WHAT, HOW, AND WHERE TO EAT IS MORE THAN AN INDIVIDUAL CHOICE: NEW WAYS TO ACHIEVE HEALTHY EATING

EDITED BY: Veronica Ginani, Ana Lúcia De Saccol and Renata Puppin Zandonadi

PUBLISHED IN: Frontiers in Nutrition, Frontiers in Sustainable Food Systems and Frontiers in Public Health

frontiers Research Topics

frontiers

ISSN 1664-8714
ISBN 978-2-83250-669-1
DOI 10.3389/978-2-83250-669-1

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

WHAT, HOW, AND WHERE TO EAT IS MORE THAN AN INDIVIDUAL CHOICE: NEW WAYS TO ACHIEVE HEALTHY EATING

Topic Editors:
Veronica Ginani, University of Brasilia, Brazil
Ana Lúcia De Saccol, UFN - Universidade Franciscana, Brazil
Renata Puppin Zandonadi, University of Brasilia, Brazil

Citation: Ginani, V., De Saccol, A. L., Zandonadi, R. P., eds. (2022). What, How, and Where to Eat is More Than an Individual Choice: New Ways to Achieve Healthy Eating. Lausanne: Frontiers Media SA. doi: 10.3389/978-2-83250-669-1

Table of Contents

frontiers | Frontiers in Sustainable Food Systems

TYPE Editorial
PUBLISHED 18 October 2022
DOI 10.3389/fsufs.2022.1048719

OPEN ACCESS

EDITED AND REVIEWED BY
Uma Tiwari,
Technological University Dublin,
Ireland

*CORRESPONDENCE
Veronica Cortez Ginani
vcginani@gmail.com
Ana Lúcia de Freitas Saccol
alsaccol@yahoo.com.br
Renata Puppin Zandonadi
renatapz@unb.br

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

RECEIVED 19 September 2022
ACCEPTED 07 October 2022
PUBLISHED 18 October 2022

CITATION
Ginani VC, Saccol ALF and Zandonadi RP (2022) Editorial: What, how, and where to eat is more than an individual choice: New ways to achieve healthy eating.
Front. Sustain. Food Syst. 6:1048719.
doi: 10.3389/fsufs.2022.1048719

Editorial: What, how, and where to eat is more than an individual choice: New ways to achieve healthy eating

Veronica Cortez Ginani[1]*, Ana Lúcia de Freitas Saccol[2]* and Renata Puppin Zandonadi[1]*

[1]University of Brasilia, Brasilia, Brazil, [2]Franciscana University, Santa Maria, RS, Brazil

KEYWORDS

food security, access to healthy foods, plant-based diet, sustainability, food production

Editorial on the Research Topic
What, how, and where to eat is more than an individual choice: New ways to achieve healthy eating

The connection between food and the environment has always existed, but this relationship is becoming more evident. While increasing environmental degradation and food waste, and scarcity of natural resources occur, malnutrition affects thousands of individuals worldwide, emphasizing the food inequalities in our most vulnerable populations. Nevertheless, food is a basic human right and must be accessible in all the various principles. These include access to nutritious and safe food, respecting cultural habits, and sustainable production systems. To guarantee this human right and make healthy eating accessible, public policies and other government or private actions should be adopted. One of the ways would be through nutrition-education action as, from the development of a collective awareness of healthy food choices, transformations in our society can be achieved. Hence, this Research Topic focused on promoting a collective awareness of healthy food choices.

Food choices are a highly complex process that reflects ways of producing and consuming food. The dietary patterns of individuals impact the physical, psychological, social, and environmental domains of their quality of life. The social, environmental, and economic domains of sustainable living are also affected. Therefore, dietary choices should be thought of as a collective act, and a healthy diet can only materialize by understanding its scope. There is an increasing interest in sustainable food products, aligned with environmental impacts and effects on health and food consumption. However, there are still gaps between sustainable food consumption and production transparency, lacking information for consumers that may impair sustainable choices. More effective communication strategies may increase consumer understanding and motivation regarding sustainable food production (Sabio and Spers).

In this sense, dietary guidelines are an important mechanism for disseminating knowledge for changing practices. Their content is a basis for public policies on food, nutrition, health, and agriculture and for nutrition education promoting healthy eating and lifestyles (Rossi et al.). Actions on different aspects of food, especially regarding more vulnerable populations, from the countryside to the table, should be widely discussed, focusing on life protection. Associations and Councils of nutritionists and dietitians can play an essential role in supporting research and discussions on the topic. Additionally, in integrating sustainable food systems ideas and concepts into healthy and sustainable dietary practices (Callaghan et al.).

The nutritional aspect stands out in the sense of providing essential elements for human health. An unhealthy diet with increased intake of sodium, calories and trans fatty acids, particularly from industrially-products, is implicated in the etiology of cardiovascular diseases, which represent the leading cause of mortality worldwide (Al-Jawaldeh et al.). Fortunatelly, consumers seem willing to consume healthier products (Di Vita et al.). In addition, an increased risk of psychosocial complications is related to an unhealthy diet. For example, skipping breakfast, eating out and consuming unhealthy foods are associated with higher odds of psychosocial and behavioral problems, potentially affecting health and sustainability (López-Gil et al.).

On the other hand, a healthy diet is associated with the prevention and treatment of several diseases. Nutrients and bioactive compounds are associated with protection against cancer (Zhao et al.) and decreasing mortality and risk of non-communicable diseases, mainly from plant-based foods such as vegetables, cereals, legumes, and nuts (Wu et al.). Despite the well-known benefits of fruits and vegetable consumption, their consumption is still under recommendations (Moraes et al.). Although plant-based diets constitute a small part of the population, their demand is growing and influencing the food industry and consumption habits. Therefore, it is important to understand the factors influencing consumers' choices regarding where to eat their meals, mainly in places offering plant-based meals. The reasons affecting the decision to eat in plant-based restaurants are related to health, and beauty, as well as personal psychological factors, such as guilt, curiosity, and environmental concerns (Park et al.). However, we must be aware of the risk of a nutritional deficit from a plant-based diet without guidance and balance. Therefore, this Research Topic calls attention to rethinking food access, food security, sustainability, and foods on health.

Author contributions

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

Acknowledgments

We thank and congratulate all the authors who published their studies on this research topic from Frontiers for their valuable collaboration. We also thank the reviewers, the Editor-in-chief, and the entire Frontiers team, without which it would be impossible to construct this successful research topic. We also thank the Brazilian National Council for Scientific and Technological Development (CNPq) for scientific support.

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

frontiers in Nutrition

SYSTEMATIC REVIEW
published: 26 November 2021
doi: 10.3389/fnut.2021.771492

A Systematic Review of Trans Fat Reduction Initiatives in the Eastern Mediterranean Region

Ayoub Al-Jawaldeh[1], Mandy Taktouk[2], Aya Chatila[2], Sally Naalbandian[3], Zahra Abdollahi[4†], Buthaina Ajlan[5†], Nawal Al Hamad[6†], Majid M. Alkhalaf[7†], Salima Almamary[8†], Rawan Alobaid[9†], Salah Abdulla Alyafei[10†], Mohammad Hosein Azizi[11†], Nimah M. Baqadir[7†], Rawhieh Barham[12†], Faisal F. Binsunaid[13†], Leila El Ammari[14†], Jalila El Ati[15†], Maha Hoteit[16†], Hanan Massad[12†], Marzeyeh Soleymani Nejad[17†] and Lara Nasreddine[2]*

[1] Regional Office for the Eastern Mediterranean (EMRO), World Health Organization (WHO), Cairo, Egypt, [2] Nutrition and Food Sciences Department, Faculty of Agriculture and Food Sciences, American University of Beirut, Beirut, Lebanon, [3] Science and Agriculture Library, American University of Beirut, Beirut, Lebanon, [4] Nutrition Department, Ministry of Health and Medical Education, Tehran, Iran, [5] Nutrition Section, Ministry of Health, Manama, Bahrain, [6] The Public Authority for Food and Nutrition, Kuwait City, Kuwait, [7] National Nutrition Committee, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [8] Nutrition Department, Ministry of Health, Muscat, Oman, [9] Senior Regulations and Standards, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [10] Health Promotion and Non Communicable Disease (NCD) Division, Public Health Department, Ministry of Public Health, Doha, Qatar, [11] Food and Beverage Office, Iran Food and Drug Administration (IFDA), Ministry of Health and Education, Tehran, Iran, [12] Nutrition Department, Ministry of Health, Amman, Jordan, [13] Healthy Food Department, Saudi Food and Drug Authority, Riyadh, Saudi Arabia, [14] Nutrition Department, Ministry of Health, Rabat, Morocco, [15] INNTA (National Institute of Nutrition and Food Technology), SURVEN (Nutrition Surveillance and Epidemiology in Tunisia) Research Laboratory, Tunis, Tunisia, [16] PHENOL Research Group (Public Health Nutrition Program-Lebanon), Faculty of Public Health, Lebanon University, Beirut, Lebanon, [17] World Health Organization (WHO), Tehran, Iran

OPEN ACCESS

Edited by:
Ana Lúcia De Saccol, UFN–Universidade Franciscana, Brazil

Reviewed by:
Aida Turrini, Independent Researcher, Rome, Italy
António Raposo, CBIOS, Universidade Lusófona Research Center for Biosciences & Health Technologies, Portugal

***Correspondence:**
Lara Nasreddine
ln10@aub.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: *06 September 2021*
Accepted: *27 October 2021*
Published: *26 November 2021*

Citation:
Al-Jawaldeh A, Taktouk M, Chatila A, Naalbandian S, Abdollahi Z, Ajlan B, Al Hamad N, Alkhalaf MM, Almamary S, Alobaid R, Alyafei SA, Azizi MH, Baqadir NM, Barham R, Binsunaid FF, El Ammari L, El Ati J, Hoteit M, Massad H, Nejad MS and Nasreddine L (2021) A Systematic Review of Trans Fat Reduction Initiatives in the Eastern Mediterranean Region. Front. Nutr. 8:771492. doi: 10.3389/fnut.2021.771492

High intakes of trans fatty acids (TFA), particularly industrially-produced TFA, are implicated in the etiology of cardiovascular diseases, which represent the leading cause of mortality in the Eastern Mediterranean Region (EMR). This systematic review aims to document existing national TFA reduction strategies in the EMR, providing an overview of initiatives that are implemented by countries of the region, and tracking progress toward the elimination of industrially-produced TFA. A systematic review of published and gray literature was conducted using a predefined search strategy. A total of 136 peer-reviewed articles, gray literature documents, websites and references from country contacts were obtained, up until 2 August 2021. Randomized-control trials, case-control studies, and studies targeting unhealthy population groups were excluded. Only articles published after 1995, in English, Arabic or French, were included. Key characteristics of strategies were extracted and classified according to a pre-developed framework, which includes TFA intake assessment; determination of TFA levels in foods; strategic approach; implementation strategies (TFA bans/limits; consumer education, labeling, interventions in public institution settings, taxation), as well as monitoring and evaluation of program impact. Thirteen out of the 22 countries of the EMR (59%) have estimated TFA intake levels, 9 have determined TFA levels in foods (41%), and 14 (63.6%) have national TFA reduction initiatives. These initiatives were mainly led by governments, or by national multi-sectoral committees. The most common TFA reduction initiatives were based on TFA limits or bans (14/14 countries), with a mandatory approach being adopted by 8 countries (Bahrain, Iran, Jordan, KSA, Kuwait, Morocco, Oman and Palestine).

Complementary approaches were implemented in several countries, including consumer education (10/14), food labeling (9/14) and interventions in specific settings (7/14). Monitoring activities were conducted by few countries (5/14), and impact evaluations were identified in only Iran and the UAE. The robustness of the studies, in terms of methodology and quality of assessment, as well as the lack of sufficient data in the EMR, remain a limitation that needs to be highlighted. Further action is needed to initiate TFA reduction programs in countries that are lagging behind, and to ensure rigorous implementation and evaluation of ongoing programs.

Keywords: trans fat, reduction, strategy, implementation, evaluation, Eastern Mediterranean Region

INTRODUCTION

Cardiovascular diseases (CVD) represent the leading cause of mortality worldwide, causing ∼17.9 million deaths each year and contributing to 31% of global deaths (1). High intake of trans fatty acids (TFA), particularly industrially produced TFA, were implicated in the etiology of CVD (2). Although available data on TFA intake globally is rather limited, it was recently reported that the 2017 global market volume of partially hydrogenated oils (PHOs), which is the major source of industrially produced TFA in food, was around 13.6 million tons (3). Wang et al. showed that compared to an optimal TFA intake of 0.5% of energy intake (%EI), excess TFA consumption was estimated to cause 537,200 coronary heart disease (CHD) deaths per year worldwide in 2010, representing 7.7% of global CHD mortality (4).

This is consistent with the unique cardiometabolic imprint of industrial TFA on both lipid and non-lipid pathways (4, 5). Physiologically, TFAs impact the lipid profile, raising the levels of the atherogenic low-density lipoprotein (LDL) cholesterol while also decreasing the levels of the cardioprotective high-density lipoprotein (HDL) cholesterol (2, 6). Randomized controlled trials have also shown that high TFA consumption produces adverse cardiovascular effects via pathways linked to the insulin resistance syndrome (5). A reduction in the population's intake of TFA has therefore been acknowledged as one of the policy priorities adopted by the World Health Organization (WHO) (5). One of the core indicators of the WHO global framework for monitoring non-communicable diseases (NCDs) by 2025, is the "adoption of national policies that virtually eliminate partially hydrogenated vegetable oils in the food supply and replace [them] with polyunsaturated fatty acids" (7). The elimination of industrially produced TFAs is in fact a relatively straightforward, low-cost and effective policy measure that is within reach of most countries, while carrying substantial long-term health benefits (3, 8, 9). However, most countries worldwide have yet to develop and implement strong policy measures to limit TFA intakes, and TFAs continue to be highly consumed around the world (10). In May 2018, the WHO has advocated for the global elimination of industrially produced TFA by 2023 and released the REPLACE action framework, with the aim of decreasing CVD-related mortality (3, 11). The REPLACE action framework consists of a roadmap for countries to implement immediate, complete and sustained elimination of industrial TFA from the food supply (12).

In the Eastern Mediterranean Region (EMR), a region that harbors a high burden of CVD, and where the consumption of TFA is high (13, 14), the WHO Regional Office for the Eastern Mediterranean, in collaboration with WHO Headquarters and Resolve to Save Lives, has been providing technical assistance to support country-level policy development and implementation. The WHO EMR regional nutrition strategy 2020–2030, has included specific objectives related to the virtual elimination of industrially-produced TFA from the food supply (15), and recommended a number of priority actions that will assist Member States in reaching these objectives (15). However, to date, there has been no comprehensive appraisal of the government-initiated public health strategies that are being adopted by countries of the region in order to eliminate TFA from the food supply and decrease the population's TFA intake. It is in this context that we conducted this systematic review, with the aim of identifying and documenting existing national TFA reduction strategies, providing an overview of initiatives that are implemented by countries of the EMR to reduce TFA intakes, and tracking progress toward the goal of TFA elimination by 2023.

MATERIALS AND METHODS

The methodology and search strategy adopted in this study were similar to the approach described by Santos et al. (16) in their systematic review of salt reduction strategies. Accordingly, data related to TFA reduction initiatives were obtained through a

Abbreviations: CHD, coronary heart disease; CVD, cardiovascular diseases; DV, daily value; EI, energy intake; EMR, Eastern Mediterranean Region; EMRO, Regional Office for the Eastern Mediterranean; FBDG, food-based dietary guideline; FNA, Food and nutrition authority; GBD, global burden of disease; GCC, Gulf Cooperation Council; GINA, Global database on the implementation of nutrition action; GSO, GCC standardization organization; HDL, high-density lipoprotein; KAB, knowledge, attitudes and behavior; KP, Khyber Pakhtunkhwa; KSA, Kingdom of Saudi Arabia; LDL, low-density lipoprotein; MOCI, Ministry of commerce and industry; MOH, Ministry of health; MOHAP, Ministry of health and prevention; MOHME, Ministry of health and medical education; MOHP, Ministry of health and population; MOPH, Ministry of public health; NA, not available; NCD, non-communicable disease; NFP, nutrition focal point; NGO, non-governmental organization; PHFS, Patient helping fund society; PHOs, partially hydrogenated oils; PMS, post marketing surveillance; PSQCA, Pakistan standard and quality control authority; SFA, Saturated fatty acid; SFDA, Saudi food and drug authority; TFA, Trans fatty acid; UAE, United Arab Emirates; UFA, Unsaturated fatty acid; WHO, World Health Organization.

series of steps, allowing for maximum coverage of the EMR and its 22 countries (17). This comprised a search of peer-reviewed and gray literature published up to 15 April 2021, in addition to seeking supplementary information by directly contacting program country leaders or focal points (**Figure 1**).

Search Strategy

The present systematic review conforms to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement. A total of 12 electronic databases were searched between 17 February 2021 and 15 April 2021. These databases included: CAB Direct (18), Directory of Open Access Journals (19), Google (20), Ovid (21), National Library of Medicine (22), Elsevier (23), Clarivate (24), EBSCO (25), Al Manhal (26), EBSCO (27), E-Marefa (28) and Ministry of Higher Education and Scientific Research of Iraq (29); the last four being databases specific to the Arab region. In addition to using controlled vocabulary (MeSH in PubMed and MEDLINE), a comprehensive list of search terms was used in the title/abstract/keyword fields to cover the four concepts (1) TFA, (2) reduction OR intake, (3) policy, and (4) EMR countries. MEDLINE (Ovid) was searched first using a combination of MeSH terms and keywords. The search strategy was mapped to PubMed after making the necessary changes. To search the remaining databases, MeSH terms were searched as keywords in title-abstract-keyword fields whenever applicable. Google Scholar was searched using title field only. **Appendix A** shows the detailed list of search terms used in PubMed. Moreover, an example of a database search on PubMed is shown in **Supplementary Table 1**. The search excluded any material published before 1995. Only English, Arabic and French languages were considered. Newly published articles after the initial search were identified by email alerts (up until 2 August 2021).

A search of the gray literature was also performed, using OpenGrey (30), Google (31), World Healh Organization (32), World Health Organization Regional Office for the Eastern Mediterranean (33) and governmental websites (e.g., Ministries of Health). The search was limited to materials published post 1995 in English, Arabic and French languages only.

EndNote X9 (Version 18.0.0.10063) was used for the export of all identified articles after conducting the search on online databases and gray literature. Two independent researchers (MT and AC) screened the titles, abstracts and full text articles of the potentially relevant articles, according to the inclusion and exclusion criteria mentioned in the below section. The two researchers discussed and resolved the minor discrepancies that resulted from the two screening stages.

Inclusion and Exclusion Criteria

Articles were included in this review if they provided information on TFA baseline assessment [intake; levels in

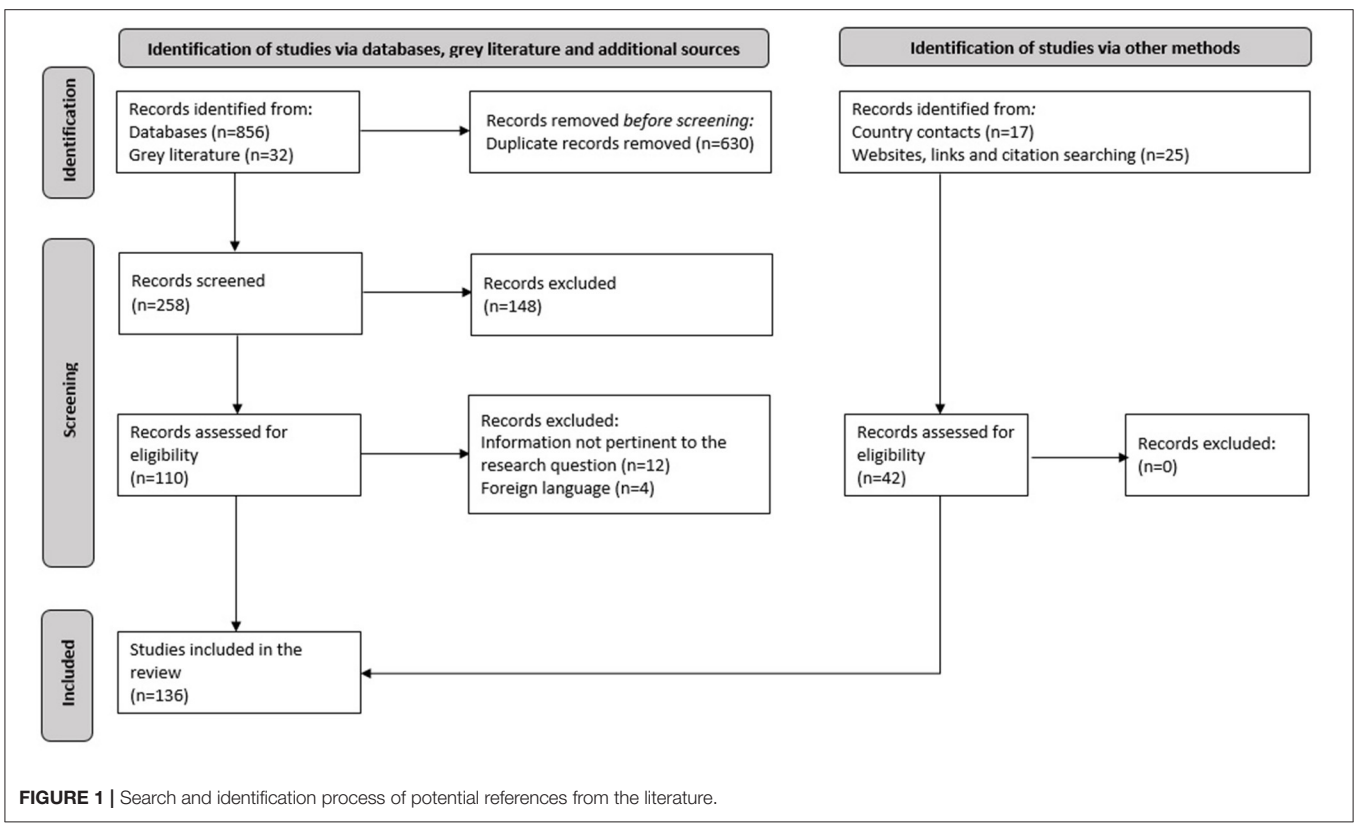


FIGURE 1 | Search and identification process of potential references from the literature.

foods; knowledge, attitudes and behavior (KAB)], or the development, implementation, monitoring or evaluation of national TFA reduction initiatives at the national level. National TFA reduction initiatives were defined as having a governmental entity involved (12, 34, 35), in addition to one or more of the following components: (1) a national action plan to reduce the population TFA intake (12); (2) a program of work on TFA replacement (e.g., banning the use of partially hydrogenated oils; setting limits for industrial TFA in food products) (36); (3) consumers' education programs or awareness campaigns with the aim of improving KAB toward TFA (12); (4) labeling schemes specific to TFA or mandatory declaration of TFA on nutrition labels (12, 36); (5) taxation policies targeting high-TFA foods, or unhealthy foods defined by their high TFA content (12); and (6) TFA reduction initiatives in specific settings (schools, hospitals, workplaces) (12).

