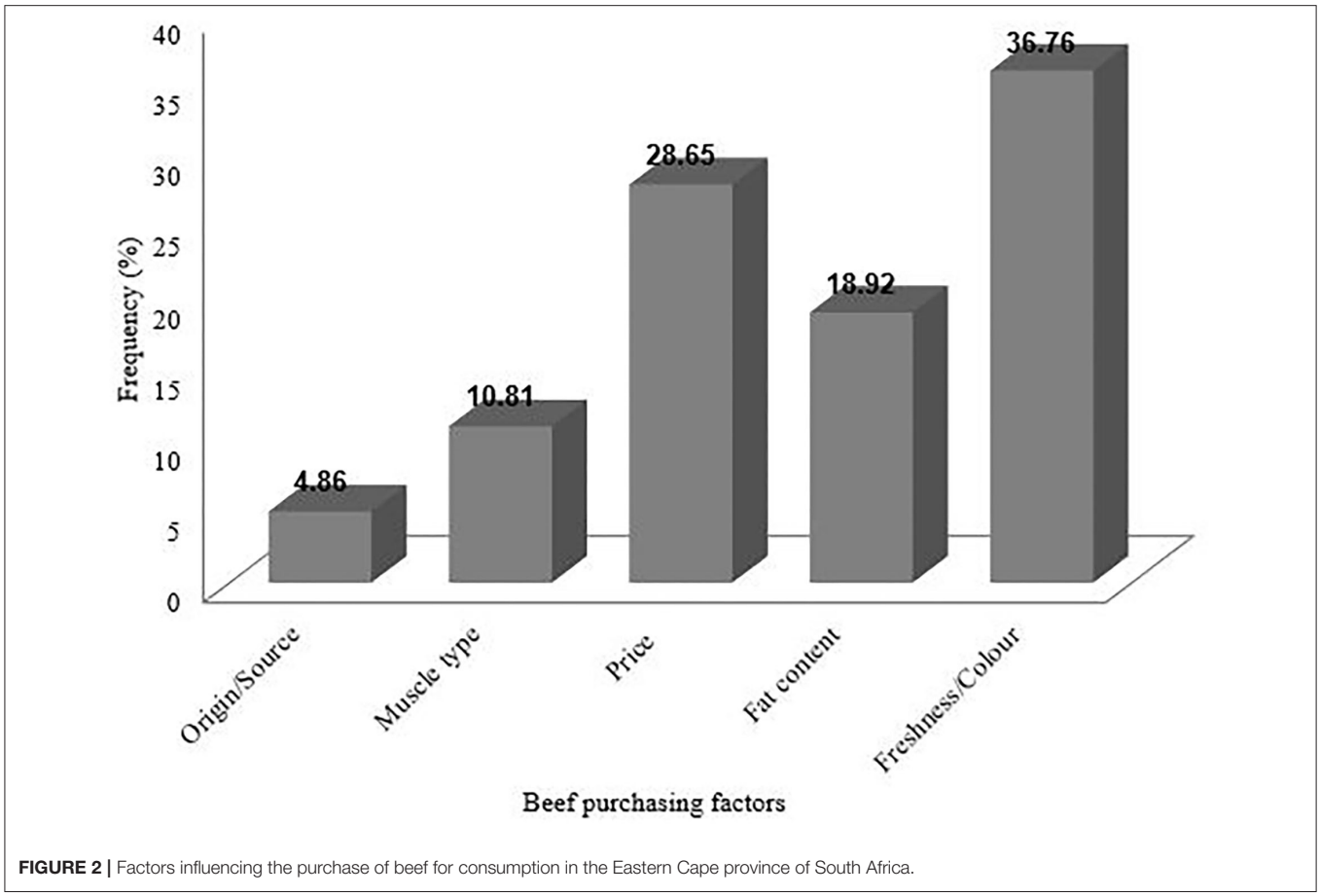


FIGURE 2 | Factors influencing the purchase of beef for consumption in the Eastern Cape province of South Africa.

TABLE 2 | Consumer awareness on cultured beef production in Eastern Cape Province of South Africa ($n = 255$).

Variable	Group	Yes (%)	No (%)	No response (%)	*P-value*
Gender	Male	20.8	26.7	–	0.018
	Female	15.3	36.1	1.0	
Location	University	23.1	16.1	0.3	
	Urban	5.1	20	0.7	0.001
	Rural	7.8	26.7	–	
Total		36.0	63.0	1.0	

influence in shaping consumers' perceptions on its production (Goodwin and Shoulders, 2013; Bryant, 2020).

After explaining the concept and production of cultured beef (*in vitro* production), 53.1% of the respondents endorsed the production of cultured beef and indicated their interest to eat cultured beef if offered to them (**Figure 3**). Out of the 53.1% of the respondents that were interested in eating cultured beef, 29.3% were men and 23.9% were women ($p < 0.05$). In addition, a greater proportion of the consumers that showed interest in the consumption of cultured beef resided in university and rural community (**Figure 4**). This finding is consistent with the findings of Bryant et al. (2019), who reported that 64.6% of their respondents in their study are willing to eat cultured meat when available. Goodwin and Shoulders (2013) also found in their study that "If cultured beef tastes like conventional meat, and is available in the supermarket people will buy it." However, there were some consumers who expressed doubt and fear about the originality, taste, healthiness, and edibility of cultured beef if provided. In particular, most respondents from the urban community mentioned that the concept of cultured meat is ridiculous and seem unnatural. Hocquette et al. (2015) and Chriki and Hocquette (2020) in their study have shown that some consumers would not accept cultured beef if offered to them because they perceived it is unnatural. In reality, it is natural that some people could be afraid of eating food that they have never tasted before. Moreover, the credibility of cultured beef has been ascertained after a sensory evaluation was conducted in London in August 2013. The panelist reported that the hamburger cultured beef tasted juicy, delicious, and comparable to conventional beef (Zaraska, 2013). Furthermore, evidence has shown that a majority of people will support the production of cultured meat if it is healthy and safe (Haagsman et al., 2009; Goodwin and Shoulders, 2013), such as vegetarians and environmentalists, since its production will eliminate any cruel

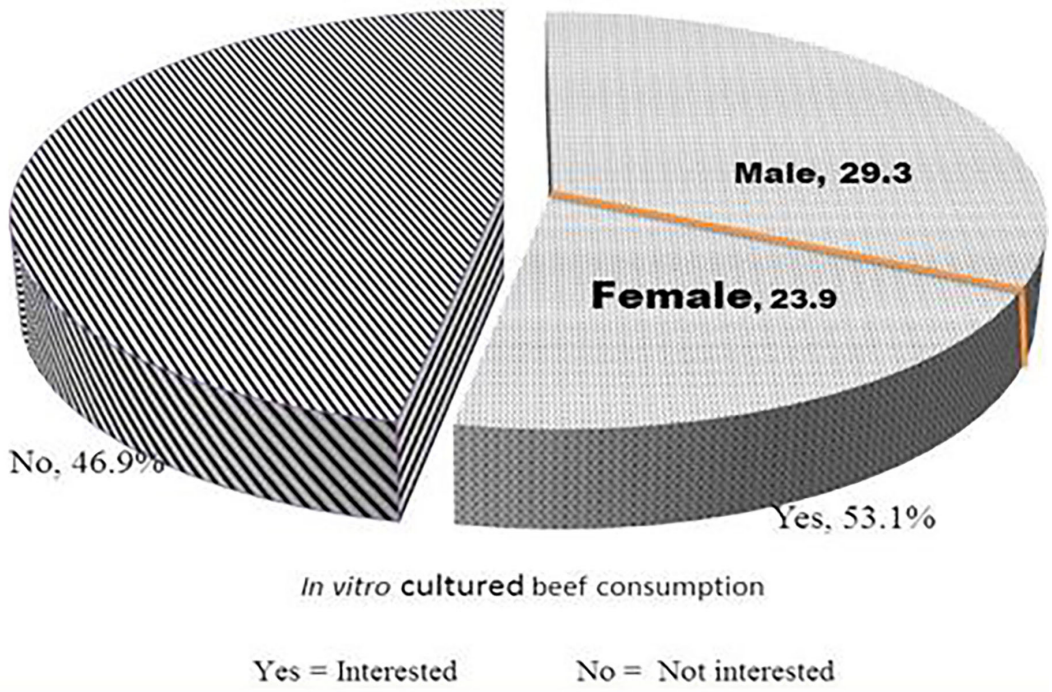


FIGURE 3 | Consumers interest in the consumption of cultured beef in Eastern Cape Province of South Africa.

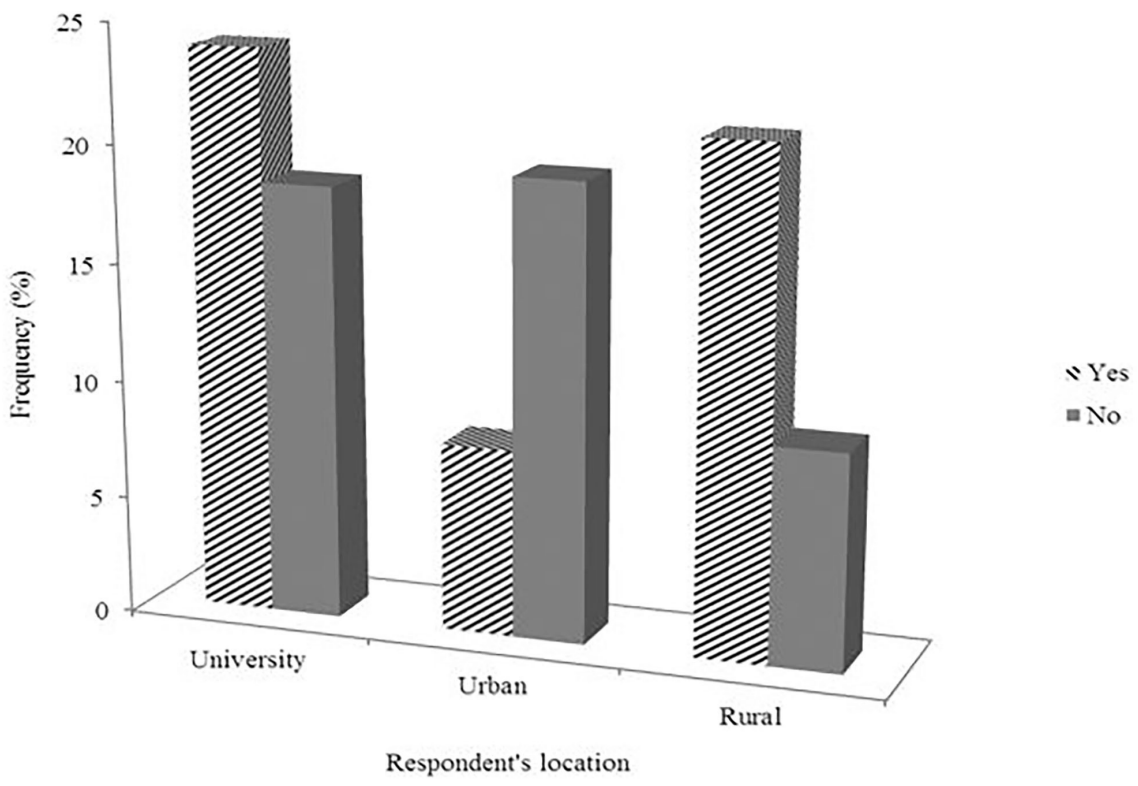


FIGURE 4 | Effect of location on consumer's interest in the consumption of cultured beef.

TABLE 3 | Effect of demographic factor on consumption of beef in Eastern Cape Province of South Africa.

Variable	X^2- value	*P-value*
Consumption of conventional beef		
Gender	9.778	0.973
Age	10.119	0.341
Education	15.472	0.078
Tribe	1.986	0.575
Location	3.520	0.172
Consumption of *in vitro* cultured beef		
Gender	6.506	0.038
Age	11.316	0.079
Education	82.909	0.001
Tribe	16.754	0.001
Location	23.561	0.001

or suffering associated with factory farmed animals (Schaefer and Savulescu, 2014). In addition, other researchers have shown that the production of cultured beef will improve the biochemical composition of meat and reduce public concern about animal welfare, greenhouse emissions, foodborne disease, and biodiversity loss (Edelman et al., 2005; Datar and Betti, 2010; Canon, 2011; Goffman, 2012; Chriki and Hocquette, 2020). Furthermore, the willingness displayed by some of the respondents to eat cultured beef when commercially available also gave them the assurance that its production would enhance meat production.

In **Table 3**, consumers' willingness to eat cultured beef was observed to be strongly influenced by their educational status among other demographic factors. This probably suggests the need for more proactive orientation to create more awareness on the importance of cultured meat to meat production across the world and especially among people living in developing countries.

CONCLUSIONS

Findings from this present study revealed that beef is commonly consumed by the majority of people in the Eastern Cape Province of South Africa. Most of the consumers were willing to eat *in vitro* cultured beef if provided. The idea that people would purchase *in vitro* cultured beef does not seem overly implausible. Moreover, consistent information on the benefits, originality, and edibility of cultured meat should be communicated to the public at large to reinforce its production to enhance meat production. More people in the study area are now getting aware of the possibility of producing *in vitro* meat from the laboratory. The study has limitations that should be addressed in future research. The geographical limitation (i.e., the study was conducted in a province in South Africa) is the most noticeable. To our knowledge, this study is the first to examine the perception of meat consumers on the concept and production of cultured meat in Africa. Therefore, further research should also be conducted in other countries in Africa to obtain a broader view and perspective of consumers on the concept of cultured meat.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethics review and approval/written informed consent was not required as per local legislation and institutional requirements.

AUTHOR CONTRIBUTIONS

BF: conceptualization, data curation, analysis, and writing—original draft. BF and EI: visualization and manuscript editing. YH: logistics and supervision. EI: original writing. All authors contributed to the article and approved the submitted version.

REFERENCES

Alexander, D. D., and Cushing, C. A. (2011). Red meat and colorectal cancer: a critical summary of prospective epidemiologic studies. *Obes. Rev.* 12, 472–493. doi: 10.1111/j.1467-789X.2010.00785.x

Alexandratos, N., and Bruinsma, J. (2012). World agriculture towards 2030/2050: The 2012 revision. Food and Agriculture Organization, Rome (FAO), 1–4. Available online at: www.fao.org/docrep/016/ap106e/ap106e.pdf (accessed May 15, 2017).

Bryant, C., Szejda, K., Parekh, N., Desphande, V., and Tse, B. (2019). A survey of consumer perceptions of plant-based and clean meat in the USA, India, and China. *Front. Sustain. Food Syst.* 3, 1–11. doi: 10.3389/fsufs.2019.00011

Bryant, C. J. (2020). Culture, meat, and cultured meat. *J. Anim. Sci.* 98, 172. doi: 10.1093/jas/skaa172

Canon, S. (2011). Meat from petri dish to plate: Credible or inedible? Chicago Tribune. Available online at: http://www.chicagotribune.com/ (accessed May 15, 2017).

Chiles, R. T. (2013). Intertwined ambiguities: meat, *in vitro* meat, and the ideological construction of the marketplace. *J. Consum. Behav.* 12, 472–482. doi: 10.1002/cb.1447

Chriki, S., and Hocquette, J. (2020). The myth of cultured meat: a review. *Front. Nutr.* 7, 1–9. doi: 10.3389/fnut.2020.00007

DAFF. (2013). Department of Agriculture, Forestry and Fisheries, South Africa (DAFF) 2013. Trends in the Agricultural Sector. Available online at: www.daff.gov.za/docs/statsinfo/Trends (accessed November 25, 2017).

Datar, I., and Betti, M. (2010). Possibilities for an *in vitro* meat production system. *Innov. Food Sci. Emerg. Technol.* 11, 13. doi: 10.1016/j.ifset.2009.10.007

Dindyal, S., and Dindyal, S. (2003). How personal factors, including culture and ethnicity, affect the choices and selection of food we make. *Internet J. Third world Med.* 1, 2. doi: 10.5580/2231

Edelman, P. D., McFarland, D. C., Mironov, V. A., and Matheny, J. G. (2005). *In vitro* cultured meat production. *Tissue Engineering.* 11, 659–662. doi: 10.1089/ten.2005.11.659

FAO. (2011). *World livestock 2011. Livestock in food security*, 76–80. Available online at: www.fao.org/docrep/014/i2373e/i2373e.pdf (accessed March, 2021).

FAO. (2014). *Food outlook-Biannual report on global food markets*, 1–8. Available online at: www.fao.org/docrep/019/i3751e/i3751e.pd (accessed June, 2021).

FAOSTAT. (2014). *Food and Agriculture Organization of the United Nations*. Available online at: http://faostat.fao.org/site/610/default.aspx#ancor (accessed December, 2020).

Fayemi, P. O., and Muchenje, V. (2014). Farmers' preference for mutton and lamb from natural velds in the Eastern Cape Province of South Africa. *J. Food Agric. Environ*. 12, 15–19. Available online at: http://world-food.net/farmers-preference-for-mutton-and-lamb-from-natural-velds-in-the-eastern-cape-province-of-south-africa/

Font-i-Furnols, M., and Guerrero, L. (2014). Consumer preference, behavior and perception about meat and meat products: an overview. *Meat Sci*. 98, 361–371. doi: 10.1016/j.meatsci.2014.06.025

Goffman, E. (2012). *The Environmental Impact of Meat. ProQuest Discovery Guides*. Available online at: http://www.csa.com/discoveryguides/discoveryguides-main.php (accessed January, 2021).

Goodwin, J. N., and Shoulders, W. C. (2013). The future of meat: a qualitative analysis of cultured meat media coverage. *Meat Sci.* 95, 445–450. doi: 10.1016/j.meatsci.2013.05.027

Guerrero, A., Valero, M. V., Campo, M. M., and Sanudo, C. (2013). Some factors that affect ruminant meat quality: from the farm to the fork review. *Acta Scientiarum Animal Sciences.* 35, 4. doi: 10.4025/actascianimsci.v35i4.21756

Haagsman, H., Hellingwerf, K., and Roelen, B. (2009). *Production of animal proteins by cell systems. Desk study on cultured meat*. Available online at: www.worldcat.org/.../production-of-animal-proteins-by-cell-systems (aaccessed May 15, 2017).

Hocquette, A., Lambert, C., Sinquin, C., Peterolff, L., Wagner, Z., Bonny, S. P., et al. (2015). Educated consumers don't believe artificial meat is the solution to the problems with the meat industry. *J. Integr. Agric.* 14, 273–284. doi: 10.1016/S2095-3119(14)60886-8

Hong, S., and Vogel, N. M. (2010). Food allergy and eosinophilic esophagitis: learning what to avoid. *Clevel. Clin. J. Med.* 77, 1. doi: 10.3949/ccjm.77a.09018

Jocumsen, A. (2005). Assessment of fresh beef quality by Australian consumers at the point of purchase. *Consum. Behav.* 109, 122–128. Available online at: http://smib.vuw.ac.nz:8081/WWW/ANZMAC2005/cd-site/authors1.html

Krejcie, R. V., and Morgan, D. W. (1970). Determining sample size for research activities. *Educ. Psychol. Meas*. 30, 607–610. doi: 10.1177/001316447003000308

Laestadius, L. I., and Caldwell, M. A. (2015). Is the future of meat palatable? Perceptions of *in vitro* meat as evidenced by online news comments. *Public Health Nutr.* 18, 2457–2467. doi: 10.1017/S1368980015000622

McCarthy, M., and Henson, S. (2004). Perceived risk and risk reduction strategies in the choice of beef by Irish consumers. *Food Qual. Prefer*. 16, 435–445. doi: 10.1016/j.foodqual.2004.08.003

Nandonde, S. W., Msuya, E., and Mtenga, L. A. (2013). Assessment of the influence of consumer characteristics on the choice of beef quality attributes in Tanzania: an experimental economic approach. *Journal of Development and Agricultural Economics*. 2, 111–119.

Nellemann, C., MacDevette, M., Manders, T., Eickhout, B., Svihus, B., Prins, A. G., and Kaltenborn, B. P. (2009). The environmental food crisis–The environment's role in averting future food crises. Available online at: www.grida.no (accessed June, 2021).

Newton, P., and Blaustein-Rejto, D. (2021). Social and economic opportunities and challenges of plant-based and cultured meat for rural producers in the US. *Front. Sustain. Food Syst.* 5, 10. | doi: 10.3389/fsufs.2021.624270

OECD-FAO. (2021). OECD-FAO Agricultural Outlook 2021–2030. OECD Agriculture statistics (database). Available online at: https://www.fao.org/3/cb5332en/Meat.pdf (accessed March, 2021).

Okoronkwo, F. C., Efedua, J. C., and Amusa, T. A. (2020). Determinants of household preference for beef to pork in umuahia metropolis of abia state, Nigeria. *Journal of Tropical Agriculture, Food, Environment and Extension.* 19, 15–18. doi: 10.4314/as.v19i3.3

O'Riordan, K., Fotopoulou, A., and Stephens, N. (2017). The first bite: imaginaries, promotional publics and the laboratory grown burger. *Public Underst. Sci.* 26, 148–163. doi: 10.1177/0963662516639001

Osei-Asare, Y. W., and Eghan, M. (2014). Meat consumption in ghana, evidence from household micro-data. *Emperical Econ. Lett*. 13, 1681–997.

Post, M. J. (2012). Cultured meat from stem cells: challenges and prospects. *Meat Sci.* 92, 297–301. doi: 10.1016/j.meatsci.2012.04.008

Post, M. J., Levenberg, S., Kaplan, D. L., Genovese, N., Fu, J., Bryant, C. J., et al. (2020). Scientific, sustainability and regulatory challenges of cultured meat. *Nat. Food*. 1, 403–415. doi: 10.1038/s43016-020-0112-z

Predanocyová, K., Kubicová, L., Kádeková, Z., and Košičiarová, I. (2019). Key factors affecting consumption of meat and meat products from perspective of slovak consumers. *Potravinarstvo Slovak Journal of Food Sciences*. 13, 1–9. doi: 10.5219/1198

Robbins, K., Jensen, J., and Ryan, K. J. C., McKeith, F. K., and Brewer, M. S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Sci.* 65, 721–729. doi: 10.1016/S0309-1740(02)00274-7

Saleh, H., Embry, S., Nauli, A., Atyia, S., and Krishnaswamy, G. (2012). Anaphylactic reactions to oligosaccharides in red meat: a syndrome in evolution. *Clin. Mol. Allergy*. 10, 5. doi: 10.1186/1476-7961-10-5

Sampson, H. A. (2004). Update on food allergy. *J. Allergy Clin. Immunol.* 113, 805–819. doi: 10.1016/j.jaci.2004.03.014

Schaefer, G. O., and Savulescu, J. (2014). The ethics of producing *in vitro* meat. *J. Appl. Philos*. 31, 2. doi: 10.1111/japp.12056

Smil, V. (2014). Eating meat: constants and changes. *Glob. Food Sec*. 3, 67–71. doi: 10.1016/j.gfs.2014.06.001

Tuomisto, H. L. (2010). Food Security and Protein Supply -Cultured meat a solution? *Aspects of Applied Biology* 102, 99–104.

van der Weele, C., and Tramper, J. (2014). Cultured meat: every village its own factory? *Trends Biotechnol*. 32, 6. doi: 10.1016/j.tibtech.2014.04.009

Van Wezemae, L., Verbeke, W., de Barcellos, M. D., Scholderer, J., and Perez-Cueto, F. (2010). Consumer perceptions of beef healthiness: results from a qualitative study in four European countries. *BMC Public Health.* 10, 342. doi: 10.1186/1471-2458-10-342

Verbeke, W., Rutsaert, A. P., Gaspar, R., Seibt, B., Fletcher, D., and Barnett, J. (2015). Would you eat cultured meat? Consumers' reactions and attitude formation in Belgium, Portugal and the United Kingdom. *Meat Sci.* 102, 49–58. doi: 10.1016/j.meatsci.2014.11.013

Wilks, M., and Phillips, C. J. (2017). Attitudes to *in vitro* meat: a survey of potential consumers in the United States. *PloS ONE.* 12, 0171904. doi: 10.1371/journal.pone.0171904

WWF Report. (2016). *Social, economic and environmental analysis of soybean and meat production in Paraguay*. Available online at: www.awsassets.panda.org (accessed November, 2021).

Wyness, L., Weichselbaum, E., O'Connor, A., Williams, E. B., Benelam, B., Riley, H., et al. (2011). Red meat in the diet: an update. *Nutr. Bull*. 36, 34–77. doi: 10.1111/j.1467-3010.2010.01871.x

Zaraska, M. (2013). Lab-grown beef taste test: "Almost" like a burger. Health and Science, The Washington Post. Available online at: www.washingtonpost.com/health-science/lab-grown-beef (accessed March, 2022).

Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's Note: All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

frontiers | Frontiers in Nutrition

TYPE Original Research
PUBLISHED 19 July 2022
DOI 10.3389/fnut.2022.956310

OPEN ACCESS

EDITED BY
Paras Sharma,
National Institute of Nutrition, India

REVIEWED BY
Anita Kumari,
Central University of Haryana, India
Nihaya A. Al-sheyab,
Jordan University of Science and Technology, Jordan

*CORRESPONDENCE
Maha Hoteit
m.hoteit@ul.edu.lb

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

RECEIVED 30 May 2022
ACCEPTED 01 July 2022
PUBLISHED 19 July 2022

CITATION
Hoteit M, Mohsen H, Bookari K, Moussa G, Jurdi N and Yazbeck N (2022) Prevalence, correlates, and gender disparities related to eating disordered behaviors among health science students and healthcare practitioners in Lebanon: Findings of a national cross sectional study. *Front. Nutr.* 9:956310. doi: 10.3389/fnut.2022.956310

Prevalence, correlates, and gender disparities related to eating disordered behaviors among health science students and healthcare practitioners in Lebanon: Findings of a national cross sectional study

Maha Hoteit[1,2,3*†], Hala Mohsen[1,2,3†], Khlood Bookari[4,5,6], Ghadir Moussa[1], Najwa Jurdi[1] and Nour Yazbeck[1,2,3†]

[1]Faculty of Public Health, Lebanese University, Beirut, Lebanon, [2]PHENOL Research Group (Public HEalth Nutrition prOgram Lebanon), Faculty of Public Health, Lebanese University, Beirut, Lebanon, [3]Lebanese University Nutrition Surveillance Center (LUNSC), Lebanese Food Drugs and Chemical Administrations, Lebanese University, Beirut, Lebanon, [4]National Nutrition Committee, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [5]Executive Department of Monitoring and Risk Assessment, Food Sector, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [6]Department of Clinical Nutrition, Faculty of Applied Medical Sciences, Taibah University, Madina, Saudi Arabia

Background: The raised prevalence of eating disorders (ED) amongst health science students and health professionals is of mounting concern. This study aims to determine the prevalence and correlates of eating disorders risk amongst a sample of Lebanese health science students and healthcare practitioners of both genders.

Methods: This cross-sectional study enrolled a convenient sample of 1,000 participants (mean age: 23 ± 5.4; females: 74.9%) from faculties of health sciences, clinics, pharmacies, and hospitals. The validated Eating Attitudes Test (EAT-26) was used to screen for eating disorders. Anthropometric data were self-reported by respondents to assess their nutritional status.

Results: The risk of eating disorders was prevalent in 22.5% of participants. Females were at higher risk of ED compared to males $p = 0.03$. Eating disorders risk did not differ between students and practitioners ($p = 0.3$). The highest proportion of high-risk participants were students studying nutrition and practitioners (40.9%), outracing their counterparts in nursing (18.7%), medicine (17.8%), pharmacy (17.7%), and midwifery (4.9%) sciences ($p = 0.02$). Most high-risk participants had normal body weight (60.4%), and 28.9% were overweight ($p = 0.001$). Female gender, nutrition profession, and dieting were associated with increasing the odd of ED. Particularly, dieting increased the risk around five times. Further, each 3 participants over 10 were facing binge eating behavior.

10.3389/fnut.2022.956310

Conclusion: This study uncovers an undervalued profession-related-health-disorder in Lebanese health science students and healthcare practitioners. Specific attention should be given to EDs in professional educational programmes across healthcare disciplines.

KEYWORDS

eating disorders, health sciences, students, practitioners, Lebanese

Introduction

Eating disorders (ED), defined by the American Psychiatric Association, are severe and persistent disturbances in eating behaviors accompanied by distressing thoughts and emotions (1). Eating disorders have a detrimental impact on psychological and social functioning and physical health (1). In general, anorexia nervosa (AN), bulimia nervosa (BN), and binge eating disorders (BED) are the three main common types of eating disorders (1). Added to these are the avoidant restrictive food intake disorder, pica, rumination disorders, and other specified feeding disorders (1). ED affects up to 5% of the population, and the mean age of onset for AN and BN is between 15 and 19 years old (1). A systematic review of data from 2000 to 2018 (2) found that eating disorders are highly prevalent worldwide, with the most emphasis on females. The estimated female-male ratio for lifetime prevalence of any eating disorder is 4.2 (2). The prevalence of eating disorders had increased from 3.5% in the 2000–2006 period to 7.8% in the 2013–2018 period (2). A recent review of studies in the Arab world found that the prevalence of eating disorders varies between 2 and 54.8%, with a higher risk of binge eating among Kuwaiti and Egyptian Arabs (3). There is no single stimulator leading to eating disorders, and the exact etiology is still not well-defined. However, the scientific consensus is that eating disorders have genetic predispositions that could be worsened by triggering environmental factors, including cultural idealization, mass media, peer pressure, and dieting (4). Virtually, nothing is known about the individual causal processes involved, or how they interact and vary during the disorder's development and maintenance (5). Individuals with eating disorders have the highest mortality rates among other psychiatric diseases (6). AN is associated with a high risk of death, and 10% of anorexic patients are estimated to die within 10 years of diagnosis (2). To add to the burden, the diagnosis of eating disorders is evasive, and many cases go undetected (7). The published data shows differences in the prevalence of eating disorders between diverse demographics, with some groups appearing to be more susceptible than others. Body image dissatisfaction and disordered eating behaviors increase during college age, and health sciences students, in particular, are an endangered subpopulation for eating disorders (8). The latter issue could endure or commence after they've started practicing their profession, with evident data on the topic of disordered eating among healthcare professionals. One study on nutrition students and dietetic professionals identified high predispositions for food restrictions and weight control issues (9). Thinness idealization, relationship changes with food and body associated with nutrition education, and keeping a continuum all contributed to disordered eating amongst nutrition students and practitioners (9). Another study on female nurses found that work stress and pressing shift hours had triggered poor eating habits, manifested by excessive snacking and binging (10). Nighttime shift duty was positively associated with restrained eating and emotional eating among nurses (10). In addition, in multiple preliminary investigations, medical students reported an appreciable prevalence of eating disorders and disordered eating behaviors, including that conducted in Lebanon (11), Egypt (12), Brazil (13), and Pakistan (14). Further, body image dissatisfaction had been reported as an important concern for pharmacy students, which was considered a serious precursor for disordered eating among them (15). As far as we know, at the moment we are drafting this paper, no studies have addressed the eating disorders topic among both students and practitioners enrolled in health professions. Based on preliminary research efforts and the significance of the topic, it becomes critical to provide national data regarding this topic. This data could serve as a foundation for future intervention and awareness programs addressing the eating disorders burden in the target population. Thus, we designed and conducted this study to be the first aiming to determine the prevalence and correlates of eating disorders amongst a sample of Lebanese health science students and healthcare practitioners of both genders.

Materials and methods

Study design and recruitment of study participants

The current investigation is a descriptive cross-sectional study conducted over 5 months, from November 2018 to March 2019, enrolling a convenient sample of health science students and healthcare practitioners from health sciences

faculties, pharmacies, clinics, and hospitals in the Beirut and Mount Lebanon districts. The research team of this study had approached student participants at the campus of their universities at the faculties of health sciences to ask them to complete the questionnaire in a self-administered manner. Healthcare practitioners were also reached, during the working hours, at their pharmacies, clinics, and hospitals. To be regarded for inclusion, participants had to be between 18 and 64 years old and willing to participate in this study. We further excluded individuals who were diagnosed previously with one or more eating disorders, and inadequately filled out the self-administered questionnaire. The final sample included 603 health science students and 397 healthcare practitioners enrolled in nutrition (32.8%), midwifery (4.1%), medicine (24.6%), pharmacy (18.4%), and nursing (20.1%) health professions.

Questionnaire

A self-administered questionnaire, composed of 2 main parts, was employed to collect the data between October and June 2018. The first part of the questionnaire assessed demographic and personal information of study participants, including age, gender, position (student or practitioner), health profession, and self-reported body weight and height. Also, this part included a supplementary question assessing participants' dieting status. The second part of the questionnaire was the Eating Attitudes Test (EAT-26) instrument, used to screen for eating disorders among our study participants. EAT-26 includes sections A and B. Section A consists of 26 questions distributed across three subscales: dieting, bulimia and food preoccupation, and oral control. Respondents answered via six-point Likert scales that offered the choices of "always," "usually," "often," "sometimes," "rarely," and "never." Based on the scoring criteria suggested elsewhere (16), a participant may have a total score ranging from 0 to 78. A score of 20 and above is indicative of an eating disorder risk. Section B of the EAT-26 inspected the disordered eating behaviors of participants in the last 6 months, including eating binges, self-induced vomiting, using laxatives, diet pills, or diuretics, exercising more than 60 min, and losing 9 kg (20 pounds) or more of body weight. Respondents had six response options from "never" to "once a day or more." Disordered eating behaviors were defined as the following: eating binges (at least 2–3 times a month), self-induced vomiting (at least once a month), using laxatives, diet pills, or diuretics (at least once a month), exercising more than 60 min (at least once a day), and losing 9 kg (20 lbs) or more.