Articles based on randomized-control trials or case-control studies, as well as those targeting unhealthy individuals or specific populations (pregnant women, individuals on therapeutic diets etc.) were excluded. Individual articles were also excluded if they were published before 1995, or in any language besides English, Arabic, or French.

Data Extraction

Data extraction was conducted independently by two researchers (MT and AC), and then a third researcher (LN) reviewed the data for accuracy. The researchers discussed the few discrepancies until reaching consensus. For each national TFA reduction initiative, the key characteristics were entered into a database constructed by the researchers, and examined in relation to baseline assessments (population TFA intake; TFA levels in food products, KAB related to TFA), leadership and strategic approach, implementation strategies (TFA bans or limits; consumer education, food labeling, interventions in public institution settings, taxation), monitoring (population intake, levels in food products, KAB), and evaluation of program impact (12, 34, 36, 37).

Seeking Supplementary Information

To seek supplementary information regarding national TFA reduction initiatives, a questionnaire was developed by the research team based on relevant literature (6, 37, 38) (**Supplementary Questionnaires**). After its development, the questionnaire was reviewed by a nutritionist and a public health professional for content validity. The questionnaire was then sent to country experts or program leaders in various countries of the EMR to verify and obtain supplementary country-specific data. Country experts or program leaders were invited to fill the questionnaire and/or pass on the questionnaire to their contacts to obtain additional information and deliver the needed details. The database was then updated accordingly with the additional obtained data.

Analysis

For each identified national TFA reduction strategy, the core characteristics were entered into the database, according to the developed framework that includes baseline assessments; leadership/strategic approach; the different types of implementation strategies; monitoring data; and evaluation of program impact. Countries were then categorized as "having a developed strategy" for TFA elimination/reduction, "having a planned strategy" or "having no strategy." Strategies were considered to be "planned" if the TFA reduction initiatives were still being developed or if an action plan had been already developed but without evidence of implementation. A quantitative evaluation of the proportion of countries reporting on each core characteristic was performed, and expressed as percentages.

RESULTS

Search Results

A total of 136 peer-reviewed articles, gray literature documents, websites and references from country contacts were obtained from the literature search; 94 were peer-reviewed articles of potential relevance and 42 were additional sources obtained from country contacts via the completed questionnaires, links, webpages, and references from within the included studies (**Figure 1**).

Assessment of TFA Intake

Out of the 22 countries of the EMR, thirteen (59%) did not have any population estimate of TFA intakes (with the exception of estimates based on Bayesian modeling and which were not considered in this review) (10). In contrast, nine countries (41%), including Egypt, Iran, Jordan, Lebanon, Morocco, Pakistan, Sudan, Tunisia, and the UAE, have estimated population TFA intakes (**Supplementary Table 2**). Some of the available studies estimated TFA intakes at the national level for specific population groups (e.g., adults) or the entire population (per capita), while others reported the intakes within specific regions of the countries (4, 12, 14, 39–51). Except for Jordan, where TFA intake assessment was based on a household budget survey, all the other countries had evaluated TFA intakes based on dietary assessment methodologies (e.g., 24-h recalls, food frequency questionnaires, diet history questionnaires) (**Supplementary Table 2**). Total diet studies investigating dietary exposure to TFA are lacking in the region.

The available estimates of TFA intakes from various countries are presented in **Figure 2**, which focuses on national studies, and **Figure 3**, which illustrates data stemming from regional studies within countries. Based on national per capita estimates of TFA intakes (entire population), the highest level was observed in Egypt (6.5% EI), while the lowest was reported from Morocco (0.34% EI) (**Figure 2**). As for regional studies conducted amongst adults (**Figure 3**), the highest levels were observed in Lebanon (2.3–2.4% EI), while the lowest were noted among females in Sudan (0.1% EI) (**Figure 3**). Few countries have evaluated TFA intake among children and adolescents. In Iran this was reported at 2.2% EI in girls and around 2.3% in boys (**Figure 3**). In Jordan, TFA intake was estimated to range between 0.8 and 1.3 g/day among 6–18 year old children (46), and in Lebanon, average intake of TFA was reported at 0.16 g/day in 5–10 year old children (47). The contributions of these estimates to energy intake were not reported.

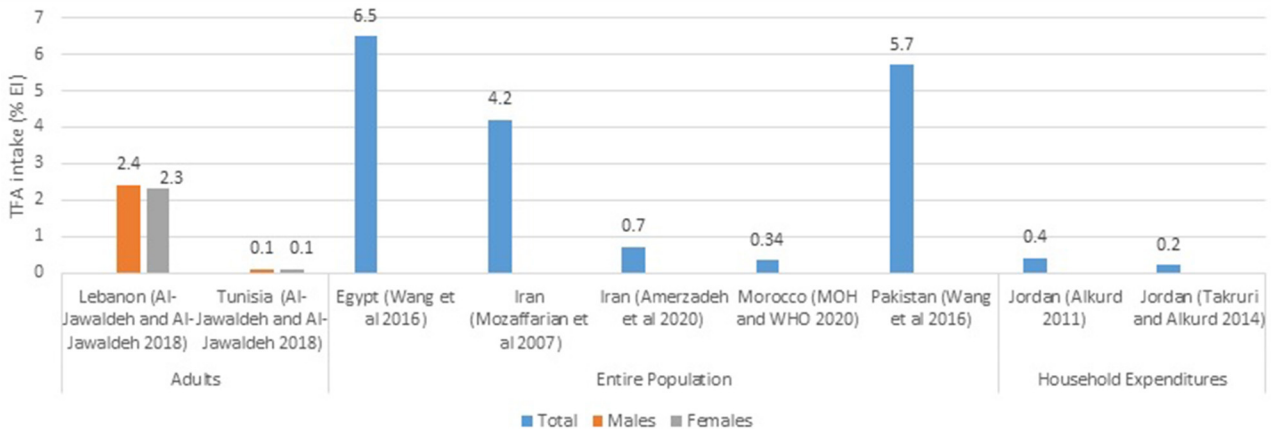


FIGURE 2 | TFA intake estimates (%EI) based on national studies in countries of the EMR. EI, energy intake; EMR, Eastern Mediterranean Region; MOH, Ministry of health; TFA, trans fatty acids; WHO, World Health Organization. References: For Adults: Lebanon and Tunisia (dietary assessment): Al-Jawaldeh and Al-Jawaldeh (14). For Entire Population: Egypt and Pakistan (dietary assessment): Wang et al. (4); Iran (dietary assessment): Mozaffarian et al. (39); Iran (consumption data): Amerzadeh and Takian (41); Morocco (consumption data): Ministry of Health-Morocco and World Health Organization (49). For Household Expenditures: Jordan: Alkurd (44) and Takruri and Alkurd (45).

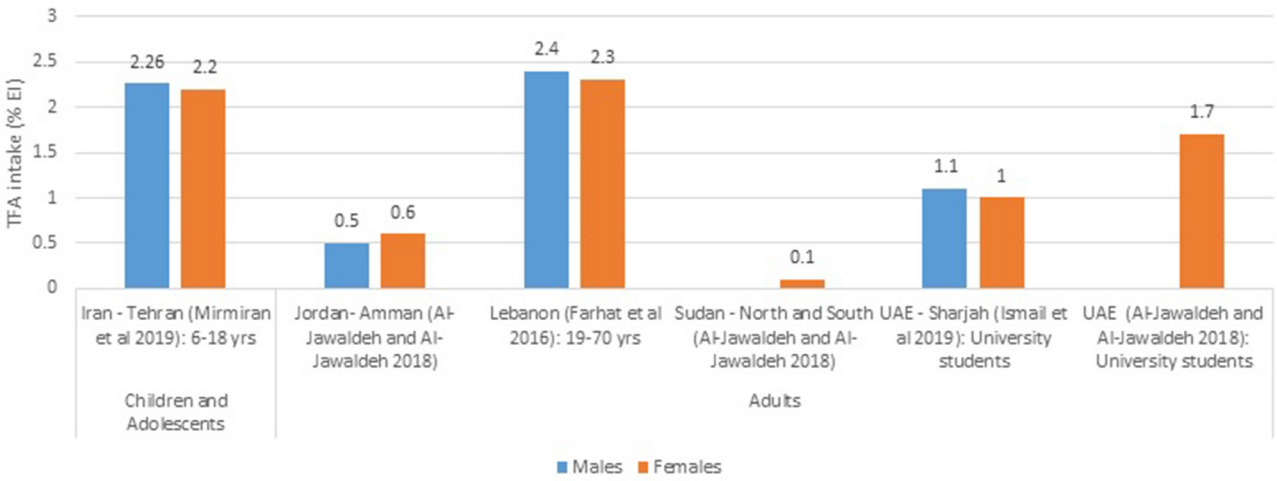


FIGURE 3 | TFA intake estimates (%EI) based on regional studies in countries of the EMR. EI, energy intake; EMR, Eastern Mediterranean Region; MOH, Ministry of health; TFA, trans fatty acids; WHO, World Health Organization. References: For Children and Adolescents: Iran (dietary assessment): Mirmiran et al. (43). For Adults: Jordan and Sudan (dietary assessment): Al-Jawaldeh and Al-Jawaldeh (14); Lebanon (dietary assessment): Farhat et al. (48); UAE (dietary assessment): Ismail et al. (51) and Al-Jawaldeh and Al-Jawaldeh (14).

Assessment of TFA Levels in Food and TFA-Related KAB

Several countries in the EMR (9/22 countries; 41%), including Egypt, Iran, Jordan, Kingdom of Saudi Arabia (KSA), Kuwait, Lebanon, Morocco, Pakistan, and Tunisia, have evaluated TFA levels in local foods and commodities (**Supplementary Table 3**) (14, 39, 49, 52–94). The majority of available TFA content data were derived based on chemical analysis of food products (39, 49, 52–56, 58, 60–70, 72–74, 77, 79–97), while very few studies have collected TFA content data based on food labels and packages (55, 75, 76). Most of the available studies have reported very high levels in fast foods (fried meats, sausages, French fries), pastries, potato chips, biscuits, wafers, cakes, donuts, chocolates, traditional sweets, as well as dairy products (milk, cream, cheeses). Interestingly, available data indicate that the levels of TFA in imported foods were higher as compared to locally produced items. For instance, Mashai et al. (72) showed that the levels of TFA in five imported popcorn items ranged from 2% to over 40% as compared to 1.26% in a locally produced popcorn. In addition, in KSA, Jradi et al. (76) have randomly collected 1,153 foods from fourteen stores in the Saudi market. Results showed that from the 228 products that had

hydrogenated fat, 67.5% were imported, while 32.5% were locally produced (76).

Iran was the only country that showed decreasing TFA levels in vegetable oil, margarines and shortenings over time (**Supplementary Table 3**). Acknowledging that different countries/studies may have used various methods for the chemical determination of TFA levels in foods, the WHO has spearheaded the development of a standardized chemical analysis protocol for TFA assessment (98). This has been already implemented in Egypt and Jordan (94, 97), as well as Lebanon and Morocco (data not published yet) (**Supplementary Table 3**).

As for baseline data on KAB, this was collected in eight EMR countries (32%), including Iran, Iraq, Jordan, KSA, Oman, Pakistan and the UAE. Most of the KAB surveys included questions relating to (1) knowledge of TFA food sources and content, familiarity with the maximum daily allowance of TFA and the adverse health effects of high TFA intakes; and (2) consumers' behavior such as the use of partially hydrogenated oils and fats when cooking, or the consumption of high TFA food products (**Supplementary Table 4**) (75, 99–107). No studies assessed the attitudes of consumers toward TFA.

Countries With National TFA Reduction Initiatives

As shown in **Table 1**, national TFA reduction initiatives were identified in 14 out of the 22 countries of the EMR (63.6%). These countries include Bahrain, Egypt, Iran, Iraq, Jordan, KSA, Kuwait, Morocco, Oman, Pakistan, Palestine, Qatar, Tunisia and the UAE. GINA database has included a TFA reduction policy for Lebanon (151). More specifically, it referred to limiting the import, fabrication and marketing of high TFA products−2014. However, the GINA database has also specified that this initiative was not adopted in the country (151). Accordingly, and given that no other TFA reduction initiatives were identified during our systematic search, Lebanon was not considered as having national TFA reduction initiatives in this review. Similarly, it was reported that Afghanistan and Syria are preparing broad national nutrition or food policies, which will include TFA reduction (108), and that legislation/standards related to TFA limits in fats and oils and/or the use of PHOs are being developed or updated in Sudan (108, 109). However, no further details were found, and accordingly Afghanistan, Sudan and Syria were not considered as having TFA reduction initiatives in this review.

Leadership and Strategic Approach

National strategies or action plans that express a commitment to reduce TFA in the food supply were identified in 12 countries of the region, as shown in **Table 2**. The identified recommendations and strategies were mainly led by governments, or by national multi-sectoral national committees that include governmental entities, as well as representatives from the food industry, academia and NGOs. In Pakistan, the responsibility for formulating and enacting TFA legislation has recently been transferred from provincial authorities to the Pakistan Standards and Quality Control Authority and a national action plan for industrial TFA elimination is being developed (108, 109). Six countries have specified targets for their population TFA intake (1% of EI or less), including Bahrain, Egypt, Iran, Jordan, KSA, and Morocco. As shown in **Table 2**, TFA reduction strategies in countries of the region were part of broader strategies or action plans targeting NCD or healthy diets and lifestyle.

Implementation Strategies

All of the 14 countries listed in **Table 1** (100%) are implementing some form of TFA limits or bans, with varying degrees in implementation and policy scope. In addition, except for Egypt, Iraq and Morocco, the other countries are implementing complementary TFA reduction interventions, with the most common being consumer education (10/14 countries; 71%), followed by food labeling (9/14 countries; 64%) and initiatives in specific settings (7/14 countries; 50%). Taxation was the least common implementation strategy. In fact, except for Qatar, where taxation of high TFA products is planned, and for Oman where taxation on the use of hydrogenated oils, was included as part of the National plan for the prevention and control of chronic non-communicable diseases 2016–2025 (not adopted yet) (143), none of the other countries have included taxation-based initiatives. **Table 1** displays the details of the initiatives implemented in the various EMR countries.

TFA Bans or Limits

Initiatives based on TFA bans or limits included the setting of limits for TFA levels in fats and oils, and other foods (such as bakery products, biscuits, cakes, snacks, and fast foods), and/or the banning or replacement of PHOs.

Iran is the first country in the region to have developed TFA regulation, a process that was initiated in 2005, when the standards for frying oil and mixed liquid oils were revised, setting the maximum level of TFA at 10%, down from over 20% (120). The 2% limit in oils and fats was later adopted, and became effective in 2016 (4, 110). In 2015, the Gulf Cooperation Council (GCC) Standardization Organization (GSO) has set TFA limits of 2% of total fat in vegetable oils and soft spreadable margarines, and 5% of total fat in other foods. The implementation of the regulation took effect in 2016 in Bahrain, while in KSA, UAE and Kuwait, it came into force in 2017. In Qatar, the GSO standard has been submitted to the cabinet in 2020 for endorsement (108), and in Oman, a ministerial decree has been issued stating that the Directorate of Standards should follow all GSO-approved standards.

As for regulating the use of PHO, KSA has become the first country to implement a complete ban on the use of PHO in food products (0 g) in 2020 (108, 110, 128, 129, 132). In Oman a Ministerial Decree to prohibit the use of PHOs is in preparation (155, 156). Iran implements a restriction of PHO use rather than a ban, while Iraq has removed the subsidy on PHOs, and replaced them by other types of oil (14, 50, 113, 122). In Oman, there has been a proposal to tax PHOs, but this has not been adopted or implemented yet (143). Jordan banned the use of PHOs in dairy products (50, 123, 124) and Pakistan has prohibited their use in formula milk (146). Initiatives that included TFA limits/bans were mandatory in 8 countries, including Bahrain, Iran, Jordan, KSA, Kuwait, Morocco, Oman and Palestine (8/14 countries; 57%) (**Table 1**).

TABLE 1 | TFA reduction implementation strategies in countries of the EMR.

Country	TFA bans or limits	Consumer Education/Behavior Change	Labeling	Work in Specific Settings
Bahrain	Name of initiative: A standard relating to TFA elimination. Decision of the Ministry of Industry, Trade and Tourism No. (16) of 2016 regarding Policy–Adopting the GSO technical regulations for food products as national technical regulations Year: 2016 Leadership: Led by the government (MOH-Public Health Directorate, Ministry of Industry, Trade and Tourism) and GSO Approach and target: Mandatory: for all food, oils and snack categories (e.g., maximum TFA content in foods and snacks or zero TFA in foods and snacks). The standard also specifies a maximum level of 2% in vegetable oils and soft spreadable margarines and 5% in all other foods, including ingredients sold to restaurants (bakery products, fast food, restaurant frying oil, biscuits and cakes, and salty snacks) (4, 108–111)	Name of initiative: Media campaign to raise the awareness of community on trans fat and workshops targeting the food importers and the food industry Year: 2017 Leadership: Led by the government (MOH and Ministry of Industry and Trade) Approach: Social marketing (e.g., campaigns); Media (TV and radio); Booklets; Workshops targeting food importers and the food industry Information provided by the NFP	Name of initiative: GSO 2483/2015 (E) Year: 2016 Leadership: Led by GSO Approach: Mandatory: provides standards which mandate the nutritional labeling of fat, including TFAs, as g/100 g and %DV (50, 111, 112), requiring declaration of TFA as part of nutrition labels for products containing 0.5/100 g or more and regulating "trans-fat free" claims (108, 111)	Name of initiative: Eliminating TFA from school canteens through the adoption of a prohibited food list and by modification of food preparation/cooking methods Year: 2017 Leadership: Led by the government (MOH and Ministry of Education) Approach: Procurement policy, workshops; the healthy food list for school canteen and the required standards for preparation Setting: Schools Information provided by the NFP
Egypt	Name of initiative: NA Year: NA Leadership: Led by the government (MOH, with the participation of all sectors) Approach: A roadmap for action on industrial TFA elimination has been drafted. Some factories are reported to have started using esterification technology, on a voluntary basis, to eliminate the hydrogenation process (108, 109)	–	–	–
Iran	Name of initiative: TFA reduction in edible oils and foods Year: 2008–2016 Leadership: Led by the National Standard Organization and High Council of Health and Food Security Approach and targets: Mandatory. In 2008, the National Standard Organization mandated the revision of standard NO.9131, so that TFAs contents of edible oils (both imported and local) are limited to 5% In 2014, the High Council of Health and Food Security approved to revise the standards of TFAs to <2% (14, 41, 50, 113–115). The permitted levels of frying oil and mixed liquid oils were reduced to <2% by 2015 (108, 116); TFA levels in table margarine from 10 to 2%, in spread margarine and minarine from 5 to 2%, after 2015 (117, 118). As of 2016, the 2% limit in fats and oils became effective (4, 108, 110, 119). For some other products, the upper limit is 5% (e.g., shortening for bakery products) (57, 108, 110, 116), while for others such as biscuits it should be under 2% of extracted fat from the biscuit (57) Initiative: Reduction of TFA in edible oils Year: 2005 Leadership: Led by an executive committee composed of members from the MOHME, Ministry of Industry, Ministry of Agriculture, Ministry of Commerce and the National Standard Organization Approach and targets: Ministry of Commerce was forced to gradually replace the hydrogenated oils (the subsidized ones) by non-hydrogenated (specifically olive oil) and liquid frying oils (14, 50, 113). The standards for frying oil and mixed liquid oils were revised in 2005 to reduce the maximum level of TFA (to <10%, down from over 20%) (120)	Name of initiative: National plan for the reduction of TFA and SFA in the Iranian diet Year: NA Leadership: Led by the government (MOHME) Approach: Public education campaign with emphasis on increasing the public's knowledge about the adverse health effects of TFA in processed food and edible oils. Mass media, magazines and newspapers were used for campaign promotion to increase people's awareness (105, 121) Name of initiative: Educational campaigns for increasing awareness on salt and sugar, total fat and TFA reduction Year: Annually since 2010 Leadership: Led by the government Approach: Social marketing (e.g. campaigns), TV advertising and events. Information provided by the NFP	Name of initiative: NA Year: 2008 Leadership: Led by the government (MOHME) and the National Standard Organization Approach: Reviewing packaging standards and mandating manufacturers and importers to affix labels to all food products, especially edible oils (14, 113) Name of initiative: Food labeling modification through designing Traffic Light Symbol Year: 2016 Leadership: Led by the Food and Drug Organization and MOHME (government and industry led) Approach: Mandatory: percentage of daily intake. Information provided by the NFP	Name of initiative: NA Year: NA Leadership: NA Approach: Educational work on TFA has been done such as inclusion of TFA related information in school books Setting: Schools Information provided by the NFP
Iraq	Name of initiative: NA Year: NA Leadership: NA Approach: Subsidy on hydrogenated ghee/shortening removed and replaced by other types of oil (14, 50, 122) No further details	–	–	–

(Continued)

TABLE 1 | Continued

Country	TFA bans or limits	Consumer Education/Behavior Change	Labeling	Work in Specific Settings
Jordan	Name of initivative: Withdraw the Jordanian Technical Base; Reformulation of specifications and regulations (1520/200l and 1605/2004) to eliminate TFA in cheese products Year: 2016 Leadership: Led by the government (MOH and JSMO) Approach: Mandatory technical specifications and regulations were developed to reduce TFA in processed cheese (adopted by JSMO). Moreover, MOH, in collaboration with JSMO, banned the use of PHOs in dairy products (local and imported) in 2016. The decree states that only animal fat occurring naturally in dairy products be permitted in milk and cheese (50, 123, 124)	Name of initiative: Low salt, low sugar, low saturated and trans fat consumption guideline for health care providers for training of trainers (TOT) and pamphlet for consumers Year: 2015 Leadership: Led by the government (MOH) Approach: Awareness and education (125) Name of initiative: Guideline for low consumption of salt, sugar, saturated fat and trans fat Year: 2020 Leadership: Led by the government Approach: Inclusion in FBDG (126)	Name of initiative: National Strategy and Plan of Action Against Diabetes, Hypertension, Dyslipidemia and Obesity Year: 2015 Leadership: Led by the government Approach: Mandatory: labeling of food products with TFA (not adopted yet) (4, 127)	Name of initiative: Reduce trans fat in canteens of public hospitals and royal medical services hospitals for inpatients and employees Year: 2019 Leadership: Led by a multi-sectoral committee and WHO Approach: Banning TFA in public sector hospital food, and increasing portions of olive and sesame oil in foods Setting: Public sector hospitals and royal medical services (108)
KSA	Name of initiative: Healthy Food Strategy Year: 2018 Leadership: Led by the government (SFDA) Approach and targets: In 2017, mandatory for all food and snack categories. The maximum limit of TFA in vegetables oils and margarine shall be 2% and the maximum limit in other foods (such as fast foods, restaurant frying oils, biscuits and cakes) shall be 5% of the total content of fats (4, 108, 110, 111, 128–131). In 2018, voluntary pledge to avoid the use of PHOs in food products with major food producers around the globe (112) In 2020, and as part of Healthy Food Strategy, KSA banned the use of PHOs in food products (0 g); it was voluntary until January 2020 when it became mandatory (108, 110, 128, 129, 132)	Name of initiative: The Healthy Food Guide for the health practitioner Year: 2020 Leadership: Led by the government (MOH) Approach: Designed to educate health care workers about the different macronutrient distribution (including TFA), their sources; provides information on the content of a full day meal, and fosters proper reading of the labels (133) Name of initiative: Healthy Food Strategy Year: 2018 Leadership: Led by the government (SFDA) Approach: Social media awareness campaigns, workshops and events (131)	Name of initiative: Reduction of TFA, and Healthy Food Strategy SFDA.FD 2483/2017 (E) SFDA.FD 2233/2018 (E) Year: 2017–2020 Leadership: Led by the government (SFDA) Approach: Mandatory: nutrition labels should include the amount of TFA (g/100 g), and the declaration of fat/oil names among the ingredients list (50, 111, 112, 128). Declaration of TFA as part of nutrition labels for food products containing 0.5 g/100 g or more and regulating "trans-fat free" claims (108, 110, 111, 128) Name of initiative: The Nutritional Label Guide Year: 2020 Leadership: Led by the government (SFDA) Approach: Mandatory: the fat value indicates the total fat: SFA in red, TFA in green, cholesterol in blue. Mandatory indication "Make sure your food is free of trans fats" (134)	Name of initiative: Guidelines for the government nutritional subsistence purchase contract Year: 2019 Leadership: Led by the government (SFDA) Approach: Provides UFAs (canola and corn oil instead of SFAs) and bans the use of PHO in foods Setting: Government subsistence nutritional purchase contract in hospitals, universities, military or social places (not adopted) (135) Name of initiative: Healthy Food Strategy Year: 2015 Leadership: Led by the government (SFDA) Approach: Education Setting: Schools, hospitals and the workplace (131)
Kuwait	Name of initiative: Standards relating to TFA elimination Year: 2017 Leadership: Led by GSO and the Public FNA, the Kuwait focal point and official representative at GSO and the Ministry of Industry and Trade Approach and targets: Mandatory: specifies a maximum level of 2% in vegetable oils and soft spreadable margarines and 5% in all other foods, including ingredients sold to restaurants (4, 108, 111, 136, 137)	Name of initiative: NA Year: 2020 but stopped due to COVID-19 pandemic (Planned to resume after Ramadan 2021) Leadership: Led by the Community Nutrition Sector in coordination with the Department of Nutrition Promotion and Education Approach: Health and Nutrition Education targeting: Manufacturers: raising awareness among manufacturers and suppliers of the adverse health effects of TFAs and finding alternatives Consumers: raising awareness through educational campaigns for all age groups to explain the adverse health effects of TFA; to read the nutrition label and identify the products that should be limited/avoided Information provided by the NFP	Name of initiative: GSO 2,483/2015 (E) Year: 2016 Leadership: Led by the Public FNA, the Kuwait focal point and official representative at GSO, Kuwaiti Ministerial decision—Ministry of Industry and Trade Approach: Mandatory: adoption of GSO standard and regulation pertinent to TFA (GSO 2483); this standard applies to the maximum amount allowed for TFA and declaring the TFA content on the nutrition label per serving, as g/100 g and %DV—back-of-pack labeling (50, 108, 111, 112, 137), while requiring declaration of TFA as part of nutrition labels for products containing 0.5 g/100 g or more and regulating "trans-fat free" claims (108, 111). A new TFA regulation will be implemented from 1 January 2021 (108, 137) Name of initiative: Kuwait Action Plan for SFA Intake Reduction and TFA Elimination Year: 2012 Leadership: Led by the FNA and the MOH Approach: Review GSO proposal for SFA and TFA standards (138)	Name of initiative: The role of the Authority of Food and Nutrition, Ministry of Health in the control and prevention of NCDs in Kuwait Year: 2021 Leadership: Led by the FNA on behalf of the Kuwait MOH, in cooperation with the PHFS Approach: Apply the traffic light system on food items sold in governmental hospital cafeterias and canteens (139) Name of initiative: Nutrition-Friendly Schools Initiative Year: NA Leadership: Led by the government (MOH) Approach: Raising nutrition and health awareness through continuous education program Setting: Schools (136, 140) Name of initiative: Kuwait Action Plan for SFA Intake Reduction and TFA Elimination Year: 2012 Leadership: Led by Kuwait's Salt and Fat Intake Reduction Task Force and the Public FNA Approach: Banning the use of TFA in governmental institutions (MOH hospitals, Ministry of Defense, Ministry of Interior, public authorities, schools and universities) (not adopted) (138)
Morocco	Name of initiative: Reduction of TFA content in food products Year: 2020 Leadership: Led by the government Approach and targets: Voluntary in general, however, for certain items such as oils, fats and snacks it is mandatory. Setting the limit for TFA content in oils and fats (such as margarines, spreads, vegetable oils, restaurant frying oils) at 2 g/100 g of product; and at 5 g/100 g of product in all other foods (such as salty snacks, biscuits and cakes) (11, 49). Moreover, there has been a decree proposal by the Ministry of Agriculture, in 2021, to ban the partial hydrogenation of vegetable oils (Planned).= Information provided by the NFP	–	–	–

(Continued)

TABLE 1 | Continued

Country	TFA bans or limits	Consumer Education/Behavior Change	Labeling	Work in Specific Settings
Oman	Name of initiative: Ministerial decision No. 2019/95 Omani standard for bread Year: 2019 Leadership: Led by the government (MOCI) Approach: Mandatory: bread benchmark for TFA should not exceed that set by GSO (141) Name of initiative: A standard relating to TFA elimination Year: Planned for initiation Leadership: Led by GSO the Ministry of Commerce Approach and targets: Mandatory: specifies a maximum level of 2% in vegetable oils and soft spreadable margarines and 5% in all other foods, including ingredients sold to restaurants (4, 108, 111) Name of initiative: Summary of proposed implementation mechanisms to reduce saturated and trans fat consumption 2016–2020 Year: 2016 Leadership: NA Approach: Proposed mechanisms to reduce the use of TFAs in industries, restaurants (not adopted) (142) Name of initiative: National plan for the prevention and control of chronic NCDs 2016–2025 Year: 2016 Leadership: Led by the government (MOH) Approach: Gradually shift from TFAs toward healthier types of fats to reach a target of 100% by 2025; taxation on the use of hydrogenated oils to reach a target of 50% by 2025 (not adopted) (143)	Name of initiative: Healthy Nutrition Campaign Year: 2021–2022 Leadership: Led by the government (MOH) and NGO Approach: Social marketing, TV advertising, and events (Planned) Information provided by the NFP Name of initiative: Summary of proposed implementation mechanisms to reduce saturated and trans fat consumption 2016–2020 Year: 2016 Leadership: NA Approach: Proposed mechanisms to spread awareness among consumers regarding impact of TFAs on health (142)	Name of initiative: GSO 2483/2015 (E) Year: 2016 Leadership: Led by GSO Approach: Mandatory: provides standards which mandate the nutritional labeling of fat, including TFAs, as g/100 g and %DV (50, 111, 112, 142), requiring declaration of TFA as part of nutrition labels for products containing 0.5 g/100 g or more and regulating "trans-fat free" claims (108, 111, 142). Voluntary: GSO standard for labeling of prepackaged food stuffs; include the percent daily intake (144). Name of initiative: NA Year: 2014 Leadership: Led by the government Approach: Require food importers to have all imported foods certified as industrial TFA free (not adopted) (145)	Name of initiative: National plan for the prevention and control of chronic NCD 2016-2025 Year: 2016 Leadership: Led by MOH Approach: Limit the availability of high TFA items Setting: Schools (not adopted) (143)
Pakistan	Name of initiative: Punjab Pure Food Regulations Year: 2018 Leadership: Led by Punjab Food Authority Approach and targets: TFA content in Vanaspati, table margarine, industrial margarine, margarine spread, spread and shortening shall not have more than 0.5% TFA. After July 2020, there shall be complete ban on any form of Vanaspati. For frying oils and fats, TFA should not be more than 5% (82, 105) Name of initiative: Punjab Pure Food Rules Year: 2011 Leadership: Led by the government and KP Food Safety and Halal Food Authority Approach and targets: The content of TFAs shall not exceed 3% of total fatty acids provided 100% milk fat is used in the formula (82, 105, 146); the use of commercially hydrogenated oils is prohibited; plant oils and fats intended to be used in follow-up formula should be virtually TFA-free and the maximum allowance level of TFA shall be proportionately decreased with increasing level of plant oils and fats in the formula (146) Name of initiative: PS 221 (Pakistan Standard Specifications for Vanaspati) Year: NA Leadership: Led by PSQCA Approach: Regulate production and import of vanaspati ghee, margarine, butter and a number of oil products under a list of compulsory items Target: TFA limit (<5%). It has also been proposed to bring TFA level at par to the guidelines of WHO by year 2023 in this mandatory standard (82)	–	Name of initiative: Punjab Pure Food Regulations and KP Food Regulations Year: 2018 Leadership: Led by Punjab Food Authority and KP Food Safety and Halal Food Authority Approach: TFA percentage of Vanaspati shall be mentioned on the label All cream analogs shall mention TFA contents on the label. The label shall also mention source of vegetable oil(s) used in their descending order Margarine shall be clearly defined on the label in Urdu "ye makhan nahi hai" ("this is not butter"). This label shall be 15% of the total package area and it shall be mentioned on both sides of the label, in two colors only. The TFA percentage must be mentioned on the label Dried ice cream mix/dried frozen dessert/confectionary should also declare % TFA per serving (82, 105)	–

(Continued)

TABLE 1 | Continued

Country	TFA bans or limits	Consumer Education/Behavior Change	Labeling	Work in Specific Settings
Palestine	Name of initiative: Amendment of the mandatory technical instructions 2011–2032 by adding vitamins, minerals and other specific substances to food Year: 2021 Leadership: Led by the government (MOH and Ministry of National Economy) Approach and targets: Mandatory: a maximum of 2 g TFA/100 g in prepared foods (147)	Name of initiative: National Nutrition Policy, Strategies and Action Plan 2017–2022 Leadership: Led by the government (MOH) Year: 2017–2022 Approach: Conducting awareness campaigns regarding the importance of reducing TFA intake (148)	–	–
Qatar	Name of initiative: Initiative to reduce fat, sugar and salt consumption in Qatar Year: 2019 Leadership: Led by the government (MOPH) Approach: Voluntary: targets for TFA levels in foods and snacks (Planned). Information provided by the NFP Name of initiative: A standard relating to TFA elimination Year: 2020 (submitted for endorsement) Leadership: Led by government (MOPH and Ministry of Municipality and Environment) and GSO Approach and targets: Voluntary: specifies a maximum level of 2% in vegetable oils and soft spreadable margarines and 5% in all other foods, including ingredients sold to restaurants (4, 108, 111). In 2020 the GSO standard 2,483 had been submitted to the cabinet for endorsement (108)	Name of initiative: Initiative to reduce fat, sugar and salt consumption in Qatar Year: 2019 Leadership: Led by the government (MOPH) Approach: Social marketing (e.g. campaigns), TV advertising, events, TV and radio interviews, inclusion in FBDG Information provided by the NFP	Name of initiative: GSO 2483/2015 (E) Year: 2016 Leadership: Led by GSO Approach: Mandatory: provides standards which mandate the nutritional labeling of fat, including TFAs, as g/100 g and %DV (50, 111, 112), requiring declaration of TFA as part of nutrition labels for products containing 0.5 g/100 g or more and regulating "trans-fat free" claims (108, 111)	Name of initiative: Food & Beverage Guidelines; School Canteen Guidelines; Educational sessions in schools and workplaces Year: Ongoing Leadership: Led by the government (MOPH) Approach: Education, procurement policy (planned), voluntary guidelines. School Canteen Guidelines are mandatory in governmental schools Setting: Schools, hospitals, workplace Information provided by the NFP
Tunisia	Name of initiative: NA Year: 2015 Leadership: Led by the food industry (one manufacturer) Approach: The manufacturer launched a margarine product without TFAs after adapting new food processing technology (14, 50) Tunisia is advocating for the implementation of legislation to ban the production/importation of industrial TFA (130)	Name of initiative: Strategy for the Prevention and Fight against Obesity Year: 2012 Leadership: Led by the government (MOH) Approach: Reducing TFA intake and helping consumers make healthier choices that provide less TFA (149)	–	–
UAE	Name of initiative: National Action Plan in Nutrition Year: 2017 Leadership: Led by GSO; MOHP of the UAE Approach and targets: Reformulate food products; Replace TFAs with UFAs; Reduction of TFA to maximum 2 g of the total fat in vegetable oils, and soft spreadable margarine, and TFA content for other foods to <5% of the total fat content including ingredients sold to restaurants (GCC legislation on TFA approved). MOHAP Task Force on Reduction of TFA in the UAE established) (4, 108, 111, 150)	Name of initiative: National Action Plan in Nutrition Year: 2017 Leadership: Led by the government MOHP Approach: Public awareness campaigns on the harmful effects of the consumption of TFA (150)	Name of initiative: GSO 2483/2015 (E) Year: 2016 Leadership: Led by GSO Approach: Mandatory: provides standards which mandate the nutritional labeling of fat, including TFAs, as g/100 g and %DV (50, 111, 112), requiring declaration of TFA as part of nutrition labels for products containing 0.5 g/100 g or more and regulating "trans-fat free" claims (108, 111)	–

DV, daily value; EMR, Eastern Mediterranean Region; FBDG, food-based dietary guideline; FNA, Food and Nutrition Authority; GCC, Gulf Cooperation Council; GSO, GCC Standardization Organization; JSMO, Jordanian Standards and Metrology Organization; KP, Khyber Pakhtunkhwa; KSA, Kingdom of Saudi Arabia; MOCI, Ministry of Commerce and Industry; MOH, Ministry of Health; MOHAP, Ministry of Health and Prevention; MOHME, Ministry of Health and Medical Education; MOHP, Ministry of Health and Population; MOPH, Ministry of Public Health; NA, not available; NCD, non-communicable disease; NFP, nutrition focal point; NGO, non-governmental organization; PHFS, Patient Helping Fund Society; PHO, partially hydrogenated oil; PSQCA, Pakistan Standard and Quality Control Authority; SFA, saturated fatty acid; SFDA, Saudi Food and Drug Authority; TFA, trans fatty acid; UAE, United Arab Emirates; UFA, unsaturated fatty acid; WHO, World Health Organization.

TABLE 2 | National TFA reduction strategies or action plans identified in the EMR countries.

Country	National strategy and/or action plan
Bahrain	Reduce intake of TFA to 1% of EI−2015 (Government and food industries) (Action Plan on Reducing the Use of Saturated and Trans Fats in the GCC Countries; Part of Policy for Ensuring the Quality and Sustainability of Health Services 2019–2022)—Information provided by the NFP
Egypt	Replace TFA (<1% of EI) with UFA−2017 (Not adopted yet) (MOHP) (National Multi-sectoral Action Plan for Prevention and Control of Non-communicable Diseases 2017–2021) (152)
Iran	Reduce intake of TFA to a maximum of 1% of EI (MOHME) (National Action Plan for Prevention and Control of Non-communicable Diseases and the Related Risk Factors in the Islamic Republic of Iran 2015–2025, Nutrition and Food Security Policy Statement—MOHME, Part of National Nutrition and Food Security Policy Statement 2015–2025) (41, 63)
Jordan	Reduce intake of TFA to <1% of EI (Government-Multi-sectoral National Committee for Combating Obesity) (Part of National Program for Combating Obesity by Low Fat, Low Sugar, Low Salt)—Information provided by the NFP
	Reduce intake of TFA to <1% of EI−2015 (Government) (National Strategy and Plan of Action Against Diabetes, Hypertension, Dyslipidemia, and Obesity) (127)
KSA	Reduce intake of TFA to <1% of EI−2015 (SFDA) (Healthy Food Strategy) (43, 131, 134)
	Reduce intake of TFA from canned foods to <1% of EI−2015 (MOH) (National Strategy for Healthy Food and Physical Activity 2015–2025) (153)
Kuwait	Lift subsidy on full fat dairy produce, cooking oils and on full fat cheese−2012 (Kuwait's Salt and Fat Intake Reduction Task Force) (Kuwait Action Plan for SFA Intake Reduction and TFA Elimination) (138)
Morocco	Replace TFA in food products with UFA−2015 (MOH) (Non-Communicable Disease Prevention: Multi-sectoral Plan of Action for the Promotion of a Healthy Lifestyle 2015–2020) (154)
	Reduce intake of TFA to 1% of EI−2019 (Planned) (MOH) (Plan to Reduce the Use of Trans Fatty Acids in Processed Products; Part of the Nutrition Program) (49)
Oman	Ban production, importation and marketing of any food containing partially hydrogenated oil (Planned) (Government) (Part of National Nutrition Strategy 2020–2030, National Plan for Prevention of NCD 2016–2025) (155, 156)
Palestine	Avoid the consumption of hydrogenated oils−2019 (MOH) (National Health Strategy 2021–2023) (157)
Qatar	Targets for TFA levels in foods and snacks and taxation on high TFA products−2019 (Planned) (MOPH) (Initiative to Reduce Fat, Sugar and Salt Consumption in Qatar; Part of Qatar Public Health Strategy 2017–2022)—Information provided by the NFP
Tunisia	Replace TFA with UFA and eliminate the intake of TFA−2018 (Not adopted yet) (MOH) (National Multi-sectoral Strategy for the Prevention and Control of Non-Communicable Diseases) (158)
UAE	Replace TFA in food products with UFA−2017 (MOHP) (National Action Plan in Nutrition) (150)

EI, energy intake; EMR, Eastern Mediterranean Region; GCC, Gulf Cooperation Council; KSA, Kingdom of Saudi Arabia; MOH, Ministry of Health; MOHME, Ministry of Health and Medical Education; MOHP, Ministry of Health and Population; MOPH, Ministry of Public Health; NCD, non-communicable disease; NFP, nutrition focal point; SFA, saturated fatty acids; SFDA, Saudi Food and Drug Authority; TFA, trans fatty acids; UAE, United Arab Emirates; UFA, unsaturated fatty acids.

Consumer Education

Ten out of the 14 countries (71%) have implemented consumer education campaigns. These countries include Bahrain, Iran, Jordan, KSA, Kuwait, Oman, Palestine, Qatar, Tunisia, and the UAE (**Table 1**). While most awareness and educational campaigns were led solely by governmental entities, NGOs were collaborators in both Bahrain and Oman. Half of the countries had their consumer education initiatives specific to TFA (Bahrain, Kuwait, Palestine, Tunisia, and the UAE). The other half had broader campaigns in relation to saturated fats, salt, sugar and healthy lifestyle (Iran, Jordan, KSA, Oman, and Qatar).

Food Labeling

Nine countries (64%), including Bahrain, Iran, Jordan, KSA, Kuwait, Oman, Pakistan, Qatar and the UAE, were found to have labeling initiatives specific to TFA. These initiatives were mandatory in Bahrain, Iran, KSA, Kuwait, Oman, Qatar and the UAE (7/9 countries; 78%), with the mandatory traffic light labeling scheme being implemented in Iran. In Jordan, and as part of the "National Strategy and Plan of Action Against Diabetes, Hypertension, Dyslipidemia and Obesity," labeling of food products with TFA was set to be mandatory as of 2015, however this initiative has not been adopted yet (4, 127) (**Table 1**).

Interventions in Specific Settings

Seven countries (50%) are implementing TFA reduction initiatives in specific settings. These include Bahrain, Iran, Jordan, KSA, Kuwait, Oman and Qatar. Bahrain is targeting school canteens through the use of a prohibited food list and by introducing modifications to food preparation methods. Iran is implementing TFA educational interventions in schools and workplaces, while in Jordan, TFA reduction interventions are being implemented in public hospitals and royal medical services (108). Under the Nutrition-Friendly Schools Initiative, Kuwaiti schools are being targeted to raise nutrition and health awareness, with a focus on TFA intake reduction (136, 140). In Qatar, the adoption of the School Canteen Guidelines is mandatory in governmental schools, while the implementation of educational sessions in workplaces remain voluntary.

Other initiatives that have been implemented and shared with various governmental entities in KSA (hospitals, universities, military, or public places) include the replacement of PHOs and saturated fatty acids with unsaturated fatty acids (UFA) in offered foods (135). Similarly, the elimination of TFA in

foods offered in governmental institutions in Kuwait has been proposed, although not adopted yet (138). In Oman, and as part of the National Plan for the Prevention and Control of Chronic Non-communicable Diseases 2016–2025, limiting high TFA items in schools is planned, but has not been implemented yet (143) (**Table 1**). Interventions or policy actions targeting the food service sector (such as restaurants and coffee-shops) were not identified in any country of the region.

Monitoring and Evaluation

Monitoring activities are being conducted in Iran and several GCC countries including Bahrain, KSA, Kuwait, and Qatar. In Iran, post marketing surveillance is conducted by the Food and Drug Organization on an annual basis. Accordingly, samples of edible oils and fats (frying oil, consumer edible vegetable oil, Margarine, minarine, and shortening), are analyzed to determine TFA levels (40). The Iran Standard Organization also monitors the TFA content in bakery products, biscuits and confectionary products. Ghazavi et al. collected samples of traditional sweets with nutritional labeling, and compared the TFA information on the label with actual TFA levels based on chemical analysis. Results showed that there was 81.8% discrepancy between the analytical levels and those listed on the label (65).