Statistical analysis

All data were analyzed using the Statistical Package of Social Sciences Software (SPSS) (Version 21.0. Armonk, NY: IBM Crop). Data were presented as mean ± *SD* for the continuous variables and as frequencies (*N*) and percentages (%) for the categorical ones. The chi-squared test was used to examine associations between our categorical variables. The binary logistic regression analysis was applied to determine the predictors of eating disorders. A *p*-value lower than 0.05 was considered significant.

Ethical consideration

The study has been performed based on the ethical standards laid down in the Helsinki Declaration. Ethical approval was obtained from the Ethical Committee at the Lebanese University (#CU-21-18). A consent form was attached to the questionnaire, informing the respondents about their privacy and rights before participating. There was no penalty for not being involved in the study, and the participation was voluntary. Individual responses were confidential as the questionnaire included no identifying information.

Results

Demographic characteristics and weight status of study participants

A total of 1,000 participants were included in this study with a mean age of 23 ± 5.4 years old (median age = 22.0 years old). Of them, 74.9% ($n = 749$) were females, and 25.1% ($n = 251$) were males. The sampled population was composed of 603 health sciences students (60.3%) and 397 healthcare practitioners (39.7%). Students studying nutrition and practitioners (32.8%) predominate compared to those in midwifery (4.1%), medicine (24.6%), pharmacy (18.4%), and nursing (20.1%) sciences. Most of our participants (64.7%) were of normal body weight. Also, 21.1% were overweight. Only a few were underweight (7.7%) and obese (6.5%). Besides, about 43% of the participants were dieting (currently or in the past). Female participants (mean ± *SD*: 23 ± 5) were younger than males (mean ± *SD*: 24 ± 7) ($p = 0.02$). Among females, the highest proportion (42.1%) were in the nutrition profession, which was significantly higher than that of their male counterparts (5.2%) ($p < 0.001$). Moreover, females were mostly of normal weight (69.7 vs. males: 49.8%, $p < 0.001$), and near to half (45.1%) of them reported having dieting experiences, $p = 0.01$ (Table 1).

Prevalence of eating disorders risk and its correlates

The overall prevalence of eating disorders risk was 22.5% (Figure 1). Table 2 reveals that the mean age of low-risk (23

10.3389/fnut.2022.956310

TABLE 1 Demographic characteristics and weight status of study participants.

		Overall ($n = 1,000$) *N* (%)	Males ($n = 251$) *N* (%)	Females ($n = 749$) *N* (%)	*p-value*
Age in years (Mean ± *SD*)		23 ± 5.4	24 ± 7	23 ± 5	0.02
Position	Student	603 (60.3)	154 (61.4)	449 (59.9)	0.69
	Practitioner	397 (39.7)	97(38.6)	300 (40.1)	
Health profession	Nutrition	328 (32.8)	13 (5.2)	315 (42.1)	<0.001
	Midwifery	41 (4.1)	0 (0)	41 (5.4)	
	Medicine	246 (24.6)	92 (36.7)	154 (20.5)	
	Pharmacy	184 (18.4)	72 (28.6)	112 (15.0)	
	Nursing	201 (20.1)	74 (29.5)	127 (17.0)	
Weight status	Underweight	77 (7.7)	4 (1.6)	73 (9.7)	<0.001
	Normal	647 (64.7)	125 (49.8)	522 (69.7)	
	Overweight	211 (21.1)	87 (34.7)	124 (16.6)	
	Obese	65 (6.5)	35 (13.9)	30 (4.0)	
Dieting (currently or in the past)	No	574 (57.4)	163 (64.9)	411 (54.9)	0.01
	Yes	426 (42.6)	88 (35.1)	338 (45.1)	

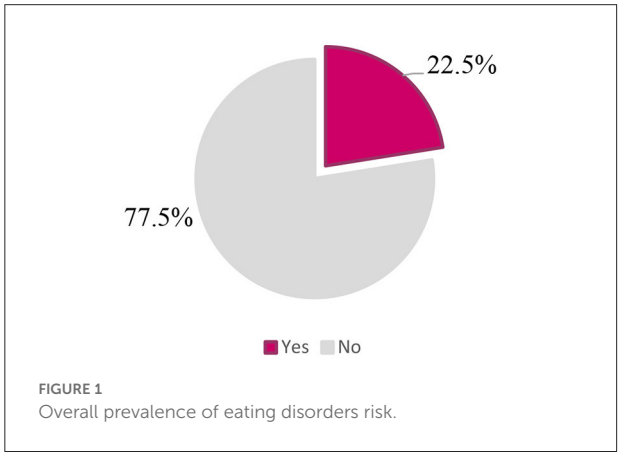


FIGURE 1
Overall prevalence of eating disorders risk.

± 5) and high-risk (24 ± 6) participants is just the same ($p = 0.14$), suggesting that participants' age did not contribute to the risk of eating disorders in our sample population. However, participants' gender had a significant association with a possible risk of eating disorders, for which the majority of high-risk participants (80.4%) were females, $p = 0.03$. Furtherly, 24.2% of females were at high risk compared to 17.5% of their male counterparts, $p = 0.03$ (Figure 2). In contrast, participants' position did not appear to predict a higher risk of eating disorders, in which comparable proportions of students (57.3%) and practitioners (42.7%) were susceptible, $p = 0.30$. Further, students studying nutrition and practitioners constituted significantly the predominant proportion (40.9%) of high-risk participants, followed by their counterparts in nursing (18.7%), medicine (17.8%), pharmacy (17.7%), and midwifery (4.9%) sciences, $p = 0.02$. The weight status also appeared to be a significant correlate to participants' risk, and the majority of high-risk participants (60.4%) were of normal body weight, 28.9% were overweight, 4.9% were obese, and 5.8% were underweight, $p = 0.01$. Dieting was a significant associate too; almost three-quarters (72%) of high-risk participants were following a diet, or did so in the past, $p < 0.001$ (Table 2).

Predictors of eating disorders among study participants

As the latter findings show that participants' gender, health profession, body weight, and dieting status were associated with the risk of eating disorders among our participants, we further applied the binary logistic regression analysis to specify the predictors of eating disorders. Based on the findings, female participants had a 21% more likelihood of developing eating disorders than males (OR = 1.21, CI = 0.79–1.84, $p = 0.39$). Moreover, students studying nutrition and practitioners had a 21% higher vulnerability for eating disorders in contrast to their counterparts in other health professions (OR = 0.79, CI = 0.56–1.11, $p = 0.18$). However, underweight/normal-weight participants had only 5% higher susceptibility for eating disorders (vs. overweight/obese OR = 0.95, CI = 0.47–1.76, $p = 0.77$). Further, participants who were dieting (currently or in the past) had around 5 times greater risk for eating disorders (vs. non-dieters OR = 4.80, CI = 3.38–6.77,

10.3389/fnut.2022.956310

TABLE 2 The correlates for the risk of eating disorders.

		Eating disorders		*p-value*
		Low risk ***N* (%)**	**High risk** ***N* (%)**	
Age in years (Mean ± *SD*)		23 ± 5	24 ± 6	0.14
Gender	Male	207 (26.7)	44 (19.6)	**0.03**
	Female	568 (73.3)	181 (80.4)	
Position	Student	474 (61.2)	129 (57.3)	0.30
	Practitioner	301 (38.8)	96 (42.7)	
Health profession	Nutrition	236 (30.5)	92 (40.9)	**0.02**
	Midwifery	30 (3.9)	11 (4.9)	
	Medicine	206 (26.6)	40 (17.8)	
	Pharmacy	144 (18.5)	40 (17.7)	
	Nursing	159 (20.5)	42 (18.7)	
Weight status	Underweight	64 (8.3)	13 (5.8)	**0.01**
	Normal	511 (65.9)	136 (60.4)	
	Overweight	146 (18.8)	65 (28.9)	
	Obese	54 (7.0)	11 (4.9)	
Dieting (currently or in the past)	No	511 (65.9)	63 (28.0)	**<0.001**
	Yes	264 (34.1)	162 (72.0)	

Bold values mean significant at p-value < 0.05 for chi-squared test.

FIGURE 2
Gender disparities in eating disorders risk.

$p < 0.001$) which was the highest among all other predictors (Table 3).

Disordered eating behaviors among study participants

Figure 3 shows that the highest behavioral ED was binge eating (28.9%), followed by excessive exercise (15.6%), rapid loss of body weight (14.1%), use of laxatives, diet pills, and diuretics (9.9%), and self-induced vomiting (5.9%). The highest proportion of participants who reported behavioral risk for binge eating were significantly females (66.8%, $p < 0.001$), dietitians (28%, $p = 0.04$), and those of normal body weight (58.8%, $p < 0.001$). However, participants' gender ($p = 0.72$ and $p = 0.21$, respectively), work position ($p = 0.51$, $p = 0.99$, respectively), and health profession ($p = 0.71$ and $p = 0.32$, respectively) did not show any statistically significant association with a behavioral risk of self-induced vomiting, and pills use. In contrast, most of the participants having a high risk for self-induced vomiting, and pills use were those having normal body weight (52.5%, $p = 0.02$ and 41.4%, $p < 0.001$, respectively). Moreover, the highest proportion of participants who reported excessive exercise were in the nursing health profession (25.6%) and of normal body weight (59%) ($p = 0.02$, and $p = 0.01$, respectively). Further, the majority who reported rapid weight loss were females (64.5%) and with normal body weight (51.1%), and these associations were statistically significant ($p = 0.01$, and $p < 0.001$, respectively) (Table 4).

Eating behaviors across risk groups

Compared to those having low EAT-26 score, high-risk participants significantly reported more disordered behaviors regarding binge eating (34.2 vs. 27.4%, $p = 0.04$), self-induced vomiting (15.6 vs. 3.1%, $p < 0.001$), the use of laxatives, diet pills, and diuretics (22.7 vs. 6.2%, $p < 0.001$), and losing 9 kg or more of body weight (25.8 vs. 10.7%, $p < 0.001$) in the last

TABLE 3 The predictors of eating disorders.

Dependent variable: Risk of eating disorders (low risk: reference; high risk)	Odds ratio (OR)	95% confidence interval (CI)		*p-value*
		Minimum	Maximum	
Gender				
Male (Reference)	1	–	–	–
Female	1.21	0.79	1.84	0.39
Health profession				
Nutrition (Reference)	1	–	–	–
Other health professions	0.79	0.56	1.11	0.18
Weight status				
Underweight/Normal (Reference)	1	–	–	–
Overweight/Obese	0.95	0.47	1.76	0.77
Dieting				
No (Reference)	1	–	–	–
Yes	**4.80**	3.38	6.77	**<0.001**

Bold values mean significant at $p < 0.05$ for binary logistic analysis test.

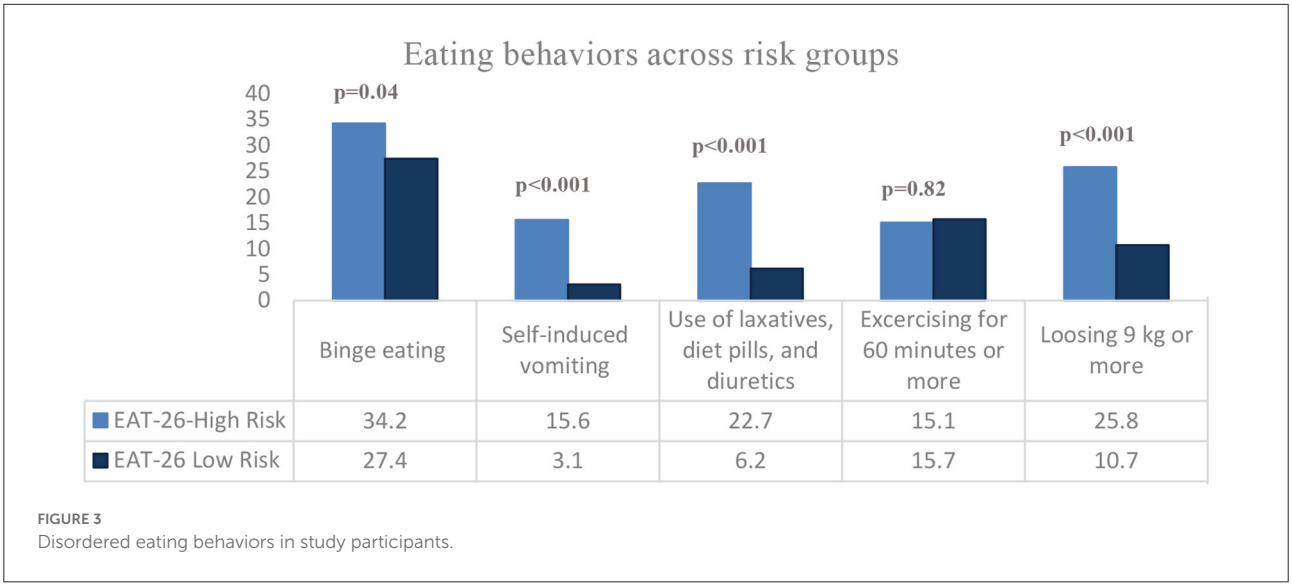


FIGURE 3
Disordered eating behaviors in study participants.

6 months. These findings suggest that participants who scored high for EAT-26 scale were more prone to be engaged in different disordered eating behaviors (Figure 4).

Discussion

In this study, we took the first attempt to provide data about the prevalence of eating disorders and their correlates among a sample of Lebanese health sciences students and healthcare practitioners. Overall, 22.5% of participants appeared to be at high risk for eating disorders, with females being predominant compromising 80.4% of high-risk participants. Female gender, nutrition health profession, and dieting augmented the risk of eating disorders, with dieting being the major contributor by increasing the risk around 5 times. Besides, 28.9% of participants showed a behavioral risk in binge eating, which was the highest proportion among other reported disordered behaviors. Participants with eating disorders risk had more disordered eating behaviors, including binge eating, self-induced vomiting, pills use, and rapid weight loss (9 kg or more) in the last 6 months.

In contrast to preliminary investigations in Lebanon, our obtained prevalence of eating disorders risk is higher than that reported among medical students at the American University of Beirut, in 2017, where 17% of students who completed the EAT-26 scale were at high risk (11). We could relate this disparity in findings to the fact that the current study enrolled both students

TABLE 4 The relationship between participant's characteristics and their behavioral risk.

In the last 6 months		Binge eating		Self-induced vomiting		Laxatives, diet pills, and diuretics use		Exercising for more than 60 min		Lose 9 kg or more of body weight		*p-values*				
		Risk *N* (%)	No risk *N* (%)	Risk *N* (%)	No risk *N* (%)	Risk *N* (%)	No risk *N* (%)	Risk *N* (%)	No risk *N* (%)	Risk *N* (%)	No risk *N* (%)	(a)	(b)	(c)	(d)	(e)
Gender	Males	96 (33.2)	155 (21.8)	18 (27.1)	235 (25)	30 (30.3)	221 (24.6)	42 (26.9)	209 (24.8)	50 (35.5)	201 (23.4)	**<0.001**	0.72	0.21	0.57	**0.01**
	Females	193 (66.8)	556 (78.2)	43 (72.9)	705 (75)	69 (69.7)	679 (75.4)	114 (73.1)	635 (75.2)	91 (64.5)	658 (76.6)					
Position	Students	180 (62.3)	423 (59.5)	38 (64.4)	565 (60.1)	55 (55.6)	548 (60.9)	87 (55.8)	516 (61.1)	87 (61.7)	516 (60.1)	0.41	0.51	0.30	0.21	0.71
	Practitioners	109 (37.7)	288 (40.5)	21 (35.6)	375 (39.9)	44 (44.4)	352 (39.1)	69 (44.2)	328 (38.9)	54 (38.3)	343 (39.9)					
Major	Nutrition	81 (28)	247 (34.7)	18 (30.5)	309 (32.8)	28 (28.2)	299 (33.2)	39 (25)	289 (29.3)	45 (31.9)	283 (32.9)	**0.04**	0.71	0.32	**0.02**	0.81
	Midwifery	15 (5.1)	29 (4)	5 (8.4)	39 (4.1)	9 (9)	35 (3.9)	5 (3.2)	39 (4.6)	4 (2.8)	40 (4.6)					
	Medicine	70 (24.2)	176 (24.8)	10 (17.0)	236 (24.8)	19 (19.2)	227 (25.2)	39 (25)	207 (24.5)	39 (27.6)	207 (24.1)					
	Pharmacy	60 (20.7)	124 (17.4)	6 (10.1)	178 (18.9)	20 (20.2)	164 (18.2)	33 (21.1)	151 (17.8)	33 (23.4)	151 (17.6)					
	Nursing	63 (21.8)	138 (19.4)	20 (33.8)	181 (19.8)	23 (23.2)	178 (19.2)	40 (25.6)	161 (19)	20 (14.2)	181 (21)					
Weight status	Underweight	9 (3.1)	68 (9.6)	2 (3.4)	75 (8)	3 (3)	74 (8.2)	5 (3.2)	72 (8.5)	3 (2.1)	74 (8.6)	**<0.001**	**0.02**	**<0.001**	**0.01**	**<0.001**
	Normal	170 (58.8)	477 (67.1)	31 (52.5)	615 (65.4)	41 (41.4)	605 (67.2)	92 (59)	555 (65.8)	72 (51.1)	575 (66.9)					
	Overweight	77 (26.6)	134 (18.8)	21 (35.6)	190 (20.2)	39 (39.4)	172 (19.1)	48 (30.8)	163 (19.3)	46 (32.6)	165 (19.2)					
	Obese	33 (11.4)	32 (4.5)	5 (8.5)	60 (6.4)	16 (16.2)	49 (5.4)	11 (7.1)	54 (6.4)	20 (14.2)	45 (5.2)					

(a) The level of significance related to binge eating.
(b) The level of significance related to self-induced vomiting.
(c) The level of significance related to laxatives, diet pills, and diuretics use.
(d) The level of significance related to exercising for more than 60 min.
(e) The level of significance related to losing 9 kg or more of body weight. Bold values mean significant at $p < 0.05$ for chi-squared test.

10.3389/fnut.2022.956310

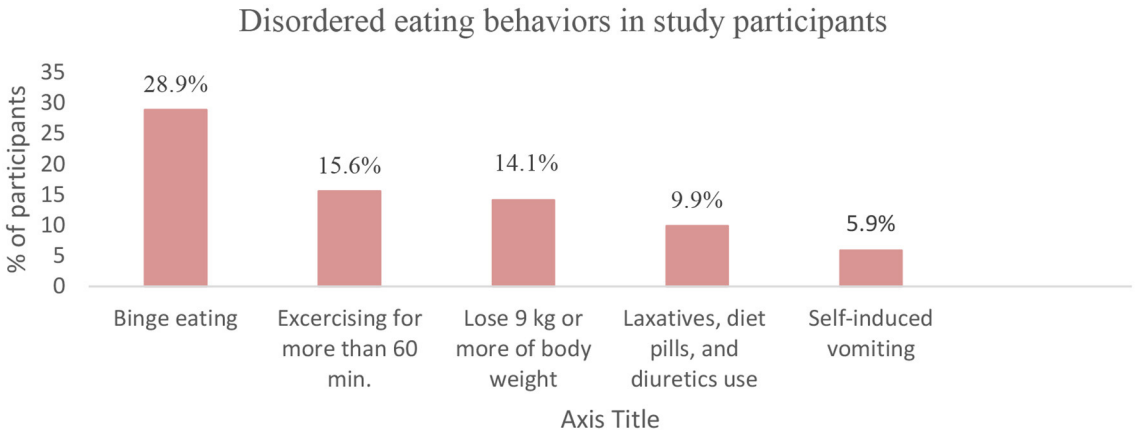


FIGURE 4
Eating behaviors across risk groups.

and practitioners from multiple health professions, including nutrition sciences, who are frequently hypothesized to have a higher prevalence of eating disorders than others. The latter assumption is further confirmed by our study findings, by which nutrition students and practitioners constituted the highest proportion (40.9%) of high-risk participants. In 2007, using the SCOFF questionnaire, a cross-sectional observation of students at the Faculty of Health Care of the Saint Joseph University in Beirut, Lebanon, detected eating disorders among 31.4% of the total population, which exceeds our reported prevalence (17). One plausible explanation for this discrepancy is that the 2007 study was conducted 6 months after the July 2006 war in Lebanon. Wartime is a traumatic life event that may cause an increment in the incidence rates of eating disorders among affected civilians (17).

The obtained prevalence in the current study is lower but comparable to that reported among Saudi female health sciences students (35.4%) (18) and Egyptian medical students in Tanta University (33%) (12). In contrast, a cross-sectional study with 575 medical students in Ain-Shams University found a 12.3% prevalence of eating disorders among Egyptian students, much lower than ours (19). The current findings are in agreement with that reported in Pakistan among a sample of medical students where 23% appeared to have a high risk of eating disorders based on EAT-26 instrument (20). On the other hand, the prevalence of eating disorders among 1,493 college students of the University of Rouen-Normandy, France, exceeded our obtained one only slightly (24.8%) (21). In the United States of America, the prevalence of eating disorder risk among a sample of registered dietitian nutritionists was about 13%, which was less alarming than that obtained in the present study (22). Besides, eating disorders were detected in 36% of the general Navy nurse community (23). Added to these, 8.1% of Saudi female nurses were shown to have eating disorders, including bulimia nervosa and binge eating (24). The understanding of eating disorders was also an interesting debate in some research studies. In one study attempting to assess the eating disorders-related knowledge of pharmacy students, it was evident that most of the participants lacked knowledge, which was also illustrated in other studies amongst healthcare professions (25). Thus, all published data disclosed that eating disorders among health sciences students and healthcare practitioners are of mounting concern in the Arab region and worldwide. However, the prevalence of eating disorders varies either slightly or widely from one country to another. We suggest that the prevalence variations are due to the differences in the study instruments used to screen or assess eating disorders which may cause heterogeneity in findings, the population diverseness, and the cultural background, which may directly impact the risk of eating disorders of demographics.

As also observed in our study, the risk of eating disorders varies significantly according to participants 'gender, and this is manifested by the finding that females predominate in the high-risk category, having a 21% higher likelihood for the risk of eating disorders than males. The latter finding appears to be in confirmation with a recent study in Lebanon, which showed that 72.7% of female medical students had high risk in the EAT-26 scale (11). Another cross-sectional study with Pakistani medical students provided similar results by observing that 87.9% of high-risk participants were females (14). Also consistent with these findings were that obtained in France (21), the United States and Canada (26), Tunis (27), and Saudi Arabia (18), which all explored that female participants were more vulnerable to eating disorders risk than male participants. The National Comorbidity Survey Replication (NCS-R), a national community household survey of the prevalence and correlates of mental disorders in the United States, found that women have 1.75–3 times higher lifetime prevalence for anorexia, bulimia, or binge eating disorder than men (28). The high

vulnerability of females for eating disorders might be related to multiple interlinked factors highlighted in previous research observations. A cross-sectional study on the gender differences in food choice found that women frequently reported avoiding high-fat foods and sugary items (29). Besides, females expressed more perceived unhealthiness for sugars, saturated fats, red meat, white flour, and dairy products. Above these, females reported feeling anxious about having unhealthy meals (29). Not only the types of food do matter, but also females expressed guilty and shameful feelings when eating at specific times of the day. In a study analyzing how frequently and under what circumstances college women did experience feelings of guilt about food, the data indicated that the most "guilty moments" were for snack time, after dinner eating, and in the evening (30). The prevalence of body image dissatisfaction among females is evident in the literature. In line with our findings, in Germany, a cross-sectional study ($N = 1{,}338$) by Quittkat et al. (31) found that women reported non-satisfaction with their body shape and appearance more than males, which is associated with low self-esteem, disordered eating, and poor health outcomes. Further, women with eating disorders often wish to achieve a BMI of 15–16 kg/m2; however, those without eating disorders are satisfied with a BMI of 18–19 kg/m2 (32). An interview with women who recovered from anorexia nervosa was performed to understand their feelings and perceptions toward their eating behaviors; they reported feeling happy and comfortable when controlling their food intake (33). However, guilt, anguish, sadness, fear, and anger were often associated with eating (33). "Food is considered a villain" was also claimed in the interview, highlighting the negative feelings anorexia nervosa patients usually have (33).

Along with this, the present study showed that more than half of participants who reported binge eating behaviors (66.8%) in the last 6 months were females. A research study in Norway ($n = 1{,}846$) provided information in this respect, showing that the prevalence of binge eating disorders in women is twice that of bulimia nervosa and five times the prevalence of anorexia nervosa disorders (34). Also of importance, dieting was presented as a major risk factor for the pathogenesis of binge eating (35). An early study showed that women who went on one or more diets within the previous year or engaged in restrained eating behavior showed frequent binge eating episodes (35). In particular, craving for sweets is the prime trigger for binge eating (35). Thus, one reasonable explanation for observing high reports of binge eating among our female participants is that near to half (45.1%) of them reported having dieting experiences.

Also of concern of the current study is that students and practitioners in the nutrition profession constitute significantly the highest proportion (40.9%) of high-risk individuals, with a 21% higher risk when compared with their counterparts in other health professions, including midwifery, medicine, pharmacy, and nursing. Besides, most of participants who had behavioral risk for binge eating were significantly in the nutrition health profession (28%). The latter finding was hypothesized and not unusual due to the abundant data on the burden of eating disorders among this susceptible subpopulation. Our findings are consistent with that of preceding review on the prevalence of eating disorders among nutrition students and dietetic professionals which classified them as being highly prone to experiencing food restrictions and weight control (9). After a cross-sectional comparison with other health professions, German nutrition students showed higher levels of dietary restraint than others, with a particular risk of orthorexia, defined as a stressful focus on eating healthily (36). Moreover, 10% of American nutrition college students were at a high level of concern for developing eating disorders, with 10.3% of them met criteria for food addiction (37). In 2012, an international study (38) found that 77% of nutrition students recognized eating disorders as a concern among their peers. Besides, a pre-enrolment study of students' motivations, awareness, and expectations relating to careers in nutrition and dietetics explored that personal experiences with family or friends, obesity, and experiencing eating disorders were the top motivators to choose nutrition profession (39).

Elaborating more on this topic, 4.6% of 283 surveyed dietitians reported feeling guilty with self-hatred when straying from their diet (40). In addition, 5% of the dietitians admitted avoiding eating away from home or in a social event with others (40). Otherwise, when inevitable, they took their food along when eating away from home (1.1%) (40). Thinness's idealization and implications of food and body associated with nutrition education exposed those in the nutrition profession to higher eating disorder risk, as reported by a recent review (9). The review adds that participants reported that their body shape defines their success as dietitians and that a successful dietitian must have the perfect body shape to convince others (9).

Another interesting finding of the present study is that nursing students and practitioners constituted 18.7% of high-risk participants, which is also an appreciable proportion and could be comparable to that reported by their counterparts in the nutrition profession. In previous investigations, in Turkey, 84.5% of nursing students were at high risk of eating disorders according to EAT-40, and 45.3% were at the risk of developing Orthorexia Nervosa (ON), which were seriously alarming findings (41). The risk of eating disorders among nurses may be related to the high-stress environment they are obliged to adapt to. Work stress and shift duty had been proven to be related to inadequate eating habits among female nurses working in Central Saudi Arabia (10). A high percentage of the female nurses reported eating more fast food, snacks, and binging (10). Further, working nighttime shift duty was positively associated with restrained eating (OR = 1.53; $p = 0.029$) and emotional eating (OR = 1.24; $p = 0.001$) among them (10).

In addition, it is worth to mention that medical students and physicians in our study represented a salient proportion

of high-risk participants (17.8%). Medical students had been shown to have a considerable risk of eating disorders in many preliminary investigations, including that reported in Lebanon (11), Egypt (12), Brazil (13), and Pakistan (14). Of note, in this study, the prevalence of eating disorders in the pharmacy health profession was also just the same (17.7%) compared to medicine. A cross-sectional study in Romania found that more than one-third of pharmacy students keep diets to reduce their weight, with participants with high body dissatisfaction tended to have fewer main meals, and to skip breakfasts and dinners (42). Besides, pharmacy students were not satisfied with their body weight, despite not being overweight or obese (15). On the other hand, midwifery was the least profession associated with eating disorders risk, although the risk must not be neglected. Due to the scarcity of data regarding the prevalence and the correlation of eating disorders among midwives and pharmacists, our current data is an initiative to highlight an existing problem that may follow an upward trend in coming observations. Health sciences students and health care practitioners are shown in the current study to have a varied risk for eating disorders, but the problem is still of concern among all professions and highlight the need for further assessment and diagnosis.

An unusual finding is that the predominant proportion of high-risk participants was of normal body weight (60.4%), with overweight participants coming next (28.9%). However, a few of the high-risk participants were obese (4.9%), $p = 0.01$. Besides, normal-weight participants reported significantly the highest risk for binge eating, self-induced vomiting, pills use, excessive exercise, and rapid weight loss in the last 6 months as opposed to underweight, overweight, and obese participants. The latter findings contradict that reported in Russia, which found that bulimia was associated with a higher risk of obesity (OR = 1.03, 95% CI: 1.02–1.05) among 13,341 adults who completed the EAT-26 (43). A systematic review (44) on body image dissatisfaction found that obese individuals had higher dissatisfaction rates than normal-weight individuals, which also comes in incongruence with our findings. Added to these, a study on prevalence and correlates of binge eating disorders in the World Health Organization World Mental Health Surveys found that binge eating disorders were estimated to be 3 to 6 times higher among obese participants (45). Binge-eating disorder (BED) and night-eating syndrome (NES) are two forms of eating disorders that are associated with weight gain, diabetic risk, and metabolic syndrome (46). Binge eating disorders are associated with an earlier onset of overweight and obesity; 30% of those with BED reported childhood obesity (47). Among bariatric surgery patients, the prevalence rate of BED ranges was estimated to reach 47%, which is considered very high (48).

Based on our findings, a large proportion of high-risk participants (72%) was dieting (currently or before) $p < 0.001$. In addition, among all other predictors, dieting contributed to about five times increase in the eating disorders risk (OR = 4.8, CI = 3.38–6.77, $p < 0.001$). Dieting has become a frequent and normalized phenomenon in many cultures, even among young children. Even though dieting may not be the only cause of eating disorders, it is a crucial precursor. According to the National Eating Disorders Association, "normal dieting" may shift into "pathological dieting"; thus, leading to disordered eating risk (49). Besides, the onset of eating disorders had been detected after following diets, especially the restrictive ones (49). Many researchers provide data in this regard. In a study entitled: "Have Our Attempts to Curb Obesity Done More Harm Than Good?", Memon et al. (14) concluded that dieting, if restrictive, may not help patients lose weight and may cause psychological and physical adverse effects. They also added that dieting induces more risks than benefits as a means to lose weight, exploring the dieting and eating disorders relationship (14). Along with media use, body image dissatisfaction, and weight-related teasing, dieting may contribute to the development of a spectrum of weight-related disorders (50).

Also, a worth noted finding in the current study is that participants had the highest behavioral risk in binge eating (28.9%), followed by excessive exercise (15.6%), rapid loss of body weight (14.1%), pills use (9.9%), and self-induced vomiting (5.9%). Besides, compared to those having a low risk for eating disorders on the EAT-26, high-risk participants significantly reported more disordered behaviors regarding binge eating (34.2 vs. 27.4%, $p = 0.04$), self-induced vomiting (15.6 vs. 3.1%, $p < 0.001$), pills use (22.7 vs. 6.2%, $p < 0.001$), and rapid weight loss (25.8 vs. 10.7%, $p < 0.001$). In a previous cross-sectional study in Italy in 2009, self-induced vomiting was reported by 35.5% of eating disorder patients, with 21.1% having multiple purging with vomiting. Besides, self-induced vomiting was associated with a higher frequency of bulimic episodes, higher levels of depression, longer eating disorder duration, and lower self-determination (51). Eating disorder patients may develop laxative abuse in a mistaken attempt to "feel thin" and "feel empty," resulting in a variety of serious health complications (52). In some cases, eating disorder patients refuse to re-hydrate, alarming for a lethal health condition, "dehydration" (52). Among Anorexia Nervosa (AN) patients, the core feature predominating is self-starvation resulting in an apparent loss in body weight and fat (53). Anorexia nervosa adolescent females lose more central body fat, while adult females lose more peripheral fat (53). The American Psychiatric Association (APA) claims that the Body Mass Index is typically under 18.5 in an adult individual with anorexia nervosa (1).

Limitations and strengths

Study findings should be interpreted with caution due to some limitations. Firstly, the cross-sectional design of the study limits reaching a causal inference. Secondly, some data may not be accurate as the questionnaire was self-reported, exploring possible bias in participants' responses. In addition, responders may intentionally under-report eating disorder-related attitudes and behaviors. Besides, we did not perform a clinical diagnosis for the high-risk participants to confirm the results of EAT-26. The conclusions drawn from this study should be treated with caution due to the use of the convenience sampling technique, as it is prone to the challenge of representativeness. However, to our knowledge, this study provides the first data on the prevalence of eating disorder risk among health sciences students and healthcare practitioners in different health professions. Besides, student participants were recruited from multiple universities, pharmacies, clinics, and hospitals across Lebanon, allowing for data generalizability.

Conclusion and recommendations

This study uncovers an undervalued health-related disorder in Lebanese health science students and healthcare practitioners. Eating disorders have complex and inter-linked etiologies and are beyond having an unhealthy relationship with food. Although it is associated with a high mortality rate in contrast to other chronic diseases, eating disorders are still not valued enough in many societies, especially where stigmatization is common. Public health workers and researchers should promote health and well-being without unintentionally inducing body image dissatisfaction and weight stigma. Eating disorder counseling for health sciences students and healthcare practitioners is recommended, as they are supposed to educate others in their community. Future research may aim to follow up high-risk individuals for clinical diagnosis and treatment initiation. Other correlates with eating disorders may also be examined to direct future interventions on the right path.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving human participants were reviewed and approved by ethical approval was obtained from the Ethical Committee at the Lebanese University (#CU-21-18). The patients/participants provided their written informed consent to participate in this study.

Author contributions

MH: conceptualization, methodology, supervision, and writing—reviewing and editing. HM, GM, NJ, and NY: data curation, writing—original draft preparation, visualization, and investigation. All authors contributed to the article and approved the submitted version.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

References

1. American Psychiatric Association. *What Are Eating Disorders?* (2021). Available online at: https://www.psychiatry.org/patients-families/eating-disorders/what-are-eating-disorders (accessed February 9, 2022)

2. Galmiche M, Déchelotte P, Lambert G, Tavolacci MP. Prevalence of eating disorders over the 2000-2018 period: a systematic literature review. *Am J Clin Nutr.* (2019) 109:1402–13. doi: 10.1093/ajcn/nqy342

3. Melisse B, de Beurs E, van Furth EF. Eating disorders in the Arab world: a literature review. *J Eat Disord.* (2020) 8:59. doi: 10.1186/s40337-020-00336-x

4. Rikani AA, Choudhry Z, Choudhry AM, Ikram H, Asghar MW, Kajal D, et al. A critique of the literature on etiology of eating disorders. *Ann Neurosci.* (2013) 20:157–61. doi: 10.5214/ans.0972.7531.200409

5. Fairburn CG, Harrison PJ. Eating disorders. *Lancet.* (2003) 361:407–16. doi: 10.1016/S0140-6736(03)12378-1

6. van Hoeken D, Hoek HW. Review of the burden of eating disorders: mortality, disability, costs, quality of life, and family burden: mortality, disability, costs, quality of life, and family burden. *Curr Opin Psychiatry.* (2020) 33:521–7. doi: 10.1097/YCO.0000000000000641

7. Iyer S, Shriraam V. Prevalence of eating disorders and its associated risk factors in students of a medical college hospital in South India. *Cureus.* (2021) 13:e12926. doi: 10.7759/cureus.12926

8. Lofrano-Prado MC, Prado WL, Barros MVG, Souza SL de. Eating disorders and body image dissatisfaction among college students. *ConScientiae Saúde.* (2016) 14:355–62. doi: 10.5585/conssaude.v14n3.5487

9. Mahn HM, Lordly D. A review of eating disorders and disordered eating amongst nutrition students and dietetic professionals. *Can J Diet Pract Res.* (2015) 76:38–43. doi: 10.3148/cjdpr-2014-031

10. Almajwal AM. Stress, shift duty, and eating behavior among nurses in Central Saudi Arabia. *Saudi Med J.* (2016) 37:191–8. doi: 10.15537/smj.2016.2.13060

11. Bizri M, Geagea L, Kobeissy F, Talih F. Prevalence of eating disorders among medical students in a Lebanese medical school: a cross-sectional study. *Neuropsychiatr Dis Treat.* (2020) 16:1879–87. doi: 10.2147/NDT.S266241

12. Ehab AA, Walaa MS. Eating disorder risk among medical students at Tanta university, Egypt. *Egypt J Community Med.* (2020) 38:17–23. doi: 10.21608/ejcm.2020.119410

13. Alberton VC, Dal-Bó MJ, Piovezan AP, Silva RM da. Abnormal eating behaviors among medical students at a university in southern Santa Catarina, Brazil. *Rev Bras Educ Med.* (2013) 37:15–20. doi: 10.1590/S0100-55022013000100003

14. Memon AN, Gowda AS, Rallabhandi B, Bidika E, Fayyaz H, Salib M, et al. Have our attempts to curb obesity done more harm than good? *Cureus.* (2020) 12:e10275. doi: 10.7759/cureus.10275

15. Jaworowska A, Bazylak G. An outbreak of body weight dissatisfaction associated with self-perceived BMI and dieting among female pharmacy students. *Biomed Pharmacother.* (2009) 63:679–92. doi: 10.1016/j.biopha.2008.08.005

16. Garner DM, Olmsted MP, Bohr Y, Garfinkel PE. The Eating Attitudes Test: psychometric features and clinical correlates. *Psychol Med.* (1982) 12:871–8. doi: 10.1017/S0033291700049163

17. Aoun A, Garcia FD, Mounzer C, Hlais S, Grigioni S, Honein K, et al. War stress may be another risk factor for eating disorders in civilians: a study in Lebanese university students. *Gen Hosp Psychiatry.* (2013) 35:393–7. doi: 10.1016/j.genhosppsych.2013.02.007

18. Alhazmi AH, Al Johani A. Prevalence and associated factors of eating disorder among students in Taiba University, Saudi Arabia: a cross-sectional study. *Malays J Public Health Med.* (2019) 19:172–6. doi: 10.37268/mjphm/vol.19/no.1/art.80

19. Essawy HI, Hashem NZ, El hawary YA, Morsy MH, El Awady SA. Prevalence of eating disorders and alexithymia among a sample of Egyptian medical students not attending psychiatric clinics. *QJM Int J Med.* (2021) 114:hcab102.024. doi: 10.1093/qjmed/hcab102.024

20. Jahrami H, Sater M, Abdulla A, Faris MA-I, AlAnsari A. Eating disorders risk among medical students: a global systematic review and meta-analysis. *Eat Weight Disord.* (2018) 24:397–410. doi: 10.1007/s40519-018-0516-z

21. Tavolacci M-P, Déchelotte P, Ladner J. Eating disorders among college students in France: characteristics, help-and care-seeking. *Int J Environ Res Public Health.* (2020) 17:5914. doi: 10.3390/ijerph17165914

22. Tremelling K, Sandon L, Vega GL, McAdams CJ. Orthorexia nervosa and eating disorder symptoms in registered dietitian nutritionists in the United States. *J Acad Nutr Diet.* (2017) 117:1612–7. doi: 10.1016/j.jand.2017.05.001

23. McNulty PAF. Prevalence and contributing factors of eating disorder behaviors in active duty navy men. *Mil Med.* (1997) 162:753–8. doi: 10.1093/milmed/162.11.753

24. Hussein RA, Hamed RA, Raya YM, Abdelghani M, Hafiz AH. Prevalence of and attitudes toward eating disorders among female nurses. *Middle East Curr Psychiatr.* (2016) 23:44–9. doi: 10.1097/01.XME.0000461679.99712.9c

25. Mahmood A, Ball P, Morrissey H. Exploring pharmacy students' knowledge and understanding of eating disorders and their impact on mental health and quality of life. *Int J Curr Pharm Res.* (2021) 63–9. doi: 10.22159/ijcpr.2021v13i5.1895

26. Falvey SE, Hahn SL, Anderson OS, Lipson SK, Sonneville KR. Diagnosis of eating disorders among college students: a comparison of military and civilian students. *Mil Med.* (2021) 186:975–83. doi: 10.1093/milmed/usab084

27. Safer M, Zemni I, Mili M, Ben Abdelaziz A, Ben Ghanaia H, Ben Salem K, et al. Eating disorders: prevalence and associated factors among health occupation students in Monastir University (Tunisia). *Tunis Med.* (2020) 98:895–912.

28. Strober, M. *Faculty Opinions Recommendation of the Prevalence and Correlates of Eating Disorders in the National Comorbidity Survey Replication*. Faculty Opinions – Post-Publication Peer Review of the Biomedical Literature (2006).

29. Wardle J, Haase AM, Steptoe A, Nillapun M, Jonwutiwes K, Bellisle F. Gender differences in food choice: the contribution of health beliefs and dieting. *Ann Behav Med.* (2004) 27:107–16. doi: 10.1207/s15324796abm2702_5

30. Steenhuis I. Guilty or not? Feelings of guilt about food among college women. *Appetite.* (2009) 52:531–4. doi: 10.1016/j.appet.2008.12.004

31. Quittkat HL, Hartmann AS, Düsing R, Buhlmann U, Vocks S. Body dissatisfaction, importance of appearance, and body appreciation in men and women over the lifespan. *Front Psychiatry.* (2019) 10:864. doi: 10.3389/fpsyt.2019.00864

32. Coker E, Abraham S. Body weight dissatisfaction: a comparison of women with and without eating disorders. *Eat Behav.* (2014) 15:453–9. doi: 10.1016/j.eatbeh.2014.06.014

33. Petry N, Vasconcelos F de AG de, Costa L da CF. Feelings and perceptions of women recovering from anorexia nervosa regarding their eating behavior. *Cad Saude Publica.* (2017) 33:e00048716. doi: 10.1590/0102-311x00048716

34. Götestam KG, Agras WS. General population-based epidemiological study of eating disorders in Norway. *Int J Eat Disord.* (1995) 18:119–26. doi: 10.1002/1098-108x(199509)18:2<119::aid-eat2260180203>3.0.co;2-u

35. Kinzl JF, Traweger C, Trefalt E, Mangweth B, Biebl W. Binge eating disorder in males: a population-based investigation. *Eat Weight Disord.* (1999) 4:169–74. doi: 10.1007/BF03339732

36. Korinth A, Schiess S, Westenhoefer J. Eating behaviour and eating disorders in students of nutrition sciences. *Public Health Nutr.* (2010) 13:32–7. doi: 10.1017/S1368980009005709

37. Yu Z, Tan M. Disordered eating behaviors and food addiction among nutrition major college students. *Nutrients.* (2016) 8:673. doi: 10.3390/nu8110673

38. Drummond D, Hare MS. Dietitians and eating disorders: an international issue. *Can J Diet Pract Res.* (2012) 73:86–90. doi: 10.3148/73.2.2012.86

39. Hughes R, Desbrow B. Aspiring dietitians study: a pre-enrolment study of student's motivations, awareness and expectations relating to careers in nutrition and dietetics. *Nutr Diet.* (2005) 62:106–9. doi: 10.1111/j.1747-0080.2005.00015.x

40. Sharp, A. Why are eating disorders like anorexia and orthorexia more common among nutrition students? *Abbey's Kitchen.* (2017). Available online at: https://www.abbeyskitchen.com/eating-disorders-like-anorexia-orthorexia-common-among-nutrition-students/ (accessed February 7, 2022).

41. Arslantaş H. Eating behaviour and Orthorexia Nervosa (healthy eating obsession) in nursing students: cross-sectional analytic study. *J Psychiatr Nurs.* (2017) 8:137–44. doi: 10.14744/phd.2017.36854

42. Iorga M, Manole I, Pop L, Muraru I-D, Petrariu F-D. Eating disorders in relationship with dietary habits among pharmacy students in Romania. *Pharmacy.* (2018) 6:97. doi: 10.3390/pharmacy6030097

43. Rukavishnikov GV, Verbitskaya EV, Vekovischeva OY, Bobrovsky AV, Kibitov AO, Mazo GE. The association of obesity with eating disorders risk: online survey of a large cohort of Russian-speaking individuals seeking medical weight correction assistance. *J Eat Disord.* (2021) 9:100. doi: 10.1186/s40337-021-00456-y

44. Weinberger N-A, Kersting A, Riedel-Heller SG, Luck-Sikorski C. Body dissatisfaction in individuals with obesity compared to normal-weight individuals: a systematic review and meta-analysis. *Obes Facts.* (2016) 9:424–41. doi: 10.1159/000454837

45. Kessler RC, Bromet EJ. The epidemiology of depression across cultures. *Annu Rev Public Health.* (2013) 34:119–38. doi: 10.1146/annurev-publhealth-031912-114409

46. McCuen-Wurst C, Ruggieri M, Allison KC. Disordered eating and obesity: associations between binge-eating disorder, night-eating syndrome, and weight-related comorbidities. *Ann N Y Acad Sci.* (2018) 1411:96–105. doi: 10.1111/nyas.13467

47. Jacobi C, Hayward C, de Zwaan M, Kraemer HC, Agras WS. Coming to terms with risk factors for eating disorders: application of risk terminology and suggestions for a general taxonomy. *Psychol Bull.* (2004) 130:19–65. doi: 10.1037/0033-2909.130.1.19

48. Adami GF, Gandolfo P, Bauer B, Scopinaro N. Binge eating in massively obese patients undergoing bariatric surgery. *Int J Eat Discord.* (1995) 17:45–50. doi: 10.1002/1098-108x(199501)17:1<45::aid-eat2260170106>3.0.co;2-s

49. Shisslak CM, Crago M, Estes LS. The spectrum of eating disturbances. *Int J Eat Disord.* (1995) 18:209–19. doi: 10.1002/1098-108x(199511)18:3<209::aid-eat2260180303>3.0.co;2-e

50. Haines J, Neumark-Sztainer D, Eisenberg ME, Hannan PJ. Weight teasing and disordered eating behaviors in adolescents: longitudinal findings from Project EAT (Eating Among Teens). *Pediatrics.* (2006) 117:e209–15. doi: 10.1542/peds.2005-1242

51. Dalle Grave R, Calugi S, Marchesini G. Self-induced vomiting in eating disorders: associated features and treatment outcome. *Behav Res Ther.* (2009) 47:680–4. doi: 10.1016/j.brat.2009.04.010

52. National Eating Disorders Association. Laxative abuse. (2018). Available online at: https://www.nationaleatingdisorders.org/learn/general-information/laxative-abuse (accessed February 9, 2022).

53. El Ghoch M, Alberti M, Capelli C, Calugi S, Dalle Grave R. Resting energy expenditure in anorexia nervosa: measured versus estimated. *J Nutr Metab.* (2012) 2012:652932. doi: 10.1155/2012/652932

frontiers | Frontiers in Nutrition

TYPE Original Research
PUBLISHED 04 August 2022
DOI 10.3389/fnut.2022.932418

OPEN ACCESS

EDITED BY
Kathleen L. Hefferon,
Cornell University, United States

REVIEWED BY
Giovanna Caparello,
University of Rome Tor Vergata, Italy
Ashuin Kammar-García,
Instituto Politécnico Nacional (IPN), Mexico

*CORRESPONDENCE
Reema Tayyem
reema.tayyem@qu.edu.qa
Maha Hoteit
m.hoteit@ul.edu.lb

SPECIALTY SECTION
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

RECEIVED 29 April 2022
ACCEPTED 06 July 2022
PUBLISHED 04 August 2022

CITATION
Tayyem R, Al-Bayyari N, Al-Awwad N, Abuhijleh H, Hoteit R, Qasrawi R, Badran E, Basha A, Allehdan S, Boukari K, Arrish J, Seir RA and Hoteit M (2022) Dietary intake and lifestyle practices of eastern mediterranean postpartum women before and during COVID-19 pandemic: An internet-based cross-sectional survey. *Front. Nutr.* 9:932418. doi: 10.3389/fnut.2022.932418

Dietary intake and lifestyle practices of eastern mediterranean postpartum women before and during COVID-19 pandemic: An internet-based cross-sectional survey

Reema Tayyem[1,2]*, Nahla Al-Bayyari[3], Narmeen Al-Awwad[4], Haya Abuhijleh[1], Reem Hoteit[5], Radwan Qasrawi[6,7], Eman Badran[8], Asma Basha[8], Sabika Allehdan[9], Khlood Boukari[10,11], Jamila Arrish[11], Rania Abu Seir[12] and Maha Hoteit[13,14]*

[1]Department of Human Nutrition, College of Health Sciences, QU-Health, Qatar University, Doha, Qatar, [2]School of Agriculture, The University of Jordan, Amman, Jordan, [3]Department of Nutrition and Food Technology, Faculty of Al-Huson University College, Al-Balqa Applied University, Al-Salt, Jordan, [4]Department of Clinical Nutrition and Dietetics, Faculty of Allied Health Sciences, The Hashemite University, Zarqa, Jordan, [5]Hariri School of Nursing, American University of Beirut, Beirut, Lebanon, [6]Department of Computer Science, Al-Quds University, Jerusalem, Palestine, [7]Department of Computer Engineering, Istinye University, Istanbul, Turkey, [8]School of Medicine, The University of Jordan, Amman, Jordan, [9]Department of Biology, College of Science, University of Bahrain, Bahrain, [10]Department of Clinical Nutrition, Faculty of Applied Medical Sciences, Taibah University, Medina, Saudi Arabia, [11]National Nutrition Committee (NNC), Saudi Food and Drug Authority (Saudi FDA), Riyadh, Saudi Arabia, [12]Department of Biomedical Technology, Al-Quds University, Jerusalem, Palestine, [13]Faculty of Public Health, Lebanese University, Beirut, Lebanon, [14]PHENOL Research Group (Public Health Nutrition program-Lebanon), Faculty of Public Health, Lebanese University, Beirut, Lebanon

Background: During the lockdown period, a substantial group of these women reported lifestyle changes.

Aim: The aim of the study is to characterize the dietary patterns, intake and the adherence to the United States Department of Agriculture (USDA) pregnancy guidelines before and during the COVID-19 pandemic in Eastern Mediterranean postartum women.

Methods: An internet-based cross-sectional survey was used to collect the data. The survey was carried out among 1,939 postpartum women from five countries from the Eastern Mediterranean region. Change in dietary intake from the five food groups and the adherence to USDA's daily recommendations were assessed.

Findings: There was a significant increase in the mean (SD) consumption of all the food groups, including bread, rice, and other cereals, fruits, vegetables, milk and milk products, white and red meat, and nuts during the pandemic. Around 84% of participants reported no/low adherence (0–2) to USDA guidelines, whereas only 15% reported moderate or high adherence (3–5)

to the guidelines before the pandemic. However, there was an increase in the proportion of subjects reporting moderate/high adherence (22%) during the pandemic.

Discussion and conclusions: A substantial proportion of our study participants reported a lower dietary intake than the recommended amounts, and low adherence to the five food groups. Reasonable and applicable actions should be taken to protect postpartum women and their children from the effects of low dietary intake, particularly during pandemics and lockdowns. More researches are needed to identify the modifiable factors which could improve the nutritional status of the postpartum women during the pandemic.

KEYWORDS

postpartum women, COVID-19, maternal nutrition, dietary intake, USDA recommendations, adherence

Problem or issue

Limited evidence exists about the dietary patterns, intake and the adherence to the USDA pregnancy guidelines before and during the COVID-19 pandemic in Eastern Mediterranean postpartum women.

What is already known

No studies available investigated the dietary patterns and the adherence to the USDA pregnancy guidelines before and during the COVID-19 pandemic in Eastern Mediterranean postartum women.

What this paper adds

A considerable percentage of the study participants reported a lower dietary intake than the recommended amounts, and low adherence to the five food groups. More researches are needed to identify the modifiable factors which could improve the nutritional status of the postpartum women during the pandemic.

Introduction

The postpartum period is a physiological stress period characterized by significant metabolic and hormonal changes (1). During this period, mothers are under a lot of stress and worry about how they will regain their health and shape after childbirth, which can lead to psychological concerns or disorders in certain cases (1). When compared to the attention given during pregnancy, mothers' and their newborns' health during the postpartum period has been neglected in both developed and developing countries (2). van der Pligt et al. (3) stated that postpartum women received less advices about healthy diet and physical activity as compared to during pregnancy (3). It is well-known that food habits and practices vary among people and are influenced by their culture. Whether their food supplies are limited or abundant, women's eating habits are influenced by their socio-cultural context. These factors will have an impact on their postpartum eating habits (2).

A healthy dietary pattern, which is characterized by fruits, vegetables, whole grains, and fish, may decrease the risk of many diseases, and cannot be overstated (1). Adequate nutrition is critical throughout the months after childbirth because the mother should recover after delivery and any nutrients ingested by the mother pass to the infant through breast milk (4). On the other hand, inadequate nutrition during the postpartum period has been associated with the development of a variety of illnesses; iron deficiency, for example, is a primary cause of chronic anemia. Iron deficiency anemia was discovered in the early postpartum period and was found to exist in 21% of women 1 month postpartum (4).

The majority of postpartum women in different countries do not receive any nutritional advice since individual dietary assessment is not a part of the hospital stay after childbirth or normal medical visits during the postpartum period (4). Nonetheless, postpartum care is very important and must include the prevention, early detection, and treatment of complications and diseases. Therefore, counseling and assistance on breastfeeding, birth spacing, immunization, and maternal nutrition must be included during postpartum care (2, 4).

Following the initial outbreak of the disease caused by the SARS-CoV-2 virus in Wuhan (China) in December 2019, the WHO declared a global health emergency, and the disease was quickly classified as a pandemic (5). There is a limited amount of information on how the novel coronavirus affects

TABLE 1 Sociodemographic characteristics of the study postpartum women ($n = 1,630$).

Variable	All $n = 1,630$	Jordan $n = 223$	Palestine $n = 391$	Lebanon $n = 604$	Saudi Arabia $n = 324$	Bahrain $n = 88$	p-Value
			Mean (SD)				
Age (year)	28.9 (5.1)	29.5 (5.1)	27.7 (4.9)	28.8 (4.7)	29.7 (5.4)	29.9 (5.5)	0.020
			n (%)				
Youth (18–24)	334 (20.5)	34 (15.2)	100 (25.6)	125 (20.7)	61 (18.8)	14 (15.9)	<0.001
Young adults(>25)	1,296 (79.5)	189 (84.8)	291 (74.4)	479 (79.3)	263 (81.2)	74 (84.1)	
Education level							
Less than high school	77 (4.7)	26 (11.7)	13 (3.3)	27 (4.5)	9 (2.8)	2 (2.3)	<0.001
High school diploma	207 (12.7)	50 (22.4)	61 (15.6)	60 (9.9)	17 (5.2)	19 (21.6)	
Diploma	222 (13.6)	23 (10.3)	37 (9.5)	131 (21.7)	21 (6.5)	10 (11.4)	
Bachelor's degree	863 (52.9)	100 (44.8)	259 (66.2)	219 (36.3)	233 (71.9)	52 (59.1)	
Graduate degree	261 (16.0)	24 (10.8)	21 (5.4)	167 (27.6)	44 (13.6)	5 (5.7)	
Employment status							
Employed	646 (39.6)	91 (40.8)	129 (33.0)	271 (44.9)	112 (34.6)	43 (48.9)	<0.001
Unemployed	984 (60.4)	132 (59.2)	262 (67.0)	333 (55.1)	212 (65.4)	45 (51.1)	
Family income							
Decreased	930 (57.1)	168 (75.3)	279 (71.4)	329 (54.5)	130 (40.1)	24 (27.3)	<0.001
Increased	100 (6.1)	4 (1.8)	21 (5.4)	50 (8.3)	19 (5.9)	6 (6.8)	
No change	600 (36.8)	51 (22.9)	91 (23.3)	225 (37.3)	175 (54.0)	58 (65.9)	

p-Value calculated based on ANOVA test/Chi-2.

postpartum women. In addition to that, women may experience increased risks as a result of COVID-19, which might affect their diet, nutrition habits, and access to nutrition services (6, 7). The impact of the COVID-19 pandemic is expected to be context-specific and differ depending on a variety of country-specific factors (8). It was reported that poor dietary quality was associated with postpartum depression in Chinese lactating women, where depressed women tended to have a more inadequate intake of vegetables and a more insufficient variety of foods (9). A significant decrease was observed in the consumption of fruits, followed by vegetables, and then salted and sweet cereals from pregnancy to post-partum in Spain. Besides that, a decreasing consumption of healthy food from the first trimester to the post-partum period was also observed (10).

The aim of the study is to characterize the dietary intake of the major food groups and the adherence to the USDA's dietary guidelines before and during the COVID-19 pandemic in Eastern Mediterranean postpartum women.

Methods

Study design and setting

In this cross-sectional observational study, a web-based questionnaire was used to compare the food intake of women during the COVID-19 pandemic to the five food groups recommended by the United States Department of Agriculture (USDA) from July-December, 2020 (11). Majority of the questionnaire elements were verified during a study conducted on postpartum women in 2018 (more than 200 pregnant women) (12, 13). There were five sections in this survey, which include sociodemographic characteristics, maternal medical history, eating patterns and food frequency questionnaire, physical activity level, anthropometric data, smoking, mental health, and food-related behaviors. The questionnaire's first section included questions about pregnancy and its progression, such as the age of the mother, health status, comorbidities, and other socio-demographic related questions including education, residency, and economic situation. The second section of the questionnaire included questions about the daily serving sizes of common food (bread, pasta, cereal, vegetables, fruits, meat, poultry, fish, and nuts) and the frequency of their consumption preceding completion of the survey. Other questions in the survey covered women's habits prior to COVID-19 pandemic. These questions asked about their mental health, smoking status, and physical activity level. The questionnaire included multiple-choice questions and other questions with open-ended answers. Each participant was informed about the study goal and assured of the confidentiality of their information before completing the questionnaire. The questionnaire was distributed through email, along with links to the website where subjects in the study could complete it. The questionnaire was completed voluntarily and anonymously, and participants had to consent to take part in the study.

10.3389/fnut.2022.932418

TABLE 2 Health related characteristics of the study postpartum women ($n = 1,630$).

Variable	All $n = 1,630$	Jordan $n = 223$	Palestine $n = 391$	Lebanon $n = 604$	Saudi Arabia $n = 324$	Bahrain $n = 88$	p-Value
			Mean (SD)				
Pre-pregnancy BMI kg/m^2	26.3 (5.1)	26.8 (3.6)	26.2 (4.2)	25.8 (4.6)	26.8 (6.9)	28.2 (6.9)	<0.001
			n (%)				
Body mass index (BMI)							
Normal	580 (43.0)	72 (37.5)	137 (42.0)	226 (46.5)	120 (43.2)	25 (37.3)	<0.001
Thin	21 (1.6)	0 (0.0)	3 (0.9)	10 (2.1)	7 (2.5)	1 (1.5)	
Overweight	489 (36.2)	80 (41.7)	133 (40.8)	167 (34.4)	93 (33.5)	16 (23.9)	
Obese class I	190 (14.1)	37 (19.3)	37 (11.3)	72 (14.8)	31 (11.2)	13 (19.4)	
Obese class II	56 (4.2)	3 (1.6)	16 (4.9)	9 (1.9)	19 (6.8)	9 (13.4)	
Obese class III	13 (1.0)	0 (0.0)	0 (0.0)	2 (0.4)	8 (2.9)	3 (4.5)	
Diagnosed with COVID-19							
No	1,523 (93.4)	201 (90.1)	386 (98.7)	570 (94.4)	296 (91.4)	70 (79.5)	<0.001
Yes	107 (6.6)	22 (9.9)	5 (1.3)	34 (5.6)	28 (8.6)	18 (20.5)	
Health problems							
No	342 (25.1)	61 (31.3)	72 (21.8)	110 (22.3)	78 (28.1)	21 (30.9)	0.034
Yes	1,022 (74.9)	134 (68.7)	258 (78.2)	383 (77.7)	200 (71.9)	47 (69.1)	
Diabetes							
No	22 (95.7)	–	22 (95.7)	–	–	–	
Yes	1 (4.3)	–	1 (4.3)	–	–	–	
Gestational diabetes							
No	1,516 (93.0)	188 (84.3)	376 (96.2)	578 (95.7)	295 (91.0)	79 (89.8)	<0.001
Yes	114 (7.0)	35 (15.7)	15 (3.8)	26 (4.3)	29 (9.0)	9 (10.2)	
Hypertension							
No	1,607 (98.6)	220 (98.7)	382 (97.7)	598 (99.0)	321 (99.1)	86 (97.7)	0.404
Yes	23 (1.4)	3 (1.3)	9 (2.3)	6 (1.0)	3 (0.9)	2 (2.3)	
Thyroid Disorders							
No	1,572 (96.4)	217 (97.3)	368 (91.4)	587 (97.2)	315 (97.2)	85 (96.6)	0.085
Yes	58 (3.6)	6 (2.7)	23 (5.9)	17 (2.8)	9 (2.8)	3 (3.4)	
Depression							
No depression	93 (12.6)	16 (9.7)	14 (8.0)	35 (13.9)	23 (20.9)	5 (14.3)	0.004
Mild	310 (42.1)	76 (46.1)	61 (34.9)	106 (42.1)	49 (44.5)	18 (51.4)	
Moderate	190 (25.8)	42 (25.5)	56 (32.0)	63 (25.0)	23 (20.9)	6 (17.1)	
Moderately severe	85 (11.5)	23 (13.9)	30 (17.1)	20 (7.9)	9 (8.2)	3 (8.6)	
Severe	59 (8.0)	8 (4.8)	14 (8.0)	28 (11.1)	6 (5.5)	3 (8.6)	
Anxiety							
No anxiety	243 (32.8)	36 (21.8)	55 (31.1)	91 (36.0)	43 (39.1)	18 (51.4)	0.006
Mild	372 (50.3)	97 (58.8)	85 (48.0)	123 (48.6)	52 (47.3)	15 (42.9)	
Moderate	98 (13.2)	26 (15.8)	33 (18.6)	26 (10.3)	12 (10.9)	1 (2.9)	
Severe anxiety	27 (3.6)	6 (3.6)	4 (2.3)	13 (5.1)	3 (2.7)	1 (2.9)	
Physical activity							
Inactive	315 (36.0)	25 (14.3)	95 (41.9)	112 (37.6)	60 (44.4)	23 (56.1)	<0.001
Active	561 (64.0)	150 (85.7)	132 (58.1)	186 (62.4)	75 (55.6)	18 (43.9)	
Smoking during pregnancy							
No	796 (77.3)	49 (70.0)	211 (80.2)	275 (66.6)	207 (92.0)	54 (91.5)	<0.001
Yes	234 (22.7)	21 (30.0)	52 (19.8)	138 (33.4)	18 (8.0)	5 (8.5)	

Variables and measurements

Body mass index

Postpartum body mass index (BMI) categories were recorded for each participant as per the World Health Organization (WHO) classification (14). BMI categories include underweight, normal, overweight, obese class I, obese class II, and obese class III.

Depression

To assess depression in postpartum women, the validated Patient Health Questionnaire (PHQ-9) was used (15). The questionnaire covered nine topics related to depression and had a score range of 0–3, with 0 being never and 3 almost every day. In this study, depression levels were classified as follows: no depression = 0–4, mild depression = 5–9, moderate depression = 10–14, moderately severe depression = 15–19, and severe depression ≥20. PHQ-9 was used in this study because it has been shown to be an efficient tool for detecting depression.

Anxiety

Anxiety symptoms were assessed using the clinically validated seven-item Generalized Anxiety Disorder-7 (GAD-7) (16). Participants responded to the GAD-7 survey by ranking items on a four-point scale ranging from 0 (never) to 3 (almost every day). Total anxiety severity was determined by scores ranging from 0 to 4 for no anxiety, 5–9 for mild anxiety, 10–14 for moderate anxiety, and ≥15 for severe anxiety.

Physical activity

Levels of physical activity were self-reported by the study participants. Physical activity levels were recorded as low, moderate, or high for any postpartum woman that participated in at least half an hour of daily physical activity (17).

Dietary guideline for postpartum women

The classification of recommended food amounts was made using the USDA guidelines for postpartum women (18). Two categories of food groups were developed using the USDA guideline cutoff points, and a score of 0 or 1 was provided for each food group based on the UDSA daily recommendations, with a score of 0 indicating lower intake and a score of 1 indicating higher intake.

The first food group is *Bread, rice, and other cereals*, and the score was provided for lower intake when serving is <6, or higher intake when serving is more than or equal to 6. The second food group is *Fruits*, and a lower intake of fruit is 2 servings, where as a higher intake is more than or equal to 2 servings. *Vegetables* represent the third food group; <2.5 servings indicate a lower intake, while 2.5 or more servings indicate a higher intake. Another food group is *Proteins*, where servings of <5.5 indicate a lower intake, and more than or equal to 5.5 servings indicate a higher intake. The last food group is *Dairy*, a lower intake is <3 servings, while more than or equal to 3 servings indicate a higher intake. Moreover, adherence to each food group was tracked and recorded in this study, and the score of adherance was added to each individual food group. The variable was then divided into two categories to indicate low adherance or high adherance. Low adherance is represented by a score between 0 and 2, and high adherance is represented by a score between 3 and 5.