In Bahrain, monitoring activities focus on the monitoring of TFA content in samples of bakery products, and fats and oils via direct chemical analyses. Moreover, the listing and proper labeling of TFA on prepackaged products (both locally produced and imported) is being monitored in Bahrain. In KSA, the SFDA, in collaboration with the Ministry of Municipal and Rural Affairs, is responsible for monitoring and inspection activities, targeting food products that are locally produced or imported. Laboratory analyses are conducted in the SFDA laboratories. In 2020, SFDA launched a campaign to ensure that manufacturers and importers of food products comply with the Saudi Technical Regulation SFDA.FD 2483 "Trans fats (fatty acids)." The inspection focused on local and imported food products such as margarine, donuts, cakes, biscuits, pies, frozen pastries, cheese, chocolates, ice cream, and other items. The total number of samples that were chemically analyzed was of 2,697 (129, 159), and the percentage of violation was estimated at 20% (200 local products and 332 imported products). An older campaign conducted in 2018 to monitor compliance to TFAs limit in food products, showed that 94% of the 400 samples that were tested were compliant with the standards (110). In 2016–2017, Jradi et al. (76) conducted a study to assess compliance with SFDA nutritional facts requirements: only 38% met the SFDA requirements for nutritional information (energy, protein, carbohydrate, sugar, total fat, saturated fat, TFA, and sodium). Among the missing nutrients, TFA was the most frequently omitted (54.5%) from the nutritional facts.

In Kuwait, the National Technical Food Committee has developed a plan to monitor the implementation of the TFA standards (136). In collaboration with the food laboratory—Ministry of Health (MOH)- measures have been put in place to monitor, inspect and evaluate the compliance of the food industry by chemically analyzing TFA content in randomly selected samples of potentially high TFA food sources. In this context, a capacity-building program has been conducted by the Department of Standards and Inspection to enhance the inspectors' capabilities, and assure compliance of the food industry with the various GSO standards and technical regulations (Trans Fatty Acids GSO 2483/2015; Requirements of nutritional labeling. GSO 2233/2012; Nutritional and Health Claims Requirements. GSO 2333/2013). In addition, the TFA content declared on the nutrition facts is monitored to evaluate compliance with the technical regulation for TFA.

In Qatar, the Health Promotion and NCD Section of the Public Health Department at the Ministry of Public Health plays a role in the development of the School Canteen Guidelines, led by the Ministry of Education and Higher Education. The Health Promotion and NCD section of the Public Health Department at the MOPH has also developed and implemented the Food & Beverage Guidelines in Cafeterias and Vending Machines in all healthcare settings and workplaces that are part of the Workplace Wellness Program. An annual evaluation tool is administered to all hospitals and workplaces that are implementing the guidelines.

Impact Assessment

Very few countries have assessed the impact of TFA reduction initiatives on the population's intake levels. In addition, the majority of countries have only one estimate of TFA intake, and therefore the investigation of trend in TFA intake is not possible. The two exceptions are Iran and UAE. In Iran, the intake of TFA for the entire population (per capita) was estimated at 4.2% EI in 2001–2003, i.e., prior to policy implementation (39). This intake had decreased to 0.7% in 2018 as reported by Amerzadeh and Takian (41), post policy implementation. In the UAE, a study conducted amongst female university students had estimated TFA intake at 1.7% in 2014 (14) before the implementation of TFA reduction initiatives. Intake level has decreased to 1% in 2017–2018 in the same population group, post policy implementation (51).

Data on the impact of TFA reduction initiatives on the levels of TFA in food products is also scarce. Available evidence suggests that the legislations that were implemented in Iran resulted in a significant reduction in the level of TFAs content in edible oil. In fact, initiatives aimed at reducing the level of TFA in edible oils were launched in 2005, when the standards for frying oil and mixed liquid oils were revised to reduce the maximum level of TFA (to <10%, down from over 20%) (120), and when the Ministry of Commerce started the gradual replacement of hydrogenated oils by non-hydrogenated (specifically olive oil) and liquid frying oils (14, 50, 113). Peymani et al. assessed the impact of this policy on the levels of TFA in edible oils. Samples were collected randomly over a 6-year period, from 2002 to 2008, from different national edible oil manufacturers. Tests were conducted by the national referral laboratory in <city>Tehran</city>, Iran. Results showed that the TFA composition (%) of edible oil represented 27–29% in 2002–2003, 31.2% in 2004–2005, decreasing to 13.7% in 2007 and 5.6% in 2008 (121). Another study was conducted in 2014 by the Post Marketing Surveillance (PMS) in Iran: It targeted households in six provinces of Iran, whereby information on the types of fats

and oils used for cooking as well as the purchase pattern and their amounts were obtained using questionnaires. In addition, the fatty acid profiles of consumed fats and oils were determined (40). The analysis of TFA in different kinds of oils (frying oil, consumer edible vegetable oil, margarine, minarine, and shortening) was performed. Results showed that the TFA content of edible oils has been reduced to <5% TFAs (40).

DISCUSSION

This systematic review is the first to focus on TFA reduction initiatives in the EMR, a region that is currently witnessing an increasing burden of cardiovascular morbidity and mortality (13). It showed that out of the 22 countries of the EMR, nine have assessed TFA intake in the population (41%), nine (41%) have evaluated TFA levels in food items, and fourteen (63.6%) have implemented national TFA reduction initiatives. The most common TFA reduction initiatives were based on TFA limits or bans in an effort to decrease/eliminate TFAs from the food supply, while the least common was taxation.

Based on available national studies conducted in countries of the region, the population's TFA intake levels were found to range between 0.34% EI in Morocco and 6.5% EI in Egypt (4, 49), while subnational studies reported estimates ranging between 0.1% EI in Sudan and 2.3–2.4% EI in Lebanon (14, 48). Available data highlight very high intake levels in Egypt (6.5% EI) (4) and Pakistan (5.7% EI) (4). These estimates are 5–6 fold higher than the upper limit of 1% EI specified by the WHO (160, 161) and the American Heart Association (162), and significantly higher that the optimal level defined by the Global Burden of Disease (GBD) collaborators, in their evaluation of dietary risk factors (0.5% EI, with an optimal range of 0–1% EI) (163). Based on the 2019 GBD data, the Institute for Health Metrics and Evaluation (IHME) has assessed the burden of CHD attributable to high TFA intake (>0.5% EI) in each country worldwide (4, 12). Accordingly, the top ten countries included three from the EMR: Egypt was ranked at the top of the list as the country with the highest burden of CHD due to high TFA intake in the world (8.4% of CHD deaths), Iran ranked as the third (6.96% of CHD deaths) and Pakistan as the ninth (4.94% of CHD deaths) (12).

Countries that had very low estimates of TFA intake included Morocco (0.34% EI) (49), Jordan (0.5–0.6% EI) (14) and Sudan (0.1% EI) (14). It is important to mention that dietary estimates of TFA intake should be interpreted with caution. These are in fact limited by the available food composition databases that either have a large number of missing data for TFA levels in foods, or are not culture-specific (164). Without country- or region-specific data, TFA elimination would often not be recognized as a priority for time and resource investment (12). Acknowledging this challenge, the WHO has published a standardized protocol for TFA analysis (98) that can be adapted for measuring TFA levels in national food supplies in different settings (12), and the WHO EMRO has supported the launch of TFA analysis projects in several Member States. This endeavor has been already completed in Egypt, Lebanon, Morocco (data not published yet), and Jordan (94). Such data should help in enhancing the robustness and accuracy of future TFA dietary assessment in countries of the region.

Very few studies have reported on TFA intake amongst children and adolescents in the EMR, although evidence suggests that this age group may have the highest TFA intake level given their tendency to consume "fashionable" processed foods as well as fast foods (165). In Iran, TFA intake amongst 6–18 year old children and adolescents was reported at 2.2–2.3% EI in 2019 (43). This estimate highlights that TFA intake remains high in this age group, even after the implementation of TFA reduction initiatives which have been launched as of 2005 (4, 14, 41, 50, 57, 105, 108, 110, 113–121). More attention should be devoted to this age group, and their food consumption patterns, since high TFA intakes in this period of the lifecycle may increase the risk for early onset CVD and related comorbidities (165).

The number of countries adopting TFA limits or bans to reduce TFA levels in the food supply is estimated at 14 (63.6%), with significant disparities between countries in policy scope and coverage. The main disparities were noted in whether the limits/bans were mandatory or not (8 mandatory vs. 6 voluntary), and the number and types of foods targeted by the standards. Iran is the first country to have adopted TFA limits and regulations in the region, while KSA is the first to have implemented a best-practice policy according to the WHO (12). A best-practice policy is defined as "Legislative or regulatory measures that limit industrially produced TFA in foods in all setting. The two best-practice policies for TFA elimination are: Mandatory national limit of 2 g of industrially produced TFA per 100 g of total fat in all foods; and Mandatory national ban on the production or use of PHO as an ingredient in all foods." Countries of the GCC have all adopted or are on the way of implementing the GSO standards for TFA which set TFA limits at 2% of total fat in vegetable oils and soft spreadable margarines, and 5% of total fat in other foods (12). More work needs to be done in the other EMR countries that do not have any TFA replacement strategy. In fact, policy interventions to eliminate industrial TFAs from food have been proposed as the most effective public health approach for reducing TFA intake and reducing the burden of NCDs (166). Based on several modeling studies, a recent systematic review showed that policies that set TFA limits are likely to be cost-saving in addition to having the greatest impact on lower socioeconomic groups (9). These are vital considerations for policymakers in countries of the region in terms of deciding whether or not to adopt a TFA reduction policy (9). Downs et al. argued that TFA bans make sense from both an economic standpoint as well as an ethical perspective, given that they could contribute to reducing social inequities (9). It is however also acknowledged that the adoption of a TFA removal policy will also require substantial political commitment and a high level of public pressure for change, which may not be readily available or achievable in many countries of the region (6).

Besides TFA limits or bans, complementary TFA reduction approaches have been implemented in several countries of the region. This is a positive finding given that multicomponent interventions, including a legislative ban on high TFA products, may increase the impact and effectiveness of TFA reduction strategies (6). Consumer education was the most common

complementary approach in countries of the EMR, with the aim of raising awareness about TFA, its main dietary sources and its adverse health effects. For instance, the reduction of TFA intake has been included in country-specific food-based dietary guidelines in Jordan and Qatar. Such guidelines and their communication to the public has been recognized as a practical and effective approach in improving the consumer's dietary knowledge and attitudes (167, 168). While none of the countries had assessed consumers' attitude toward TFA, the few available studies that have assessed consumers' knowledge had in fact shown that consumers have poor or little knowledge related to the sources of TFA (101) and the potential health effects of excessive TFA consumption (102). From the few available studies on practices, one study conducted in KSA, has shown that the vast majority of adolescents and adults are not interested in checking TFA-related information on the food label (75). While, few studies have shown that a large percentage of consumers (31.5–45%) continue to use high TFA sources (e.g., hydrogenated vegetable oils) in Iran and Pakistan (99, 105, 106), other studies reported much smaller estimates (0–7.3%) in Iran, Iraq, KSA and the UAE (100, 103, 104, 107). It is recommended that countries of the region consult findings stemming from the available knowledge and practice investigations when developing or further tailoring their consumer education initiatives in order to address culture-specific gaps in knowledge and identify barriers against TFA reduction. Acknowledging that labeling can be an important element of national strategies aimed at improving the population's diets and reducing TFA intake (6), a promising finding of this review is the fact that TFA-specific labeling initiatives are being implemented or planned in 9 countries of the region. Of these, front of pack labeling, which is recognized as being easily understood by the consumer (169), is being implemented in Iran. The fact that taxation was the least implemented/adopted in the region is in line with reports from other parts of the world (6).

This review showed that a number of countries have included a legislative component within their TFA reduction strategies, instead of implementing solely voluntary initiatives. Previous studies have shown that mandatory or legislative approaches tend to be more effective, producing more significant reductions in TFA intake levels within the population, compared to voluntary approaches (6). A recent systematic review has concluded that, although all policy approaches may lead to reductions in TFA levels in foods and subsequent intakes, stronger policies (i.e., mandatory TFA limits or bans) will have more pronounced effects than voluntary food reformulation or labeling approaches (6).

The implementation of clear monitoring activities is essential to demonstrate program effectiveness, and to incite greater impact on TFA reduction (12). In the EMR, five countries only (Iran, Bahrain, KSA, Kuwait, and Qatar) have established mechanisms for the monitoring of TFA content in edible oils, fats, bakery and snack products, using laboratory analyses. The lack of laboratory capacity to perform TFA measurements in foods, especially in lower-resourced countries, may in fact be a barrier to monitoring and enforcement (12). Some countries in the region have mandatory labeling (TFA declaration on nutrient facts panels and/ or PHO on the ingredients list), which should ensure compliance with regulations. However, even when labeling requirements are already in place, it is crucial for countries to be able to confirm, through laboratory testing, that the food industry is complying with the information on the labels. For those countries that do not have mandatory labeling requirements, these have to rely solely on laboratory testing of TFA levels to monitor compliance. More work needs to be done to support countries, particularly in low resource settings, in conducting TFA laboratory analyses. An additional measure that can be explored is the identification of laboratories in the region that have demonstrated capacities for analyzing TFAs in foods and which can support laboratory testing in neighboring countries (12).

Data on the impact of TFA reduction initiatives is scarce in the region. Except for Iran and the UAE, where there is evidence of a decrease in the population's TFA intake after the implementation of TFA reduction strategies (14, 39, 41, 51), none of the other countries have conducted impact evaluation. The impact on TFA levels in foods is also sparsely described, with only Iran having provided such evidence (41, 116, 170). The scarcity of data may be partially due to the fact that many reduction initiatives in the region are relatively recent and there has been insufficient time to assess impact. There is a need for well-designed impact evaluations in countries of the region. The WHO analytical protocol for TFA analysis (98) provides a valuable tool for such undertakings, allowing for the implementation of standardized methodologies in the analysis of TFA in foods and hence the documentation of change in TFA levels over time. Standardized comparable dietary approaches to measuring TFA intake in the population are also needed. Although dietary approaches carry their own inherent limitations in TFA intake assessment (164), if the adopted method of assessment is consistent, it can still be a useful measure of change over time (171, 172). Since the regular measurement of changes in population TFA intake and in TFA levels in foods may be complex and costly, the incorporation of process evaluations that examine the strategy implementation and its progress, collects process indicators, and identifies existing barriers and facilitators of implementation is also vital in providing real-time information and identifying specific areas for improvement (173).

This review has a number of strengths and limitations. This is the first systematic review of existing TFA reduction initiatives in countries of the EMR, their implementation and progress over time. In addition to the systematic search of databases and gray literature, additional input was sought from focal points or program leaders in the various countries that were identified as having existing TFA reduction initiatives, to verify and obtain supplementary country-specific data. Although not all country contacts were identified and there were some non-respondents, the triangulation of data from multiple sources allowed us to document the existing initiatives and implementation of strategies, and present the information in a relatively standardized manner. Through this, it is unlikely that any major TFA reduction initiatives were omitted, although this possibility cannot be totally disregarded. While one of the major strengths of the review is the fact that it included a comprehensive

search of the gray literature, comprising governmental reports, presentations or questionnaires completed by country program leaders, a potential limitation associated with this approach is the fact that the methodological rigor within some of the reports is not ascertained. More specifically, the robustness of the studies, their methodology and the quality of the data used for the assessment of TFA intake and TFA levels in foods were not assessed and hence should be interpreted with caution. It is also important to note that studies that have reported on TFA intake were scarce and that dietary estimation of TFA intake levels is by itself limited by the scarcity of up-to date, culture-specific food composition databases.

CONCLUSION

Despite the ongoing TFA reduction initiatives in several countries of the region, this study showed that intake estimates from several countries of the EMR remain high, exceeding the WHO upper limit of 1%. This review has also shown that 14 countries (63.6%) have adopted TFA limits or bans to reduce TFA levels in the food supply, albeit with significant disparities between countries in policy scope and coverage. It is recommended that all countries of the region align with the global best practice policies by implementing a ban on PHO and setting mandatory national limit of 2 g of industrially produced TFA per 100 g of total fat in all foods (12). Further action is needed to make sure that countries strengthen their regulatory capacities to help accelerate implementation, compliance monitoring and enforcement of TFA policy actions, and meet the targeted elimination of industrially produced TFA in 2023.

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

AA-J and LN: conceptualization, investigation, resources, and supervision. LN: methodology and writing—original draft preparation. SN: systematic database search. MT, AC, and LN: data curation. MT and AA-J: writing—review and editing. AA-J: project administration. ZA, BA, NA, MMA, SA, RA, SAA, MHA, NB, RB, FB, LE, JE, MH, HM, and MN: critical review of country-specific data and of manuscript. All authors have read and agreed to the published version of the manuscript.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.771492/full#supplementary-material

REFERENCES

1. World Health Organization. *Cardiovascular Diseases*. Available online at: https://www.who.int/health-topics/cardiovascular-diseases#tab=tab_1 (accessed 25 January 2021).
2. Verneque BJF, Machado AM, de Abreu Silva L, Lopes ACS, Duarte CK. Ruminant and industrial trans-fatty acids consumption and cardiometabolic risk markers: a systematic review. *Crit Rev Food Sci Nutr.* (2020) 1–11. doi: 10.1080/10408398.2020.1836471. [Epub ahead of print].
3. Persistence Research Market. *PHO and Non PHO Based Oils and Fats Market: Global Industry Analysis 2013–2017 and Forecast 2018–2026*. New York, NY: Persistence Research Market (2018).
4. Wang Q, Afshin A, Yakoob MY, Singh GM, Rehm CD, Khatibzadeh S, et al. Impact of nonoptimal intakes of saturated, polyunsaturated, and trans fat on global burdens of coronary heart disease. *J Am Heart Assoc.* (2016) 5:e002891. doi: 10.1161/JAHA.115.002076
5. Mozaffarian D, Willett WC. Trans fatty acids and cardiovascular risk: a unique cardiometabolic imprint? *Curr Atheroscler Rep.* (2007) 9:486–93. doi: 10.1007/s11883-007-0065-9
6. Hyseni L, Bromley H, Kypridemos C, O'Flaherty M, Lloyd-Williams F, Guzman-Castillo M, et al. Systematic review of dietary trans-fat reduction interventions. *Bull World Health Organ.* (2017) 95:821–30. doi: 10.2471/BLT.16.189795
7. World Health Organization. *Web-Based Consultation on the Development of a Global Monitoring Framework and Targets for the Prevention and Control of NCDs.* New York, NY: World Health Organization (2012). Available online at: https://www.who.int/nmh/events/2012/ncd_discussion_paper/en/
8. Mozaffarian D, Jacobson MF, Greenstein JS. Food reformulations to reduce trans fatty acids. *N Engl J Med.* (2010) 362:2037–39. doi: 10.1056/NEJMc1001841
9. Downs SM, Bloem MZ, Zheng M, Catterall E, Thomas B, Veerman L, et al. The impact of policies to reduce trans fat consumption: a systematic review of the evidence. *Curr Dev Nutr.* (2017) 1:117–26. doi: 10.3945/cdn.117.000778
10. 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
11. World Health Organization. *WHO Plan to Eliminate Industrially-Produced Trans-Fatty Acids From Global Food Supply*. Available online at: https://www.who.int/news/item/14-05-2018-who-plan-to-eliminate-industrially-produced-trans-fatty-acids-from-global-food-supply (accessed 1 June (2021)
12. World Health Organization. *Countdown to 2023: WHO Report on Global Trans-Fat Elimination 2019*. Geneva: World Health Organization (2019). Available online at: https://apps.who.int/iris/bitstream/handle/10665/331300/9789241516440-eng.pdf?sequence=1&isAllowed=y
13. Mokdad A, Tehrani-Banihashemi A, Moradi-Lakeh M, El Bcheraoui C, Charara R, Afshin A, et al. Burden of cardiovascular diseases in the Eastern Mediterranean Region, 1990-2015: findings from the global burden of disease 2015 study. *Int J Public Health.* (2018) 63:S1. 137–49. doi: 10.1007/s00038-017-1012-3
14. Al Jawaldeh A, Al-Jawaldeh H. Fat intake reduction strategies among children and adults to eliminate obesity and non-communicable diseases in the Eastern Mediterranean region. *Child Basel.* (2018) 5:89–107. doi: 10.3390/children5070089
15. World Health Organization Regional Office for the Eastern Mediterranean. *Strategy on Nutrition for the Eastern Mediterranean Region 2020–2030*. Cairo: World Health Organization (2019). Available online at: https://applications.emro.who.int/docs/9789290222996-eng.pdf