Inclusion/exclusion criteria

Participants were chosen at conveniently, and data collection was carried out under certain criteria, which include: (i) postpartum since the pre-COVID-19 pandemic period; (ii) pregnancy of normal course; (iii) age >18; (iv) place of residence is in the five countries listed; (v) responding to all questions; and (vi) participants providing written consent to participate in the study. However, conception during the intra-COVID-19 pandemic period, as well as specific risk factors such as miscarriage, were exclusion criteria.

Statistics and data analysis

Study factors such as sociodemographic characteristics, health status, and other study cofactors were summarized as descriptive statistics. Means and standard deviations (SD) were used to express continuous variables. Frequencies and percentages were used to represent categorical variables. The Chi-square test was applied to verify any statistically significant difference between the five countries involved in this study, and each categorical variable. The ANOVA test was applied for continuous variables. To compare continuous variables before and during the pandemic, the paired sample *t*-test was used, while the McNemar test (a marginal homogeneity test for paired data) was used to compare categorical variables. The statistical significance level was set at $p < 0.05$, and the statistical analysis was performed using SPSS version 25.

Results

Sociodemographic characteristics

A total of 1,630 postpartum women completed the questionnaire. Table 1 shows that the mean age (SD) of the study participants was 28.9 (5.1) years, with Bahrain having the highest mean age of 29.9 (5.5) years and Palestine having

TABLE 3 Daily intake of the main food groups per country according to USDA.

Food group	Number of servings before the pandemic *n* (%)						*p*-Value	Number of servings during the pandemic n (%)						*p*-Value	*p*-Value # (Before vs. during the pandemic)
	All *n* = 1,630	Jordan *n* = 223	Palestine *n* = 391	Lebanon *n* = 604	Saudi Arabia *n* = 324	Bahrain *n* = 88		All *n* = 1,630	Jordan *n* = 223	Palestine *n* = 391	Lebanon *n* = 604	Saudi Arabia *n* = 324	Bahrain *n* = 88		
Bread, rice and other cereals [Mean (SD)]	4.6 (3.2)	4.2 (2.4)	4.7 (3.9)	4.4 (2.5)	4.8 (3.6)	5.8 (2.9)	0.203	5.2 (3.8)	5.8 (3.8)	5.3 (4.6)	4.9 (3.0)	5.3 (3.9)	5.3 (2.9)		<0.001
Bread, rice and other cereals *n* (%)															
<6	320 (65.0)	58 (74.4)	110 (67.5)	95 (63.3)	48 (62.3)	9 (37.5)	0.018	265 (57.0)	25 (46.3)	98 (60.9)	84 (57.1)	48 (60.8)	10 (41.7)	0.18	0.003
≥6	172 (35.0)	20 (25.6)	53 (32.5)	55 (36.7)	29 (37.7)	15 (62.5)		200 (43.0)	29 (53.7)	63 (39.1)	63 (42.9)	31 (39.2)	14 (58.3)		
Fruits [Mean (SD)]	2.0 (1.6)	1.7 (1.1)	2.1 (1.6)	2.1 (1.8)	1.8 (1.4)	2.4 (2.6)	0.217	2.2 (1.6)	2.6 (1.7)	2.1 (1.5)	2.2 (1.6)	2.0 (1.7)	2.1 (1.5)	0.218	0.016
Fruits *n* (%)															
<2	231 (52.4)	54 (61.4)	68 (48.9)	59 (46.1)	42 (61.8)	8 (44.4)	0.078	183 (44.9)	21 (33.3)	64 (47.4)	54 (44.3)	38 (53.5)	6 (35.3)	0.162	0.078
≥2	210 (47.6)	34 (38.6)	71 (51.1)	69 (53.9)	26 (38.2)	10 (55.6)		225 (55.1)	42 (66.7)	71 (52.6)	68 (55.7)	33 (46.5)	11 (64.7)		
Vegetables [Mean (SD)]	1.9 (1.3)	1.8 (1.3)	2.0 (1.4)	1.8 (1.0)	1.7 (1.5)	2.5 (1.7)	0.055	2.3 (1.9)	2.8 (1.9)	2.2 (1.6)	1.9 (1.2)	2.4 (3.3)	2.3 (1.6)	0.045	<0.001
Vegetables *n* (%)															
<2.5	356 (76.7)	76 (77.6)	104 (72.7)	106 (80.9)	56 (80.0)	14 (63.6)	0.274	297 (67.8)	39 (52.0)	100 (71.4)	97 (75.2)	49 (68.1)	12 (54.5)	0.006	<0.001
≥2.5	108 (23.3)	22 (22.4)	39 (27.3)	25 (19.1)	14 (20.0)	8 (36.4)		141 (32.2)	36 (48.0)	40 (28.6)	32 (24.8)	23 (31.9)	10 (45.5)		
Milk and milk products [Mean (SD)]	1.8 (1.8)	1.7 (1.4)	1.8 (1.4)	1.9 (2.4)	2.0 (1.8)	2.1 (1.4)	0.768	2.0 (1.6)	2.3 (1.9)	1.9 (1.6)	1.8 (1.5)	2.1 (1.8)	2.0 (1.4)	0.321	0.015
Milk and milk products *n* (%)															
<3	378 (84.0)	80 (88.9)	111 (81.0)	113 (86.9)	58 (79.5)	16 (80.0)	0.32	323 (77.6)	47 (70.1)	105 (80.2)	100 (80.6)	56 (75.7)	15 (75.0)	0.473	0.001
≥3	72 (16.0)	10 (11.1)	26 (19.0)	17 (13.1)	15 (20.5)	4 (20.0)		93 (22.4)	20 (29.9)	26 (19.8)	24 (19.4)	18 (24.3)	5 (25.0)		
White and red meats and nuts [Mean (SD)]	3.7 (2.7)	3.7 (2.4)	3.5 (2.7)	3.6 (2.8)	3.8 (2.9)	3.8 (1.9)	0.939	4.2 (3.5)	5.4 (3.0)	3.7 (2.6)	3.6 (2.8)	4.1 (3.1)	6.7 (9.2)	<0.001	<0.001
White and red meats and nuts *n* (%)															
<5.5	328 (80.0)	77 (73.3)	96 (82.1)	84 (81.6)	58 (85.3)	13 (76.5)	0.319	263 (71.1)	37 (48.7)	86 (76.8)	76 (81.7)	54 (76.1)	10 (55.6)	<0.001	0.004

(Continued)

10.3389/fnut.2022.932418

TABLE 3 Continued

Food group	Number of servings before the pandemic *n* (%)						*p*-Value	Number of servings during the pandemic n (%)						*p*-Value	*p*-Value # (Before vs. during the pandemic)
	All *n* = 1,630	Jordan *n* = 223	Palestine *n* = 391	Lebanon *n* = 604	Saudi Arabia *n* = 324	Bahrain *n* = 88		All *n* = 1,630	Jordan *n* = 223	Palestine *n* = 391	Lebanon *n* = 604	Saudi Arabia *n* = 324	Bahrain *n* = 88		
≥5.5	82 (20.0)	28 (26.7)	21 (17.9)	19 (18.4)	10 (14.7)	4 (23.5)		107 (28.9)	39 (51.3)	26 (23.2)	17 (18.3)	17 (23.9)	8 (44.4)		
Adherence to food groups	1.1 (1.4)	0.9 (1.1)	1.3 (1.5)	1.1 (1.3)	1.2 (1.4)	1.7 (1.5)	<0.001	1.4 (1.5)	1.5 (1.1)	1.4 (1.6)	1.3 (1.4)	1.5 (1.6)	2.0 (1.7)	<0.001	<0.001
Adherence to food groups															
No/low (0–2) *n* (%)	478 (84.6)	115 (89.1)	138 (82.6)	138 (84.1)	67 (82.7)	20 (83.3)	0.589	425 (78.4)	90 (80.4)	127 (77.9)	129 (80.6)	65 (78.3)	14 (58.3)	0.168	<0.001
Moderate/high (3–5) n (%)	87 (15.4)	14 (10.9)	29 (17.4)	26 (15.9)	14 (17.3)	4 (16.7)		117 (21.6)	22 (19.6)	36 (22.1)	31 (19.4)	18 (21.7)	10 (41.7)		

Adherence to food groups	**Before pandemic *n* (%)**	**During pandemic *n* (%)**
No/low (0–2)	478 (84.6)	425 (78.4)
Moderate/high (3–5)	87 (15.4)	117 (21.6)

10.3389/fnut.2022.932418

the lowest mean age of 27.7 (4.9). Moreover, most of the study participants were from Lebanon ($n = 604$) and the overall study subjects belonged to the young adults age subgroup, as 79.5% were older than 25 years, with Jordan having the highest proportion (84.8%) and Palestine having the lowest proportion (74.4%) of this age subgroup (p-value < 0.001). More than half of the study participants own a bachelor's degree (53%), with Saudi Arabia having the highest proportion (72%) and Lebanon having the lowest (36%) among all. On the other hand, the highest proportion of participants having a graduate degree is in Lebanon (27%; p-value < 0.001). The majority of the women in this study are unemployed (60.4%) with Palestine having the highest percentage of unemployed women (67%), while Bahrain, on the other hand, has the highest percentage of employed women (48.9%; p-value < 0.001). Only a few subjects reported an increase in the family income (6.1%), whereas the vast majority reported a drop in their family household income (57.1%), with Jordan having the highest percentage of this drop in income (75.3%) and Bahrain having the least drop (27.3%; p-value < 0.001).

Health related characteristics of postpartum women

The health characteristics of the study participants are summarized in Table 2. The mean (SD) pre-pregnancy BMI was 26.3 (5.1) kg/m^2. Lebanon had the lowest mean (SD) BMI of 25.8 (6.9) kg/m^2, and Bahrain had the highest mean (SD) BMI of 28.2 (6.9) kg/m^2 (p-value < 0.001). The majority of the study participants had a normal BMI (43%), 36.2% were overweight, 19.3% were obese, and only 1.6% were underweight. The highest proportion of normal BMI was in Lebanon (46.5%), and Jordan had the highest proportion of overweight (41.7%), Bahrain had the highest proportion of obesity among all, with 19.4, 13.4, and 4.5% in class I, II, and III respectively, while Saudi Arabia had the highest proportion of underweight (2.5%; p-value < 0.001). Only a small proportion of the respondents were diagnosed with COVID-19 (6.6%), with Bahrain having the highest percentage (20.5%), and Palestine had the lowest percentage (1.3%; p-value < 0.001). The vast majority of the study participants reported having health complications, with Palestine having the highest proportion (78.2%), and Jordan having the least (68.7%). Most of the participants reported having no diabetes (95.7%), gestational diabetes (93%), hypertension (98.6%), or thyroid disorders (96.4%). However, a large proportion reported mild to severe depression (87.4%). Mild depression was reported by 42.1% of the participants, with more than half of them being in Bahrain (51.4%), while 25.8% reported moderate depression, with the highest proportion being in Palestine (32%). Moreover, around 67% were anxious, with the highest proportion of mild anxiety being in Jordan (58.8%), moderate anxiety being in Palestine (18.6%), and severe anxiety being in Lebanon (5.1%). Most of the respondents were physically active (64%), with Jordan placing first (85.7%), and Bahrain placing last (43.9%; p-value < 0.001). Smoking during pregnancy was not high among the respondents. 22.7% reported smoking during pregnancy, with Lebanon having the highest proportion (33.4%) and Saudi Arabia having the lowest proportion (8%; p-value < 0.001).

TABLE 4 Adherence to recommended number of food groups according to USDA.

Number of food groups	Before pandemic *n* (%)	During pandemic *n* (%)	*p*-Value
0	237 (41.9)	185 (34.1)	<0.001
1	169 (29.9)	157 (29.0)	
2	72 (12.7)	83 (15.3)	
3	40 (7.1)	56 (10.3)	
4	24 (4.2)	30 (5.5)	
5	23 (4.1)	31 (5.7)	

Daily intake of the main food groups according to usda

Daily consumption of the main food groups before and during COVID-19 pandemic is presented in Table 3. There was a substantial increase in the mean (SD) consumption of all the food groups, including bread, rice, and other cereals, fruits, vegetables, milk and milk products, white and red meat, and nuts (p-value < 0.05). Prior to the pandemic, Bahrain had the highest consumption of bread, rice, and other cereals (62.5%; $\geq$6 servings/day), fruits (55.6%; $\geq$2 servings/day), and vegetables (36.4%; $\geq$2.5 servings/day) compared to Jordan, Palestine, Lebanon, and Saudi Arabia. However, this difference was only significant in the bread, rice, and cereal group (p-value < 0.05). Saudi Arabia had the highest consumption of milk and milk products (20.5%; $\geq$3 servings/day), while Jordan had the highest consumption of white and red meats and nuts (26.7%; $\geq$5.5 servings/day). However, this difference was not significant. In contrast, Jordan had lower consumption of bread, rice, and cereals (25.6%; $\geq$6 servings/day; p-value < 0.05). After the COVID-19 pandemic, Bahrain had the highest consumption of bread, rice, and cereals, while Jordan had the highest consumption of fruits (66.7%; $\geq$2 servings/day) and a significant increase in consumption of vegetables (48%; $\geq$2.5 servings/day; p-value $= 0.006$). Other than that, Jordan had a significant increase in white and red meat and nut consumption and was the highest among the other countries even after the pandemic (51.3%; $\geq$5.5 servings/day; p-value < 0.001).

Moreover, there was a significant change in the adherence to food groups as per the USDA guidelines, which is presented in Table 3. Before the pandemic, around 84% of participants reported no/low adherence (0–2) to USDA guidelines, whereas only 15% reported moderate or high adherence (3–5) to the guidelines. On the other hand, during the pandemic, there was an increase in the proportion of subjects reporting moderate/high adherence (22%; p-value < 0.001).

Table 4 shows a clear presentation of the adherence to recommendations of USDA guidelines before and after the pandemic. Adherence to consumption of bread, rice, and cereals decreased during the pandemic to 29%, whereas adherence to the rest of the food groups (fruits, vegetables, milk and milk products, white and red meat, and nuts) significantly increased (p-value < 0.001)

Mitigation measures adopted by post-partum women to cope with the situation during the COVID-19 pandemic are presented in Figure 1. Majority of the women reported no change in food related behaviors during the pandemic. However, 9% stated that they go for easy to prepare foods, 8% go for dishes that require less food during preparation, and 7% reported worsened food quality and choosing cheaper food.

Discussion

This study mainly focuses on comparing postpartum women's dietary intake of the main food groups and their adherence to the USDA dietary guidelines in five Eastern Mediterranean countries (Jordan, Palestine, Lebanon, Saudi Arabia, and Bahrain) before and during the COVID-19 pandemic. Overall, the study finds a decent improvement in the number of servings of all food groups and a slight improvement in their adherence to USDA dietary recommendations during the COVID-19 pandemic. Yet, the dietary consumption of the five food groups among the majority of the study participants was still below the recommendations.

The sociodemographic characteristics (age, education level, employment status, and family income) of postpartum women showed statistically significant differences between the five countries. The majority (80%) of the participants included were young adults (>25 years old), and more than half of the participants were educated and held a bachelor's degree, which is similar to most studies conducted on postpartum women (3, 9, 19). On the contrary, in a study conducted in Egypt, only a quarter of the postpartum women had a university education (2). In addition, more than 50% of the participants were unemployed and reported a decrease in their family income during the COVID-19 pandemic. In the Australian first-time mothers' study, only (1.8%) were unemployed and (88.6%) were keeping house and raising children (3). Although they were doing a full-time job, this group was considered unemployed in our study. Additionally, a decrease in family income was reported in 38 countries worldwide during the COVID-19 pandemic (20) as in our reported results.

Prior to pregnancy, the mean body mass index (BMI) of the participants was 26.3 (5.1) indicating that they were overweight. However, during postpartum (36.2%) were overweight, which might be related to breastfeeding or due to the reduction in their family's income during the pandemic. Moreover, a statistically significant difference between the BMI categories among the five countries was found. Previous studies conducted in China (9) and Australia (3) showed a lower percentage (28.1%) of overweight postpartum women, where the mean postpartum BMI was 26.2 (5.0) which is similar to our participants' pre-pregnancy BMI. Regarding the other health characteristics, most of the postpartum women were not diagnosed with COVID-19, diabetes or gestational diabetes, hypertension, and thyroid disorders, despite that (75%) reported having health problems. Other than that, 64% of our participants were physically active and 77% did not smoke during pregnancy, which decreased the risk of chronic diseases as mentioned above. Around half of them reported suffering from mild depression and anxiety, which is higher than the proportion reported in the Urban China study (9). These results might be related to the lower intake of fish or omega-3 polyunsaturated fatty acids during pregnancy and the postpartum period, as reported by Hamazaki et al. (21).

The COVID-19 pandemic and its socio-economic effects are likely to negatively impact the dietary intake and nutrition status of women, particularly during pregnancy and breastfeeding. Postpartum is a nutritionally vulnerable period since the maternal nutrient needs increase to meet physiological requirements, support the infants' and children's growth and development, and protect the health of the mother while breastfeeding. In the context of COVID-19, women may face additional risks affecting their diet quality and quantity (6). Unfortunately, the current literature lacks research articles that study the change in dietary intake from the main food groups and the adherence to the dietary guidelines and recommendations during the COVID-19 pandemic among postpartum women. However, there were a few longitudinal studies that examined the changes in the dietary intake of pregnant mothers in the third trimester and the first 40 days or months during the postpartum period, and a second study that examined postpartum maternal diet quality overtime in a population at high risk for obesity (10, 22, 23).

In general, our study results showed significant differences in the mean number of servings of bread, rice, and other cereals, fruits, vegetables, milk and milk products, and white and red meat and nuts consumption during the pandemic compared to before the pandemic. This was expected since more than 95% of the postpartum women did not reduce their intake of the main five groups, the number of meals, or the amount of food consumed to cope with the situation during the pandemic. Additionally, the only significant difference was in bread, rice, and other cereal consumption among the five countries before

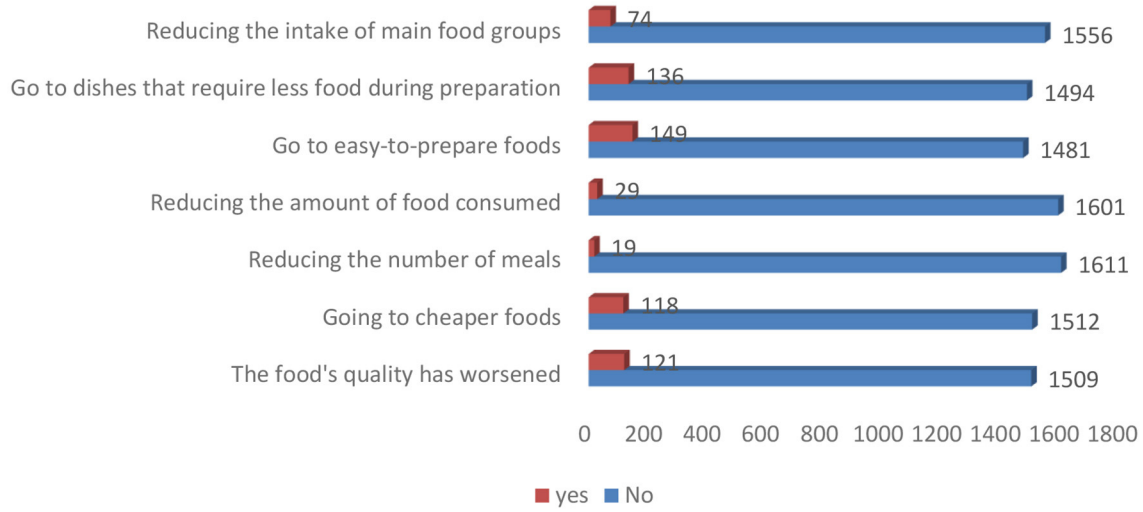


FIGURE 1
Mitigation measures adopted by post-partum women to cope with the situation during the pandemic.

the pandemic, where 63% of Bahraini women had an intake of >6 servings. Even though during the pandemic, a difference was noticed in the consumption of vegetables, white and red meat and nuts, where 48% of Jordanian women consumed >2.5 servings of vegetables and 82% of Lebanese women consumed <5.5 servings of meat and nuts group. Moreover, there was no difference in the postpartum women's adherence to the five food groups' consumption before or during the pandemic when compared to the USDA's recommendations. Although, a statistically significant difference was detected in the moderate/high adherence when compared to the overall adherence (represented by an increase from 15 to 22% during the pandemic), the majority of the women showed low adherence.

Kay et al. (22) conducted a longitudinal observational study on a cohort of low-income, non-Hispanic black mothers in the postpartum period from 3 to 18 months to investigate the consumption of key food groups and the adherence to the 2010 Dietary Guidelines for Americans (DGAs). They found most mothers' median intake of grains was near recommended levels, but whole grain intake was low, suggesting most grains are coming from refined, processed foods. Another recent study reported a decrease in the Health Eating Index scores based on the number of servings consumed after 6 months postpartum in total grain products and whole grains compared to 3 months postpartum (23). The mean dietary grain intakes among two groups (community dwelling and residents in the Maternity Care Center) of lactating women in Shanghai during the puerperium were around the recommended values based on the Food Graph Reference for Retrospective Dietary Survey, although in the community sample it was slightly lower (24). Also, a study conducted on 32 healthy German women at 6 weeks post-partum revealed a decrease in carbohydrate intake (25). In this study, only 43% of women during the pandemic met the recommendations (>6 servings/day) for bread, rice, and other cereals. The mean dietary intake from this food group was below the recommendation. During the pandemic, a slight increase in the mean 5.2 (3.8) was noticed compared to the mean intake 4.6 (3.2) before the pandemic in the five countries.

Recently, Pligt et al. (3) used the Cancer Council of Australia's Food Frequency Questionnaire to assess the fruit and vegetable intake (servings/day) of postpartum women. Their results showed that approximately half of the participants (55.4%) met the fruit recommendations defined as two or more servings/day. Furthermore, no change was recorded in the median daily servings of fruits (two servings) at 3, 6, 9, 12, and 18 months during the periodical postpartum follow-up (22). Our results are in-line with the previous results where 55.1% of mothers consumed >2 servings of fruits during the pandemic and the mean number of servings significantly increased during the pandemic to reach 2.2 servings.

In the Shanghai study, all lactating mothers' mean intake of vegetables, tubers, and fruit was lower than the recommendations (24). In a large prospective cohort study conducted to explore the changes in vegetable intake between pregnancy and the postnatal period using the diet history questionnaire, researchers found that 44% of women were not meeting vegetable recommendations during pregnancy or in the postpartum period. Remarkably, at 4 months postpartum, 15% of women consumed the recommended number of servings of vegetables during pregnancy but did not meet the recommendation (26). Moreover, Pliget et al. (3) reported that 8.6% of all Australian postpartum women

met the recommendations for vegetable intake, defined as >5 servings per day, with 44.9% of women consuming <2 servings per day of vegetables (27) and only 7.2% of total women met the recommendations for both fruit and vegetable intake (3). In our study, 32% of women met the recommendations (>2.5 servings/day) of vegetable intake during the pandemic, and the mean servings 2.3 (1.9) of vegetable intake was lower than the recommended amounts, although there was a significant increase in the mean vegetable serving during the pandemic among the five countries. Nevertheless, 68% of participants consume <2.5 servings per day. Our results agree with previous studies regarding the adherence to the dietary intake of vegetables but also disagree with other results due to not considering the women's dietary intake during pregnancy in the current study and the difference in the dietary guidelines used in each study

The postpartum women's milk and milk product intake was below the recommendations, and the mean intake was 2.0 (1.6) cups during the pandemic, which is higher than their intake 1.8 (1.8) before the pandemic. More than three-fourths (78%) of them consumed <3 cups daily during the pandemic. Kay et al. (22) assessed the dietary intake of postpartum women at each home visit using a computerized 24-h recall and investigated the adherence to the Dietary Guidelines for Americans. They found many mothers consuming dairy foods, but the median number of servings was approximately one-third of the recommendation of 3 servings per day. Our results disagree with Kay et al. because we have approximately one fourth of our participants (22%) consuming >3 servings per day. In agreement with our results, at 6 months postpartum, Cuervo et al. (28) observed a decrease in milk and milk product intake. Similar observations were reported at 26 weeks postpartum (29) and at 4 months postpartum in Australian women with obesity (30). Similarly, in the Shanghai study, the milk intake was low in the 2 groups of postpartum lactating mothers, with an overall mean intake of approximately a quarter of the recommended quantity (24).

The last food group studied was proteins, or white and red meats and nuts. Results showed that during the pandemic, 71% of the postpartum women had an intake that was below the recommendations. Their mean daily intake during the pandemic was 4.2 (3.5) ounces, while it was less before the pandemic 3.7 (2.7 ounce/day). Only 29% of the participants during the pandemic met the recommendation of > 5.5 ounces/day. On the contrary, the mean meat/poultry, egg, and fish/shrimp intakes of all studied Shanghai lactating mothers were higher than the recommendations (24). Furthermore, in the Kay et al. study, almost all mothers consumed protein foods (i.e. meat, poultry, seafood, eggs, soy products, nuts, and seeds) and they met the recommendations. Similar to our results, a study that followed mothers from pregnancy to 4 months postpartum reported a decrease in the quality and quantity of meat consumption (30). Research also focused on fish and omega-3 consumption postpartum, and they linked the higher intake with a reduction in postpartum depression risk at 6 months after delivery and serious mental illness at 1 year after delivery (21).

Due to differences in selected postpartum periods, the results of research articles on the dietary intake of postpartum women varied. For instance, one study looked at 26 weeks postpartum (29) and showed a decrease in the intake of fruits, vegetables, cereals, and oils. Another study looked at 6 months postpartum and found a decrease in the intake of cereals, vegetables, fruits, and dairy products (28). Moreover, a different study looked at 4 months postpartum and found a reduction in the consumption of milk, meat, and oil (30). Recently, in research that evaluated and compared the immediate postpartum (up to 40 days after delivery) dietary intake with the third trimester of pregnancy, a significant lower intake of fruits, vegetables, salted, and sweet cereals was observed, but there was no change regarding adherence to the Mediterranean diet (10). Lebrun et al. studied dietary intake and diet quality from the third trimester of pregnancy to 6 months postpartum using completed 2–3 Web-based 24-h recalls. They discovered that the total intake of several micronutrients (vitamins A, C, D, group B vitamins, iron, magnesium, zinc, calcium, phosphorus, manganese, and copper) and supplements intake decreased significantly over time, while the total Canadian healthy eating index score and its components did not change (23). Additionally, similar results were found regarding the dietary intake of postpartum women at different times in cross-sectional studies, where mothers were not meeting the recommended intake levels, especially fruits and vegetables, while they were consuming excessive amounts of sugar-sweetened beverages (3, 31–34).

Several studies (10, 22–24) found that postpartum women did not adhere to the recommended number of food groups. These results are similar to our findings, but the difference was that we studied the change in adherence during the COVID-19 pandemic according to USDA dietary guidelines. A statistically significant difference was found in women's adherence to the five-food groups, although the percentage of women adhering to the five food groups was 4.1% before the pandemic and 5.7% during the pandemic. This means most women have low adherence either before or during the pandemic. Unfortunately, no studies were found about postpartum women's dietary adherence to guidelines during the COVID-19 pandemic except through pregnancy (5, 35). For instance, in an internet-based cross-sectional survey, the adherence of pregnant Spanish women to the Mediterranean diet showed that more than half (57.8%) had moderate adherence, around a third (35.6%) had high adherence, and only a small percentage (6.6%) reported low adherence (5).

This study has several strengths. It is the first of its type in the Eastern Mediterranean Region that examined the change in postpartum women's dietary intake and adherence to USDA dietary guidelines before and during the COVID-19 pandemic. In addition, it included an acceptable number of participants from five different countries. However, the study has a number

of limitations, including that it was an internet-based cross-sectional survey and that bias selection might have occurred. Besides the limits/cutoffs of the five food groups, dietary intake was adopted from the USDA dietary guidelines because of a lack of common Eastern Mediterranean guidelines, yet this may not give us the right picture about the Eastern Mediterranean women's dietary status. Lastly, this study contained many questions, which designed to identify the woman's dietary intake situation during the pandemic, thereby determining the amount of food consumed and identifying the nutrients level was not possible.

Conclusions

The COVID-19 pandemic has positive effects on dietary intake and adherence to guidelines among postpartum Eastern Mediterranean women. However, a large proportion of our study participants maintained their dietary intake below the recommended amounts, and low adherence to the five food groups. Therefore, urgent actions should be taken to protect postpartum women and their children from the effects of low dietary intake, particularly during pandemics and lockdowns, through focusing on nutrition support programs, nutrition education, and the promotion of adopting healthy eating behaviors and lifestyle. Further research is needed to assess dietary intake in quality and quantity in a larger cohort of postpartum women using longitudinal follow-up studies and to identify mothers at higher risk of inadequate intake to cover them in nutrition intervention programs.

Data availability statement

The raw data supporting the conclusions of this article will be provided by the corresponding authors when requested and without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Ethics Committee in Scientific Research of University of Jordan (19/2020/585). The patients/participants provided their written informed consent to participate in this study.

Author contributions

RT: conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, and writing—original draft preparation. NA-B: data curation, methodology, writing—original draft preparation, and writing—review and editing. NA-A: methodology, writing—original draft preparation, and writing—review and editing. HA: writing—original draft preparation and review and editing. RH: data curation, formal analysis, methodology, and writing—review and editing. RQ: conceptualization, data curation, formal analysis, and writing—review and editing. RS: data curation, methodology, and writing—review and editing. SA, JA, and KB: conceptualization, data curation, methodology, and writing—review and editing. AB: data curation and writing—review and editing. EB: conceptualization, data curation, and writing—review and editing. MH: conceptualization, data curation, formal analysis, investigation, methodology, project administration, supervision, validation, writing—original draft preparation. All authors have read and agreed to the published version of the manuscript.

Research group

Bahrain (Mahmoud Samy Ismail and Nada Omar Abduljawad; King Hamad University Hospital); Lebanon (Mariane Abi Nasr, Sarah Obeid, Mohamad El Hajj: Lebanese University; Chadi Fakih: Al Hadi Laboratory and IVF Center); Palestine (Diala Abu Al Halawa: Al-Quds University; Firas Abdel Jawad: Makassed Hospital; Nabil Thawabteh: Makassed Hospital; Hazem Agha: Al Quds University); Kingdom of Saudi Arabia (Areej Alamer: Ministry of Health (MOH); Majid M Alkhalaf: National Nutrition Committee (NNC), Saudi Food and Drug Authority (Saudi FDA).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Author disclaimer

The authors alone are responsible for the views expressed in this article and they do not necessarily represent the views, decisions or policies of WHO or the other institutions with which the authors are affiliated.

References

1. World Health Organization. *Maternal and Newborn Health/Safe Motherhood Unit*. Postpartum care of the mother and newborn: a practical guide: report of a technical working group. World Health Organization (1998). Available online at: https://apps.who.int/iris/handle/10665/66439

2. Mahmoud AA, Ismail NA, El-Habashy MM. Dietary Practices among Postpartum Women. *J High Inst Public Health.* (2007) 37:711–36. doi: 10.21608/jhiph.2007.22550

3. van der Pligt P, Olander EK, Ball K, Crawford D, Hesketh KD, Teychenne M, et al. Maternal dietary intake and physical activity habits during the postpartum period: associations with clinician advice in a sample of Australian first time mothers. *BMC Pregnancy Childbirth.* (2016) 16:1–10. doi: 10.1186/s12884-016-0812-4

4. Shiraishi M, Matsuzaki M, Tsunematsu R, Watanabe S, Kobayashi R, Haruna M. Effects of individual dietary intervention on nutrient intake in postpartum Japanese women: a randomized controlled trial. *Nutrients.* (2021) 13:3272. doi: 10.3390/nu13093272

5. Biviá-Roig G, La Rosa VL, Gómez-Tébar M, Serrano-Raya L, Amer-Cuenca JJ, Caruso S, et al. Analysis of the impact of the confinement resulting from COVID-19 on the lifestyle and psychological wellbeing of Spanish pregnant women: an Internet-based cross-sectional survey. *Int J Environ Res Public Health.* (2020) 17:5933. doi: 10.3390/ijerph17165933

6. UNICEF. *Global Nutrition Cluster, Global Technical Assistance Mechanism for Nutrition (GTAM), World Food Programme (WFP), Protecting Maternal Diets and Nutrition Services and Practices in the Context of COVID-19.* (2020). Available online at: https://www.ennonline.net/attachments/3445/UNICEF-GTAM-GNC-Maternal-Nutrition-Programming-COVID19-V3_22-April-2020.pdf

7. Navarro-Cruz AR, Kammar-García A, Mancilla-Galindo J, Quezada-Figueroa G, Tlalpa-Prisco M, Vera-López O, et al. Association of differences in dietary behaviours and lifestyle with self-reported weight gain during the COVID-19 lockdown in a university community from chile: a cross-sectional study. *Nutrients*. (2021) 13:3213. doi: 10.3390/nu13093213

8. Kotlar B, Gerson E, Petrillo S, Langer A, Tiemeier H. The impact of the COVID-19 pandemic on maternal and perinatal health: a scoping review. *Reprod Health.* (2021) 18:1–39. doi: 10.1186/s12978-021-01070-6

9. Yang C, Zhao A, Lan H, Ren Z, Zhang J, Szeto IM-Y, et al. Association between dietary quality and postpartum depression in lactating women: a cross-sectional survey in Urban China. *Front Nutr*. (2021) 8:705353. doi: 10.3389/fnut.2021.705353

10. Jardí C, Aparicio E, Bedmar C, Aranda N, Abajo S, March G, et al. Food consumption during pregnancy and post-partum. ECLIPSES study. *Nutrients.* (2019) 11:2447. doi: 10.3390/nu11102447

11. AGRICULTURE USDO. *Nutrition During Pregnancy National Agricultural Library* (2021).

12. Tayyem RF, Allehdan SS, Alatrash RM, Asali FF, Bawadi HA. Adequacy of nutrients intake among Jordanian pregnant women in comparison to dietary reference intakes. *Int J Environ Res Public Health.* (2019) 16:3440. doi: 10.3390/ijerph16183440

13. Tayyem R, Allehdan SS, Al-Awwad NJ, Alatrash RM, Mahfouz IA, Alasali F. Food group intake of pregnant jordanian women based on the three pregnancy trimesters. *Prev Nutr Food Sci.* (2020) 25:346. doi: 10.3746/pnf.2020.25.4.346

14. World Health Organization. *Diet, nutrition and the prevention of chronic diseases: report of a joint WHO/FAO expert consultation*. Geneva: World Health Organization (2003). Available online at: https://apps.who.int/iris/handle/10665/42665

15. Kroenke K, Spitzer RL, Williams JB. The PHQ-9: validity of a brief depression severity measure. *J Gen Intern Med.* (2001) 16:606–13. doi: 10.1046/j.1525-1497.2001.016009606.x

16. Spitzer RL, Kroenke K, Williams JB, Löwe B. A brief measure for assessing generalized anxiety disorder: the GAD-7. *Arch Intern Med.* (2006) 166:1092–7. doi: 10.1001/archinte.166.10.1092

17. Kaiser LL, Campbell CG. Practice paper of the Academy of Nutrition and Dietetics abstract: nutrition and lifestyle for a healthy pregnancy outcome. *J Acad Nutr Diet.* (2014) 114:1447. doi: 10.1016/j.jand.2014.07.001

18. USDA. *Tips for pregnanct women.* (2016). Available online at: https://wicworks.fns.usda.gov/resources/tips-pregnant-moms (accessed May 3, 2022).

19. Yahya NFS, Teng NIMF, Shafiee N, Juliana N. Association between breastfeeding attitudes and postpartum depression among mothers with premature infants during COVID-19 pandemic. *Int J Environ Res Public Health.* (2021) 18:10915. doi: 10.3390/ijerph182010915

20. De Backer C, Teunissen L, Cuykx I, Decorte P, Pabian S, Gerritsen S, et al. An evaluation of the COVID-19 pandemic and perceived social distancing policies in relation to planning, selecting, and preparing healthy meals: an observational study in 38 countries worldwide. *Front Nutr*. 2021:375. doi: 10.3389/fnut.2020.621726

21. Hamazaki K, Matsumura K, Tsuchida A, Kasamatsu H, Tanaka T, Ito M, et al. Dietary intake of fish and n-3 polyunsaturated fatty acids and risk of postpartum depression: a nationwide longitudinal study–the Japan Environment and Children's Study (JECS). *Psychol Med.* (2020) 50:2416–24. doi: 10.1017/S0033291719002587

22. Kay MC, Wasser H, Adair LS, Thompson AL, Siega-Riz AM, Suchindran CM, et al. Consumption of key food groups during the postpartum period in low-income, non-Hispanic black mothers. *Appetite.* (2017) 117:161–7. doi: 10.1016/j.appet.2017.06.023

23. Lebrun A, Plante A-S, Savard C, Dugas C, Fontaine-Bisson B, Lemieux S, et al. Tracking of dietary intake and diet quality from late pregnancy to the postpartum period. *Nutrients.* (2019) 11:2080. doi: 10.3390/nu11092080

24. Hu R, Fei J, Zhai Y, Feng Y, Warren J, Jin Y, et al. The dietary intake of two groups of lactating women in Shanghai during the puerperium. *Asia Pac J Clin Nutr.* (2019) 28:106–15. doi: 10.6133/apjcn.201903_28(1).0015

25. Rad NT, Ritterath C, Siegmund T, Wascher C, Siebert G, Henrich W, et al. Longitudinal analysis of changes in energy intake and macronutrient composition during pregnancy and 6 weeks post-partum. *Arch Gynecol Obstet.* (2011) 283:185–90. doi: 10.1007/s00404-009-1328-1

26. Tovar A, Kaar JL, McCurdy K, Field AE, Dabelea D, Vadiveloo M. Maternal vegetable intake during and after pregnancy. *BMC Pregnancy Childbirth.* (2019) 19:1–9. doi: 10.1186/s12884-019-2353-0

27. Baghurst KI. Dietary guidelines: the development process in Australia and New Zealand. *J Am Diet Assoc.* (2003) 103:17–21. doi: 10.1016/j.jada.2003.09.032

28. Cuervo M, Sayon-Orea C, Santiago S, Martínez JA. Dietary and health profiles of Spanish women in preconception, pregnancy and lactation. *Nutrients.* (2014) 6:4434–51. doi: 10.3390/nu6104434

29. Ferrer C, García-Esteban R, Mendez M, Romieu I, Torrent M, Sunyer J. Determinantes sociales de los patrones dietéticos durante el embarazo. *Gaceta Sanitaria.* (2009) 23:38–43. doi: 10.1016/j.gaceta.2008.05.004

30. Moran L, Sui Z, Cramp C, Dodd J, A. decrease in diet quality occurs during pregnancy in overweight and obese women which is maintained post-partum. *Int J Obes.* (2013) 37:704–11. doi: 10.1038/ijo.2012.129

31. George GC, Hanss-Nuss H, Milani TJ, Freeland-Graves JH. Food choices of low-income women during pregnancy and postpartum. *J Am Diet Assoc.* (2005) 105:899–907. doi: 10.1016/j.jada.2005.03.028

32. George GC, Milani TJ, Hanss-Nuss H, Freeland-Graves JH. Compliance with dietary guidelines and relationship to psychosocial factors in low-income women in late postpartum. *J Am Diet Assoc.* (2005) 105:916–26. doi: 10.1016/j.jada.2005.03.009

33. Fowles ER, Walker LO. Correlates of dietary quality and weight retention in postpartum women. *J Community Health Nurs.* (2006) 23:183–97. doi: 10.1207/s15327655jchn2303_5

34. Durham HA, Lovelady CA, Brouwer RJ, Krause KM, Østbye T. Comparison of dietary intake of overweight postpartum mothers practicing breastfeeding or formula feeding. *J Am Diet Assoc.* (2011) 111:67–74. doi: 10.1016/j.jada.2010.10.001

35. Hori N, Shiraishi M, Harada R, Kurashima Y. Association of lifestyle changes due to the COVID-19 pandemic with nutrient intake and physical activity levels during pregnancy in Japan. *Nutrients.* (2021) 13:3799. doi: 10.3390/nu13113799

frontiers | Frontiers in Nutrition

TYPE Original Research
PUBLISHED 27 September 2022
DOI 10.3389/fnut.2022.977288

OPEN ACCESS

EDITED BY
Reema Fayez Tayyem,
Qatar University, Qatar

REVIEWED BY
Dalal Usamah Zaid Alkazemi,
Kuwait University, Kuwait
Yonna Sacre,
Holy Spirit University of Kaslik, Lebanon
Narmeen Al-Awwad,
Hashemite University, Jordan

*CORRESPONDENCE
Tatiana Papazian
tatiana.wahanian@usj.edu.lb

SPECIALTY SECTION
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Nutrition

RECEIVED 24 June 2022
ACCEPTED 15 August 2022
PUBLISHED 27 September 2022

CITATION
Papazian T, Salameh P, Abi Tayeh G, Kesrouani A, Aoun C, Abou Diwan M and Rabbaa Khabbaz L (2022) Dietary patterns and birth outcomes of healthy Lebanese pregnant women. *Front. Nutr.* 9:977288. doi: 10.3389/fnut.2022.977288

Dietary patterns and birth outcomes of healthy Lebanese pregnant women

Tatiana Papazian[1,2]*, Pascale Salameh[3,4,5,6], Georges Abi Tayeh[7], Assaad Kesrouani[7], Carla Aoun[1], Mia Abou Diwan[1] and Lydia Rabbaa Khabbaz[2]

[1]Department of Nutrition, Faculty of Pharmacy, Saint-Joseph University of Beirut, Beirut, Lebanon, [2]Laboratoire de Pharmacologie, Pharmacie Clinique et Contrôle de Qualité des Médicaments, Faculty of Pharmacy, Saint-Joseph University of Beirut, Beirut, Lebanon, [3]School of Medicine, Lebanese American University, Byblos, Lebanon, [4]Institut National de Santé Publique, Épidémiologie Clinique et Toxicologie-Liban (INSPECT-LB), Beirut, Lebanon, [5]Department of Primary Care and Population Health, University of Nicosia Medical School, Nicosia, Cyprus, [6]Faculty of Pharmacy, Lebanese University, Hadat, Lebanon, [7]Department of Gynecology and Obstetrics, Hotel Dieu de France Hospital, Beirut, Lebanon

Background: The aim of this study was to define the dietary patterns (DPs) of a sample of Lebanese pregnant women and to establish their correlation with maternal and neonatal outcomes.

Methods: A cross-sectional study was conducted among 358 Lebanese pregnant women. Maternal socio-demographic variables, anthropometric measurements, gestational weight gain and neonatal outcomes such as weight, length, head circumference and Apgar score were collected by qualified dietitians. Dietary intake was assessed by a validated food frequency questionnaire and three 24-h dietary recalls. DPs were determined, *a posteriori*, by a factor analysis to distinguish the inter-correlations between the food groups and a cluster analysis method to assemble the participants into groupings based on similarities in food consumption.

Results: The identified DPs were not exclusively composed of specific food groups, since some components were overlapping in the DPs. The first one was characterized by a high consumption of starchy vegetables, unsaturated fats and unhealthy foods, the second was rich in fruits and vegetables, seeds, rice and pasta, and in fried local meals and the third was mainly based on protein-rich foods like poultry, fish, eggs and dairy products. They were named respectively as "Westernized," "Mixed" and "Neo-Mediterranean" by the research team. Women having the lowest pre-gestational body mass index (BMI) and higher gestational age followed mainly the "Neo-Mediterranean" eating pattern.

Conclusion: The three identified DPs among Lebanese pregnant women were correlated with the pre-gestational BMI, and some maternal variables. However, neither the maternal nor the neonatal outcomes were correlated with the DP adopted by the mothers.

KEYWORDS

dietary patterns, pregnancy, neonatal outcomes, body mass index, gestational weight gain

Background

Eating habits are the outcome of complex interactions of internal (hormonal, metabolic, physiological) and external (cultural, socio-demographic, economical) stimuli, leading the individual to select a specific set of certain foods, determining his dietary pattern (DP). Environmental and genetic factors affect the health of individuals, thus assessing single nutrient intake alone cannot accurately predict its impact on health and disease (1). Hence, the current approach in research is to move from the analysis of nutrients to a more holistic approach through the determination of DPs, in order to capture actual trends in dietary habits and achieve a reliable and valid dietary output, since people eat a combination of foods, not nutrients, composed of bioactive components that act synergically (2, 3).

Optimal fetal development and maternal health depend on a constant supply of high quality nutrients. In fact, higher adherence to healthier DPs was positively associated with better neonatal outcomes: appropriate birth weight, reduced fetal growth restriction and lower risk of preterm birth (2). Medical health authorities such as the World Health Organization (WHO) advise women to adopt a healthier lifestyle, monitor gestational weight gain, promote daily physical activity and abstain from smoking, alcohol and illicit drugs (2, 4, 5). Assessing the nutritional status of pregnant women and its short and long term repercussions on gestational complications such as diabetes (6), preeclampsia and adverse neonatal outcomes (7) is influenced by eating habits, environmental factors, and maternal hormonal fluctuations. The variability in research results justifies the need to conduct culture-based studies.

In a recent review and metanalysis published in 2019, adopting a "healthy" DP by pregnant women reduced the risk of preterm delivery and, hence improved several birth outcomes such as birth weight and gestational age (2).

Although future mothers become highly motivated and tend to adopt healthier eating habits, however, nutrition transition affects the eating patterns of all subgroups of the population worldwide. Lebanon is a small middle-income country on the Eastern shore of the Mediterranean Sea, reputed for its cuisine. However, during the last decades, the traditional Mediterranean meals have gone from high-fiber foods, such as non-refined cereals, nuts and seeds, fruits and vegetables, olive oil and vegetable-based proteins, to high-fat, low-fiber foods, rich in animal-based proteins and saturated fats (8). This dietary shift, together with the decline of the economic situation in the country, affected the nutritional status of the population, leading them to buy cheaper and unhealthy food alternatives, thus, increasing the prevalence of chronic diseases such as metabolic syndrome and cancer (9).

We hypothesized that pregnant women opting for an unhealthy DP, rich in refined foods, sugars and saturated fat would have a higher gestational weight gain and may encounter adverse maternal and neonatal outcomes. Because of the scarcity of the scientific publications related to the DPs of pregnant females living in the Mediterranean region, the aim of this research was primarily to identify the DPs of Lebanese pregnant females, and secondly to examine their associations with maternal factors, neonatal parameters and dietary intakes.

Abbreviations: BMI, body mass index; DP, dietary pattern; FFQ, Food Frequency Questionnaire; FG, food group; GWG, gestational weight gain; HDF, Hôtel Dieu de France; IOM, Institute of Medicine; KMO, Kaiser-Meyer-Olken; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids; SFA, saturated fatty acids; SD, standard deviation; USJ, Saint-Joseph University; WHO, World Health Organization.

Methods and materials

Study design and population

This research is part of a prospective cohort conducted from 2014 till 2018, among pregnant Lebanese women, assessing the relationship between maternal dietary habits, inflammatory markers, genetic polymorphisms, together with gestational and neonatal outcomes. Healthy, non-vegan, Lebanese singleton pregnant females, aged between 18 and 40 years old, were recruited during their first prenatal consultation, post pregnancy confirmation, in private clinics in different geographic districts in the capital Beirut, in the regions of Mount Lebanon, and in the North and South. Field work was conducted between October 2016 and March 2018 by trained dietitians. The study protocol was approved by the Institutional Review Board of Saint-Joseph University (USJ) at Beirut Lebanon, the Hotel-Dieu Hospital Ethics Committee (CE HDF624/FP49) and the participating gynecologists. All participants gave their written consent prior to their participation for which no financial incentive was proposed.

Maternal and neonatal data extraction

The research team, led by dietitians, conducted face to face interviews with the participants, to collect basic sociodemographic data and food recalls. Anthropometric measurements (weight and height) and age were taken from the medical files, or measured by a digital scale and a stadiometer, if data were unavailable. Body mass index (BMI) was calculated as the ratio of pre-gestational weight in kilograms to the square of height in meter. It was then categorized according to the WHO cut-off points (underweight < 18.5, normal 18.5–24.9, overweight 25–29.9 and obese >30) (10). The indicator of socio-economic status was the crowding index, calculated as the ratio of total co-residents per household, excluding newborn infants, on the number of rooms, excluding the kitchen and bathrooms.

A crowding index more than one suggests a household with limited economic resources.

Throughout pregnancy, a follow-up was maintained with all participants *via* face-to-face appointments during prenatal visits or phone calls, to collect information related to maternal health and neonatal outcomes.

Total gestational weight gain (GWG) was calculated by deducting weight at delivery from the pre-conceptional weight and comparing it to the values defined by the Institute of Medicine (IOM). Neonatal characteristics of the participants who delivered at the department of Gynecology and Obstetrics of Hotel-Dieu de France Hospital (HDF), were obtained from the medical charts by the research team on the day of the delivery and classified according to WHO standards (11).

Dietary assessment

Trained dietitians filled the dietary assessment questionnaires, composed by a validated food frequency questionnaire (FFQ) (Supplementary Table 3) and 24-h dietary recalls. Participants were provided pictures of real food portions to estimate usual quantities of foods consumed. The FFQ was filled during the prenatal visit at the beginning of the third trimester and it included foods characteristic to the Mediterranean eating pattern, to capture the usual intake with more precisions. This FFQ was initially developed and validated in a previous study (12). It was subdivided into 12 categories of food groups: bread and cereals (12 items), rice, pasta, potato and legumes (14 items), milk and dairy products (9 items), fruit and fruit juices (10 items), vegetables (12 items), meat, poultry, fish, eggs and ham (25 items), nuts and condiments (16 items), sugar based sweets, desserts and jams (23 items), bakery products (11 items), salty snacks (3 items), oils and fats (9 items), and beverages (13 items). These subdivisions ended up with a total of 157 food items. The weight in grams of each food was multiplied by its frequency of consumption, and divided, for example, by 7, if it was consumed just once a week. Participants' responses were then converted into average daily intake, in grams.

It is worth to mention that FFQs reflect more the habitual diet over a certain period of time, and cannot predict only the exact composition of nutrients, since it should match with dietary records such as recalls, which are more representative and precise (13, 14). Therefore, in any epidemiological study, a dietary recall should accompany the FFQ to assess the nutritional intake. Concerning the assessment obtained from the three 24-h dietary recalls (each at the beginning of a trimester), participants had to recall all food items and drinks with maximum details possible, consumed the day before, from morning till evening. All interviews during data collection were conducted from Tuesday till Saturday, to avoid recalling the intake of a participant during a weekend, since people usually modify their eating patterns at the end of the week.

Data compiled from the three 24-h dietary recalls and from the FFQ were converted into serving sizes in grams and frequency of consumption and analyzed by a special software (Nutrilog 2.30), to obtain mean daily nutrients and caloric intake estimates. Subjects with extreme values for total energy intake (<800 Kcal/day or more than 3,500 Kcal/day) were excluded from the study pool.

We collected detailed information on supplement use (date of first use, time, frequency, dose and brand names), however the contribution of micronutrients from dietary supplements to the recall was not included in the analysis, because our focus was mainly on nutrients provided from the daily diet.

Identification of dietary patterns

DPs are usually assessed either *a priori*—or index-based, when dietary indices are used to determine the adherence to a predefined DP, or *a posteriori*—data-driven, when DPs are statistically identified depending on the reported dietary intake of the participants (15). In this research, this latter technique was applied.

Factorial and cluster analyses are the main techniques applied in nutritional epidemiology to identify the DPs of a population. The research relied on both methods: factorial analysis, to distinguish the inter-correlations between the food groups, and cluster analysis, to assemble the participants into groupings based on similar frequency patterns in food consumption (16, 17).

Twenty three food families with related nutritional characteristics were compiled from the initial pool of the items present in the FFQ as introduced in Supplementary Table 1.

Statistical analyses

Statistical tests were performed using the SPSS statistical software package version 23. Sample size requirements were calculated by applying the formula published by Tabachnick and Fidell (18). The following took into account: the number of independent variables related to predictable maternal factors included in the model: $N = 50 + 8\ m$ (m representing the number of independent variables counted in the study). Those variables were maternal age, educational level, crowding index, profession, pregestational BMI, GWG, smoking habits, and multivitamin supplement intake; given that $m = 8$, at least 114 subjects had to be included in the present study. This formula will assure a statistical power of 80%. Neonatal variables should not be included in the model, since they were unpredictable and unavailable at the time of the recruitment.

10.3389/fnut.2022.977288

After performing a descriptive analysis and showing mean and standard deviation for continuous variables, as well as frequency and percentage of multinomial variables, the population of women was divided according to DPs. The latter were generated according to 2 steps: in step 1, a factor analysis of food items was conducted based on the principal component analysis technique with Kaiser normalization after appropriate checking of assumptions and sample adequacy, followed by a Varimax rotation, since the factors that were output were not correlated. In step 2, the step 1 factors were included in a cluster analysis, by using a K-Means clustering method. The clusters were named and used as DPs in bivariate and multivariable analyses.

Neonatal outcomes were lacking for some participants who did not deliver in HDF. Hence, multiple imputation method, which is a general approach to deal with missing data, was used for neonates' characteristics, using the methods automatically adapting to the missing values types in the analysis. For bivariate analysis, we used the ANOVA to compare means of continuous variables between the three DPs, after checking for normality and homoscedasticity assumptions; these were followed by a *post-hoc* analysis using Bonferroni correction. To compare percentages, a Chi square test was used when calculated results were higher or equal to five; if not so, the Fisher exact test was used. Finally, for multivariate analysis, a MANCOVA was conducted using a General Linear Model, with mother and babies characteristics as continuous dependent variables, dietary patterns as a major independent variable, and other potential confounders for adjustment. In all cases, results were considered significant at a p value <0.05.

Results

Maternal characteristics and birth outcomes are summarized in Table 1. Three hundred and fifty-eight women participated in the study, with a mean age of 30.54 ± 5.23. Almost three quarters of women (72.1%) had a pre-gestational BMI in the normal range (mean BMI 22.96 ± 3.76), and only 31.8% achieved an adequate GWG, according to the recommended norms of IOM. Sociodemographic data analysis has revealed that almost 88% of the participants had a crowding index equal or <1, with 60% of them employed and having achieved a university degree (56.7%). Women having a university degree had pregestational BMI values ($p = 0.015$) in the normal range and a crowding index equal or less than 1 ($p = 0.019$), respectively compared to women who attended only high school, showing a statistically significant positive correlations between pregestational BMI and educational and socio-economic levels (data not shown).

Table 2 presents the neonatal parameters of babies born to women who delivered full term, in the affiliated hospital of USJ. Baby boys had significantly higher anthropometric measurements (weight, height, head circumference) and Apgar

TABLE 1 Descriptive characteristics of the sample (N = 358[†]).

Characteristic	Mean	SD
Age (years)	30.54	5.21
Pre-gestational BMI[§] (kg/m^2)	22.96	3.76
	N	**%**
Age (years)		
18–30	197	55
>30	161	45
Place of residence		
Beirut	105	29.3
Mount Lebanon	184	51.4
South	25	7
North	20	5.6
Nabatieh	17	4.7
Baalbek	7	2
Educational level[†]		
Primary	5	1.4
Complementary	25	7
Secondary	35	9.8
Technical	25	7
Bachelor	203	56.7
Higher education	63	17.6
Occupation		
Housewife	112	31.3
Employee	216	60.3
CEO	10	2.8
Unemployed	3	0.8
Freelancer	13	3.6
Intern	2	0.6
Student	2	0.6
Crowding index[‡]		
≤1	286	88.0
>1	39	12
Smoking		
Yes	23	6.4
No	335	93.6
Pre-gestational BMI[§] (kg/m^2)		
<18.5	19	5.3
18.5–24.99	258	72.1
≥25	81	22.6
Gestational weight gain[†¶]		
Insufficient	62	17.3
Adequate	114	31.8
Excessive	66	18.4
Multivitamin supplement use[†]		
Yes	168	46.9
No	184	51.4

[†] Missing data.
[‡] Calculated as the ratio of total number of co-residents on the numbers of rooms in a household.
[§] Body mass index.
[¶] Gestational weight gain classified according to the norms of IOM (11).

TABLE 2 Descriptive characteristics of neonatal outcomes of the participants (N = 248†).

Characteristic	Mean	SD
Gestational age (days)	269.55	10.37
	N	**%**
Mode of delivery†		
Vaginal	129	36
C-section	116	32.4
Sex of the child†		
Female	113	31.6
Male	134	37.4
Height (cm)†		
<46 cm	7	2
46–54 cm	231	64.5
>54 cm	1	0.3
Weight (kg)†		
<2.5 kg	16	4.5
2.5–4 kg	228	63.7
>4 kg	4	1.1
Head circumference (cm)†		
<35 cm	124	34.6
35 cm	58	16.2
>35 cm	54	15.1
Apgar score (1 min)†		
<7	14	3.9
≥7	229	64
Apgar score (5 mins)†		
<7	4	1.1
≥7	239	66.8

† Missing data.

scores than baby girls, reflecting gender differences between neonates. Results are shown in Supplementary Table 2.

Food categories and consumption patterns

Principal component analysis of the 23 food groups identified the factors of foods consumed with identical frequencies on individual level. Kaiser-Meyer-Olken (KMO) value was 0.754 (p value <0.001 for Bartlett's test of Sphericity), confirming the adequacy of the sample for the analysis. Absolute values <0.4 were excluded from the table. All food groups are considered to have an interpretable association with a factor. Seven factors, with positive loadings, were derived explaining together 53.056% of the total variance:

- Factor 1 assembled high loadings of Westernized fast food, snacks (chocolate, candies, etc.) and desserts.
- Factor 2 was characterized mainly by fruits, vegetables and seeds.
- Factor 3 had high loadings of rice, pasta, beverages such as coffee and sweetened carbonated choices.
- Factor 4 presented high loadings of lean meats, poultry, fish and plant-based protein sources.
- Factor 5 showed loadings from starchy vegetables and healthy fatty acids (monounsaturated and polyunsaturated lipids).
- Factor 6 was composed of refined cereals (white bread), together with fried and caloric dense Lebanese street foods such as falafel and shawarma, rich in trans and saturated fatty acids, respectively.
- Factor 7 was reserved to eggs and dairy food.

All details are summarized in Table 3.

Dietary patterns' assessment

A cluster analysis derived from the seven factors led to three main clusters, as presented in Table 4. The nomination of each DP was defined according to the food load of the categories presented in Table 3.

- The first DP was characterized by high consumption of Western-type fast food and Lebanese street foods, with low consumption of fruits, vegetables, seeds, rice, and pasta and was tagged as "Westernized" DP (Cluster 1 with 102 participants).
- The second DP was characterized by moderate consumption of fruits, vegetables, beverages, rice/pasta, and Lebanese street foods, together with a low consumption of proteins, starchy vegetables and healthy fats and was categorized as " Mixed" DP (Cluster 2 with 99 participants).
- The third DP composed mainly of proteins from lean meat sources, such as poultry and fish, eggs, dairy, fruits, vegetables, legumes and seeds associated with a low consumption of Lebanese street foods, was entitled "Neo-Mediterranean" DP (Cluster 3 with 145 participants). This nomenclature was chosen since the traditional, culture-driven Mediterranean diet pyramid stresses on high intakes of fruits, vegetables, unrefined cereals, legumes and seeds and fish, and moderate consumption of poultry, eggs and dairy (19). However, the younger generation of people living in the Mediterranean region nowadays incorporate more often lean protein sources such as poultry, eggs and dairy, that were consumed in less frequencies by elder generation. This actual food trend led us to propose the connotation of "Neo-Mediterranean."

TABLE 3 Factor loadings of the food groups (FG) (N = 358).

Food groups	FG1	FG2	FG3	FG4	FG5	FG6	FG7
Westernized fast food	0.740						
Sweets/confectionary	0.702						
Lebanese pies	0.565						
Pastries	0.494						
Salty snacks	0.481						
Fruits/fruit juices		0.681					
Nuts/seeds		0.655					
Vegetables (Raw/cooked)		0.531					
Hot beverages			0.709				
Sweetened beverages			0.660				
Rice/pasta			0.610				
Lean meat				0.752			
Fish				0.636			
Legumes				0.442			
Starchy vegetables					0.715		
MUFA[a]					0.501		
PUFA[b]					0.414		
Refined cereals						0.679	
SFA[c]						0.628	
Lebanese fast food						0.440	
Eggs							0.854
Dairy products							0.550

Extraction Method: Principal Component Analysis; Rotation method: Varimax with Kaiser Normalization; Absolute values <0.4 were excluded from the table. KMO Value for sample adequacy = 0.754 (P value for Bartlett's test of Sphericity <0.001). Total variance explained = 53.056%. All food groups are considered to have an interpretable association with a factor.
[a]MUFA, monounsaturated fatty acids.
[b]PUFA, polyunsaturated fatty acids.
[c]SFA, saturated fatty acids.

TABLE 4 Dietary patterns: cluster analysis of food groups (N = 358).

	DP1: Westernized (N = 102)	DP2: Mixed (N = 99)	DP3: Neo-Mediterranean (N = 145)
FG1: Westernized fast food and snacks	0.513	*−0.466*	−0.043
FG2: Fruits, vegetables and seeds	*−0.409*	0.394	0.019
FG3: Beverages and rice/Pasta	*−0.559*	0.399	0.121
FG4: Proteins mainly food	*−0.431*	*−0.660*	0.754
FG5: Starchy vegetables and healthy fatty acids	0.548	*−0.615*	0.034
FG6: Westernized Lebanese food	0.333	0.328	*−0.458*
FG7: Eggs and dairy food	−0.013	*−0.355*	0.251

Method: Quick cluster analysis. Number of iterations = 21.

Correlations of dietary patterns with maternal characteristics

Details concerning the correlations between participants' characteristics and their dietary patterns are presented in Table 5. Significant results were obtained for females adhering to the "Neo-Mediterranean" DP (DP3), who were employed and lived in an urban area (Mount Lebanon), with p values ranging from 0.000 to 0.024 respectively. On the other hand, pregnant women following the "Mixed" DP (DP2) had a higher pre-gestational BMI (23.54 ± 4.17) as compared to those adopting the two other DPs ($p = 0.048$).

TABLE 5 Sociodemographic, lifestyle and environmental maternal factors and dietary patterns during pregnancy (N = 358[†]).

Variables	DP1: Westernized	DP2: Mixed	DP3: Neo-Mediterranean	*p*-value
Sociodemographic				
Age (years)	29.4 ± 5.33	30.94 ± 5.41	30.81 ± 4.82	0.056*
Place of residence [a,c]				
Beirut	29 (28.7)	33 (32.7)	39 (38.6)	0.024**
Mount Lebanon	40 (22.6)	54 (30.5)	83 (46.9)	
South	13 (52)	5 (20)	7 (28)	
North	8 (40)	3 (15)	9 (45)	
Nabatieh	10 (58.8)	3 (17.6)	4 (23.5)	
Baalbek	2 (33.3)	1 (16.7)	3 (50)	
Educational level[†]				
Primary	3 (60)	1 (20)	1 (20)	0.054**
Complementary	10 (41.7)	7 (29.2)	7 (29.2)	
Secondary	16 (48.5)	8 (24.2)	9 (27.3)	
Technical	9 (36)	4 (16)	12 (48)	
University	54 (27.7)	56 (28.7)	85 (43.6)	
Higher education	10 (16.1)	22 (35.5)	30 (48.4)	
Occupation [a,b,c]				
Housewife	50 (46.7)	18 (16.8)	39 (36.4)	0.000**
Employee	45 (21.5)	77 (36.8)	87 (41.6)	
CEO	4 (40)	1 (10)	5 (50)	
Unemployed	1 (33.3)	0 (0)	2 (66.7)	
Freelancer	2 (15.4)	1 (7.7)	10 (76.9)	
Intern	0 (0)	1 (50)	1 (50)	
Student	0 (0)	1 (50)	1 (50)	
Crowding index				
≤1	78 (27.9)	79 (28.2)	123 (43.9)	0.308**
>1	24 (35.9)	20 (29.7)	22 (34.4)	
Lifestyle/health behavior				
Smoking				
Yes	9 (40.9)	4 (18.2)	9 (40.9)	0.379**
No	93 (28.7)	95 (29.3)	136 (42)	
Pre-gestational BMI (kg/m^2)	23.15 ± 3.88	23.54 ± 4.17	22.38 ± 3.29	0.048*
Pre-gestational BMI [b]				
<18.5	5 (27.8)	4 (22.2)	9 (50)	0.357**
18.5–24.99	71 (28.4)	68 (27.2)	111 (44.4)	
≥25	26 (33.3)	27 (34.6)	25 (32.1)	
Gestational weight gain[†,¶]				
Insufficient	9 (15.8)	21 (36.8)	27 (47.4)	0.977**
Adequate	21 (18.6)	40 (35.4)	52 (46)	
Excessive	11 (17.2)	21 (32.8)	32 (50)	
Multivitamin supplement intake[†]				
Yes	42 (25.8)	46 (28.2)	75 (46)	0.246**
No	59 (33.1)	51 (28.7)	68 (38.2)	

[†] Missing data.
*Analysis of variance (ANOVA).
** χ^2 test.
[¶]Gestational Weight Gain classified according to the norms of IOM (2009).
Categorical variables are presented as N (%) and continuous variables as Mean ± SD.
Correlations are considered significant at $p < 0.05$.
[a]Significant difference between DP 1 and 2.
[b]Significant difference between DP 2 and 3.
[c]Significant difference between DP 1 and 3.

TABLE 6 Pregnancy related factors and dietary patterns during pregnancy (N = 358[†]).