16. Santos JA, Tekle D, Rosewarne E, Flexner N, Cobb L, Al-Jawaldeh A, et al. A systematic review of salt reduction initiatives around the world: a midterm evaluation of progress towards the 2025 global non-communicable diseases salt reduction target. *Adv Nutr.* (2021) 12:1768–80. doi: 10.1093/advances/nmab008
17. World Health Organization Regional Office for the EasternMediterranean. *Countries in the Eastern Mediterranean Region.* Available online at: http://www.emro.who.int/countries.html (accessed October 7, 2021).
18. CAB International. *CAB Direct.* Available online at: https://www.cabdirect.org/ (accessed February 17, 2021).
19. *Directory of Open Access Journals*. Available online at: https://www.doaj.org/ (accessed February 17, 2021).
20. Google. *Google Scholar.* Available online at: https://scholar.google.com/ (accessed February 17, 2021).
21. Ovid. *MEDLINE.* Available online at: https://ovidsp.dc2.ovid.com/ovid-a/ovidweb.cgi (accessed February 18, 2021).
22. National Library of Medicine. *Pubmed.* Available online at: https://pubmed.ncbi.nlm.nih.gov/ (accessed February 18, 2021).
23. Elsevier. *Scopus.* Available online at: https://www.scopus.com/standard/marketing.uri#basic (accessed February 18, 2021).
24. Clarivate. *Web of Science Core Collections*. Available online at: https://www.webofscience.com/wos/woscc/basic-search (accessed February 19, 2021).
25. EBSCO. *Food Science and Technology Abstracts*. Available online at: https://web.a.ebscohost.com/ehost/search/basic?vid=0&sid=6fc621d0-de07-408a-9c52-1aa847338022%40sdc-v-sessmgr03 (accessed February 19, 2021).
26. *Al Manhal.* Available online at: https://platform.almanhal.com/ (accessed February 19, 2021).
27. EBSCO. *Arab World Research Source.* Available online at: https://web.b.ebscohost.com/ehost/search/basic?vid=0&sid=c408c320-39e4-4969-8c91-4e9e892fd2c0%40pdc-v-sessmgr03 (accessed February 20, 2021).
28. *E-Marefa.* Available online at: https://search.emarefa.net/en (accessed February 20, 2021).
29. Ministry of Higher Education and Scientific Research of Iraq. *Iraqi Academic Scientific Journals.* Available online at: https://www.iasj.net/iasj?func=search&uiLanguage=en (accessed February 20, 2021).
30. *OpenGrey.* Available online at: http://www.opengrey.eu/ (accessed March 1, 2021).
31. *Google.* Available online at: https://www.google.com/ (accessed March 8, 2021).
32. World Healh Organization. *Global Database on the Implementation of Nutrition Action.* Available online at: https://extranet.who.int/nutrition/gina/en/policies/summary (accessed March 15, 2021).
33. *World Health Organization Regional Office for the Eastern Mediterranean*. Available online at: http://www.emro.who.int/index.html (accessed March 22, 2021).
34. Resolve to save lives-an initiative of vital strategies. *7-Step Guide for Country Policy Makers to Develop and Implement a Trans Fat Elimination Policy: Fact Sheet*. New York, NY: Resolve to Save Lives. Available online at: https://linkscommunity.org/assets/PDFs/7-step-trans-fat-elimination-guide_fact-sheet.pdf
35. World Health Organization. *REPLACE Trans Fat.* Available online at: https://www.who.int/teams/nutrition-and-food-safety/replace-trans-fat (accessed July 26, 2021).
36. Resolve to save lives-an initiative of vital strategies. *Policy Inventory for Effective Trans Fat Regulations: Fact Sheet.* New York, NYUS: Resolve to Save Lives. Available online at: https://linkscommunity.org/assets/PDFs/policy-inventory-for-effective-tfa-regulations_fact-sheet.pdf
37. Colón-Ramos U, Monge-Rojas R, Campos H. Impact of WHO recommendations to eliminate industrial trans-fatty acids from the food supply in Latin America and the Caribbean. *Health Policy Plan.* (2014) 29:529–41. doi: 10.1093/heapol/czt034
38. 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) 91:262–69. doi: 10.2471/BLT.12.111468
39. Mozaffarian D, Abdollahi M, Campos H, Houshiarrad A, Willett W. 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
40. Esmaeili M, Abdollahi M, Abdollahi Z, Salehi F, Ajami M, Houshiarrad A. *Effect of Policymaking to Reduce TFA Intake in 6 Provinces of Iran.* Tehran: National Nutrition and Food Technology Research Institute (2014).
41. 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) 34:136–43. doi: 10.47176/mjiri.34.136
42. Hosseini H, Abedi A, Abdollahi Z, Hajfaraji M, Mohammadi A. *Fatty Acid Compositions of Frequently Consumed Edible Fat and Oil in Iran With Special Emphasis on Trans Fatty Acids.* Tehran: Department of Research of Food Technology, National Nutrition and Food Technology Research Institute, Shahid Beheshti University of Medical Sciences (2013).
43. Mirmiran P, Ziadlou M, Karimi S, Hosseini-Esfahani F, Azizi F. The association of dietary patterns and adherence to WHO healthy diet with metabolic syndrome in children and adolescents: Tehran lipid and glucose study. *BMC Public Health.* (2019) 19:1457. doi: 10.1186/s12889-019-7779-9
44. Alkurd RA. Estimated intakes of fats, cholesterol, fiber, sodium, calcium, potassium, and magnesium in Jordan. *Aust J Basic Appl Sci.* (2011) 5:3171–78. Available online at: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.378.4001&rep=rep1&type=pdf
45. Takruri HR, Alkurd RA. Intakes of fats, cholesterol, fiber and micronutrients as risk factors for cardiovascular disease in Jordan. *Jordan J Biol Sci.* (2014) 7:119–26. doi: 10.12816/0008225
46. Tayyem RF, Albataineh SR, Allehdan SS, Badran EF. Development and validation of a food frequency questionnaire for assessing nutrient intake during childhood in Jordan. *Nutr Hosp.* (2020) 37:1095–106. doi: 10.20960/nh.03079
47. Moghames P, Hammami N, Hwalla N, Yazbeck N, Shoaib H, Nasreddine L, et al. Validity and reliability of a food frequency questionnaire to estimate dietary intake among Lebanese children. *Nutr J.* (2016) 15:1–12. doi: 10.1186/s12937-015-0121-1
48. Farhat AG, Jaalouk D, Moukarzel SR, Ayoub JJ. Consumption of trans fatty acid and omega 6 to omega 3 ratio in Lebanese adults. *Nutr Food Sci.* (2016) 46:120–29. doi: 10.1108/NFS-07-2015-0089
49. Ministry of Health-Morocco, World Health Organization. *Reduction, Replacement or Elimination Trans Fatty Acids in Foods.* Rabat: Ministry of Health-Morocco (2020).
50. Al Jawaldeh A, Al-Jawaldeh H. Scaling up obesity and NCD prevention in the Eastern Mediterranean region through fat reduction intake strategies at population levels. *Preprints.* (2018) 2018:2018040218. doi: 10.20944/preprints201804.0218.v1
51. Ismail LC, Hashim M, Jarrar AH, Mohamad MN, Saleh ST, Jawish N, et al. Knowledge, attitude, and practice on salt and assessment of dietary salt and fat intake among university of sharjah students. *Nutrients.* (2019) 11:941–55. doi: 10.3390/nu11050941
52. Abd El-Gawad IA, Hamed EM, Zidan MA, Shain AA. Fatty acid composition and quality characteristic of some vegetable oils used in making commercial imitation cheese in Egypt. *J Nutr Food Sci.* (2015) 5:380–84. doi: 10.4172/2155-9600.1000380
53. Sadek MAS, Daoud JR, Ahmed HY, Mosaad GM. Nutritive value and trans fatty acid content of fast foods in Qena city, Egypt. *Nutr Food Sci.* (2018) 48:498–509. doi: 10.1108/NFS-11-2017-0235
54. Taher E, El-Essawy H, Saudi A, Aly S. Fatty acid profile of some fat rich foods with special reference to their trans fatty acids content. *Int J Pharm Chem Sci.* (2018) 7:31–7. Available online at: https://www.researchgate.net/publication/327557156_Fatty_Acid_Profile_of_Some_Fat_Rich_Foods_with_Special_Reference_to_their_Trans_Fatty_Acids_Content
55. Abdel-Moemin AR. Consumer satisfaction and nutrient profile of reformulated dry soups. *Agricultura.* (2014) 11:27–34. Available online at: https://www.dlib.si/stream/URN:NBN:SI:DOC-KLVSNLI8/3b109178-5cc3-4ea6-b2bd-46bd54eebabb/PDF
56. Jamali A, Moslemi M, Akramzadeh N, Khaneghah AM, Dadgarnejad M. Safety factors of oils marketed in Iran and applicable strategies in control of food derived cardiovascular diseases. *Curr Nutr Food Sci.* (2020) 16:571–77. doi: 10.2174/1573401315666181204110604
57. 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

58. Farmani J, Gholitabar A. Characterization of vanaspati fat produced in Iran. *J Am Oil Chem Soc.* (2015) 92:709–16. doi: 10.1007/s11746-015-2641-4
59. Butt MS, Sultan MT. Levels of trans fats in diets consumed in developing economies. *J AOAC Int.* (2009) 92:1277–83. doi: 10.1093/jaoac/92.5.1277
60. Hajimahmoodi M, Arami S, Nosrati M, Moghaddam G, Sadeghi N, Oveisi MR, et al. Trans fatty acid content of iranian edible oils. *Food Nutr Sci.* (2013) 4:1167–74. doi: 10.4236/fns.2013.411150
61. Chaharmahali NV, Asadollahi S, Hosseini E. Measurement and comparison of trans fatty acids amount in some of the vegetable oils, frying oils and animal and vegetable fats in Iran. *Int J Bio-Inorg Hybr Nanomater.* (2018) 7:59–64. Available online at: http://ijbihn.iauvaramin.ac.ir/article_661308_2c4be74369787ba8fb04bbb56c17c91c.pdf
62. Abedi AS, Hosseini H, Mohammadi A, Abdollahi Z, Hajifaraji M, Khaneghah AM. Fatty acid (FA) compositions and trans content of frequently consumed edible oils and fats from iran' market. *Curr Nutr Food Sci.* (2016) 12:56–64. doi: 10.2174/1573401311666150930215645
63. Stender S. Trans fat in foods in Iran, South-Eastern Europe, caucasia and central Asia: a market basket investigation. *Food Policy.* (2020) 96:101877–86. doi: 10.1016/j.foodpol.2020.101877
64. Pasdar Y, Bahrami G, Alghasi S, Darbandi M, Hemati Azandaryani A, Bahrami S, et al. Trans fatty acids contents among selected foods in Western Iran. *Int J Health Life Sci.* (2016) 2:32–41. Available online at: https://en.civilica.com/doc/752250/
65. Ghazavi N, Rahimi E, Esfandiari Z, Shakerian A. Accuracy of the amount of trans-fatty acids in traffic light labelling of traditional sweets distributed in Isfahan, Iran. *ARYA Atheroscler.* (2020) 16:79–84. doi: 10.22122/arya.v16i2.2005
66. Nazari B, Asgary S, Azadbakht L. Fatty acid analysis of Iranian junk food, dairy, and bakery products: special attention to trans-fats. *J Res Med Sci.* (2012) 17:952–57. Available online at: https://www.proquest.com/docview/1312683984/citation/F4F1B50C56764213PQ/1?accountid=8555
67. Teimouri M, Najafi M, Eskandarion MR, Parto F. Assessment of Trans Fatty Acids content in Iranian food products. *Innov Food Technol.* (2014) 2:93–100. doi: 10.22104/JIFT.2014.69
68. Bahrami G, Mirzaeei S, Kiani A, Atefi G. Assessment of profile of fatty acids and trans fats in hydrogenated oils in Iran. *J Kermanshah Univ Med Sci.* (2003) 7:1–2. doi: 10.22110/JKUMS.V7I1.860
69. Pasdar Y, Bahrami G, Karvand F, Khodadoost M, Rezaei M, Niazi S. Determining the fatty acid content of the most common meat products in Kermanshah, Iran. *Jorjani Biomed J.* (2013) 1:42–51. Available online at: http://goums.ac.ir/jorjanijournal/article-1-120-en.html
70. Asgary S, Nazari B, Sarrafzadegan N, Parkhideh S, Saberi S, Esmaillzadeh A, et al. Evaluation of fatty acid content of some Iranian fast foods with emphasis on trans fatty acids. *Asia Pac J Clin.* (2009) 18:187–92. doi: 10.6133/APJCN.2009.18.2.06
71. Asgary S, Nazari B, Sarrafzadegan N, Saberi S, Azadbakht L, Esmaillzadeh A. Fatty acid composition of commercially available Iranian edible oils. *J Res Med Sci.* (2009) 14:211–15. Available online at: https://pdfs.semanticscholar.org/f3b0/fab82f684f81734bcadf0a38adfd37114863.pdf?_ga=2.224134749.756192505.1636364596-1571069892.1585236721
72. Mashai R, Ai-Ismail K, Al-Domi H, Al-Mousa T. Variability in trans fatty acid content of selected local and imported foods in Jordan. *Riv Ital Sostanze Gr.* (2012) 89:193–200. Available online at: https://www.academia.edu/21339388/Variability_in_trans_fatty_acid_content_of_selected_local_and_imported_foods_in_Jordan
73. Bakeet ZAN, Alobeidallah FMH, Shaista A. Fatty acid composition with special emphasis on unsaturated trans fatty acid content in margarines and shortenings marketed in Saudi Arabia. *Int J Biosci.* (2013) 3:86–93. Available online at: https://www.cabdirect.org/cabdirect/abstract/20133097510
74. Alfawaz MA. Trans fatty acids in a selection of foods and oils available in Riyadh markets. *Bull Fac Agric Cairo Univer.* (2004) 55:315–30.
75. Kamel S, Al Otaibi H. Trans-fats declaration, awareness and consumption in Saudi Arabia. *Curr Res Nutr Food Sci.* (2018) 6:748–56. doi: 10.12944/CRNFSJ.6.3.17
76. Jradi H, AlMughthem A, Bawazir AA. *Does the Current Scope of Nutrition Labelling Provided in the Saudi Markets Cope With the Increasing Trend of Chronic Disease*? Durhan: Research square (2020). doi: 10.21203/rs.2.23201/v1
77. Al-Amiri HA, Ahmed N, Al-Sharrah T. Fatty acid profiles, cholesterol composition, and nutritional quality indices of 37 commonly consumed local foods in Kuwait in relation to cardiovascular health. *medRxiv.* (2020) 1–28. doi: 10.1101/2020.11.18.20233999
78. Nasreddine L, Naja F, Sibai A-M, Helou K, Adra N, Hwalla N. Trends in nutritional intakes and nutrition-related cardiovascular disease risk factors in Lebanon: the need for immediate action. *Leb Med J.* (2014) 62:83–91. doi: 10.12816/0004102
79. Saadeh C, Toufeili I, Zuheir Habbal M, Nasreddine L. Fatty acid composition including trans-fatty acids in selected cereal-based baked snacks from Lebanon. *J Food Compost Anal.* (2015) 41:81–5. doi: 10.1016/j.jfca.2015.01.014
80. Saade CN. *Fatty Acid Composition, Including Trans Fatty Acids, of Some Local and Regional Bakery and Snack Products in the Lebanese Market-by Carol Nakhle Saade*. Beirut: American University of Beirut (2007).
81. Sherazi S, Kandhro A, Mahesar S, Bhanger M, Talpur MY, Arain S. Application of transmission FT-IR spectroscopy for the trans fat determination in the industrially processed edible oils. *Food Chem.* (2009) 114:323–27. doi: 10.1016/j.foodchem.2008.09.058
82. Tarar OM, Ahmed KM, Nishtar NA, Achakzai AB, Gulzar Y, Delles C, et al. Understanding the complexities of prevalence of trans fat and its control in food supply in Pakistan. *J Clin Hypertens.* (2020) 22:1338–46. doi: 10.1111/jch.13943
83. Anwar F, Bhanger M, Iqbal A, Sultana B. Fatty acid composition of different margarines and butters from Pakistan with special emphasis on trans unsaturated contents. *J Food Qual.* (2006) 29:87–96. doi: 10.1111/j.1745-4557.2006.00058.x
84. Mahesar S, Kandhro AA, Cerretani L, Bendini A, Sherazi S, Bhanger M. Determination of total trans fat content in Pakistani cereal-based foods by SB-HATR FT-IR spectroscopy coupled with partial least square regression. *Food Chem.* (2010) 123:1289–93. doi: 10.1016/j.foodchem.2010.05.101
85. Karim Z, Khan KM, Ahmed S, Karim A. Assessment of trans fatty acid level in French fries from various fast food outlets in Karachi, Pakistan. *J Am Oil Chem Soc.* (2014) 91:1831–36. doi: 10.1007/s11746-014-2530-2
86. Sherazi S, Kandhro AA, Mahesar S, Talpur MY, Latif Y. Variation in fatty acids composition including trans fat in different brands of potato chips by GC-MS. *Pak J Anal Environ Chem.* (2010) 11:36–41. Available online at: https://www.researchgate.net/publication/236021398_Variation_in_Fatty_Acids_Composition_Including_Trans_Fat_in_Different_Brands_of_Potato_Chips_by_GC-MS
87. Kandhro A, Sherazi S, Mahesar S, Bhanger M, Talpur MY, Arain S. Monitoring of fat content, free fatty acid and fatty acid profile including trans fat in Pakistani biscuits. *J Am Oil Chem Soc.* (2008) 85:1057–61. doi: 10.1007/s11746-008-1297-8
88. Shah F, Rasool G, Sharif MK, Pasha I, Ahmad S, Sharif HR. Determination of trans fat in traditional Pakistani breakfast and snack foods. *Int Food Res J.* (2016) 23:849–53.
89. Aftab A, Sherazi S, Rubina S, Razia S, Arfa Y. Consequence of fatty acids profile including trans fat in chocolate and pastry samples. *Int Food Res J.* (2013) 20:601–05. Available online at:https://www.semanticscholar.org/paper/Consequence-of-fatty-acids-profile-including-trans-Aftab-Sherazi/17701e734d0c97aad1f029d01801d52d13a2e615
90. Kandhro A, Sherazi S, Mahesar S, Bhanger M, Talpur MY, Rauf A. GC-MS quantification of fatty acid profile including trans FA in the locally manufactured margarines of Pakistan. *Food Chem.* (2008) 109:207–11. doi: 10.1016/j.foodchem.2007.12.029
91. Bhanger MI, Anwar F. Fatty acid (FA) composition and contents of trans unsaturated FA in hydrogenated vegetable oils and blended fats from Pakistan. *J Am Oil Chem Soc.* (2004) 81:129–34. doi: 10.1007/s11746-004-0870-2
92. Naz R, Anjum FM, Rasool G, Nisar MA, Batool R, Saeed F. Total trans fat content in commercially available hydrogenated vegetable oils. *Pak J Nutr.* (2012) 11:145–49. doi: 10.3923/pjn.2012.145.149
93. Selmi S, Ghiloufi R, El-Ati J. Trans fatty acids content of selected popular Tunisian fast food. *J New Sci.* (2019) 68:4232–39. Available online

at: https://www.jnsciences.org/agri-biotech/99-volume-68/600-trans-fatty-acids-content-of-selected-popular-tunisian-fast-food.html
94. Al-Ismail KM, Takruri HR, Tayyem RF, Al-Dabbas MM, Abdelrahim DN. Trans fatty acids content of sweets and appetisers traditionally consumed in Jordan. *Riv Ital Sostanze Gr.* (2021) 98:129–35. Available online at: https://www.innovhub-ssi.it/kdocs/2012987/2021_vol._982_-_art._06_-_al-ismail.pdf
95. Dashti B, Al-Awadi F, Sawaya W, Al-Otaibi J, Al-Sayegh A. Fatty acid profile and cholesterol content of 32 selected dishes in the state of Kuwait. *Food Chem.* (2003) 80:377–86. doi: 10.1016/S0308-8146(02)00277-7
96. Sawaya WN, Al-Awadhi F, Naeemi I, Al-Sayegh A, Ahmad N, Khalafawi MS. Dietary fat profiles of composite dishes of the Arabian Gulf country of Kuwait. *J Food Compost Anal.* (1998) 11:200–11. doi: 10.1006/jfca.1997.0557
97. Ismail G, Naga RAE, Zaki MES, 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) 13:3087–95. doi: 10.3390/nu13093087
98. World Health Organization. *Protocol for Measuring Trans Fatty Acids in Foods*. (2021). Available online at: https://www.who.int/docs/default-source/documents/replace-transfats/a-food-analysis-lab-protocol.pdf?sfvrsn=b27e4111_2
99. Dogani F, Najjari F, Naghizadeh MM, Dehghan A, Jeihooni AK, Askari A, et al. Analyzing food patterns and preferences of urban population of fasa (phase i of studying the nutritional healthy city in fasa). *Gazi Med J.* (2019) 30:352–57. doi: 10.12996/gmj.2019.91
100. Borzouei A, Azadbakht L. Describing the dietary habits of Isfahan young girls: assessing the status of tea consumption, processed foods, fats and cooking methods. *Health Syst Res.* (2010) 6:2. Available online at: https://www.sid.ir/en/Journal/ViewPaper.aspx?ID=201295
101. Al-Akash HY, AbuRuz ME, Arrah A. The university of Jordan students' concerns and awareness about trans-fatty acids. *Adv Studies Biol.* (2017) 9:63–81. doi: 10.12988/asb.2017.713
102. Manickavasagan A, Al-Mahdouri AA, Al-Mufargi AMS, Al-Souti A, Al-Mezeini ASM, Essa MM. Healthy eating knowledge among college students in Muscat: a self reported survey. *Pak J Nutr.* (2014) 13:397–403. doi: 10.3923/pjn.2014.397.403
103. Ministry of Health-Iraq, World Health Organization. *Noncommunicable Diseases Risk Factors STEPS SURVEY IRAQ 2015*. (2015). Available online at: https://www.who.int/ncds/surveillance/steps/Iraq_2015_STEPS_Report.pdf
104. Ministry of Health-Saudi Arabia, World Health Organization. *WHO STEPwise Approach to NCD Surveillance: Country-Specific Standard Report*. (2005). Available online at: https://www.who.int/ncds/surveillance/steps/2005_SaudiArabia_STEPS_Report_EN.pdf
105. Rashid A, Amjad S, Nishtar MK, Nishtar NA. Trans-Fatty acid (TFA) elimination in Pakistan: a situational analysis. *J Pak Med Assoc.* (2020) 70:S1–30. Available online at: https://www.semanticscholar.org/paper/Trans-Fatty-Acid-%28TFA%29-elimination-in-Pakistan%3A-A-Rashid-Amjad/2f2eddad70f9314a8580a2a88b23d45a1042b42b
106. Global Alliance for Improved Nutrition (GAIN), SUN Business Network (SBN). *Mapping of Industrially-Produced Trans-Fatty Acids (iTFA) in Pakistan*. Global Alliance for Improved Nutrition (2020). Available online at: https://sunbusinessnetwork.org/mapping-industrially-produced-trans-fatty-acids-in-pakistan/
107. Ministry of Health Prevention-UAE. *UAE Nutritional Status Study*. Abu Dhabi: Statistic and Research Center (2020)
108. 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
109. World Health Organization Regional Office for the Eastern Mediterranean. *Summary Report of the Virtual Meeting on Implementation of Trans Fatty Acid Elimination in the Eastern Mediterranean Report 10–11 August 2020*. Cairo: World Health Organization (2020).
110. NCD Alliance. *Trans Fat Free by 2023: Case Studies in Trans Fat Elimination*. Geneva: NCD Alliance (2019). Available online at: https://ncdalliance.org/sites/default/files/resource_files/NCDA%20Trans%20Fats%20Acids_Case%20Studies_Web_single%20pages_FINAL.pdf
111. GCC Standardization Organization (GSO). *Trans Fatty Acids GSO 2483/2015 (E)*. Riyadh (2015). Available online at: https://www.gso.org.sa/store/gso/standards/GSO:693058/GSO%202483:2015?lang=en
112. GCC Standardization Organization (GSO). *Requirements of Nutritional Labelling. Final Draft of Standard FDS. Prepared by GSO Technical Committee No. TC05. GSO 05/FDS 2233*. (2018). Available online at: https://members.wto.org/crnattachments/2018/TBT/SAU/18_5864_00_e.pdf
113. Morocco O. Moving forward on salt and fat reduction in the Region. *East Mediter Health J.* (2015) 21:374–76. doi: 10.26719/2015.21.5.374
114. World Health Organization Regional Office for the Eastern Mediterranean. *Policy Statement and Recommended Actions for Reducing Fat Intake and Lowering Heart Attack Rates in the Eastern Mediterranean Region*. Geneva: World Health Organization (2014). Available online at: https://applications.emro.who.int/docs/policy_brief_Fat_reduction_2014_EN.pdf?ua=1%20&ua=1&ua=1
115. Tehran: Iranian National Standardization Organization. *Consumer Edible Vegetable Oil: Specifications and Test Methods. INSO 9131. First Revision*. Available online at: http://standard.isiri.gov.ir/StandardView.aspx?Id=44637 (accessed May 10, 2021).
116. Moslemi M, Kheirandish M, Mazaheri RNF, Hosseini H, Jannat B, Mofid V, et al. National food policies in the islamic republic of iran aimed at control and prevention of noncommunicable diseases. *East Medit Health J.* (2020) 26:1556–64. doi: 10.26719/emhj.20.024
117. Tehran: Iranian National Standardization Organization. *Vegetable Butter (Margarine): Specifications and Test Methods. INSO 143. Fifth Revision*. Available online at: http://standard.isiri.gov.ir/StandardView.aspx?Id=43121 (accessed May 10, 2021).
118. Tehran: Iranian National Standardization Organization. *Edible Fats and Oils – Minarine: Specifications and Test Methods. INSO 10500. First Revision*. Available online at: http://standard.isiri.gov.ir/StandardView.aspx?Id=43120 (accessed May 10, 2021).
119. World Health Organization. *Cutting Into Trans Fat Consumption in Iran*. Available online at: https://www.who.int/news-room/feature-stories/detail/cutting-into-trans-fat-consumption-in-iran (accessed April 28, 2021).
120. World Health Organization. *Report on the Consultation on Developing Strategic Directions for Salt and Fat Reduction in the Eastern Mediterranean Region, <city>Cairo</city>, Egypt, 28–29 November 2012*. Cairo: World Health Organization (2013). Available online at: https://apps.who.int/iris/handle/10665/116172
121. Peymani P, Joulaie H, Zamiri N, Ahmadi SM, Dinarvand R, Hosseini H, et al. Iran's experience on reduction of trans-fatty acid content in edible oils. *Middle East J Sci Res.* (2012) 11:1207–11. doi: 10.3923/pjn.2012.768.773
122. World Health Organization Regional Office for the Eastern Mediterranean. *Report on the Technical Consultation on Salt and Fat Reduction Strategies in the Eastern Mediterranean Region, <city>Tunis</city>, Tunisia 30–31 March 2015*. World Health Organization (2015). Available online at: https://applications.emro.who.int/docs/IC_Meet_Rep_2015_EN_16339.pdf
123. Prime Ministry-Directorate of the Official Journal. *Withdraw the Jordanian Technical Base.* Jordan: Government of the Hashemite Kingdom of Jordan (2016).
124. World Health Organization Regional Office for the Eastern Mediterranean. *Nutrition: Success Stories–Jordan*. Available online at: http://www.emro.who.int/nutrition/success-stories/index.html (accessed August 18, 2021).
125. Ministry of Health-Jordan. *Low Salt, Low Sugar, Low Saturated and Trans Fat Consumption Guideline for Health Care Providers for Training of Trainees (TOT) and Pamphlet for Consumers*. Amman: Ministry of Health (2015).
126. Ministry of Health-Jordan. *Food-Based Dietary Guidelines for Jordanians*. Amman: Nutrition Department (2020). Available online at: https://www.moh.gov.jo/EchoBusV3.0/SystemAssets/PDFs/Jordan%20Guide%20Book_Website.pdf
127. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–The National Strategy And Plan of Action Against Diabetes, Hypertension, Dyslipidemia And Obesity in Jordan*. (2015). Available online at: https://extranet.who.int/nutrition/gina/en/node/25926
128. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–SFDA.FD 2483/2018 [Trans Fatty Acids]–Saudi Arabia*. (2018). Available online at: https://extranet.who.int/nutrition/gina/en/node/36039

129. Bin Sunaid FF, Al-Jawaldeh A, Almutairi MW, Alobaid RA, Alfuraih TM, Bin Saidan FN, et al. Saudi Arabia's healthy food strategy: progress & hurdles in the 2030 road. *Nutrients.* (2021) 13:2130–43. doi: 10.3390/nu13072130
130. World Health Organization Regional Office for the Eastern Mediterranean. *Summary Report on the Regional Workshop on Healthy Diet with a Focus on Trans-Fatty Acid Elimination Beirut Lebanon 19–21 March 2019*. Cairo: World Health Organization (2019). Available online at: https://apps.who.int/iris/bitstream/handle/10665/331993/WHOEMNUT283E-eng.pdf?sequence=1&isAllowed=y
131. Saudi Food Drug Authority. *Healthy Food Strategy*. Riyadh: SFDA (2018). Available online at: https://old.sfda.gov.sa/ar/awareness/Documents/SFDA-HealthyFoodStrategy.pdf
132. Saudi Food Drug Authority. *SFDA Prevents "Partially Hydrogenated Oils"(PHOs) in the Food Industry Gives a Period to the Manufacturers to Comply with the Saudi Technical Regulations*. Riyadh: SFDA (2018). Available online at: https://old.sfda.gov.sa/en/food/news/Pages/f6-12-2018a2.aspx
133. Ministry of Health-Kingdom of Saudi Arabia. *The Healthy Food Guide for the Health Practitioner*. Riyadh: Ministry of Health-Kingdom of Saudi Arabia (2020).
134. Saudi Food and Drug Authority. *The Nutritional Label Guide*. Riyadh: SFDA (2020).
135. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–A Guide for Healthy Food Terms and Conditions in Government Subsistence Purchase Contracts–Saudi Arabia*. (2019). Available online at: https://extranet.who.int/nutrition/gina/en/node/40344
136. Ministry of Health-Kuwait, Gulf Health Council, United Nations Development Programme, World Health Organization, Secretariat of the UN Inter-Agency Task Force on NCDS. *The Case for Investment in Prevention and Control of Non-Communicable Diseases in Kuwait*. Kuwait: Ministry of Health-Kuwait (2021).
137. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Kuwaiti Technical Regulation of Trans Fatty Acids (KWS GSO 2483/2017)*. (2017). Available online at: https://extranet.who.int/nutrition/gina/en/node/38174
138. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Kuwait Action PIan for SFA Intake Reduction and TFA Elimination.* Kuwait Salt lntake Reduction Strategy Preliminary Plan – Kuwait (2012). Available online at: https://extranet.who.int/nutrition/gina/en/node/36226
139. Health-Kuwait AoFaNMo. *The Role of Administration of Food and Nutrition Ministry of Health in Controlling and Prevention of Non-Communicable Diseases in Kuwait*. (2021). Kuwait City: Ministry of Health.
140. World Health Organization Regional Office for the Eastern Mediterranean. *Health Profile 2015: Kuwait*. Cairo: World Health Organization (2016). Available online at: https://rho.emro.who.int/sites/default/files/Profiles-briefs-files/EMROPUB_EN_19271-KUW.pdf
141. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Ministerial Decision No. 2019/95 Omani Standard for Bread – Oman*. (2019). Available online at: https://extranet.who.int/nutrition/gina/en/node/39755
142. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Summary of Proposed Implementation Mechanisms to Reduce Saturated and Trans Fat Consumption 2016-2020–Oman*. (2016). Available online at: https://extranet.who.int/nutrition/gina/en/node/38166
143. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–National Plan for the Prevention and Control of Chronic Non-Communicable Diseases 2016–2025*. Oman (2016). Available online at: https://extranet.who.int/nutrition/gina/en/node/39383
144. GCC Standardization Organization (GSO). *Labeling of Prepackaged Food Stuffs GSO 9/2013 (E)*. Riyadh (2013). Available online at: https://www.gso.org.sa/store/standards/GSO:615544/GSO%209:2013?lang=en
145. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Combating the Epidemic of Non-Communicable Diseases in Oman by Changing the Nutritional Quality of the Food Chain – Oman*. (2014). Available online at: https://extranet.who.int/nutrition/gina/en/node/39432.
146. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Punjab Pure Food Rules–Pakistan*. (2011). Available online at: https://extranet.who.int/nutrition/gina/en/node/38485
147. State of Palestine, Ministry of Health. *Certification Form for Mandatory Technical Instructions*. State of Palestine; Ministry of Health (2021).
148. State of Palestine, Ministry of Health. *National Nutrition Policy, Strategies and Action Plan (NNPSAP) (2017–2022)*. State of Palestine, Ministry of Health (2016).
149. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Stratégie de Prévention et de Lutte contre l'Obésité – Tunisia*. (2013). Available online at: https://extranet.who.int/nutrition/gina/en/node/23769
150. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–National Action Plan in Nutrition–UAE*. (2017). Available online at: https://extranet.who.int/nutrition/gina/en/node/37425
151. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Non Communicable Disease Prevention and Control Plan (NCD-PCP) for Lebanon 2015-2020 – Lebanon*. (2014). Available online at: https://extranet.who.int/nutrition/gina/en/node/26377
152. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Egypt National Multisectoral Action Plan for Prevention and Control of Noncommunicable Diseases (EgyptMAP-NCD) – Egypt*. (2017). Available online at: https://extranet.who.int/nutrition/gina/en/node/25915
153. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–The National Strategy for Healthy Food and Physical Activity 2015-2025–Saudi Arabia*. (2018). Available online at: https://extranet.who.int/nutrition/gina/en/node/39384
154. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Prevention des Maladies Non Transmissibles: Plan d'action Multisectoriel Pour la Promotion d'un Mode de vie sain 2015-2020 – Morocco*. (2015). Available online at: https://extranet.who.int/nutrition/gina/en/node/36194
155. Sultanate of Oman. *National Nutrition Strategy 2020-2030, National Plan for Prevention of NCD (2016-2025)*. Sultanate of Oman (2016).
156. Al Shabiba. *Muscat-Atyab Products Are Free of Hydrogenated Oils*. Available online at: https://shabiba.com/article/230570https:/alroya.om/post/240669/300-%d9%85%d9%86%d8%aa%d8%ac-%d9%85%d9%86-%d8%a3%d8%b7%d9%8a%d8%a7%d8%a8-%d8%a8%d9%84%d8%a7-%d8%b2%d9%8a%d9%88%d8%aa-%d9%85%d9%87%d8%af%d8%b1%d8%ac%d8%a9-%d9%84%d8%b3%d9%84%d8%a7%d9%85%d8%a9-%d8%a7%d9%84%d9%85%d8%b3%d8%aa%d9%87%d9%84%d9%83 (accessed May 17, 2021).
157. Ministry of Health-Palestine. *National Health Strategy*. Ministry of Health-Palestine (2019). Available online at: http://site.moh.ps/Content/Books/Byh2ENRn64uTVaLncGL6AjD1Z3dzHMEuLvgQDEC55ujpNihg8YPEVv_OTxQv6uPfFIRmT9xs7dwgvatwShEN8VoqHs83y5NWwua3THGRD73OO.pdf
158. World Health Organization Global Database on the Implementation of Nutrition Action (GINA). *Policy–Stratégie Nationale Multisectorielle de Prévention et Contrôle des Maladies Non Transmissibles (MNT) – Tunisia*. (2018). Available online at: https://extranet.who.int/nutrition/gina/en/node/39424
159. Saudi Food and Drug Authority. *Campaign to Control Trans Fats in Food Products*. Riyadh: SFDA (2020).
160. World Health Organization. *Healthy Diet. Fact Sheet No. 394*. (2020). Available online at: https://www.who.int/en/news-room/fact-sheets/detail/healthy-diet (accessed July 29, 2021.
161. World Health Organization. *Draft Guidelines on Saturated Fatty Acid and Trans-Fatty Acid Intake for Adults and Children: Draft for Public Consultation*. World Health Organization (2018). Available online at: https://extranet.who.int/dataform/upload/surveys/666752/files/Draft%20WHO%20SFA-TFA%20guidelines_04052018%20Public%20Consultation(1).pdf
162. Lichtenstein AH, Appel LJ, Brands M, Carnethon M, Daniels S, Franch HA, et al. Diet and lifestyle recommendations revision 2006: a scientific statement from the American heart association nutrition committee. *Circulation.* (2006) 114:82–96. doi: 10.1161/CIRCULATIONAHA.106.176158

163. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet.* (2019) 393:1958–72.
164. Wanders AJ, Zock PL, Brouwer IA. Trans fat intake and its dietary sources in general populations worldwide: a systematic review. *Nutrients.* (2017) 9:840–53. doi: 10.3390/nu9080840
165. Te Morenga L, Montez JM. Health effects of saturated and trans-fatty acid intake in children and adolescents: systematic review and meta-analysis. *PLoS ONE.* (2017) 12:e0186672. doi: 10.1371/journal.pone.0186672
166. Mozaffarian D, Stampfer MJ. Removing industrial trans fat from foods. *BMJ.* (2010) 340:c1826. doi: 10.1136/bmj.c1826
167. Serra-Majem L, Tomaino L, Dernini S, Berry EM, Lairon D, Ngo de la Cruz J, et al. Updating the mediterranean diet pyramid towards sustainability: focus on environmental concerns. *Int J Environ Res Public Health.* (2020) 17:8758–77. doi: 10.3390/ijerph17238758
168. Fernandez ML, Raheem D, Ramos F, Carrascosa C, Saraiva A, Raposo A. Highlights of current dietary guidelines in five continents. *Int J Environ Res Public Health.* (2021) 18:2814–22. doi: 10.3390/ijerph18062814
169. 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) 12:330–45. doi: 10.3390/nu12020330
170. Takian A, Amerzadeh M. *An International Comparative Policy Analysis to Accelerate Actions against Non-Communicable Diseases: The Experience of Iran*. Prince Mahidol Award Confrence (PMAC) (2019).
171. McLean RM. Measuring population sodium intake: a review of methods. *Nutrients.* (2014) 6:4651–62. doi: 10.3390/nu6114651
172. World Health Organization. *Reducing Salt Intake in Populations: Report of a WHO Forum and Technical Meeting, 5-7 October 2006, Paris, France*. Geneva: World Health Organization (2007). Available online at: https://www.who.int/dietphysicalactivity/Salt_Report_VC_april07.pdf
173. World Health Organization. Module 1: review. how-to guide for landscape assessment and roadmap development for elimination of trans fats. In: *REPLACE Trans Fat: An Action Package to Eliminate Industrially Produced Trans-Fatty Acids*. Geneva: World Health Organization (2019). Available online at: https://www.who.int/docs/default-source/replace-transfat/replace-module-1-re.pdf?sfvrsn=1885eaed_2

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.

APPENDIX

TABLE A1 | List of search terms.

Trans fats	"trans fat*" OR TFA OR trans fatty acids OR "partially hydrogenated oil*" OR "partially hydrogenated fat*" OR "partially hydrogenated vegetable oil*"
	AND
Reduction	reduce* OR reduction* OR reducing OR decreas* OR limit OR limits OR limitation* OR limiting OR restrict* OR reformulat* OR low*
	OR
Intake	consumption OR consuming OR consume OR consumes OR intake* OR food* OR nutrition OR diet*
	AND
Strategy/policy	standard* OR polic* OR initiative* OR tax* OR program* OR regulation* OR strateg* OR guideline* OR practice* OR legislat* OR action* OR plan OR plans OR intervention* OR law* OR campaign* OR marketing OR advertise* OR label* OR incentive* OR ban* OR recommendation*
	AND
EMR	Afghan* OR Bahrain* OR Iran* OR Persia* OR Iraq* OR Jordan* OR Kuwait* OR Lebanon* OR Lebanese OR Libya* OR Oman* OR Palestin* OR Gaza* OR "West Bank" OR Qatar* OR Saud* OR KSA OR Syria* OR Tunis* OR "United Arab Emirate*" OR UAE OR Djibouti* OR Egypt* OR Morocc* OR Pakistan* OR Somal* OR Sudan* OR Yemen* OR Levant* OR "East* Mediterranean" OR Gulf OR GCC OR Arab OR Arabia OR Arabs OR EMR OR "Middle East*" OR MENA OR "North* Africa*" OR "East* Africa*" OR "Near East*" OR "Abu Dhabi" OR Dubai OR Ajman OR Fujaira* OR Sharja* OR *Khaima* OR *Qaiwain OR *Quwain

EMR, Eastern Mediterranean Region; GCC, Gulf Cooperation Council; KSA, Kingdom of Saudi Arabia; MENA, Middle East and North Africa; TFA, trans fatty acid; UAE, United Arab Emirates.

frontiers in Nutrition

ORIGINAL RESEARCH
published: 16 December 2021
doi: 10.3389/fnut.2021.796894

Exploring Psychosocial Determinants of Eating Behavior: Fruit and Vegetable Intake Among Brazilian Adolescents

César Henrique de Carvalho Moraes[1,2]*, *Marle dos Santos Alvarenga*[1], *Jéssica Maria Muniz Moraes*[1] and *Denise Cavallini Cyrillo*[2]

[1] Graduate Program in Nutrition in Public Health, School of Public Health, University of São Paulo, São Paulo, Brazil,
[2] Department of Economics, School of Economics, Business and Accounting, University of São Paulo, São Paulo, Brazil

In most Western countries, children and adolescents do not eat the recommended amount of fruits and vegetables (FVs). Theoretical frameworks on social psychology of eating, such as the Reason Action Approach, Social Cognitive Theory, and Theory of Normal Conduct have been applied to understand how psychosocial variables can explain FV intake. However, considering those predictors is still rare on the understanding of FV intake among adolescents (particularly in Brazil) despite its importance within eating behavior. Therefore, this study explored important psychosocial determinants of weekly frequency of FV intake among Brazilian adolescents in a model testing socioeconomic status (SES) and body mass index (BMI). A cross-sectional design was performed with 429 students (58% female), mean age 14.45 (SD 1.86). Key variables of theoretical framework on social psychology of food were investigated by structural equation modeling. The model included self-efficacy, attitudes, and social norms (with its subcomponents descriptive and injunctive) as psychosocial predictors of weekly frequency of FV intake along with SES and BMI. An instrument developed for Brazilian Portuguese was used to collect psychosocial variables as well as to verify FV reported intake. The total model explained 45.5% of weekly frequency of FV intake, and self-efficacy was the only significant psychosocial determinant ($\lambda = 0.51$, $p = 0.001$). SES also showed an important effect on the model ($\lambda = 0.21$, $p = 0.001$), while for BMI no significance was observed. In conclusion, the model was adequate to understand psychosocial determinants of weekly frequency of FV intake for Brazilian adolescents, with self-efficacy and SES as the major determinants of this eating behavior.

Keywords: eating behavior, adolescent, health diet, motivation, socioeconomic status, self-efficacy, social norms

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brasilia, Brazil

Reviewed by:
Diogo Thimoteo Da Cunha, State University of Campinas, Brazil
Dayanne Maynard, University of Brasilia, Brazil

***Correspondence:**
César Henrique de Carvalho Moraes
cesar.moraes@alumni.usp.br

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

Received: *18 October 2021*
Accepted: *17 November 2021*
Published: *16 December 2021*

Citation:
Moraes CHC, Alvarenga MS, Moraes JMM and Cyrillo DC (2021) Exploring Psychosocial Determinants of Eating Behavior: Fruit and Vegetable Intake Among Brazilian Adolescents. Front. Nutr. 8:796894. doi: 10.3389/fnut.2021.796894

INTRODUCTION

In most Western countries, children and adolescents eat far less fruit and vegetables (FV) than recommended (1). Among adolescents and young adults, 45% of individuals eat FV <5 times a week (2). Particularly in Brazil, 80% of adolescents eat inadequate amounts of this food group, and 30% do not eat any FV (3). Additionally, 90% of Brazilians ingest FV below the

recommendations established by the Ministry of Health (400g/day) (4), a common situation since adolescence and which has become a public health concern in the country (5).

Many aspects can explain the lack of FV intake by adolescents, as eating behavior has multiple determinants. Among them, psychosocial determinants can have an important impact on FV, as they contribute to food preferences, the perception of what is healthy and to meaning and knowledge of food (6). Thus, knowing the relevance of key psychosocial determinants for adolescents in different contexts, and identifying the magnitude and which of these determinants have the greatest effect on FV intake are required. This knowledge can support initiatives for more assertive clinical practices, interventions, and recommendations aiming improvement of this class of eating behavior. Additionally, it is rare to find studies that evaluate sociodemographic variables (7, 8) and body mass index (BMI) (9) as moderators of psychosocial determinants of FV intake, even though consideration of these interactions is important (10, 11).

For those reasons, in a cross-sectional design, we aimed to (1) evaluate the relevance of psychosocial determinants, SES, and BMI as predictors of FV intake for Brazilian adolescents. Second, we aimed to (2) evaluate the magnitude of each determinant to FV intake, checking which one or ones are the most significant predictors.

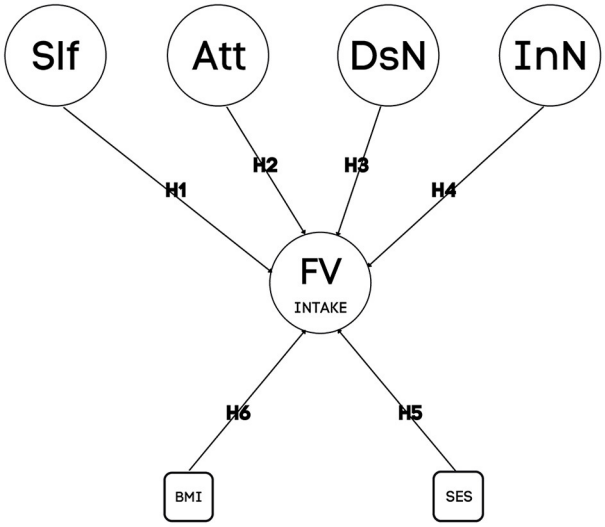


FIGURE 1 | Proposed prediction model with hypotheses for weekly frequency of Fruit and Vegetable Intake regarding social psychological determinants, Socioeconomic Status (SES), and Body Mass index (BMI). H1–H6, Hypothesis 1–6; Sl, Self-efficacy; Att, Attitudes; DsN, Descriptive social norms; InN, Injunctive social norms.

Theoretical Framework

When assessed, psychosocial determinants that potentially explain FV intake are evaluated within theoretical frameworks from social psychology (10, 12–15). Adults are the most studied group in the context of psychosocial determinants of FV intake through these frameworks, and few studies with adolescents are found (10). In Brazil, there is also a lack of studies investigating psychosocial determinants of FV intake among adolescents (16–21).