Variables	DP1: Westernized	DP2: Mixed	DP3: Neo-Mediterranean	*p*-value
Gestational age (days)	268.20 ± 10.54	271.92 ± 6.85	267.64 ± 12.74	0.064*
Sex of the child				
Girl	19 (17.3)	47 (42.7)	44 (40)	0.051**
Boy	25 (19.4)	36 (27.9)	68 (52.7)	
Mode of delivery				
Vaginal	17 (13.4%)	48 (37.8%)	62 (48.8%)	0.069**
Cesarean	27 (24.5%)	32 (29.1%)	51 (46.4%)	
Height (cm)				
<46 cm	1 (14.3)	1 (14.3)	5 (71.4)	0.462**
46–54 cm	40 (17.9)	80 (35.9%)	103 (46.2)	
>54 cm	0	1 (100)	0	
Weight (kg)				
<2.5 kg	4 (25.0)	4 (25.0)	8 (50.0)	0.804**
2.5–4 kg	39 (17.7)	78 (35.5)	103 (46.8)	
>4 kg	1 (25.0)	1 (25.0)	2 (50.0)	
Head circumference (cm)				
<35 cm	24 (20.2)	40 (33.6)	55 (46.2)	0.445**
35 cm	11 (19.3)	19 (33.3)	27 (47.4)	
>35 cm	5 (9.6)	23 (44.2)	24 (46.2)	
Apgar score (1 min)				
<7	3 (21.4)	6 (42.9)	5 (35.7)	0.710**
≥7	40 (18.1)	76 (34.4)	105 (47.5)	
Apgar score (5 mins)				
<7	0	2 (50.0)	2 (50.0)	0.829**
≥7	43 (18.6)	80 (34.6)	108 (46.8)	

[†] Missing data.
*Resulted from analysis of variance (ANOVA).
**Resulted from X^2 test.
Categorical variables are presented as N (%) and continuous variables as Mean ± SD; Correlations are considered significant at $p < 0.05$.

Correlations of dietary patterns with neonatal outcomes

Correlations between neonatal outcomes and the three maternal DPs are summarized in Table 6. The "Mixed" DP was associated with a higher gestational age (271.92 ± 6.85days) and with adequate neonatal anthropometric measurements. However, all three maternal DPs did not mediate any significant effect on neonatal outcomes.

Correlations of dietary patterns with nutrient intakes

As summarized in Table 7, women following the "Westernized" DP were consuming significantly more calories, fats, sodium, choline and selenium with *p* values below 0.05. On the other hand, nutrient profiles of women adherent to the "Neo-Mediterranean" DP were significantly higher in proteins ($p = 0.043$), fiber ($p = 0.109$), cholesterol ($p = 0.015$) and vitamin A ($p = 0.014$), compared to those following the "Westernized" and the "Mixed" DPs.

Multivariate analysis of maternal outcomes

The results of multivariate analysis taking separately maternal characteristics (GWG and pre-gestational BMI) as dependent variables, with and without energy adjustments, are presented in Table 8. No significant correlations were highlighted between GWG and maternal socio-demographic variables. However, after energy adjustment, women living in the capital Beirut had a significantly greater GWG than those living in rural regions ($\beta = 0.937$; $p < 0.05$). Besides, pre-gestational BMI was positively associated with maternal age (β

TABLE 7 Energy and nutrients intake of the participants across the three dietary patterns (N = 358).

	DP1: Westernized	DP2: Mixed	DP3: Neo-Mediterranean	$p^{\star}$
Energy (Kcal/d)[a]	2,168.95 ± 527.23	1,966.25 ± 554.77	2,045.55 ± 505.93	0.023
CHO (g/day)	272.20 ± 75.97	253.85 ± 80.03	248.78 ± 76.77	0.059
CHO (% EI[+]/d)[b]	50.27 ± 9.86	51 ± 6.18	48.08 ± 5.83	0.005
Protein (g/d)[b]	76.76 ± 21.87	73.86 ± 23.48	81.15 ± 22.71	0.043
Protein (% EI/d)[a,b,c]	13.99 ± 2.12	14.93 ± 2.57	15.93 ± 2.56	0.000
Fat (g/day)[a,c]	92.26 ± 42.58	74.88 ± 22.8	81.06 ± 19.77	0.000
Fat (% EI/d)[a,b]	36.53 ± 5.33	34.22 ± 5.4	35.99 ± 5.26	0.006
Sugar (g/d)	69.33 ± 24.06	166.09 ± 881.12	74.15 ± 27.6	0.247
Fiber (g/d)	17.24 ± 5.84	18.35 ± 8.75	19.29 ± 7.61	0.109
Cholesterol(mg/d)[b]	158.52 ± 74.68	136.32 ± 72.54	163.54 ± 73.63	0.015
Iron (mg/day)	13.72 ± 4.4	14.2 ± 17.4	13.22 ± 4.08	0.748
Calcium (mg/d)	732 ± 322.77	694.98 ± 279.77	745.91 ± 298.19	0.423
Sodium (mg/d)[a,c]	4,863.51 ± 825.35	4,565.76 ± 860.31	4,569.74 ± 798.97	0.011
Vitamin D (μg/d)	8.48 ± 1.87	7.95 ± 1.59	11.38 ± 34.97	0.438
Folate (μg/d)	249.16 ± 98.83	264.65 ± 113.44	313.64 ± 460.06	0.227
Vitamin A (μg/d)[b]	144.77 ± 81.76	117.59 ± 95.23	150.35 ± 87.47	0.014
Vitamin E (μg/d)	9.28 ± 3.52	17.02 ± 85.74	14.53 ± 59.86	0.643
Vitamin C (mg/d)	115.06 ± 65.29	113.98 ± 58.82	104.88 ± 54	0.322
Magnesium (μg/d)[c]	229.64 ± 76.69	258.02 ± 101.6	265.73 ± 104.4	0.013
Zinc (mg/d)	7.09 ± 2.46	7.48 ± 3.15	7.45 ± 2.65	0.512
Iodine (mg/d)	6.96 ± 4.9	8.66 ± 8.76	7.58 ± 6.08	0.190
Choline (mg/d)[a]	208.4 ± 76.06	169.45 ± 81.44	197.79 ± 111.7	0.011
Selenium (μg/d)[a,c]	56.45 ± 20.94	46.98 ± 19.58	47.63 ± 19.38	0.001
Copper (mg/d)	1.3 ± 0.45	1.37 ± 0.48	1.32 ± 0.48	0.543

[*] Analysis of variance One-way ANOVA and Bonferroni *post-hoc* testing, with a p value <0.05 considered as significant.
[+] EI, energy intake; CHO, carbohydrates; Values are presented as mean ± SD.
[a] Significant difference between DP 1 and 2.
[b] Significant difference between DP 2 and 3.
[c] Significant difference between DP 1 and 3.

= 0.156; $p < 0.05$), and inversely with the educational level (β = −0.624; $p < 0.05$). These associations were conserved even after energy adjustment.

Multivariate analysis of neonatal outcomes

The results of multivariate analysis considering each neonatal parameter as a dependent variable, with and without energy adjustments and missing values replacement, are presented in Tables 9–12. First, maternal factors were not correlated with the neonates' length. But, following the missing values replacement, this parameter was negatively associated with maternal age (β = −0.004; $p < 0.05$) and positively with pre-gestational BMI (β = 0.007; $p < 0.05$). This association was conserved independently of the energy adjustment.

With each one-unit increase in pre-gestational BMI, neonate's weight increased by 1.3% (β = 0.013; $p < 0.05$). In addition, when the analysis was adjusted for energy intake, the weight was directly associated with the maternal pre-gestational BMI ($\beta = 0.011$) and the GWG ($\beta = 0.060$), and inversely associated with the energy intake ($\beta = -8.108E{-}5$). After missing values replacement, this neonatal outcome was positively associated with the pre-gestational BMI (β = 0.008) and the GWG (β = 0.058) but negatively correlated with the maternal age (β = −0.006) and energy intake (β = −8.210E−5).

Neonates' head circumference was inversely associated with maternal smoking (β = −0.516), and directly associated with maternal educational level (β = 0.213), their crowding index (β = 0.274) and their GWG (β = 0.254); all these correlations were significant ($p < 0.05$) and were conserved even after energy adjustment. Following the missing values replacement, this parameter remained positively associated with the professional status, the educational level, the crowding index and the GWG, but was lower in neonates whose mothers were smoking before or during the pregnancy (β = −0.478). These results were maintained after energy adjustment.

TABLE 8 Multivariate analysis of gestational weight gain and pre-gestational BMI of participants.

	With energy adjustment			Without energy adjustment		
	Beta	***p*-value**	**(95% CI)**	**Beta**	***p*-value**	**(95% CI)**
Dependent variable: gestational weight gain						
Age	−0.006	0.525	(−0.024, 0.012)	−0.007	0.446	(−0.026, 0.012)
Education	−0.035	0.510	(−0.139, 0.069)	−0.014	0.794	(−0.121, 0.093)
Crowding index	0.087	0.464	(−0.147, 0.321)	0.134	0.274	(−0.106, 0.373)
DP[†]						
1 vs. 3 (Ref)	0.003	0.980	(−0.259, 0.266)	0.003	0.981	(−0.267, 0.274)
2 vs. 3 (Ref)	−0.034	0.753	(−0.247, 0.179)	−0.056	0.614	(−0.276, 0.163)
Residence[§]						
1 vs. 6 (Ref)	0.937	0.030	(0.093, 1.780)	0.832	0.060	(−0.036, 1.700)
2 vs. 6 (Ref)	0.807	0.056	(−0.022, 1.637)	0.695	0.110	(−0.158, 1.548)
3 vs. 6 (Ref)	0.915	0.060	(−0.038, 1.868)	0.775	0.120	(−0.204, 1.754)
4 vs. 6 (Ref)	0.706	0.118	(−0.180, 1.592)	0.631	0.175	(−0.282, 1.543)
5 vs. 6 (Ref)	0.641	0.233	(−0.416, 1.697)	0.441	0.424	(−0.643, 0.524)
Energy	0.000	<0.001	(0.000, 0.001)	–	–	–
Dependent variable: pre–gestational BMI						
Age	0.153	0.002	(0.059, 0.248)	0.156	0.001	(0.061, 0.250)
Education	−0.588	0.032	(−1.125, −0.050)	−0.624	0.023	(−1.160, −0.088)
Crowding index	−0.244	0.691	(−1.452, 0.965)	−0.326	0.594	(−1.531, 0.878)
DP						
1 vs. 3 (Ref)	0.223	0.746	(−1.132, 1.578)	0.223	0.746	(−1.134, 1.581)
2 vs. 3 (Ref)	1.056	0.060	(−0.046, 2.158)	1.095	0.051	(−0.007, 2.197)
Residence						
1 vs. 6 (Ref)	3.489	0.117	(−0.879, 7.840)	3.666	0.099	(−0.692, 8.023)
2 vs. 6 (Ref)	3.053	0.162	(−1.236, 7.342)	3.253	0.136	(−1.033, 7.538)
3 vs. 6 (Ref)	4.520	0.072	(−0.404, 9.443)	4.769	0.057	(−0.148, 9.686)
4 vs. 6 (Ref)	3.687	0.114	(−0.893, 8.267)	3.821	0.102	(−0.762, 8.405)
5 vs. 6 (Ref)	2.475	0.373	(−2.985, 7.934)	2.830	0.307	(−2.612, 8.272)
Energy	−0.001	0.192	(−0.002, 0.000)	–	–	–

[†] Dietary Pattern 1: Westernized, 2: Mixed, 3: Neo-Mediterranean.
[§] Residence 1: Beirut, 2: Mount-Lebanon, 3: South, 4: North, 5: Nabatiyeh, 6: Baalbek.
*Significant p value (<0.05) in bold.

No significant correlations were observed between the Apgar score at 1 minute and maternal socio-demographic variables, with or without energy adjustment. However, after missing values replacement and energy adjustment, this variable was higher in smoking mothers but was inversely associated with the crowding index ($\beta = -0.041$), the GWG ($\beta = -0.033$) and the total energy intake ($\beta = -4.956E{-}5$). These correlations were sustained even without energy adjustment.

Finally, an inverse association was significantly noted between the Apgar score at 5 mins and maternal smoking ($\beta = -0.072$; $p < 0.05$) as well as with maternal age ($\beta = -0.005$; $p < 0.05$) and GWG ($\beta = -0.036$; $p < 0.05$). These associations were preserved after energy adjustment. In addition to these correlations and after missing values replacement, the Apgar score at 5 mins was higher in mothers adopting the "Westernized" DP ($\beta = 0.031$), compared to those adopting the "Neo-Mediterranean" one, and it was positively associated with the pre-gestational BMI ($\beta = 0.003$), and negatively with the crowding index ($\beta = -0.026$). These correlations were conserved even without energy adjustment.

Discussion

The present research is the first study evaluating the DPs of pregnant females, in a Middle-Eastern country of the Mediterranean basin, correlated to maternal and neonatal parameters. In our sample, three DPs were detected: the Westernized, Mixed and Neo-Mediterranean patterns. DPs did not have any significant impact on maternal and neonatal

TABLE 9 Multivariate analysis of neonatal outcomes.

Variables		Height	Weight	Head circumference	Apgar test (1 min)	Apgar test (5 mins)
No missing value replacement; with energy adjustment¶						
Smoking	Yes vs. No (Ref.)	0.02	0.015	**−0.513**	0.057	**−0.075**
		(−0.092 to 0.132)	(−0.148 to 0.178)	**(−0.993 to −0.033)***	(−0.086 to 0.199)	**(−0.145 to −0.005)***
DP†	1 vs. 3 (Ref.)	0.003	−0.37	−0.124	−0.007	0.023
		(−0.067 to 0.073)	(−0.139 to 0.064)	(−0.423 to 0.175)	(−0.095 to 0.082)	(−0.02 to 0.067)
	2 vs. 3 (Ref.)	0.029	−0.38	0.056	−0.005	−0.009
		(−0.028 to 0.086)	(−0.121 to 0.045)	(−0.189 to 0.301)	(−0.078 to 0.068)	(−0.045 to 0.026)
Age		−0.004	−0.006	−0.006	0.000	**−0.005**
		(−0.009 to 0.001)	(−0.13 to 0.001)	(−0.027 to 0.016)	(−0.007 to 0.006)	**(−0.008 to −0.002)***
Education level		0.006	−0.004	**0.213**	0.002	−0.005
		(−0.022 to 0.033)	(−0.45 to 0.036)	**(0.094 to 0.332)***	(−0.034 to 0.037)	(−0.023 to 0.012)
Crowding index		−0.011	0.009	**0.275**	−0.025	−0.01
		(−0.071 to 0.049)	(−0.079 to 0.097)	**(0.017 to 0.533)***	(−0.102 to 0.051)	(−0.048 to 0.027)
Pre-gestational BMI		0.006	**0.011**	0.004	−0.002	0.003
		(−0.002 to 0.013)	**(0.000 to 0.021)***	(−0.027 to 0.035)	(−0.011 to 0.007)	(−0.001 to 0.008)
Gestational weight gain		0.011	**0.060**	**0.25**	−0.023	**−0.033**
		(−0.026 to 0.048)	**(0.006 to 0.114)***	**(0.091 to 0.409)***	(−0.071 to 0.024)	**(−0.056 to −0.01)***
Energy intake (Kcal)		−1.431E−5	**−8.108E−5**	2.011E−5	−6.263E−5	−1.740E−5
		(−6.468E−5 to 3.607E−5)	**(0.000 to −7.548E−6)***	(0.000 to 0.000)	(0.000 to 1.676E−6)	(−4.883E−5 to 1.404E−5)
Gestational age (days)		5.883E−5	0.000	0.000	0.000	0.000
		(0.000 to 0.000)	(−9.668E−5 to 0.001)	(−0.001 to 0.001)	(0.000 to 0.000)	(−4.382E−5 to 0.000)

¶Sex of the child and delivery mode were removed from the analysis because there were not correlated with neonatal outcomes.
† Dietary Pattern 1: Westernized; 2: Mixed; 3: Neo-Mediterranean.
*Significant p value (<0.05) in bold.

outcomes, thus rejecting our hypothesis. The percentage of variance by the three DPs was found to be 53%, higher than the results of 31% reported by Itani et al. (20), in a study among pregnant Emirati women.

Frequent consumption of fast food, associated with low ingestion of fruits, vegetables, seeds and protein sources was identified as the "Westernized" DP. The dietary intakes of women adherent to this profile depict higher caloric intake, associated with a higher consumption of carbohydrates, fats and sodium, and lower intakes of fiber, folate, vitamin E, magnesium, and iodine. This can be explained by the frequent inclusion of fast food (Western and Lebanese types) in their meal plan, thus potentially contributing to energy dense choices, low in crucial nutrients such as folate and high in lipids and salt. Our results are comparable to those obtained by Arkkola et al. (21), where higher intakes of calories, lipids and sugars were dominant in pregnant women following the "Fast Food" DP.

The "Mixed" DP was based on a frequent consumption of healthy food choices (fruits, vegetables, seeds) combined with Westernized ones (Lebanese street foods), thus the mean dietary intakes of those following this eating pattern showed high loads of carbohydrates, sugars, iron, vitamin E, zinc and iodine with low levels of cholesterol and vitamin D. The inclusion of those food groups enhanced the overall diet quality of women following this dietary profile. Statistical analysis identified that those following the DP "Mixed," were females having initially a higher pre-gestational BMI. This issue is explained by the fact that during pregnancy, women with higher pre-gestational BMI become more motivated than others to adopt a healthier lifestyle, especially regarding food patterns, to counterbalance the negative influence of excess weight and unbalanced food choices on gestational outcomes (22). Thus, in our sample, those initially having higher BMI values tried to include in their daily diets fruits, vegetables and seeds more often than before, in addition to consuming rice, pasta and some traditional fast-foods. In a recent publication conducted among Emirati pregnant women, those adherent to the "Diverse" DP were older than 30 years old and had a higher income, compared with those following the Western DP (20). Our results confirm that mean maternal age was the highest among those having a "Mixed" DP. As for the socioeconomic status, it was determined by the crowding index and no direct question was addressed to collect data on income, because usually participants are reluctant to share their financial status.

TABLE 10 Multivariate analysis of neonatal outcomes.

Variables		Height	Weight	Head circumference	Apgar test (1 min)	Apgar test (5 mins)
No missing value replacement; without energy adjustment¶						
Smoking	Yes vs. no (Ref.)	0.022	0.028	**−0.516**	0.067	**−0.072**
		(−0.089 to 0.134)	(−0.137 to 0.192)	**(−0.994 to −0.038)***	(−0.077 to 0.21)	**(−0.142 to −0.003)***
DP†	1 vs. 3 (Ref.)	0.003	−0.037	−0.124	−0.006	0.024
		(−0.066 to 0.073)	(−0.14 to 0.065)	(−0.423 to 0.174)	(−0.096 to 0.083)	(−0.02 to 0.067)
	2 vs. 3 (Ref.)	0.03	−0.035	0.055	−0.003	−0.009
		(−0.027 to 0.087)	(−0.119 to 0.049)	(−0.189 to 0.299)	(−0.076 to 0.071)	(−0.044 to 0.27)
Age		−0.004	−0.006	−0.006	−0.001	**−0.005**
		(−0.009 to 0.001)	(−0.014 to 0.001)	(−0.027 to 0.016)	(−0.007 to 0.006)	**(−0.008 to −0.002)***
Education level		0.006	−0.005	**0.213**	0.002	−0.005
		(−0.022 to 0.033)	(−0.045 to 0.036)	**(0.095 to 0.332)***	(−0.034 to 0.037)	(−0.023 to 0.012)
Crowding index		−0.011	0.012	**0.274**	−0.023	−0.01
		(−0.071 to 0.049)	(−0.077 to 0.1)	**(0.017 to 0.532)***	(−0.1 to 0.054)	(−0.047 to 0.028)
Pre-gestational BMI		0.006	**0.013**	0.003	0.000	0.004
		(−0.001 to 0.013)	**(0.003 to 0.024)***	(−0.027 to 0.033)	(−0.009 to 0.009)	(0.000 to 0.008)
Gestational weight gain		0.009	0.044	**0.254**	−0.035	**−0.036**
		(−0.027 to 0.044)	(−0.009 to 0.097)	**(0.1 to 0.407)***	(−0.081 to 0.011)	**(−0.059 to −0.014)***
Gestational age (days)		4.192E−5	0.000	0.000	0.000	8.154E−5
		(0.000 to 0.000)	(0.000 to 0.000)	(−0.001 to 0.001)	(−0.001 to 7.301E−5)	(−5.963E−5 to 0.000)

¶Sex of the child and delivery mode were removed from the analysis because there were not correlated with neonatal outcomes.
† Dietary Pattern 1: Westernized; 2: Mixed; 3: Neo-Mediterranean.
*Significant p value (<0.05) in bold.

On the other hand, the majority of our participants were adherent to the "Neo-Mediterranean" DP, represented mostly by protein based choices, similar to the "High protein" DP described by Grieger et al. (23). It was characterized by high loads of proteins, fibers, cholesterol, calcium, vitamins A and D, folate and magnesium, due to the fact of frequent intakes of eggs, milk and dairy products, and lean meat choices. Women following this regimen had a higher educational level and initially a lower pre-gestational BMI, as compared to the other subgroups of the sample. Living in urban areas and being employed were some maternal factors significantly correlated to this particular DP. Our results join the ones of Arkkola et al. (21), where educated, older, employed and having a higher income pregnant women had a "Healthy" DP, compared to other groups.

Starting pregnancy with an excess body weight and GWG influences directly maternal and neonatal outcomes (24). In this sample, a BMI higher than 25 kg/m^2 was positively associated with maternal age and inversely with the educational level. In a large US cohort, pregnant women with initially excess body weight were mostly adherent to "Westernized" DP (25), unlike our results where those following the "Mixed" and "Neo-Mediterranean" DPs had respectively the highest and the lowest pre-gestational BMI. The reason behind is the low incidence of underweight, overweight and obesity in the sample, with only 18% of participants having a BMI higher than 25 kg/m^2. As for GWG, the results of Rohatgi et al. (26) reported significant links between maternal age and the adoption of "Westernized" diets with weight gain. Unlike our results, where no significant associations were observed, probably because the majority of our participants respected the recommendations, and few gained below or above the norms. In addition, weight gain was directly correlated with energy intake, thus eating more was responsible for putting on more weight. No significant associations were observed between the DPs, maternal weight gain and pre-gestational BMI in our sample. The cause may be the dispersion of both nutritious and energy dense foods among the "Westernized" and the "Mixed" DPs, which decreased the force of this association.

Fetal nicotine exposure impairs oxygen availability and normal placental nutrient transfer; this may decrease birth weight by 150–200 gm, contribute to intrauterine growth retardation, prematurity and small-for-gestational age infants, compared to not exposed neonates (27). In our research, smoking was among the maternal factors leading to adverse neonatal outcomes reflected on head circumference and Apgar score at 5 mins, but not on birth weight.

Concerning neonatal outcomes, in a recent review, Raghavan et al. (28) concluded that "Healthy" DPs (higher in fruits, vegetables, whole grains, legumes, nuts and seeds) during pregnancy were associated with a lower risk of preterm

TABLE 11 Multivariate analysis of neonatal outcomes.

Variables		Height	Weight	Head circumference	Apgar test (1 min)	Apgar test (5 mins)
Missing value replacement; with energy adjustment¶						
Smoking	Yes vs. No (Ref.)	0.001	0.047	**−0.478**	**0.068**	**−0.055**
		(−0.051 to 0.054)	(−0.019 to 0.113)	**(−0.662 to −0.293)***	**(0.013 to 0.123)***	**(−0.088 to −0.022)***
DP†	1 vs. 3 (Ref.)	0.002	−0.03	−0.085	−0.001	**0.031**
		(−0.031 to 0.034)	(−0.071 to 0.011)	(−0.2 to 0.029)	(−0.036 to 0.033)	**(0.01 to 0.051)***
	2 vs. 3 (Ref.)	0.02	−0.02	0.022	−0.013	−0.013
		(−0.008 to 0.047)	(−0.055 to 0.014)	(−0.074 to 0.118)	(−0.042 to 0.016)	(−0.03 to 0.004)
Age		**−0.004**	**−0.006**	−0.007	−0.001	**−0.005**
		(−0.006– −0.002)*	**(−0.009 – −0.003)***	(−0.015 to 0.002)	(−0.004 to 0.001)	**(−0.006 to −0.003)***
Education level		0.002	0.01	**0.196**	0.000	−0.002
		(−0.012 to 0.015)	(−0.006 to 0.027)	**(0.149 to 0.242)***	(−0.014 to 0.014)	(−0.011 to 0.006)
Crowding index		−0.003	−0.006	**0.29**	**−0.041**	**−0.026**
		(−0.032 to 0.026)	(−0.042 to 0.031)	**(0.188 to 0.391)***	**(−0.072 to −0.011)***	**(−0.044 to −0.008)***
Pre-gestational BMI		**0.007**	**0.008**	0.006	−0.001	**0.003**
		(0.004 to 0.011)*	**(0.003 to 0.012)***	(−0.006 to 0.018)	(−0.005 to 0.002)	**(0.001 to 0.005)***
Gestational weight gain		0.012	**0.058**	**0.245**	**−0.033**	**−0.04**
		(−0.006 to 0.03)	**(0.035 to 0.08)***	**(0.183 to 0.308)***	**(−0.051 to −0.014)***	**(−0.052 to −0.029)***
Energy (Kcal)		−1.246E−5	**−8.210E−5**	3.933E−5	**−4.956E−5**	−7.726E−6
		(−3.621E−5–1.128E−5)	**(0.00– −5.225E−5)***	(−4.40E−5 to 0.000)	**(−7.453E−5 to −2.458E−5)***	(−2.259E−5 to 7.136E−6)
Gestational age (days)		3.663E−5	**0.000**	0.000	**0.000**	**0.000**
		(−7.48E−5 to 0.00)	**(0.000 to 0.000)***	(0.000 to 0.001)	**(0.000 to −7.69E−6)***	**(5.177E−5 to 0.000)***

¶ Sex of the child and delivery mode were removed from the analysis because they were not correlated with neonatal outcomes.
† Dietary Pattern 1: Westernized; 2: Mixed; 3: Neo-Mediterranean.
*Significant p value (<0.05) in bold.

deliveries, but no clear conclusion was made with regards to the impact of any DP, before or during pregnancy, on birth outcomes. In our research, no significant differences were detected pertaining to gestational age and the three DPs, unlike the results of Martin et al. (29) that revealed that the risk of preterm delivery was greater in those having a poor diet quality. Besides, according to Grieger et al. (23), a "High protein" DP reduced the risk premature birth in a sample of Australian women.

Hu et al. identified that adherence to a "Fast Food" DP, rich in fat and sugar by pregnant females, induced adverse postnatal outcomes in offspring, leading to a rapid weight gain during childhood (30). On the other hand, Japanese women in the lowest nutritional adequacy pattern (Wheat products) gave birth to offsprings with significantly lower birth weight and head circumference, unlike those following the "Meat and egg" and "Rice, fish and vegetables" patterns (31). In a Danish prospective study, women in the "Health conscious" profile had lower risk of small birth weight than those in the "Western diet" cluster (32). In contrast, neither the adherence to a "Mediterranean" DP (33), nor the "Mixed" DP had an impact on fetal growth and birth outcomes (34). According to other studies in the field, higher intake of fruits, vegetables and lean protein sources reduces the risk of negative birth outcomes (31, 32, 35). In the present research, no significant associations were mediated between neonatal outcomes and the three DPs, similar to the study of Xie et al. (36). The inconsistency of our results could be explained by the fact that all participants had full term deliveries, with no gestational complications and, thus, infants were generally born at a healthy weight. In addition, no single DP contained only fruits, vegetables and lean proteins in our analyses, because they were dispersed between the "Mixed" and the "Neo-Mediterranean" classes.

Furthermore, after adjusting for potential confounders, the inclusion of maternal factors in the multivariate models did not change their associations with offspring's outcomes. The reason behind may be due to the distribution of pre-gestational BMI and GWG in the acceptable norms.

Our neonatal outcomes were not significantly correlated with any of the studied DPs, similar to the results of Colon-Ramos et al. (34) and of Saunders et al. (33). Unlike our results, in a recent publication, women adopting "Westernized"

TABLE 12 Multivariate analysis of neonatal outcomes.

Variables		Height	Weight	Head circumference	Apgar test 1 min	Apgar test 5 mins
Missing value replacement; without energy adjustment¶						
Smoking	Yes vs. no (Ref.)	0.003	0.057	**−0.482**	**0.074**	**−0.054**
		(−0.049 to 0.055)	(−0.01 to 0.124)	**(−0.666 – −0.299)***	**(0.019 to 0.129)***	**(−0.087 to −0.021)***
DP†	1 vs. 3 (Ref.)	0.001	−0.032	−0.084	−0.003	**0.03**
		(−0.031 to 0.034)	(−0.074 to 0.009)	(−0.199 to 0.03)	(−0.037 to 0.032)	**(0.01 to 0.051)***
	2 vs. 3 (Ref.)	0.02	−0.016	0.02;	−0.01;	−0.012;
		(−0.007 to 0.048)	(−0.051 to 0.019)	(−0.076 to 0.116)	(−0.039 to 0.018)	(−0.029 to 0.005)
Age		**−0.004;**	**−0.006; –**	−0.007;	−0.001;	**−0.005;**
		(−0.006 to −0.002)*	**(0.009 to −0.003)***	(−0.015 to 0.002)	(−0.003 to 0.001)	**(−0.006 to −0.003)***
Education level		0.002;	0.01;	**0.196;**	−6.416E−6;	−0.002;
		(−0.012 −0.015)	(−0.007 to 0.027)	**(0.15 to 0.243)***	(−0.014 to 0.014)	(−0.011 to 0.006)
Crowding index		−0.003;	−0.002	**0.288**	**−0.039**	**−0.026**
		(−0.032 to 0.026)	(−0.039 to 0.034)	**(0.187 to 0.389)***	**(−0.07 to −0.009)***	**(−0.044 to −0.008)***
Pre-gestational BMI		**0.008**	**0.01**	0.005	−4.228E−5	**0.004**
		(0.004 to 0.011)*	**(0.006 to 0.14)***	(−0.007 to 0.017)	(−0.004 to 0.004)	**(0.001 to 0.006)***
Gestational weight gain		0.01	**0.043**	**0.252**	**−0.042**	**−0.042**
		(−0.007 to 0.027)	**(0.021 to 0.065)***	**(0.191 to 0.313)***	**(−0.06 to −0.023)***	**(−0.053 to −0.031)***
Gestational age (days)		2.200E−5	**0.000**	0.000	**0.000**	**0.000**
		(−8.59E−5 −0.00)	**(2.09E−5 to 0.00)***	(0.000 to 0.001)	**(0.000 to −6.90E−5)***	**(4.492E−5 to 0.000)***

¶ Sex of the child and delivery mode were removed from the analysis because they were not correlated with neonatal outcomes.
† Dietary Pattern 1: Westernized; 2: Mixed; 3: Neo-Mediterranean.
*Significant p value (<0.05) in bold.

DPs gave birth to small-for-age infants with smaller head circumference (37). It should be noted that among our participants, those adopting the "Neo-Mediterranean" eating pattern gave birth to infants with better anthropometric outcomes, within WHO norms. This highlights the impact of good quality food, among the multiple factors interfering with genetic and environmental cues, on fetal development.

Even though Lebanese cuisine is reputed for its taste, variety and having common basis with the Mediterranean diet, a major drawback from this study is the fact that we couldn't identify a Mediterranean DP representing separately this healthy model, among our sample. This underlines the ongoing nutrition mutation affecting traditional societies, that shifts toward a modernized cuisine and the adoption of westernized dietary profiles with low quality nutrients. However, our finding of a "Neo-Mediterranean" DP, composed of lean sources and mostly from dairy products may represent the actual tendency of a healthy move of our traditional Mediterranean pattern.

Potential limitations of this research are due to the observed associations that don't represent causal effects, but are related to the nature of this observational study. In addition, misclassification of outcomes is a limitation that needs to be reported, since dietary intake was compiled retrospectively. Despite the fact that a follow-up was kept with the participating women until delivery, some did not agree to share with the research team data related to neonatal outcomes and this explains some missing data. However, this drawback was corrected by using the statistical method of value prediction. Another limitation concerns the subjective labeling by the research team of the DPs, derived from factor analysis, since some patterns with similar content, have an alternative designation in other publications (38). However, the selection of those food groupings were in accordance to other studies published worldwide (20, 28, 39). Finally, although the recruitment was done in different regions of the country and the high follow-up rate until delivery, the participants were not a representative sample of the Lebanese women, thus, the present findings cannot be generalized, and should be conducted on a larger scale, by applying proper sampling strategies. In addition, no clear distinction regarding the classification of the regions according to their urban or rural settings was taken into consideration from the start of the study.

On the other hand, the added value of this paper is the use of a validated FFQ, created by the main authors and filled by well-trained dietitians. This contributed to the strengths of the results, since tools assessing nutrient intake should be culturally adapted. Seasonality of food selection was taken into consideration by interviewing participants once at the beginning of each trimester of gestation. In addition, maternal and neonatal parameters were compiled by the research team, in order not to end-up with irrelevant information, and dietary data collection and nutrient analysis were performed by the same person. To

minimize the effect of under or mis-reporting of food intakes, analyses with and without energy adjustment were conducted to limit measurement bias. Finally, to our knowledge, this research is the first assessing the DP of Arab women in the Middle-East and living in the Mediterranean basin.

Conclusion

Although DPs are culture sensitive, population specific and help capturing the complexities of a diet (30), the three DPs identified in the present study were not exclusively compatible with the traditional Mediterranean dietary pattern, as expected among those living in the Mediterranean region. The categorized DPs in this research were in correlation with pre-gestational BMI and other socio-demographic maternal variables, such as age and educational level, but did not impact infants' birth characteristics. Future research should aim the inclusion of a larger sample, on national level, to achieve a global picture on the impact of maternal nutrition on gestational and neonatal outcomes.

Nevertheless, knowing that adequate nutritional status is vital during this critical period of life, public health policies, under the auspices of the government, should reinforce awareness campaigns among women in child-bearing age, in order to optimize nutrients intakes during pregnancy, while incorporating healthier food choices with more ingredients from the traditional Mediterranean cuisine.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board of Saint-Joseph University at Beirut Lebanon, the Hotel-Dieu Hospital Ethics Committee (CE HDF624/FP49). The patients/participants provided their written informed consent to participate in this study.

Author contributions

TP conceived the study, supervised the recruitment of the participants, and prepared the manuscript. PS conducted the statistical analysis. GA and AK contributed to the design of the study. CA contributed to the design of the study and in the preparation of the manuscript. MA did the interviews and arranged the data. LR provided complete supervision, critical revision, data interpretation, and correction of the manuscript. All authors constituted the research team.

Funding

This research received a grant from the Research Council of Saint-Joseph University (FP49/Nov 2014).

Acknowledgments

The authors would like to thank the research council of Saint-Joseph University and all the participants in this study.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.977288/full#supplementary-material

References

1. Doyle IM, Borrmann B, Grosser A, Razum O, Spallek J. Determinants of dietary patterns and diet quality during pregnancy: a systematic review with narrative synthesis. *Public Health Nutr.* (2017) 20:1009–28. doi: 10.1017/S1368980016002937

2. Chia AR, Chen LW, Lai JS, Wong CH, Neelakantan N, van Dam RM, et al. Maternal dietary patterns and birth outcomes: a systematic review and meta-analysis. *Adv Nutr.* (2019) 10:685–95. doi: 10.1093/advances/nmy123

3. Hu FB. Dietary pattern analysis: a new direction in nutritional epidemiology. *Curr Opin Lipidol.* (2002) 13:3–9. doi: 10.1097/00041433-200202000-00002

4. Procter SB, Campbell CG. Position of the Academy of Nutrition and Dietetics: nutrition and lifestyle for a healthy pregnancy outcome. *J Acad Nutr Diet.* (2014) 114:1099–103. doi: 10.1016/j.jand.2014.05.005

5. World Health Organization. *WHO Antenatal Care Recommendations for a Positive Pregnancy Experience: Nutritional Interventions Update: Multiple Micronutrient Supplements During Pregnancy*. Geneva: World Health Organization (2020).

6. Mahajan A, Donovan LE, Vallee R, Yamamoto JM. Evidenced-based nutrition for gestational diabetes mellitus. *Curr Diab Rep*. (2019) 19:94. doi: 10.1007/s11892-019-1208-4

7. Stang J, Huffman LG. Position of the Academy of Nutrition and Dietetics: obesity, reproduction, and pregnancy outcomes. *J Acad Nutr Diet.* (2016) 116:677–91. doi: 10.1016/j.jand.2016.01.008

8. Nasreddine L, Ayoub JJ, Hachem F, Tabbara J, Sibai AM, Hwalla N, et al. Differences in dietary intakes among Lebanese adults over a decade: results from two national surveys 1997–2008/2009. *Nutrients.* (2019) 11:1738. doi: 10.3390/nu11081738

9. Nasreddine L, Naja F, Chamieh MC, Adra N, Sibai AM, Hwalla N. Trends in overweight and obesity in Lebanon: evidence from two national cross-sectional surveys (1997 and 2009). *BMC Public Health.* (2012) 12:798. doi: 10.1186/1471-2458-12-798

10. WHO. Physical status: the use and interpretation of anthropometry. Report of a WHO Expert Committee. *World Health Organ Tech Rep Ser.* (1995) 854, 1–452.

11. Rasmussen KM, Yaktine AL, Institute of Medicine (US) and National Research Council (US) Committee to Reexamine IOM Pregnancy Weight Guidelines, editors. *Weight Gain During Pregnancy: Reexamining the Guidelines.* Washington (DC): National Academies Press (US); 2009.

12. Papazian T, Hout H, Sibai D, Helou N, Younes H, El Osta N, et al. Development, reproducibility and validity of a food frequency questionnaire among pregnant women adherent to the Mediterranean dietary pattern. *Clin Nutr.* (2016) 35:1550–6. doi: 10.1016/j.clnu.2016.04.015

13. Willett W. *Nutritional Epidemiology*. 2nd ed. New York: Oxford University Press (1998).

14. Cade J, Thompson R, Burley V, Warm D. Development, validation and utilisation of food-frequency questionnaires—a review. *Public Health Nutr*. (2002) 5:567–87. doi: 10.1079/PHN2001318

15. Cespedes EM, Hu FB. Dietary patterns: from nutritional epidemiologic analysis to national guidelines. *Am J Clin Nutr.* (2015) 101:899–900. doi: 10.3945/ajcn.115.110213

16. Devlin UM, McNulty BA, Nugent AP, Gibney MJ. The use of cluster analysis to derive dietary patterns: methodological considerations, reproducibility, validity and the effect of energy mis-reporting. *Proc Nutr Soc.* (2012) 71:599–609. doi: 10.1017/S0029665112000729

17. Lo Siou G, Akawung AK, Solbak NM, McDonald KL, Al Rajabi A, Whelan HK, et al. The effect of different methods to identify, and scenarios used to address energy intake misestimation on dietary patterns derived by cluster analysis. *Nutr J.* (2021) 20:42. doi: 10.1186/s12937-021-00696-3

18. Tabachnik BG, Fidell LS. *Using Multivariate Statistics*. 4th ed. Needham Heights, New York: Harper Collins.

19. Biagi C, Di Nunzio M, Bordoni A, Gori D, Lanari M. Effect of adherence to Mediterranean diet during pregnancy on children's health: a systematic review. *Nutrients.* (2019) 11:997. doi: 10.3390/nu11050997

20. Itani L, Radwan H, Hashim M, Hasan H, Obaid RS, Ghazal HA, et al. Dietary patterns and their associations with gestational weight gain in the United Arab Emirates: results from the MISC cohort. *Nutr J.* (2020) 19:36. doi: 10.1186/s12937-020-00553-9

21. Arkkola T, Uusitalo U, Kronberg-Kippilä C, Männistö S, Virtanen M, Kenward MG, et al. Seven distinct dietary patterns identified among pregnant Finnish women—associations with nutrient intake and sociodemographic factors. *Public Health Nutr.* (2008) 11:176–82. doi: 10.1017/S1368980007000420

22. Gardner B, Croker H, Barr S, Briley A, Poston L, Wardle J, et al. Psychological predictors of dietary intentions in pregnancy. *J Hum Nutr Diet.* (2012) 25:345–53. doi: 10.1111/j.1365-277X.2012.01239.x

23. Grieger JA, Grzeskowiak LE, Clifton VL. Preconception dietary patterns in human pregnancies are associated with preterm delivery. *J Nutr.* (2014) 144:1075–80. doi: 10.3945/jn.114.190686

24. Goldstein RF, Abell SK, Ranasinha S, Misso M, Boyle JA, Black MH, et al. Association of gestational weight gain with maternal and infant outcomes: a systematic review and meta-analysis. *JAMA.* (2017) 317:2207–25. doi: 10.1001/jama.2017.3635

25. Rifas-Shiman SL, Rich-Edwards JW, Kleinman KP, Oken E, Gillman MW. Dietary quality during pregnancy varies by maternal characteristics in Project Viva: a US cohort. *J Am Diet Assoc.* (2009) 109:1004–11. doi: 10.1016/j.jada.2009.03.001

26. Rohatgi KW, Tinius RA, Cade WT, Steele EM, Cahill AG, Parra DC. Relationships between consumption of ultra-processed foods, gestational weight gain and neonatal outcomes in a sample of US pregnant women. *PeerJ.* (2017) 5:e4091. doi: 10.7717/peerj.4091

27. Shea AK, Steiner M. Cigarette smoking during pregnancy. *Nicotine Tob Res.* (2008) 10:267–78. doi: 10.1080/14622200701825908

28. Raghavan R, Dreibelbis C, Kingshipp BL, Wong YP, Abrams B, Gernand AD, et al. Dietary patterns before and during pregnancy and birth outcomes: a systematic review. *Am J Clin Nutr.* (2019) 109:729S–56S. doi: 10.1093/ajcn/nqy353

29. Martin CL, Sotres-Alvarez D, Siega-Riz AM. Maternal dietary patterns during the second trimester are associated with preterm birth. *J Nutr.* (2015) 145:1857–64. doi: 10.3945/jn.115.212019

30. Hu Z, Tylavsky FA, Kocak M, Fowke JH, Han JC, Davis RL, et al. Effects of maternal dietary patterns during pregnancy on early childhood growth trajectories and obesity risk: the CANDLE study. *Nutrients.* (2020) 12:465. doi: 10.3390/nu12020465

31. Okubo H, Miyake Y, Sasaki S, Tanaka K, Murakami K, Hirota Y, et al. Maternal dietary patterns in pregnancy and fetal growth in Japan: the Osaka Maternal and Child Health Study. *Br J Nutr.* (2012) 107:1526–33. doi: 10.1017/S0007114511004636

32. Knudsen VK, Orozova-Bekkevold IM, Mikkelsen TB, Wolff S, Olsen SF. Major dietary patterns in pregnancy and fetal growth. *Eur J Clin Nutr.* (2008) 62:463–70. doi: 10.1038/sj.ejcn.1602745

33. Saunders L, Guldner L, Costet N, Kadhel P, Rouget F, Monfort C, et al. Effect of a Mediterranean diet during pregnancy on fetal growth and preterm delivery: results from a French Caribbean Mother–Child Cohort Study (TIMOUN). *Paediatr Perinat Epidemiol.* (2014) 28:235–44. doi: 10.1111/ppe.12113

34. Colón-Ramos U, Racette SB, Ganiban J, Nguyen TG, Kocak M, Carroll KN, et al. Association between dietary patterns during pregnancy and birth size measures in a diverse population in Southern US. *Nutrients.* (2015) 7:1318–32. doi: 10.3390/nu7021318

35. Thompson JMD, Wall C, Becroft DMO, Robinson E, Wild CJ, Mitchell EA. Maternal dietary patterns in pregnancy and the association with small-for-gestational-age infants. *Br J Nutr.* (2010) 103:1665–73. doi: 10.1017/S0007114509993606

36. Xie Y, Madkour AS, Harville EW. Preconception nutrition, physical activity, and birth outcomes in adolescent girls. *J Pediatr Adolesc Gynecol.* (2015) 28:471–6. doi: 10.1016/j.jpag.2015.01.004

37. Hajianfar H, Esmaillzadeh A, Feizi A, Shahshahan Z, Azadbakht L. Major maternal dietary patterns during early pregnancy and their association with neonatal anthropometric measurement. *Biomed Res Int.* (2018) 2018:4692193. doi: 10.1155/2018/4692193

38. Chen X, Zhao D, Mao X, Xia Y, Baker PN, Zhang H. Maternal dietary patterns and pregnancy outcome. *Nutrients.* (2016) 8:351. doi: 10.3390/nu8060351

39. Abbasi R, Bakhshimoghaddam F, Alizadeh M. Major dietary patterns in relation to preeclampsia among Iranian pregnant women: a case-control study. *J Matern Fetal Neonatal Med.* (2021) 34:3529–36. doi: 10.1080/14767058.2019.1686474

frontiers | Frontiers in Sustainable Food Systems

TYPE Original Research
PUBLISHED 10 October 2022
DOI 10.3389/fsufs.2022.946645

OPEN ACCESS

EDITED BY
Radwan Qasrawi,
Al-Quds University, Palestine

REVIEWED BY
Hazem Agha,
Al-Quds University, Palestine
Diala Abu Al-Halawa,
Al-Quds University, Palestine

*CORRESPONDENCE
Tareq M. Osaili
tosaili@just.edu.jo;
tosaili@sharjah.ac.ae

†These authors have contributed equally to this work and share first authorship

SPECIALTY SECTION
This article was submitted to Nutrition and Sustainable Diets, a section of the journal Frontiers in Sustainable Food Systems

RECEIVED 17 May 2022
ACCEPTED 20 September 2022
PUBLISHED 10 October 2022

CITATION
Taybeh AO, Osaili TM, Al-Nabulsi AA, Ben Hassen T, Faour-Klingbeil D, Cheikh Ismail L and Olaimat AN (2022) Effect of availability and COVID-19 vaccination on food shopping and consumption behaviors among Jordan universities students. *Front. Sustain. Food Syst.* 6:946645. doi: 10.3389/fsufs.2022.946645

Effect of availability and COVID-19 vaccination on food shopping and consumption behaviors among Jordan universities students

Asma' O. Taybeh[1†], Tareq M. Osaili[1,2*†], Anas A. Al-Nabulsi[1], Tarek Ben Hassen[3], Dima Faour-Klingbeil[4], Leila Cheikh Ismail[2] and Amin N. Olaimat[5]

[1]Department of Nutrition and Food Technology, Faculty of Agriculture, Jordan University of Science and Technology, Irbid, Jordan, [2]Department of Clinical Nutrition and Dietetics, College of Health Sciences, University of Sharjah, Sharjah, United Arab Emirates, [3]Program of Policy, Planning, and Development, Department of International Affairs, College of Arts and Sciences, Qatar University, Doha, Qatar, [4]DFK for Safe Food Environment, Hannover, Germany, [5]Department of Clinical Nutrition and Dietetics, Faculty of Applied Medical Sciences, The Hashemite University, Zarqa, Jordan

The COVID-19 pandemic influenced the lives of university students all across the globe. Indeed, the pandemic has impacted many aspects of their daily routine, changing their social and health habits and food-related behaviors. There is now no approved therapy, and vaccination is the only clinical preventative measure that provides the highest protection against the virus. While these vaccines have been beneficial in curbing the pandemic's effect, they may also influence food-related behaviors. Accordingly, this paper aims to investigate the impact of vaccination availability on university students' food shopping and consumption habits, vaccine-related opinions, and back on-campus behaviors in Jordan. The research is based on an online survey conducted in Jordan using a structured questionnaire and distributed through Google Forms between January 1 and March 20, 2022. A total of 624 valid answers were collected. The findings revealed no significant changes in the way students consumed, shopped, and handled food compared to the pre-vaccine period. However, there is a slight post-vaccine trend toward shopping more groceries online and ordering more meals *via* delivery apps and takeout services. Regarding health-related food choices, there was an increase in the consumption of healthy food, water, and fruits and vegetables. Further, following the availability of the vaccination, students' adoption of COVID-19 food-related habits was maintained. Gender, engagement in food preparation activities, and living status (e.g., whether or not living with parents) substantially affected several food-related behaviors. The findings are expected to guide both current emergency preparations and long-term food-related policies

in Jordan. This information may also be helpful to researchers interested in the effects of COVID-19 vaccination on student nutrition and related food behaviors.

KEYWORDS

survey, food behavior, consumption habit, nutrition, vaccine, food safety

Introduction

During the COVID-19 pandemic, the Jordanian government took several strict measures, including the shutdown of higher education institutions, to minimize the virus's spread among university students. This included switching classrooms to virtual learning, shutting dorms, and sending students off-campus (Jordan Times, 2020). After the COVID-19 vaccine became available in December 2020, Jordan started its COVID-19 vaccination campaign on January 13, 2021. The vaccine was initially distributed to persons over 60, those with chronic diseases, and healthcare personnel. Later, with an expanded supply of COVID-19 vaccinations, inoculations were made available to all adult Jordanians, including students (Al Ghad, 2021).

Consequently, starting from the fall of 2021, universities and all other educational institutions across the country re-opened, and in-person teaching at campuses was reinstated (MOHE, 2021). Opening universities safely during the COVID-19 pandemic is a challenging task that relies on various safety policies, such as deploying preventative measures and vaccine coverage, to welcome students and university workers back to their campuses (Paltiel and Schwartz, 2021). Indeed, the Jordanian Ministry of Higher Education announced that full COVID-19 vaccination would be mandatory for all students, faculty members, and administrators beginning January 1, 2022, in order to reduce the spread of COVID-19 among university students, as they are at high risk of exposure due to their close contact with classmates and colleagues (Jordan Times, 2022).

The pandemic influenced the lives of university students all across the globe. They were forced to alter their daily routines and food habits when university and college campuses closed in March 2020 (Powell et al., 2021). As a result, they are more likely to be food insecure and eat unhealthily than the overall population (DeBate et al., 2021). Furthermore, stress and anxiety related to adaptation and isolation may also be caused by online learning and a lack of social interaction. Pandemic-related stresses, such as financial instability and disordered eating, might cause students to gain weight and alter their diets and food-related activities (Palmer et al., 2021). Moreover, the pandemic impacted universities' cafeterias and food services. COVID-19 has also been reported to impact students' diet and food-related behaviors in Jordan. Osaili et al. (2021) highlighted that Jordanian students reduced the frequency of eating with colleagues or in restaurants during the pandemic. Less shopping frequencies, ordering food through fast food delivery or takeaway less often, buying groceries online more often, and reducing the consumption of certain foods due to concern about their safety have also been reported.

Likewise, the pandemic affected the general population's food-related behaviors (Ben Hassen et al., 2020). Panic buying was seen at the beginning of the pandemic, stockpiling food in response to the fear of running out of food or reducing the number of shopping frequencies (Fanelli, 2021). People's dietary choices and habits have also been impacted. They tended to cook more, eat and snack more, and move toward healthy diets (Ben Hassen et al., 2020; Sidor and Rzymski, 2020). A previous work had evaluated food safety knowledge, attitudes and practices among university students in Jordan and the changes in food-related behaviors during the COVID-19 pandemic before the vaccine rollout (Osaili et al., 2021). However, these behaviors are subjected to change, and the remaining question is whether these behaviors and concerns are still present after the availability of the vaccines or not. It is suggested that people might take this opportunity to determine the habits they want to keep, while others might find maintaining habits challenging. Accordingly, this paper aims to investigate the impact of vaccination availability and receipt on university students' food shopping and consumption habits, vaccine-related opinions, and on campus protective measures and food-related behavior in Jordan.

Materials and methods

Study design

The present study is a cross-sectional survey conducted between January 1 and March 20, 2022. The target demographic consisted of Jordanian university students aged 18 and above enrolled in one of the programs during the second semester of the academic year 2021/2022. The optimal sample size was calculated using the Yamane Statistical Formula (Tejada and Punzalan, 2012) based on the number of students enrolled at Jordanian universities the previous year ($N = 322{,}349$).

Questionnaire

Step 1: Questionnaire construction

The research was based on an online questionnaire that was adapted from World Health Organization (WHO), and Centers for Disease Control and Prevention (CDC) reports, as well as previously published studies (Ben Hassen et al., 2020; Cheikh Ismail et al., 2020; WHO, 2020a; CDC, 2022a,b). The questionnaire was initially designed in English; however, the final version was translated into Arabic language (the official language in Jordan). To ensure the quality of the translation, back-translation was carried out by two bilingual native Arabic speakers. The questionnaire included 64 multiple-choice, Likert-scale, and close ended questions separated into four sections: (1) socio-demographics (14 questions); (2) opinions on the COVID-19 vaccine (nine questions); (3) food behavior and consumption habits (29 questions); and (4) back on campus students' behaviors (12 questions).

Step 2: Content validity

Two food studies experts assessed the questionnaire for content validity based on topic relevancy, clarity, simplicity, and ambiguity. Moreover, they were asked to complete the questionnaire and evaluate the length of the survey, the clarity of the content, and the language and vocabulary used. The questionnaire was then amended based on their feedback with only few corrections reported. The time required for completing the questionnaire was reported to be 5–10 min.

Step 3: Reliability of the questionnaire

Before the actual data collection, the questionnaire was piloted with 30 students chosen at random from several institutions to check content reliability and ensure that the questions were understandable. A reliability analysis test was performed using Cronbach's alpha to measure the internal consistency. Cronbach's alpha value was 0.834, indicating a high internal consistency level.

Data collection

The survey was conducted as an anonymous online survey through Google Forms. The link to access the survey and a brief explanation of the study were spread and shared over selected social media platforms, such as Facebook and Twitter. The link was shared by the researchers and by using the snowball approach; participants were also encouraged to invite friends, and colleagues to participate by sharing the online survey link. Before participating in the study, participants had been informed that their participation is entirely voluntary, all of their responses will be kept confidential, and they may opt-out of the survey at any time. The study and the protocol were approved by Institutional Review Board (IRB) at Jordan University of Science and Technology (ref: 22/146/2021).

Statistical analysis

The collected data was analyzed using SPSS program version 25.0 (SPSS Inc, USA). Descriptive statistical analysis; frequencies, percentages, means, and standard deviations were used to summarize the continuous and categorical variables. Kolmogorov-Smirnov test was used to test the normality of the data. Non-parametric tests such as the Kruskal-Wallis test and Mann-Whitney *U*-test were used to compare behavior changes between the different independent variables (gender, university, prepare or help in preparing food, and living status). Statistical significance levels were set at $P < 0.05$.

Results

Socio-demographic characteristics

A total of 624 university students participated in the study. The demographics (Table 1) indicate that 63.8% of the respondents were female, the majority (91.0%) were single, living with their families (87.5%), and were enrolled in bachelor's studies (89.7%). Further, 66.7% were studying at a public university, and 62.0% were from non-health-related majors. Around 75.0% were unemployed and reported helping or preparing food. Only 12.5% have a family member engaged in the health sector. The majority of the students were vaccinated (93.1%). Regarding how comfortable they were about returning to in-person classes on campus (hybrid mode), 30.3% were very comfortable, 42.6% were somewhat comfortable, and 13.5% were not comfortable.

Students' opinions on the COVID-19 vaccine

Regarding students' opinions about vaccinations, more than a third (38.5%) indicated that the vaccine should not be administered on an empty stomach (Table 2). More than half of the participants (50.5 and 59.1%, respectively) stated that the vaccination had no impact on appetite or taste. Also, 64.6% of the respondents indicated it was unnecessary to eat or drink differently the day or two following vaccination. Nevertheless, 29.8 and 35.7% thought it was vital to drink plenty of water and avoid smoking after vaccination. Moreover, 74.8% of the respondents believed that consuming anti-inflammatory foods would boost their immunity. Further, 50.2% believed that people with common allergies might suffer an adverse reaction to the

TABLE 1 Socio-demographic characteristics of the study participants ($n = 624$).

Character	Frequency	Percentage
Age		
18	53	8.5%
19	85	13.6%
20	67	10.7%
21	67	10.7%
22	99	16.0%
23	65	10.4%
24	50	8.0%
25	138	22.1%
Gender		
Male	226	36.2%
Female	398	63.8%
Marital status		
Single	568	91.0%
Married	56	9.0%
University type		
Public university	416	66.7%
Private university	208	33.3%
Level of education		
BSc	560	89.7%
MSc/PhD	64	10.3%
Field of study		
Health	237	38.0%
Non-health	387	62.0%
Monthly allowance		
<100 JD	277	44.4%
100–300 JD	267	42.8%
>300 JD	80	12.8%
Occupation		
Unemployed	472	75.6%
Part-time	76	12.2%
Full-time	76	12.2%
Living status		
Alone	42	6.7%
With family	546	87.5%
With roommate	36	5.8%
Preparing/help in preparing food		
Yes	474	76.0%
No	150	24.0%
Vaccinated against COVID-19		
Yes	581	93.1%
No	43	6.9%
Do you have any family members engaged in the health sector?		
Yes	78	12.5%
No	546	87.5%
How comfortable would you feel about returning to in-person classes on campus?		
Very comfortable	189	30.3%
Somewhat comfortable	266	42.6%
Not too comfortable	85	13.6%
Not at all comfortable	84	13.5%
When ordering food on campus, are you concerned about your health?		
Yes	354	56.7%
No	270	43.3%

TABLE 2 Jordanian university students' opinions on the COVID-19 vaccine ($n = 624$).

Item	Percentage		
	Yes	No	Not sure
Do you think you should get your vaccine on an empty stomach?	8.0%	38.5%	53.5%
Do you think the COVID-19 vaccine may affect your appetite?	25.5%	50.5%	24.0%
Do you think the COVID-19 vaccine may affect your sense of taste?	20.9%	59.1%	20.0%
Do we need to eat or drink differently the day or two after getting vaccinated?	17.1%	64.6%	18.3%
Do you believe people with food allergies might have an adverse reaction to the COVID-19 vaccine?	50.2%	19.2%	30.6%
Do you think you should drink a lot of water after your vaccination?	29.8%	41.3%	28.8%
Do you think you should avoid tobacco after your vaccination?	35.7%	34.1%	30.1%
Do you believe eating anti-inflammatory foods can boost immunity?	74.8%	13.0%	12.2%
Full vaccination against COVID-19 will prevent you from infection while eating outside the house without following standard safety precautions?	28.5%	59.3%	12.2%

COVID-19 vaccination. More than half (59.3%) of respondents stated that being completely vaccinated is insufficient to protect them if they do not take precautions while eating outdoors (Table 2).

Food behavior and consumption habits

Food shopping behaviors

Regarding food shopping, 70% of the participants stated that vaccine availability had not changed the amount of

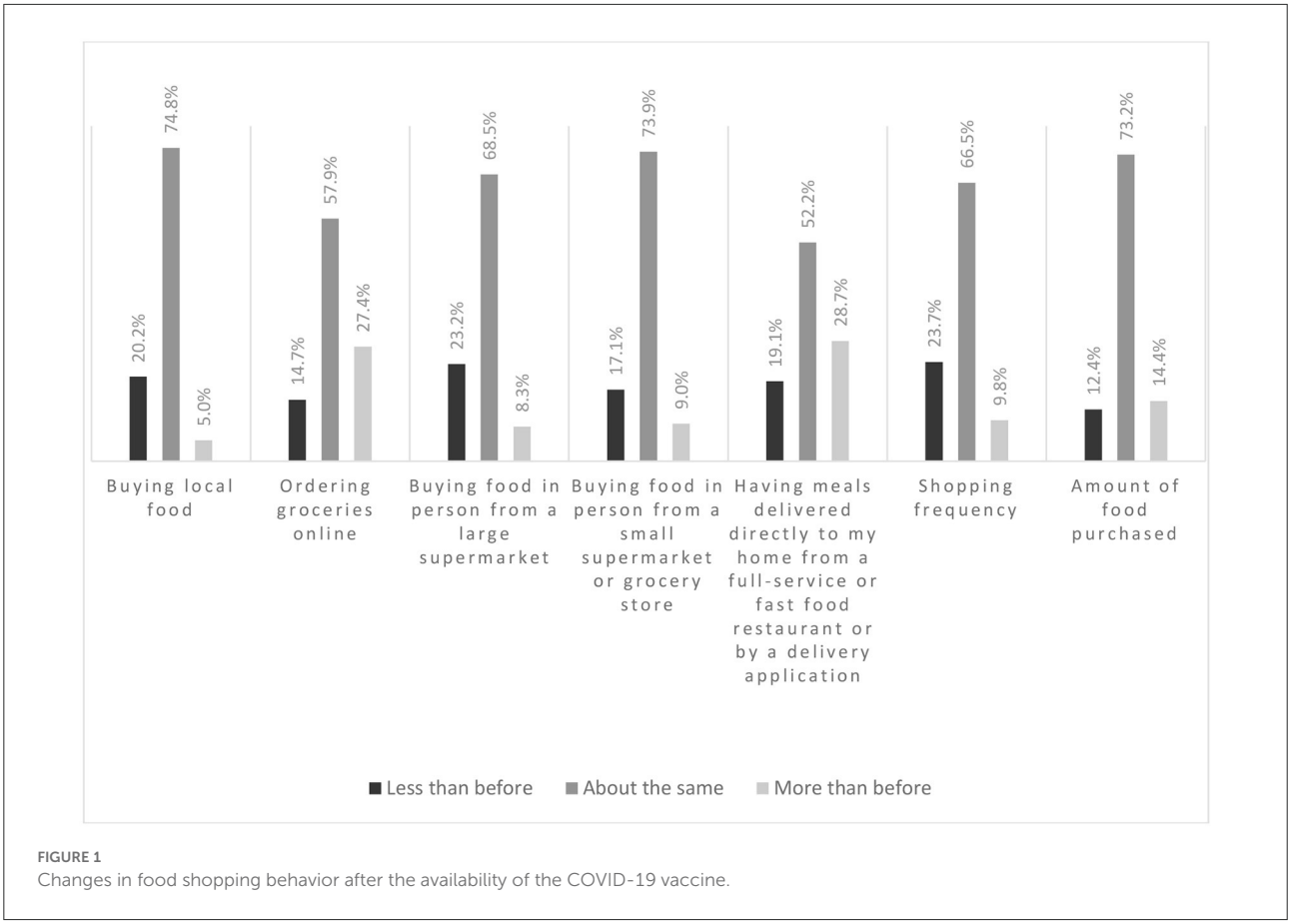


FIGURE 1
Changes in food shopping behavior after the availability of the COVID-19 vaccine.

food purchased, buying local food, and shopping from small supermarkets compared to pre-vaccine time, implying that behaviors during the pandemic remained the same after vaccine availability. More than 25% of students reported ordering groceries online and ordering meals using delivery applications more frequently post-vaccine. On the other hand, around 23% have a reduced level of shopping frequency and shopped less often in large supermarkets (Figure 1).

Kruskal Wallis and Mann Whitney *U*-tests showed that some variables such as gender, university type, engagement in preparing food, and living status significantly affected certain food-related behaviors (Table 3). For example, there is a significant difference between students who prepare or help in preparing food and those who do not in terms of shopping from large markets ($p = 0.030$). Students who prepare food shopped from large supermarkets less than students who do not prepare food.

Dietary habits

Regarding dietary habits, it was noticed that after the availability of the COVID-19 vaccine, consumption behavior generally had not changed compared to pre-vaccine times (Figure 2). However, 23.6% of the respondents increased their consumption of fruits and vegetables, 25.5 and 16.2% increased their consumption of healthy food and healthy snacks, respectively, and 27.6% increased their water consumption. On the other hand, some participants reduced their consumption of meat, fast food, unhealthy snacks, packaged frozen food, and canned food (13.1, 25.2, 20.4, 20.2, and 23.6%, respectively).

A Mann-Whitney *U*-test showed a statistically significant difference between students who prepare food or help in preparing it and those who do not in terms of consuming packaged frozen food ($p < 0.001$) and canned food ($p < 0.001$). Students engaged in preparing food reduced their consumption of packaged frozen food and canned food after vaccine availability. There is also a significant difference between female and male students in terms of consuming unhealthy snacks ($p = 0.025$) and healthy food ($p < 0.05$). Female students tended to consume less unhealthy snacks and more healthy food than male students during the time after vaccination. Also, living status significantly affected some behaviors, such as consuming healthy foods ($p < 0.05$), and students living with their families have eaten more healthy food.

Food-related behaviors

Figure 3 also highlights some changes in food-related behaviors. Less than a third (26.8%) of the participants stated that they were eating with friends, 33.5% were eating out,

TABLE 3 Socio-demographic effects on food behavior and consumption habits after the availability of the COVID-19 vaccine.