Social Cognitive Theory (22), the Normative Conduct Theory (23), the Reasoned Action Approach (24, 25), and strands, such as the Theory of Planned Behavior (26–29), are examples of frameworks that include psychosocial variables, such as self-efficacy, attitudes, and social norms (descriptive and injunctive) in models.

Self-efficacy, also called perceived behavioral control (30), includes individual's beliefs about abilities to overcome obstacles in the attempt to accomplish a behavior (22, 31). Attitudes refer to the beliefs arising from favorable or unfavorable evaluations that one makes about a goal, behavior, or another individual (32, 33). Social norms are a set of beliefs that emerge from environmental "cues" coming from a social group considered relevant to the person. Once perceived as social pressure, social norms lead to the adjustment of the individual to a social group considered relevant (34, 35). Descriptive social norms are characterized when individuals observe what the relevant social group around them does or thinks, while injunctive social norms refer to a perceived obligation imposed by the relevant group (36).

These factors are assessed together in various ways in studies that aimed to investigate psychosocial determinants for FV intake in adults and young adults (10, 13, 15, 37–40). For adolescents, these determinants were evaluated in three studies: one of them through focus groups (41) and two by non-validated instruments (11, 42). A meta-analysis (25) shows that social norms are rarely considered in their descriptive and injunctive subcomponents in health behavior scenarios. To our knowledge, there are three studies considering the subcomponents (11, 37, 43), two of which refer to FV intake (11, 37). Of these, only one study evaluated adolescents (11) and none of them used a validated instrument. In Brazil, we found only one study that evaluated psychosocial determinants of eating behavior according to social psychology theories, but with focus on fish intake and no exclusive evaluation among adolescents considering SES and BMI as moderators (44).

Because of that, we tested the hypotheses that weekly frequency of FV intake among adolescents is explained by self-efficacy (Hypothesis 1); attitudes (Hypothesis 2); descriptive social norms (Hypothesis 3); injunctive social norms; (Hypothesis 4); socioeconomic status (Hypothesis 5); and body mass index (Hypothesis 6). The model of our hypotheses is illustrated in **Figure 1**.

MATERIALS AND METHODS

Participants

A cross-sectional study was conducted with a sample of adolescents of both sexes recruited from six middle and high schools in three cities in the state of São Paulo, Southeast Brazil. Eligible participants were between 10 and 19 years old, without intellectual disabilities as identified by teachers. Both the participants and their caregivers signed the informed consent form. A non-probability-type sample was used. Sample size was

defined based on Forero et al. (45) who recommend 200 to 500 cases to studies using *Factor Analyses with ordinal indicators*.

Measures

Sex, age, level of education of adolescent and respective caregiver, and skin color were self-reported. SES was evaluated by the number of items present in the individual's daily life, based on a questionnaire from the Brazilian Association of Business and Research (46). The items were bathroom, computer, microwave oven, refrigerator, freezer, washing machine, dishwasher, dryer, and monthly cleaning assistant (responses from "none" to "2 or more items").

Self-reported weight and height were considered equivalent to the measurement versions (46). BMI was calculated by dividing each participant's weight in kg by height in square meters (m).

The refined instrument *Psychosocial Influences for fruit and vegetable Eating Scale* (PSI-FAVES)–*submitted manuscript*–evaluated the frequency of weekly FV intake reported and its psychosocial determinants for adolescents. The instrument is composed of 28 items distributed in five factors: (1) Weekly frequency of FV intake (three items) with responses from 1 (never) to 8 (7 times a week); (2) Self-efficacy (eight items) ranging from 1 (not sure) to 5 (completely sure); (3) Attitudes (nine items) ranging from 1 (strongly disagree) to 5 (strongly agree); (4) Descriptive social norms (four items) ranging from 0 (don't know) to 5 (strongly agree); and 5. Injunctive social norms (four items) ranging from 1 (do not know) to 5 (strongly agree). The complete instrument can be found in Table 2 of **Supplementary Material**.

The predictive model proposed (**Figure 1**) considered as dependent variable the frequency of weekly FV intake. Independent variables were self-efficacy, attitudes, descriptive social norms, injunctive social norms, SES, and BMI.

Procedures

The participants answered an online survey in their schools directly from computer rooms in each site. The computer rooms were prepared in advance with a link to access the set of survey instruments. The link was generated by the REDCap data management system (47), which stored the instruments and collected data securely simultaneously and online.

Data Analysis

The analyses were conducted using R (48) and JASP (49). Descriptive statistics were performed to characterize the sample. The predictive mean matching (PMM) technique was used for problems with missing data (50). Missing data frequencies below 5% were considered irrelevant (51). The significance level adopted for all analyses was $p < 0.05$. The distribution of items in each factor and the SES and BMI variables were tested for multivariate normality through skewness and kurtosis. Data normality was verified with values between −2 and 2 for skewness, and between −7 and 7 for kurtosis (52). Descriptive statistics were calculated by means and standard deviation for continuous variables, and frequency and percentages for categorical variables.

FV Intake Prediction Model

Descriptive statistics (means and standard deviation) of PSI-FAVES are presented in **Table 2**. All multivariate analyses were performed by diagonally weighted least squares (DWLS) estimation (53). First, the adjustment of PSI-FAVES to the sample was presented through a measurement model by confirmatory factor analysis (CFA), while a structural equation model (SEM) was used to verify the psychosocial variables, SES, and BMI as predictors of weekly frequency of FV. For both CFA and SEM, results indicate acceptable model fit when values of Comparative Fit Index (CFI) and Tucker-Lewis Index (TLI) are ≥ 0.9; Root Mean Square Error of Approximation (RMSEA) for a 90% Confidence Interval (CI) is ≤ 0.08 and Standardized Root Mean Residual (SRMR) is ≤ 0.08 (52–54).

For the measurement model from PSI-FAVES, convergent validity was calculated using the average extracted variance (AVE). Factors with values of AVE $\geq$0.5 indicated adequate convergent validity (55). The reliability per items and factors, and the total reliability of PSY-FAVES were calculated by McDonald's omega coefficient (ω). With a range between zero and one, the higher the values of ω, the higher the reliability indicator (56). Factors that had AVE values $\leq$0.5 but reliability $\geq$0.6 were still considered adequate for convergent validity (57). Discriminant validity was calculated by hetero-trait mono-trait (HTMT) analysis. Values of HTMT $\leq$0.9 indicated adequate discriminant validity (58).

The *R*-squared (R^2) coefficient of determination was used to measure the explained variance of the full model. Once these quality criteria were met, it was possible to test our hypotheses. To this end, the factor loadings (λ) of the determinants were considered as effect sizes and they were compared to each other to verify which had the greatest relative weights in determining the weekly frequency of FV intake (53). From zero to one, values of $\lambda \geq 0.4$ were considered acceptable. From that, the higher the value of λ, the more significant was the determinant (52).

RESULTS

Participants and Characteristics

The sample consisted of 429 participants (58% women), with mean age of 14.5 (SD 1.88) (women = 14.4, SD 2.13; men = 14.5, SD 1.82). The mean BMI (Kg/m²) was 21.37 (SD 3.97). The mean of socioeconomic items used to estimate socioeconomic status was 8 items (SD 0.23). The participants self-identified as white (52.2%), brown (36.5%), black (8%), yellow (2.6%), and indigenous (0.7%). The sample characteristics are described in **Table 1**.

All parameters showed normal distribution considering the properties of skewness and kurtosis (Table 1 of **Supplementary Material**). PSY-FAVES showed adequate adjustment to the sample [CFI = 0.96; TLI = 0.95; RMSEA (90% CI) = 0.043 (0.038–0.049); SRMR = 0.066]. Convergent validity was observed for FV (AVE = 0.78; ω = 0.52), self-efficacy (AVE = 0.57; ω = 0.83), attitudes (AVE = 0.54; ω = 0.82), and injunctive norms (AVE = 0.45; ω = 0.64). Convergent validity concerns were observed for descriptive norms (AVE = 0.3; ω = 0.52). As for discriminant validity, all values were

TABLE 1 | Sample characteristics.

	N (%)	Mean (SD)	Range
Sex*			
Female	249 (58.0%)		
Male	180 (42.0%)		
Age (in years)		14.45 (1.86)	10.91–19.33
BMI (kg/m²)		21.48 (4.14)	13.21–38.89
SES[a]		0.79 (0.23)	0.00–2.00
Adolescents' caregiver*			
Mother/father	395 (92.07%)		
Grandmother/grandfather	25 (5.82%)		
Partner	1 (0.23%)		
Uncle/aunt	4 (0.93%)		
Him/Herself	3 (0.69%)		
Another person	1 (0.23%)		
Caregiver's level of education**			
Incomplete elementary School	25 (5.82%)		
Elementary School or Grade School	36 (8.40%)		
Middle School	104 (24.29%)		
High School	113 (26.34%)		
University education	120 (27.97%)		
Postgraduate	31 (7.23%)		
Ethnicity*			
White	222 (51.74%)		
Mixed race	157 (36.59%)		
Black	36 (8.39%)		
Japanese	11 (2.56%)		
Indigenous	3 (0.69%)		

[a]*Obtained by the average number of socioeconomic items (bathroom, computer, microwave, oven, refrigerator, freezer, washing machine, dishwasher, clothes dryer, housekeeper, car, motorcycle, and DVD).* *Missing values lower than 1%.** *Missing values lower than 3%.*

adequate for all factors (HTMT = 0.06–0.65) (Tables 3, 4 of **Supplementary Material**). All factor loadings (λ) of items of the instrument were adequate (λ = 0.42–0.96). The descriptive statistics, fit indices, reliability, factor loadings, and convergent validity of PSY-FAVES are presented in **Table 2**.

FV Intake Prediction Model Using SEM

The SEM showed adequate fit of the model to the data, with CFI = 0.94, TLI = 0.93, RSMEA = 0.047 (90% CI = 0.045–0.053), and SRMR = 0.068. The full model had an explanatory power of 45.5% ($R^2 = 0.455$) (**Table 3**).

Self-efficacy was the only significant determinant of weekly frequency of FV intake corroborating prior hypothesis 1. Hypotheses 2, 3, and 4 were not confirmed in our sample and the less significant psychosocial determinant was attitudes. SES was a significant determinant for the model (confirming hypothesis 5), and no effect of BMI was found (rejecting hypothesis 6).

By analyzing the items that determined each factor (**Table 3**), weekly frequency of FV intake, self-efficacy (Slf), descriptive social norms (DsN), injunctions (InN), and attitudes (Att), we found that the most significant determinants of FV intake were Fr2: "How many times do you eat fruits in your lunch?" and Fr3: "how many times do you eat vegetables in your intervals ("e.g., sandwich with thin carrots. lettuce or tomatoes for a morning or afternoon snack)." The most significant determinants of self-efficacy (Slf) were Sefl5: "I feel able to eat fruit and vegetable when my friends are around" and Self2: "I feel able to eat more fruit and vegetables when I get home from school or work." Despite being not significant as a determinant of FV intake, attitudes had as most relevant predictors At1: "If I eat fruits and vegetables, I'll like myself better" and At: "If I eat more fruits and vegetables. I will also influence my friends to eat more." Descriptive social norms (DsN) had as main determinants DsN3: "My friends eats fruits and vegetables," DsN2: "My father eats fruits and vegetables," and DsN1: "My mother eats fruits and vegetables." Injunctive social norms (InN), which showed a negative non-significant relationship with FV intake, had as most expressive predictors InN3: "My friends think I should eat more fruits and vegetables" and InN4: "People I follow on social networks (Facebook, Instagram, Periscope, Snapchat, Blogs) argue that healthy habits like eating fruits and vegetables are important things and that's why I think I should think and do the same." The complete predictive model is shown in the diagram presented in **Figure 2**.

DISCUSSION

This study explored key psychosocial determinants (self-efficacy, attitudes, descriptive social norms, and injunctive social norms), along with potential moderators SES and BMI, to understand the weekly frequency of FV intake among Brazilian adolescents. A prediction model to test the relationship of these variables was elaborated. The model showed adequate predictive capacity and indicated that among psychosocial determinants, self-efficacy was the only one that significantly determined FV intake. Additionally, SES showed a significant effect on the model, while BMI showed no effect on the model.

Theoretical Implications of FV Intake Prediction Model

There is limited evaluation of the psychosocial determinants of FV intake among adolescents (11, 42), and to our knowledge, there is none in Brazil. Most of the studies were conducted among adults [e.g., (10, 15, 39)], and previous findings with this group have indicated that the explained variance by psychosocial determinants for FV intake in multivariate models range from 11 to 68% ($0.11 < R^2 < 0.68$) [e.g., (10, 39, 54)]. For adolescents, a study that evaluated these determinants using a multivariate model found that the explained variance of the model was 45% ($R^2 = 0.45$) (38). The explained variance in the model of our study was very similar to that: 45.5% ($R^2 = 0.455$).

We had an issue with the convergent validity for descriptive social norms. This may indicate that descriptive social norms were not equally consistent for our sample. Thus, there may be divergence regarding which reference group (father, mother,

TABLE 2 | Descriptive statistics, McDonald's omega coefficient (for the whole instrument, items and their factors), factor loadings (λ), and average variance extracted (AVE) of the *Psychosocial Influences for fruit and vegetable Eating Scale* (PSY-FAVES)[a].

Factor and determinants	Mean (SD)	McDonald's omega (ω)	λ	SE	*p*-value	AVE[d]
		ω total (PSY-FAVES) = 0.86				
FV[b,c]						
Fr1: *"How many times do you eat fruits in your breakfast"*	1.29 (1.65)	0.32	0.79	0.08	***	0.78
Fr2: *"How many times do you eat fruits in your lunch"*	1.32 (1.70)	0.47	0.91	0.09	***	
Fr3: "*how many times do you eat vegetables in your intervals ("e.g., sandwich with thin carrots. lettuce or tomatoes for a morning or afternoon snack)"*	1.76 (1.93)	0.45	0.96	0.09	***	
		ω (factor): 0.52				
Self-efficacy (Slf)						
Self1: "*I feel able to eat more fruit and vegetables everyday"*	3.65 (1.18)	0.80	0.74	0.03	***	0.57
Self2: *"I feel able to eat more fruit and vegetables when I get home from school or work"*	3.41 (1.17)	0.81	0.77	0.03	***	
Self3: *"I feel able to eat more fruit and vegetables while watching TV"*	3.17 (1.27)	0.81	0.79	0.03	***	
Self4: *"I feel able to eat more fruit and vegetable while using computer or cellphone"*	2.88 (1.32)	0.82	0.70	0.03	***	
Self5: *"I feel able to eat fruit and vegetable when my friends are around"*	2.88 (1.25)	0.88	0.88	0.03	***	
Self6: *"I feel able to eat fruit and vegetable when I'm bored"*	2.38 (1.22)	0.81	0.70	0.03	***	
Self7: *"I feel able to eat fruit and vegetable when I'm in a bad mood"*	2.38 (1.19)	0.81	0.73	0.03	***	
Self8: "I feel able to eat fruit and vegetables when I'm busy"	2.70 (1.26)	0.82	0.72	0.03	***	
		ω (factor): 0.83				
Attitudes (Att)						
At1: *"If I eat fruits and vegetables I'll like myself better"*	3.22 (1.31)	0.79	0.90	0.04	***	0.54
At2: *"If I eat fruit and vegetables I'll lose weight"*	3.66 (1.21)	0.82	0.46	0.03	***	
At3: *"If I eat fruits and vegetables I'll look better (e.g., my skin. hair and nails will look better)"*	4.09 (1.08)	0.81	0.52	0.03	***	
At4: *"If I eat fruits and vegetables I'll look better (e.g., my skin. hair and nails will look better) and I'll be more confident with myself when my friends are around"*	3.62 (1.24)	0.79	0.79	0.03	***	
At5: *"If I eat fruits and vegetables I will look better (e.g., my skin. hair and nails will look better) and I would like to show this improvement by posting texts and/or photos on social media (Facebook®. Instagram®. Periscope®. Snapchat®. Blogs. Etc.)*	3.03 (1.41)	0.80	0.76	0.04	***	
At6: *"If I eat more fruits and vegetables my family will also eat more"*	3.26 (1.28)	0.80	0.75	0.03	***	
At7: *"If I eat more fruits and vegetables my family will be proud of me"*	3.66 (1.23)	0.80	0.75	0.03	***	
At8: *"If I eat more fruits and vegetables. I will also influence my friends to eat more"*	3.04 (1.30)	0.80	0.86	0.04	***	
At9: *"If I eat more fruits and vegetables. I will be an example of health to my friends"*	3.61 (1.25)	0.81	0.70	0.03	***	
		ω (factor): 0.82				
Descriptive norms (DsN)						
Descriptive1: *"My mother eats fruits and vegetables"*	4.28 (0.96)	0.44	0.42	0.04	***	0.30
Descriptive2: "M*y father eats fruits and vegetables"*	3.86 (1.28)	0.48	0.58	0.05	***	
Descriptive3: "M*y friends eat fruits and vegetables"*	2.96 (1.12)	0.50	0.61	0.05	***	
Descriptive4: *"People I follow on social media (Facebook. Instagram. Periscope. Snapchat. Blogs) post photos eating fruits and vegetables because they seem to care about their health"*	2.63 (1.37)	0.58	0.55	0.05	***	
		ω (factor): 0.52				

(Continued)

TABLE 2 | Continued

Factor and determinants	Mean (SD)	McDonald's omega (ω)	λ	SE	*p*-value	AVE[d]
Injunctive norms (InN)						
Injunctive1: *"My mother thinks I should eat more fruits and vegetables"*	4.24 (1.06)	0.53	0.45	0.03	***	0.45
Injunctive2: "*My father thinks I should eat more fruits and vegetables"*	3.95 (1.26)	0.54	0.58	0.04	***	
Injunctive3: "*My friends think I should eat more fruits and vegetables"*	2.59 (1.27)	0.86	0.86	0.05	***	
Injunctive4: *"People I follow on social networks (Facebook. Instagram. Periscope. Snapchat. Blogs) argue that healthy habits like eating fruits and vegetables are important things and that's why I think I should think and do the same"*	3.27 (1.34)	0.76	0.76	0.05	***	
		ω (factor): 0.64				

[a]*Based on Confirmatory Factor Analysis (CFA) for a measurement model. Fit indices: Comparative Fit Index (CFI) = 0.96; Tucker-Lewis Index (TLI) = 0.95; Root Mean Square Error of Approximation (RMSEA) = 0.043 (90% Confidence Interval = 0.038–0.049); Standardized Root Mean Square Residual (SRMR) = 0.066.*
[b]*The weekly frequency was measure by the item: "Thinking in an ordinary week" following by the frequency options for each situation.*
[c]*Missing values lower than 3%.*
[d]*Calculated by the sum squares of factors loadings from CFA divided by the number of indicators of each factor.*
****p < 0.001.*

friends, or social media) is most relevant to the adolescents. Similar reliability issues were found by Pedersen et al. (11). Although the authors did not present convergent validity analyses, low reliability for descriptive social norms for the Danish adolescents was also found. They suggest that despite this norm being not equally coherent, it is still reasonable to assume that it exists (11).

Practical Implications of FV Intake Prediction Model

In our study, among the relevant contexts for our sample, the weekly frequency of FV intake came from fruits eaten during main lunch meals (i.e., "How many times do you eat fruits in your lunch"), breakfast (i.e., "How many times do you eat fruits in your breakfast"); and vegetables in the intervals [i.e., "How many times do you eat vegetable in your intervals" (e.g., sandwich with thin carrots, lettuce or tomatoes for a morning or afternoon snack)]. One possible explanation why the frequency of fruit during lunch was the strongest predictor of FV intake is that the sample was from public schools that provide fruits as part of school lunch menu. No other data of this nature were found for adolescents and in Brazil. Leal et al. investigated the pattern of FV intake of adolescents (59), but there was no focus on which of the meals these foods were most frequently eaten.

Regarding psychosocial determinants, with few exceptions (14, 39, 57), self-efficacy is shown to be the most relevant determinant of intentions to eat FV by adults [e.g., (10, 15, 58)], which is not always the case when self-efficacy is assessed as a direct determinant of FV intake (12, 15, 60). Of the two studies that quantitatively assessed psychosocial determinants for adolescents' FV intake (11, 42), one found a higher correlation between daily intake and self-efficacy ($r = 0.373$, $p < 0.001$) (42), while the other found greater relevance of self-efficacy directly on FV intake in a multivariate analysis ($\lambda = 0.39$, $p < 0.001$) (11).

In our study, the most relevant predictor of self-efficacy was Self5: "I feel able to eat fruit and vegetable when my friends are around." Thus, our data agree with theories of social behavior, which describes that the influence of parents on adolescents gradually decreases throughout this phase, and that the influence of friends predominates (61). Notably, even though the psychosocial determinants descriptive and injunctive social norms and attitudes were not significant for adolescents' FV intake, we found that the reference group *friends* was always present among the most significant predictors of each factor. However, in our sample, friends were more relevant as encouragers of adolescents' sense of their abilities to eat FV (i.e., self-efficacy).

Self2: "I feel able to eat more fruit and vegetables when I get home from school or work" and Self3: "I feel able to eat more fruit and vegetables while watching TV" were the next most relevant predictors for self-efficacy. In fact, adolescent's home may be a place where they may express fewer barriers to eat fruit, as parents and caregivers become the reference in the absence of friends. In addition, fruits may be more readily available at home, which may provide adolescents greater insight into their ability to eat them. Previous data with American adolescents verify significant effects of self-efficacy evaluated by one question (i.e., "I feel confident in my ability to eat fruits and vegetables every day") and perceived availability of FV over fruit and vegetables intake. Regarding self-efficacy to eat fruits and vegetables while watching TV, our data indicated an inverse relationship between TV-watching time and FV intake (62, 63). The television show content watched by adolescents should be assessed, as different contents can elicit different patterns of food intake (64).

Our study also showed a significant effect of SES on the weekly frequency of FV intake among adolescents, which highlights the

TABLE 3 | Goodness-of-fit, explained variance, and factor loadings for the prediction model to weekly frequency of fruit and vegetable (FV) intake[a].