	Gender	University	Preparing/help in preparing food	Living status	Field of study	Monthly allowance
	Mann-Whitney *U*			Kruskal Wallis		
Food shopping behaviors						
Buying local food (produced in your country)	$P = 0.426$	$P = 0.417$	$P = 0.122$	$\mathbf{P = 0.000}$*	$P = 0.714$	$P = 0.063$
Ordering groceries online	$P = 0.862$	$\mathbf{P = 0.046}$*	P = 0.458	$P = 0.716$	P = 0.096	$\mathbf{P = 0.011}$*
Buying food in person from a large supermarket	$P = 0.117$	$P = 0.223$	$\mathbf{P = 0.030}$*	$P = 0.522$	$P = 0.991$	$P = 0.770$
Buying food in person from a small supermarket or grocery store	$P = 0.086$	$\mathbf{P = 0.029}$*	$P = 0.538$	$P = 0.050$	$P = 0.346$	$P = 0.128$
Having meals delivered directly to my home from a full-service or fast food restaurant or by a delivery application	$P = 0.287$	$P = 0.113$	$P = 0.990$	$P = 0.650$	$P = 0.263$	$P = 0.050$
Shopping frequency	$\mathbf{P = 0.046}$*	$P = 0.794$	$P = 0.113$	$P = 0.165$	$P = 0.802$	$P = 0.246$
Amount of food purchased	$P = 0.821$	P = 0.381	$P = 0.050$	$P = 0.187$	$P = 0.993$	$P = 0.832$
Eating habits						
Fruits/vegetables	$P = 0.083$	$P = 0.159$	$P = 0.062$	$\mathbf{P = 0.002}$*	$P = 0.980$	$P = 0.569$
Meat	$P = 0.177$	$P = 0.710$	$P = 0.183$	$P = 0.106$	$P = 0.379$	$P = 0.251$
Healthy food	$\mathbf{P = 0.001}$*	$P = 0.489$	$P = 0.173$	$\mathbf{P = 0.006}$*	$P = 0.866$	$P = 0.868$
Unhealthy food (Fast food)	$P = 0.052$	$P = 0.410$	$\mathbf{P = 0.002}$*	$P = 0.807$	$P = 0.442$	$P = 0.286$
Water	$P = 0.218$	$P = 0.228$	$P = 0.143$	$P = 0.185$	$P = 0.350$	$P = 0.770$
Candy, cookies, cakes, and pastries	$P = 0.945$	$P = 0.220$	$P = 0.669$	$P = 0.614$	$P = 0.381$	$P = 0.160$
Healthy snacks	$P = 0.076$	$P = 0.370$	$P = 0.087$	$\mathbf{P = 0.004}$*	$P = 0.638$	$P = 0.152$
Unhealthy snacks	$\mathbf{P = 0.025}$*	$\mathbf{P = 0.040}$*	$\mathbf{P = 0.038}$*	$P = 0.245$	$\mathbf{P = 0.023}$*	$P = 0.279$
Packaged frozen foods	$P = 0.697$	$P = 0.366$	$\mathbf{P = 0.000}$*	$P = 0.676$	$P = 0.144$	$P = 0.595$
Canned food	$P = 0.177$	$P = 0.052$	$\mathbf{P = 0.000}$*	$P = 0.505$	$P = 0.521$	$P = 0.199$
Food-related behaviors						
Eating at home alone	$P = 0.333$	$\mathbf{P = 0.039}$*	$P = 0.913$	$P = 0.154$	$P = 0.991$	$\mathbf{P = 0.014}$*
Eating with family members	$P = 0.076$	$P = 0.080$	$P = 0.413$	$\mathbf{P = 0.005}$*	$P = 0.218$	$P = 0.667$
Eating with friends	$\mathbf{P = 0.033}$*	$P = 0.184$	$P = 0.611$	$P = 0.315$	$P = 0.578$	$P = 0.535$
Eating out (e.g., restaurants/cafeteria/fast food)	$P = 0.060$	$P = 0.411$	$\mathbf{P = 0.005}$*	$P = 0.736$	$P = 0.493$	$P = 0.590$
Eating at someone else's place (e.g., family, friends)	$P = 0.122$	$P = 0.190$	$P = 0.431$	$P = 0.867$	$P = 0.735$	$P = 0.939$
Ordering take-away or fast food meals with deliveries	$P = 0.394$	$\mathbf{P = 0.014}$*	$P = 0.353$	$P = 0.967$	$P = 0.579$	$P = 0.065$
Cooking and preparing food	$\mathbf{P = 0.007}$*	$P = 0.198$	$\mathbf{P = 0.013}$*	$\mathbf{P = 0.001}$*	$P = 0.463$	$P = 0.767$
Spending a lot of time cooking	$P = 0.676$	$P = 0.454$	$P = 0.686$	$P = 0.656$	$P = 0.654$	$P = 0.834$
Making easy meals (e.g., instant foods, frozen foods, etc.)	$P = 0.097$	$P = 0.581$	$P = 0.253$	$P = 0.129$	$P = 0.632$	$P = 0.415$
Eating between meals (e.g., snacks)	$P = 0.679$	$P = 0.286$	$P = 0.627$	$\mathbf{P = 0.031}$*	$P = 0.599$	$P = 0.784$
Food wastage	$P = 0.614$	$P = 0.850$	$P = 0.190$	$P = 0.132$	$P = 0.719$	$P = 0.952$
Stocking up food and beverages	$P = 0.051$	$\mathbf{P = 0.025}$*	$P = 0.419$	$\mathbf{P = 0.011}$*	$\mathbf{P = 0.003}$*	$P = 0.418$

*Significance level at $P < 0.05$.

and 26.3% were eating at someone's else place with a reduced frequency than before the availability of the vaccine. Conversely, 17.5% stated that they were eating with family more often after the vaccination. Additionally, 21.5% of the respondents ordered takeaway or delivered fast food meals more than in the pre-vaccine times. Whereas, 18.3 and 11.4% cooked/prepared food more often and were spending a lot of time cooking, respectively. Regarding food wastage and stocking up food

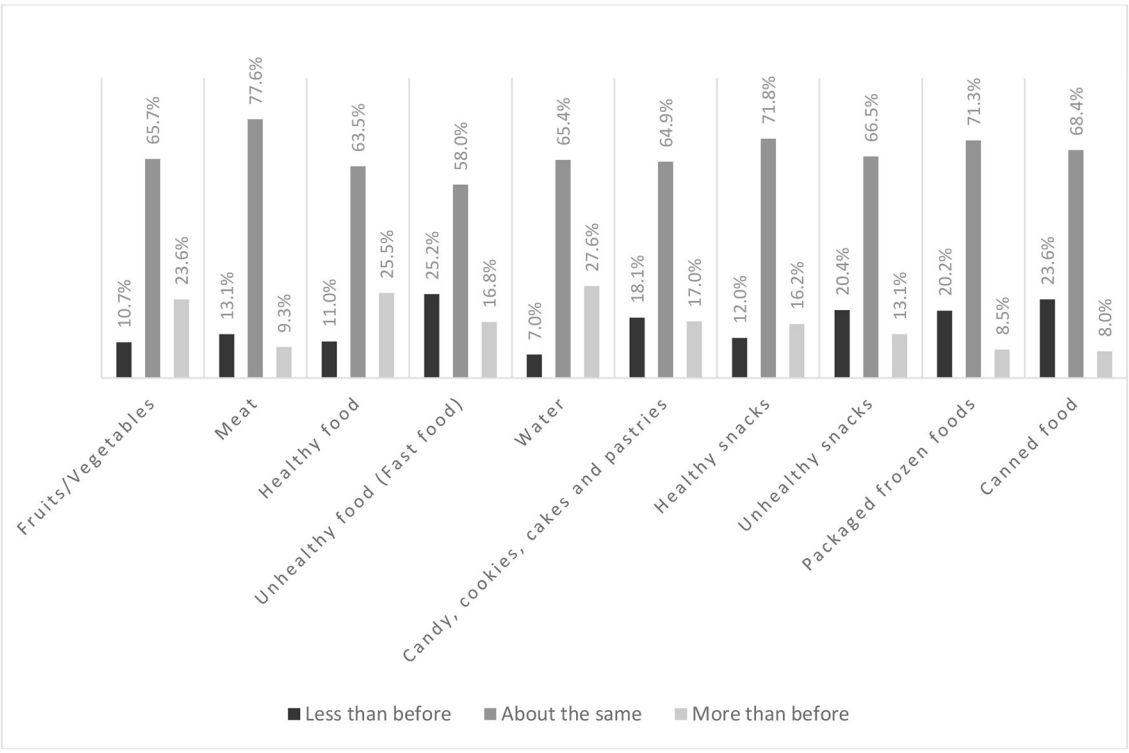


FIGURE 2
Changes in dietary habits after the availability of the COVID-19 vaccine.

and beverages, 21.3% decreased their food wastage, and 12.0% reduced food stocking.

There is a significant difference between students who prepare food and those who do not in terms of eating out ($p = 0.005$). Those who prepare their food or help in preparing food tended to eat out in restaurants and cafeterias less than students who do not engage in preparing food after the vaccine.

On campus protective measures and food-related behaviors

Although more than half (56.7%) were concerned about ordering food on campus (as mentioned in Table 1), 58.7% purchased meals from on-campus restaurants, while 42.3% brought food from home. Those who do not dine on campus were asked to indicate the reasons; almost one-third (31.9%) said they did not have enough time, 16.5% were concerned about becoming poisoned, and 13.6% were concerned about becoming infected with COVID-19.

After returning to on-campus learning, students' behaviors were explored using a five-point Likert scale (always, usually, sometimes, rarely, never). About a third (34.5%) of students always carried alcohol-based hand sanitizer, 26.6% always washed their hands frequently with water and soup, and 59.3 and 25.4% never shared water bottles and cigarettes with friends, respectively. After the vaccine availability, only 18.6% continually followed social distancing and avoided gatherings, and 22.1% all the time wore face masks when sitting with friends. Additionally, 30.8% of respondents always followed the protective measures for using elevators on campus (Table 4).

Discussion

The results revealed some favorable attitudes, nonetheless, incorrect perceptions regarding the vaccines and their effects after administration were observed among students. Furthermore, some students reported changes in their food shopping and consumption after COVID-19 vaccination, although certain behaviors remained unchanged relative to pre-vaccination times. The finding is consistent with broad literature on the food shopping and consumption behavior during pandemics (Ben Hassen et al., 2020; Cheikh Ismail et al., 2020; Sidor and Rzymski, 2020; Fanelli, 2021) and extends research into the back on campus behaviors after 2 years closure of universities.

After the first section of the questionnaire which was related to sociodemographic characteristics, the second section of the

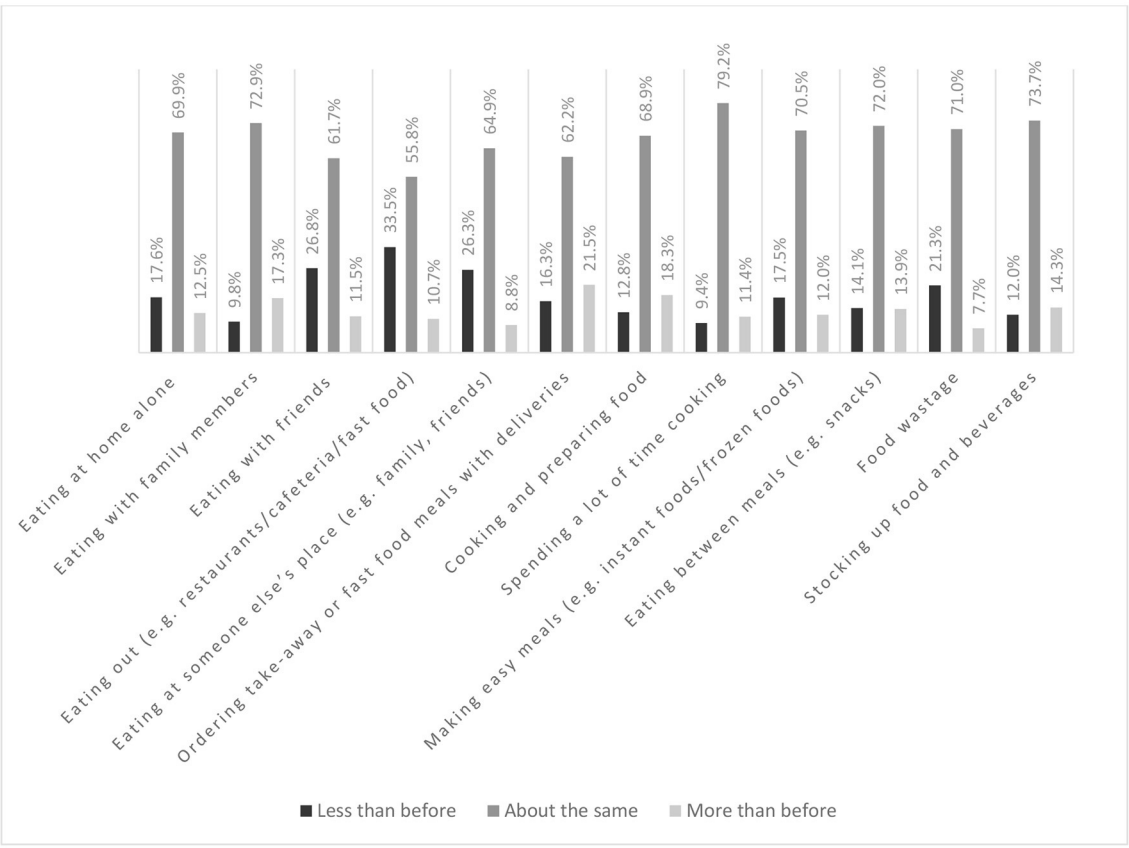


FIGURE 3
Changes in food-related behaviors after the availability of the COVID-19 vaccine.

questionnaire was concerning measures related to consumption that need to be taken prior to and after the vaccination. One study reported side effects which may affect consumption like loss of taste and decreased appetite after receiving the first dose of the COVID-19 vaccine (1.5 and 9.4%, respectively) (Omeish et al., 2022). In this study, half of the participants believed that COVID-19 vaccines did not affect taste or appetite. Moreover, staying hydrated after getting the vaccine is recommended to avoid the vaccine's stressful side effects (CDC, 2022b). Nevertheless, only 29.8% believed that the individual should drink much water after receiving the vaccine. Some health experts also recommend no smoking after taking the vaccine because exposure to cigarette smoke may impair the ability to form memory cells essential to maintain the vaccine-induced protective immune response (Ferrara et al., 2022). However, only a third of participants believed that they should temporarily stop smoking after vaccine administration. Prior to COVID-19 vaccine administration, an assessment of the individual's past medical history for allergic reactions to any cause and especially to the vaccine's components should be performed since there is a possibility of developing an allergic reaction to the COVID-19 vaccine among individuals who have common allergies to certain foods, medications, inhalants and latex (Kounis et al., 2021). This evidence was well-believed by half of the participants in the present study. It is important to note that the CDC recommends vaccination even with a history of allergic reactions unrelated to vaccines or injectable medications (CDC, 2022a). Moreover, a high number of participants in this study correctly believed that being fully vaccinated is not enough when eating in public places. They believed that they could still get infected upon viral exposure when socializing/upon contact at food establishments despite being vaccinated. Actions have been taken by the Jordanian government in easing of COVID-19 measures amid high vaccination rates. However, the WHO continues to recommend people to keep following safety precautions, wearing masks, maintaining physical distance, and avoiding crowded places post-vaccination (WHO, 2021).

The third section of the questionnaire was regarding the change in consumption behavior after mass inoculations with the COVID-19 vaccination. Multiple studies indicate that the COVID-19 pandemic was associated with a significant shift in people's attitudes and behavior concerning food and health (Ben

TABLE 4 Back on campus-level of protective behaviors.

Item	Frequency (%)					Mean*	SD
	Never	Rarely	Sometimes	Usually	Always		
Carrying alcohol-based hand sanitizer and use it when cannot wash hands	60 (9.6%)	63 (10.1%)	116 (18.6%)	170 (27.2%)	215 (34.5%)	3.67	1.301
Sharing water bottles with friends	370 (59.3%)	92 (14.7%)	72 (11.5%)	39 (6.3%)	51 (8.2%)	1.89	1.298
Sharing cigarettes with friends ($n = 213$)	54 (25.4%)	27 (12.7%)	52 (24.4)	33 (15.5)	47 (22.0%)	2.96	1.479
Following the guidelines for using elevators ($n = 383$)	38 (9.9%)	55 (14.4%)	85 (22.2%)	87 (22.7%)	118 (30.8%)	3.50	1.324
Applying social distancing and avoid gatherings	67 (10.7%)	76 (12.2%)	190 (30.5%)	175 (28.0%)	116 (18.6%)	3.32	1.216
Frequently washing hands with water and soap	54 (8.7%)	84 (13.4%)	151 (24.2%)	169 (27.1%)	166 (26.6%)	3.50	1.254
Wearing face mask when sitting with friends	100 (16.0%)	94 (15.1%)	152 (24.4%)	140 (22.4%)	138 (22.1%)	3.20	1.366
I use the toilets and/or public water taps on campus	242 (38.8%)	134 (21.5%)	111 (17.8%)	59 (9.4%)	78 (12.5%)	2.35	1.395
I use vending machines that offer contactless ordering and payment on campus	173 (27.7%)	109 (17.5%)	155 (24.8%)	125 (20.0%)	62 (10.0%)	2.67	1.332
I eat covered ready to eat food (such as packed croissant, cake) rather than uncovered site prepared food (such Falafel or Shawirma sandwich) on campus	100 (16.0%)	96 (15.4%)	163 (26.1%)	148 (23.7%)	117 (18.8%)	3.14	1.329

*Scale: 5 points-Likert scale.

Hassen et al., 2020; Osaili et al., 2021). It was seen that people increased their consumption of healthy food and reduced their intake of unhealthy food (Ben Hassen et al., 2020). Consumers avoided shopping in person from markets and relied on online grocery shopping, delivery, and pick-up services (Ben Hassen et al., 2020). However, after the availability/inoculations of the vaccine, limited data is available about food-related behaviors. In the current study, most students did not change their food consumption and shopping behaviors pre and post-vaccination. A previously published study found that participants with online grocery shopping experience during the COVID-19 pandemic are more likely to continue post-COVID-19 (Shen et al., 2022). Interestingly in this study, a slight increase in online ordering products for ready-to-eat meals/ raw ingredients was observed after the vaccine availability. This could perhaps be related to the convenience of online food delivery apps and an increased new normal of contactless shopping.

With regards to food choices, a previous study among university students in the United States reported significant and negative changes in food choices during the pandemic, where many students increased their consumption of ice cream and cookies (Powell et al., 2021). In contrast, our results showed a transition toward a healthier diet even post-vaccination. The participants reduced the consumption of unhealthy food and snacks, packaged frozen food, and canned food. At the same time, they increased their intake of fruits and vegetables, healthy food (rich in fibers and whole grains, unprocessed, low in saturated and trans-fat…) and water consumption. The current findings reflect participant's belief that a healthy diet would couple up the effect of the vaccination. Moreover, the present study results were in line with a previous study, which reported an increased consumption of healthy and fresh food amongst its participants (Powell et al., 2021).

Even though Jordan has a culture of enjoying food sharing and dining out with others, Jordanian universities students reduced eating out to less than before the pandemic and even eat at home with friends or family members (Osaili et al., 2021). After the COVID-19 vaccine became available, precaution measures and restricting practices eased down leading to a slight increase in the frequency of meeting families and friends to jointly eat together, yet, eating in public or restaurants remained limited due to a persistent fear as evidenced by our study.

The last section of the questionnaire was regarding on-campus students' behaviors related to general food safety. Food in cafeterias and vending machines are components of the food environment that influences students' dietary choices (Hasan

et al., 2021). Their use was expected to increase post vaccinations because of their contactless form of delivery. However, this was not the case. This could be because food present in vending machines is considered as "too unhealthy", as reported by many students in a previous study (Hasan et al., 2021). On the other hand, a comparable number of students had more trust in the food prepared under their sight (where they can see and control the way food is prepared for them).

Furthermore, smoking among university students in Jordan is widespread, with a prevalence rate of 57.1% (Al-Sawalha et al., 2021). Sharing smoking cigarettes among young adults, such as university students, within groups of friends is not uncommon (Liu et al., 2021). Because sharing a cigarette with an infected colleague or friend increases the chance of COVID-19 viral transmission, the WHO advises against sharing any smoking or e-cigarette products during the pandemic (WHO, 2020b). However, many students in the present study (40.7%) continued with this practice.

One of the unintended consequences of vaccination is reducing population adherence to protective behaviors such as mask-wearing, hand-cleansing, and maintaining physical distance. A national survey in the United Kingdom to assist people's adherence to COVID-19 measures after vaccination observed that 50% will keep following the restricted measures even after getting the vaccine, while 11% said they would no longer follow the safety measures (SPI-B, 2020). However, the results of our study showed lower levels of adherence. Less than a third of participants continued wearing face masks when interacting with friends, following hygiene practices, and applying physical distancing inside the university campus. It is worth mentioning that full vaccination for students, faculty members, and administrators is mandatory for entering university campuses in Jordan for the year 2022. Those who have uncertainties regarding the COVID-19 vaccine may be less caring about the practice of preventive measures post-vaccination. On the other hand, overconfidence in the vaccine's effectiveness may decrease the likelihood of vaccinated individuals following suggested precautionary measures due to their belief that the vaccine would provide protection even from COVID-19 exposure (Chandu et al., 2021).

Since the beginning of the pandemic, an increase in the usage of several hand hygiene products, such as soaps, alcohol-based hand sanitizers (ABHS), and disinfectant wipes, was noted (Montero-Vilchez et al., 2022). Zhang et al. (2021) reported that Chinese university students washed their hands an average of 5.76 times per day during the pandemic. However, 17.1% of them were less likely to wash their hands after being vaccination. Moreover, only 22% of the students wore masks in their classrooms, offices, libraries, canteens, shops, and crowded indoor environments after vaccination. Furthermore, people may get worried about the risk of transmission of infectious diseases, including COVID-19 and other viral or bacterial infections, through washrooms settings using water taps, toilets, and touching other surfaces (Vardoulakis et al., 2022). This could explain why more than 30% of the surveyed students in the current study never used toilets and water taps on campus even after the availability of the vaccines.

This study has limitations related to the sample bias due to the use of web-based survey, however, it has become a crucial tool during the COVID-19 pandemic and post-vaccination time, since social distance is still needed and face-to-face surveys are complicated and unsafe. Moreover, the responses of the study are based on recall making it prone to bias. Another limitation is that the use of a questionnaire may have led to expression of students' ideas rather than their actual behavior (social desirability bias).

Conclusion

This study assessed the degree to which the roll-out of the vaccination program affects students' food consumption and shopping behaviors. To the best of our knowledge, this is the first study that contributes to a better understanding of the impact of COVID-19 vaccination availability and campaigns on students' dietary choices, food shopping and their behavior when living on campus. The results support that most respondents did not change their food consumption and shopping behaviors after the vaccine roll-out, but induced positive changes in some students represented by their adoption of healthier diets and reducing ready-to-eat food. Returning to university campuses after the vaccine availability influenced the decision to continue or quit food-related habits adopted during the pandemic. This information may be helpful to researchers interested in the effects of COVID-19 vaccination on student nutrition and related food behaviors.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Ethics statement

The studies involving human participants were reviewed and approved by Institutional Review Board (IRB) at Jordan University of Science and Technology. The patients/participants provided their written informed consent to participate in this study.

Author contributions

AT, TO, and AA-N: conceptualization, methodology, and formal analysis. AT, TO, TB, DF-K, AA-N, LC,

and AO: investigation and writing—original draft. TO, TB, and DF-K: review and editing. All authors contributed to manuscript revision, read, and approved the submitted version.

Funding

The authors thank Jordan University of Science and Technology for funding the project.

Conflict of interest

DF-K was employed by DFK for Safe Food Environment.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

References

Al Ghad (2021). *Jordan Will Start Giving the Corona Vaccine*. Available online at: https://alghad.com/%D8%A7%D9%84%D8%A3%D8%B1%D8%AF%D9%86-%D9%8A%D8%A8%D8%AF%D8%A3-%D8%A8%D8%A7%D8%B9%D8%B7%D8%A7%D8%A1-%D9%84%D9%82%D8%A7%D8%AD-%D9%83%D9%88%D8%B1%D9%88%D9%86%D8%A7-%D8%A7%D8%B9%D8%AA%D8%A8%D8%A7%D8%B1/ (accessed April 15, 2022).

Al-Sawalha, N. A., Almomani, B. A., Al-Shatnawi, S. F., and Almomani, B. N. (2021). Attitudes and knowledge of the harmful effects of waterpipe tobacco smoking among university students: a study from Jordan. *Environ. Sci. Pollut. Res.* 28, 43725–43731. doi: 10.1007/s11356-021-13888-5

Ben Hassen, T., El Bilali, H., and Allahyari, M. S. (2020). Impact of COVID-19 on food behavior and consumption in Qatar. *Sustainability* 12, 6973. doi: 10.29117/quarfe.2020.0296

CDC (2022a). *COVID-19 Vaccines for People with Allergies*. Centers for Disease Control and Prevention. Available online at: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/recommendations/specific-groups/allergies.html#:%7E:text=CDC%20recommends%20that%20people%20get,%2C%20environmental%2C%20or%20latex%20allergies (accessed April 15, 2022).

CDC (2022b). *Possible Side Effects After Getting a COVID-19 Vaccine*. Centers for Disease Control and Prevention. Available online at: https://www.cdc.gov/coronavirus/2019-ncov/vaccines/expect/after.html#:%7E:text=Fever%2C%20headache%2C%20fatigue%2C%20and,are%20rare%20but%20can%20occur (accessed April 15, 2022).

Chandu, V. C., Baddam, V. R. R., Mupparapu, M., and Marella, Y. (2021). Vaccination induced complacency in adherence to COVID-19 precautionary measures among oral health care professionals in India and the United States: a retrospective pretest-posttest design. *Hum. Vacc. Immunother.* 17, 5105–5113. doi: 10.1080/21645515.2021.1978794

Cheikh Ismail, L., Osaili, T. M., Mohamad, M. N., Al Marzouqi, A., Jarrar, A. H., Abu Jamous, D. O., et al. (2020). Eating habits and lifestyle during COVID-19 lockdown in the United Arab Emirates: a cross-sectional study. *Nutrients* 12, 3314. doi: 10.3390/nu12113314

DeBate, R., Himmelgreen, D., Gupton, J., and Heuer, J. N. (2021). Food insecurity, well-being, and academic success among college students: implications for post COVID-19 pandemic programming. *Ecol. Food Nutr.* 60, 564–579. doi: 10.1080/03670244.2021.1954511

Fanelli, R. M. (2021). Changes in the food-related behaviour of Italian consumers during the COVID-19 pandemic. *Foods* 10, 169. doi: 10.3390/foods10010169

Ferrara, P., Gianfredi, V., Tomaselli, V., and Polosa, R. (2022). The effect of smoking on humoral response to COVID-19 vaccines: a systematic review of epidemiological studies. *Vaccines* 10, 303. doi: 10.3390/vaccines10020303

Hasan, H., Faris, M. A.-I. E., Mohamad, M. N., Al Dhaheri, A. S., Hashim, M., Stojanovska, L., et al. (2021). Consumption, attitudes, and trends of vending machine foods at a university campus: a cross-sectional study. *Foods* 10, 2122. doi: 10.3390/foods10092122

Jordan Times (2020). *Schools Suspended, Borders Closed, Gatherings Banned as Gov't Responds to Continued Coronavirus Spread*. Available online at: https://www.jordantimes.com/news/local/schools-suspended-borders-closed-gatherings-banned-govt-responds-continued-coronavirus (accessed April 15, 2022).

Jordan Times (2022). *Full Vaccination Mandatory for University Students—Ministry*. Available online at: https://www.jordantimes.com/news/local/full-vaccination-mandatory-university-students-%E2%80%94-ministry (accessed April 15, 2022).

Kounis, N. G., Koniari, I., de Gregorio, C., Velissaris, D., Petalas, K., Brinia, A., et al. (2021). Allergic reactions to current available COVID-19 vaccinations: pathophysiology, causality, and therapeutic considerations. *Vaccines* 9, 221. doi: 10.3390/vaccines9030221

Liu, J., Ramamurthi, D., and Halpern-Felsher, B. (2021). Inside the adolescent voice: a qualitative analysis of the appeal of different tobacco products. *Tob. Induc. Dis.* 19, 1–10. doi: 10.18332/tid/132856

MOHE (2021). *The Higher Education Council Confirms the Return of Face-to-Face Education on Campus for the 2021-2022 Academic Year and Sets Dates for the Start of Teaching in Higher Education Institutions*. The Ministry of Higher Education and Scientific Research. Available online at: https://bit.ly/3RxMjXz (accessed April 15, 2022).

Montero-Vilchez, T., Martinez-Lopez, A., Cuenca-Barrales, C., Quiñones-Vico, M. I., Sierra-Sanchez, A., Molina-Leyva, A., et al. (2022). Assessment of hand hygiene strategies on skin barrier function during COVID-19 pandemic: a randomized clinical trial. *Contact Derm.* 86, 276–285. doi: 10.1111/cod.14034

Omeish, H., Najadat, A., Al-Azzam, S., Tarabin, N., Abu Hameed, A., Al-Gallab, N., et al. (2022). Reported COVID-19 vaccines side effects among Jordanian population: a cross sectional study. *Hum. Vacc. Immunother.* 18, 1981086. doi: 10.1080/21645515.2021.1981086

Osaili, T. M., Al-Nabulsi, A. A., and Taybeh, A. O. (2021). Food safety knowledge, attitudes, and practices among Jordan universities students during the COVID-19 pandemic. *Front. Public Health* 9, 729816. doi: 10.3389/fpubh.2021.729816

Palmer, K., Bschaden, A., and Stroebele-Benschop, N. (2021). Changes in lifestyle, diet, and body weight during the first COVID 19 'lockdown' in a student sample. *Appetite* 167, 105638. doi: 10.1016/j.appet.2021.105638

Paltiel, A. D., and Schwartz, J. L. (2021). Assessing COVID-19 prevention strategies to permit the safe opening of residential colleges in fall 2021. *Ann. Intern. Med.* 174, 1563–1571. doi: 10.7326/M21-2965

Powell, P. K., Lawler, S., Durham, J., and Cullerton, K. (2021). The food choices of US university students during COVID-19. *Appetite* 161, 105130. doi: 10.1016/j.appet.2021.105130

Shen, H., Namdarpour, F., and Lin, J. (2022). Investigation of online grocery shopping and delivery preference before, during, and after COVID-19. *Transport. Res. Interdiscipl. Perspect.* 14, 100580. doi: 10.1016/j.trip.2022.100580

Sidor, A., and Rzymski, P. (2020). Dietary choices and habits during COVID-19 lockdown: experience from Poland. *Nutrients* 12, 1657. doi: 10.3390/nu12061657

SPI-B (2020). *Possible Impact of the COVID-19 Vaccination Programme on Adherence to Rules and Guidance About Personal Protective Behaviours Aimed at Preventing Spread of the Virus*. Scientific Pandemic

Insights Group on Behaviours. Available online at: https://www.gov.uk/government/publications/spi-b-possible-impact-of-the-covid-19-vaccination-programme-on-adherence-to-rules-and-guidance-about-personal-protective-behaviours-aimed-at-preventi (accessed April 15, 2022).

Tejada, J. J., and Punzalan, J. R. B. (2012). On the misuse of Slovin's formula. *Philippine Stat.* 61, 129–136.

Vardoulakis, S., Espinoza Oyarce, D. A., and Donner, E. (2022). Transmission of COVID-19 and other infectious diseases in public washrooms: a systematic review. *Sci. Total Environ.* 803, 149932. doi: 10.1016/j.scitotenv.2021.149932

WHO (2020a). *Coronavirus Disease (COVID-19): Food Safety and Nutrition*. World Health Organization. Available online at: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-food-safety-and-nutrition (accessed April 15, 2022).

WHO (2020b). *Coronavirus Disease (COVID-19): Tobacco*. World Health Organization. Available online at: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-tobacco (accessed April 15, 2022).

WHO (2021). *Coronavirus Disease (COVID-19): How Is it Transmitted?* World Health Organization. Available online at: https://www.who.int/news-room/questions-and-answers/item/coronavirus-disease-covid-19-how-is-it-transmitted (accessed April 15, 2022).

Zhang, N., Liu, X., Jin, T., Zhao, P., Miao, D., Lei, H., et al. (2021). Weakening personal protective behavior by Chinese university students after COVID-19 vaccination. *Build. Environ.* 206, 108367. doi: 10.1016/j.buildenv.2021.108367

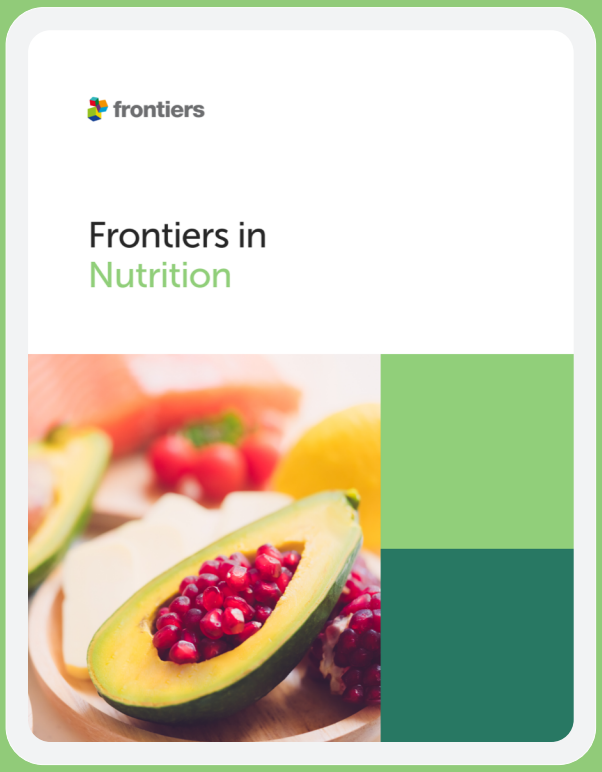
Frontiers in Nutrition

Explores what and how we eat in the context of health, sustainability and 21st century food science

A multidisciplinary journal that integrates research on dietary behavior, agronomy and 21st century food science with a focus on human health.

Discover the latest Research Topics

See more →



Frontiers

Avenue du Tribunal-Fédéral 34
1005 Lausanne, Switzerland
frontiersin.org

Contact us

+41 (0)21 510 17 00
frontiersin.org/about/contact