CFI = 0.94, TLI = 0.93, RMSEA = 0.047 (90% CI = 0.042–0.052), SRMR = 0.068					
			R^2 **(whole model) = 0.455**		
Factor		**Determinant**	**λ**	**SE**	***p*-value**
FV	→	Fr1	0.47	0.00	-[a]
FV	→	Fr2	0.52	0.13	***
FV	→	Fr3	0.51	0.14	***
Self-efficacy	→	Self1	0.63	0.00	–[a]
Self-efficacy	→	Self2	0.66	0.06	***
Self-efficacy	→	Self3	0.62	0.07	***
Self-efficacy	→	Self4	0.54	0.06	***
Self-efficacy	→	Self5	0.70	0.07	***
Self-efficacy	→	Self6	0.57	0.060	***
Self-efficacy	→	Self7	0.62	0.06	***
Self-efficacy	→	Self8	0.57	0.06	***
Atittudes	→	At1	0.68	0.00	***
Atittudes	→	At2	0.38	0.04	***
Atittudes	→	At3	0.48	0.04	***
Atittudes	→	At4	0.64	0.05	***
Atittudes	→	At5	0.54	0.05	***
Atittudes	→	At6	0.59	0.05	***
Atittudes	→	At7	0.60	0.05	***
Atittudes	→	At8	0.67	0.06	***
Atittudes	→	At9	0.56	0.05	***
DescritiveNorms	→	DsN1	0.44	0.00	–[a]
DescritiveNorms	→	DsN2	0.45	0.14	***
DescritiveNorms	→	DsN3	0.55	0.14	***
DescritiveNorms	→	DsN4	0.40	0.15	***
InjuntiveNorms	→	InN1	0.42	0.00	–[a]
InjuntiveNorms	→	InN2	0.46	0.13	***
InjuntiveNorms	→	InN3	0.67	0.17	***
InjuntiveNorms	→	InN4	0.56	0.16	***
FV	←	Self-efficacy (Slf)	0.51	0.12	***
FV	←	Atittudes (Att)	0.17	0.13	0.24
FV	←	DescritiveNorms (DsN)	0.27	0.38	0.18
FV	←	InjuntiveNorms (InN)	−0.39	0.42	0.10
FV	←	BMI	−0.01	0.01	0.91
FV	←	SES	0.21	0.20	***

*[a]Based on Structural Equation Modeling (SEM) for a structural model. CFI, Comparative Fit Index; TLI, Tucker-Lewis Index; RMSEA, Root Mean Square Error of Approximation [90% Confidence Interval (CI)]; SRMR, Standardized Root Mean Square Residual; BMI, Body Mass Index; SES, Socioeconomic Status; ***p < 0.001. [a]Dashed lines represent non-standardized estimates that were constraint to one as reference to the scale.*

importance of routinely testing such variables in studies looking at determinants of FV intake, including those investigating psychosocial determinants. It is not common in studies of this nature to assess variables pertaining to context such as life experience or sociodemographic variables (10), but it is known that socioeconomic variables play a crucial role in food preferences and may present themselves as barriers to the adoption of a healthy eating behavior (65) or to be positively associated with FV intake by adolescents and children (5). The absence of this evaluation in other surveys does not allow us to understand if the finding is particular to a country with more serious socioeconomic issues, like Brazil, or if it is also valid for more developed countries, which can also be explored in future studies.

The lack of relevance of BMI for the weekly frequency of FV intake in our findings may be justified by the fact that a single analysis of weekly frequency FV intake is very specific data. Additionally, it is known that changes in weight and nutritional status result from a complex interaction of factors (such as genetic, metabolic, and behavioral) and a great impact of environmental factors on the prevalence of obesity (66), which makes it unreasonable to justify BMI only by the weekly

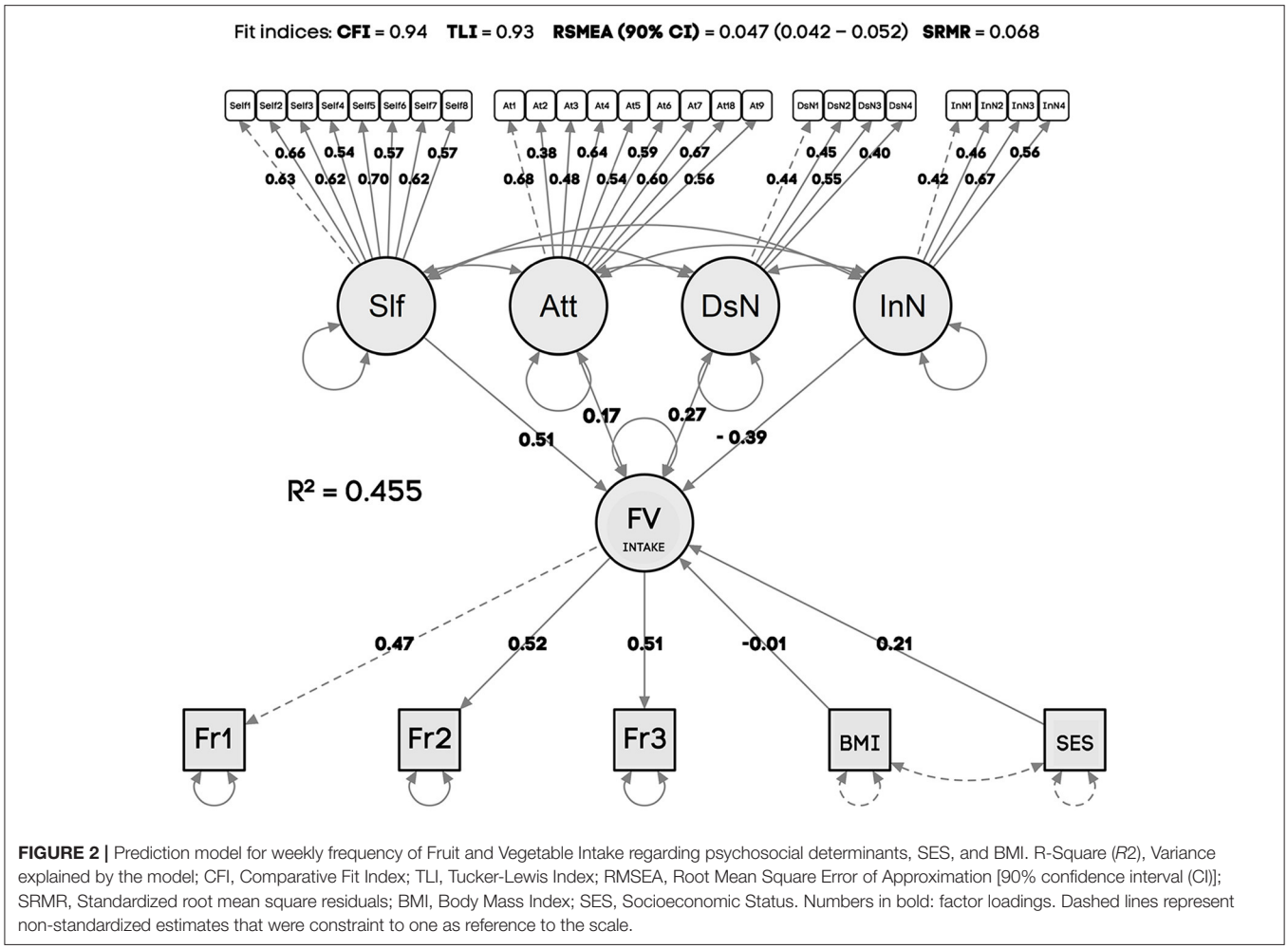


FIGURE 2 | Prediction model for weekly frequency of Fruit and Vegetable Intake regarding psychosocial determinants, SES, and BMI. R-Square (*R2*), Variance explained by the model; CFI, Comparative Fit Index; TLI, Tucker-Lewis Index; RMSEA, Root Mean Square Error of Approximation [90% confidence interval (CI)]; SRMR, Standardized root mean square residuals; BMI, Body Mass Index; SES, Socioeconomic Status. Numbers in bold: factor loadings. Dashed lines represent non-standardized estimates that were constraint to one as reference to the scale.

frequency of FV intake. This fact also highlights the need discuss obesity not only because of individual choices (67, 68).

Some limitations in this study need to be highlighted. First, all the data were cross-sectional, and although our objective was not to propose a definitive predictive model according to psychosocial variables, caution is needed in interpretation of the results. Additionally, the participants provide a self-report on weekly frequency of FV intake, which does not represent necessarily the actual intake. Another aspect is that the participants knew that the researcher was a dietitian, which may have influenced the results. The use of scales may also bring limitations because of the restricted possibility of responses or natural biases from self-report measures. Social acceptance may underlie these biases. Finally, regarding the evaluation of SES, the option to evaluate this aspect through a scale ranging only from "0 to 2 items or more" may have modified the magnitude of the effect of this variable on the weekly frequency of FV intake.

Despite the limitations, as far as we know, this study is the first to explore psychosocial determinant FV intake among adolescents using a validated instrument that investigates the descriptive and injunctive subcomponents of social norms in a model with two intervening variables: SES and BMI. Thus, our findings open the opportunity for more studies to investigate and identify which of these variables show more significance for adolescents in different contexts. Interventions aimed at promoting healthy eating encounter many barriers (5, 69) starting with communication strategies that routinely focus only on the benefit of consuming FV and do not generate improved intake when compared to alternative strategies (70–72). Thus, better understanding of factors related to FV intake for different groups can bring more effective actions, such as reinforcing skills and reducing barriers for FV intake (as suggested by self-efficacy as a relevant element in our sample). That situation was already verified in an experiment that evoked self-efficacy beliefs to encourage switching from energy-dense foods to fruits and vegetables among adolescents (73). Considering the reference group "friends" in the communication approach with adolescents is also an important strategy to encourage FV intake because this social group was the most relevant in the evaluation of the various psychosocial determinants investigated.

Future research should focus more on experimental models to test the effects of each one of the psychosocial determinants of FV intake among adolescents in more controlled settings. They may also include other variables of interest, such as body image, media influence, and the comparison of diverse sociocultural contexts.

CONCLUSION

This research found that among the key psychosocial determinants of FV intake among adolescents, self-efficacy was the only significant one for our sample. Our findings suggest that psychosocial variables and socioeconomic variables should be in the routine of adolescents' eating behavior evaluation. Finally, this research calls for more studies to assess different kinds of adolescents from different regions and backgrounds to increase data that will support more accurate interventions aimed at increasing weekly frequency of FV intake. Through this knowledge-based communication of psychosocial determinants, emphasizing those determinants that already influence adolescents (e.g., self-efficacy) and increasing the relevance of those that are not significantly influential to the group (e.g., descriptive social norms or attitudes) can be fundamental tools to increase FV intake.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The research was approved by the Ethics Committee of the Faculty of Pharmaceutical Sciences of the University of São Paulo under registered number 1.919.946. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

CM was the principal investigator responsible for the study. CM and DC planned the design and made a substantial contribution to the editing of the manuscript. CM defined and ran the statistical analysis, established the size of the sample, and collected the data for the study. MA contributed greatly to the drafting of the manuscript. MA, JM, and DC read and approved the final version of the manuscript. All authors contributed to the article and approved the submitted version.

FUNDING

The project was supported by the National Council for Scientific and Technological Development (CNPq) through a master's scholarship (CNPq, process 134136/2015-2).

ACKNOWLEDGMENTS

We would like to thank Ms. Maria Aracy de Faria Carvalho, Ana Valeria de Faria Carvalho Silva, Jemima Giron, Dagmar do Amaral Borges, Maria Marta Rangel Odoni, Gisele Gasparini Silva, Helena de Cacia Ferreira, Mrs. César Silva Moraes, Alberto de Carvalho Filho, and Marco Maluf for their support.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2021.796894/full#supplementary-material

REFERENCES

1. Beal T, Morris SS, Tumilowicz A. Global patterns of adolescent fruit, vegetable, carbonated soft drink, and fast-food consumption: a meta-analysis of global school-based student health surveys. *Food Nutr Bull.* (2019) 40:444–59. doi: 10.1177/0379572119848287
2. INCA. *Inquérito Domiciliar sobre Comportamentos de Risco e Morbidade Referida de Doenças e Agravos Não Transmissíveis*. Rio de Janeiro: INCA (2003). Available online at: http://www.inca.gov.br/publicacoes/publicacao_inquerito22_06.pdf (accessed October 10, 2021).
3. Machado RHV, Feferbaum R, Leone C. Consumo de frutas no Brasil e prevalência de obesidade. *Rev Bras crescimento e Desenvolv Hum.* (2016) 26:243–52. doi: 10.7322/jhgd.119293
4. IBGE. *POF 2008-2009: mais de 90% da população comem poucas frutas, legumes e verduras*. Brasília: IBGE (2011). Available online at: https://agenciadenoticias.ibge.gov.br/agencia-sala-de-imprensa/2013-agencia-de-noticias/releases/14059-asi-pof-2008-2009-mais-de-90-da-populacao-comem-poucas-frutas-legumes-e-verduras (accessed October 10, 2021).
5. Rasmussen M, Krølner R, Klepp K-I, Lytle L, Brug J, Bere E, et al. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part I: Quantitative studies. *Int J Behav Nutr Phys Act.* (2006) 3:22. doi: 10.1186/1479-5868-3-22
6. Story M, Neumark-Sztainer D, French S. Individual and environmental influences on adolescent eating behaviors. *J Am Diet Assoc.* (2002) 102:S40–51. doi: 10.1016/S0002-8223(02)90421-9
7. Van Lenthe FJ, Jansen T, Kamphuis CBM. Understanding socio-economic inequalities in food choice behaviour: can Maslow's pyramid help? *Br J Nutr.* (2015) 113:1139–47. doi: 10.1017/S0007114515000288
8. Li ASW, Figg G, Schüz B. Socioeconomic status and the prediction of health promoting dietary behaviours: a systematic review and meta-analysis based on the theory of planned behaviour. *Appl Psychol Heal Well-Being.* (2019) 11:382–406. doi: 10.1111/aphw.12154
9. Caso D, Capasso M, Fabbricatore R, Conner M. Unhealthy eating and academic stress: the moderating effect of eating style and BMI. *Heal Psychol Open.* (2020) 7:2055102920975274. doi: 10.1177/2055102920975274
10. Guillaumie L, Godin G. Psychosocial determinants of fruit and vegetable intake in adult population: a systematic review. *Int J Behav Nutr Phys Act.* (2010) 7:12. doi: 10.1186/1479-5868-7-12
11. Pedersen S, Grønhøj A, Thøgersen J. Following family or friends. Social norms in adolescent healthy eating. *Appetite.* (2014) 86:54–60. doi: 10.1016/j.appet.2014.07.030
12. Povey R, Conner M, Sparks P, James R, Shepherd R. Application of the theory of planned behaviour to two dietary behaviours: roles of perceived control and self-efficacy. *Br J Health Psychol.* (2000) 5:121–39. doi: 10.1348/135910700168810
13. Allom V, Mullan B. Self-regulation versus habit: the influence of self-schema on fruit and vegetable consumption. *Psychol Health.* (2012) 27:7–24. doi: 10.1080/08870446.2011.605138
14. Kothe EJ, Mullan BA, Butow P. Promoting fruit and vegetable consumption. Testing an intervention based on the theory of planned behavior. *Appetite.* (2012) 58:997–1004. doi: 10.1016/j.appet.2012.02.012
15. Menozzi D, Sogari G, Mora C. Explaining vegetable consumption among young adults: an application of the theory of planned

behaviour. *Nutrients.* (2015) 7:7633–50. doi: 10.3390/nu7095357
16. Cunha DB, Souza B da SN de, Pereira RA, Sichieri R. Effectiveness of a randomized school-based intervention involving families and teachers to prevent excessive weight gain among adolescents in Brazil. *PLoS ONE.* (2013) 8:e0057498. doi: 10.1371/journal.pone.0057498
17. Toral N, Slater B. Intervention based exclusively on stage-matched printed educational materials regarding healthy eating does not result in changes to adolescents' dietary behavior. *Sci World J.* (2012) 2012:174640. doi: 10.1100/2012/174640
18. Kokanović A, Mandić M, Banjari I. Does individual dietary intervention have any impact on adolescents with cardiovascular health risks. *Med Glas (Zenica).* (2014) 11:234–7.
19. Yusoff H, Wan Daud WN, Ahmad Z. Effectiveness of nutrition education vs. non-nutrition education intervention in improving awareness pertaining iron deficiency among anemic adolescents. *Iran J Public Health.* (2013) 42:467–71.
20. Leme ACB, Philippi ST. Cultural adaptation and psychometric properties of social cognitive scales related to adolescent dietary behaviors. *Cad Saúde Coletiva.* (2014) 22:252–9. doi: 10.1590/1414-462X201400030006
21. Tucunduva Philippi S, Guerra PH, Barco Leme AC. Health behavioral theories used to explain dietary behaviors in adolescents: a systematic review. *Nutrire.* (2016) 41:22. doi: 10.1186/s41110-016-0023-9
22. Bandura A. *Social Foundations of Thought and Action*. Hobokem, NJ: Prentice-Hall (1986).
23. Herman CP, Roth DA, Polivy J. Effects of the presence of others on food intake: a normative interpretation. *Psychol Bull.* (2003) 129:873–86. doi: 10.1037/0033-2909.129.6.873
24. Fishbein M, AJZEN I. *Predicting and Changing Behavior: The reason action approach*, *1st edn*. New York, NY: Psychology Press - Taylor & Francis Group (2010).
25. McEachan R, Taylor N, Harrison R, Lawton R, Gardner P, Conner M. Meta-analysis of the reasoned action approach (RAA) to understanding health behaviors. *Ann Behav Med.* (2016) 50:592–612. doi: 10.1007/s12160-016-9798-4
26. Steinmetz H, Knappstein M, Ajzen I, Schmidt P, Kabst R. How effective are behavior change interventions based on the theory of planned behavior? *Zeitschrift für Psychologie*. (2016) 224:216–33. doi: 10.1027/2151-2604/a000255
27. Ajzen I. *Attitudes, Personality and Behavior*. Milton Keynes: Open University Press (1988).
28. Ajzen I. The theory of planned behavior. *Org Behav Hum Decis Process.* (1991) 50:179–211. doi: 10.1016/0749-5978(91)90020-T
29. Ajzen I, Fishbein M. *Understanding Attitudes and Predicting Social Behavior*. Hoboken, NJ: Prentice-Hall (1980).
30. AJZEN I. Icek Ajzen. *Freq Asked Quest What is Differ Between Perceived Behav Control self-efficacy*? (2020). Available online at: http://people.umass.edu/aizen/faq.html (accessed July 11, 2020).
31. Fishbein M. A reasoned action approach to health promotion. *Med Decis Mak.* (2008) 28:834–44. doi: 10.1177/0272989X08326092
32. Eagly AH, Chaiken S. *The Psychology of Attitudes*. New York, NY: Harcourt Brace Jovanovich College Publishers (1993).
33. Ajzen I, Dasgupta N. *Explicit and Implicit Beliefs, Attitudes, and Intentions: the Role of Conscious and Unconscious Processes in Human Behavior*. *Oxford: Oxford University Press.* (2015). doi: 10.1093/acprof:oso/9780190267278.003.0005
34. Higgs S. Social norms and their influence on eating behaviours. *Appetite.* (2015) 86:38–44. doi: 10.1016/j.appet.2014.10.021
35. Roth D, Herman C, Polivy J, Pliner P. Self-presentational conflict in social eating situations: a normative perspective. *Appetite.* (2001) 36:165–71. doi: 10.1006/appe.2000.0388
36. Cialdini RB, Goldstein NJ. Social influence: compliance and conformity. *Annu Rev Psychol.* (2004) 55:591–621. doi: 10.1146/annurev.psych.55.090902.142015
37. Povey R, Conner M, Sparks P, James R, Shepherd R. The theory of planned behaviour and healthy eating: examining additive and moderating effects of social influence variables. *Psychol Health.* (2000) 14:991–1006. doi: 10.1080/08870440008407363
38. Cox DN, Anderson AS, Lean ME, Mela DJ, UK. consumer attitudes, beliefs and barriers to increasing fruit and vegetable consumption. *Public Health Nutr.* (1998) 1:61–8. doi: 10.1079/PHN19980009
39. Kothe EJ, Mullan BA. Interaction effects in the theory of planned behaviour: predicting fruit and vegetable consumption in three prospective cohorts. *Br J Health Psychol.* (2015) 20:549–62. doi: 10.1111/bjhp.12115
40. Pandey S, Budhathoki M, Yadav DK. Psychosocial determinants of vegetable intake among nepalese young adults: an exploratory survey. *Front Nutr.* (2021) 8:688059 doi: 10.3389/fnut.2021.688059
41. Hartman H, Wadsworth DP, Penny S, van Assema P, Page R. Psychosocial determinants of fruit and vegetable consumption among students in a New Zealand university. Results of focus group interviews. *Appetite.* (2013) 65:35–42. doi: 10.1016/j.appet.2013.02.005
42. Sato Y, Miyanaga M, Wang DH. Psychosocial determinants of fruit and vegetable intake in japanese adolescents: a school-based study in japan. *Int J Environ Res Public Health.* (2020) 17:1–11. doi: 10.3390/ijerph17155550
43. Berg C, Jonsson I, M C. Understanding choice of milk and bread for breakfast among Swedish children aged 11–15 years: an application of the Theory of Planned Behaviour. *Appetite*. (2000) 34:5–19. doi: 10.1006/appe.1999.0269
44. Nunes LP, Dutra FM, Borges JAR. Consumo de peixes: uma aplicação da teoria do comportamento planejado. *Rev Bras Adm Científica.* (2020) 11:189–204. doi: 10.6008/CBPC2179-684X.2020.001.0014
45. Forero CG, Maydeu-Olivares A, Gallardo-Pujol D. Factor analysis with ordinal indicators: a monte carlo study comparing DWLS and ULS estimation. *Struct Equ Model A Multidiscip J.* (2009) 16:625–41. doi: 10.1080/10705510903203573
46. de Jesus Mendes da Fonseca M, Faerstein E, Chor D, Lopes CS. Validade de peso e estatura informados e índice de massa corporal: Estudo pró-saúde. *Rev Saude Publica.* (2004) 38:392–8. doi: 10.1590/S0034-89102004000300009
47. Klipin M, Mare I, Hazelhurst S, Kramer B. The process of installing REDCap, a web based database supporting biomedical research: the first year. *Appl Clin Inform.* (2014) 5:916–29. doi: 10.4338/ACI-2014-06-CR-0054
48. R Core Team. *A language and Environment for Statistical Computing*. Vienna: R Core Team (2013).
49. JASP team. *JASP*. (2021). Available online at: https://jasp-stats.org/ (accessed September 20, 2021).
50. Morris TP, White IR, Royston P. Tuning multiple imputation by predictive mean matching and local residual draws. *BMC Med Res Methodol.* (2014) 14:1–13. doi: 10.1186/1471-2288-14-75
51. Schafer JL, Olsen MK. Multiple imputation for multivariate missing-data problems: a data analyst's perspective. *Multivariate Behav Res.* (1998) 33:545–71. doi: 10.1207/s15327906mbr3304_5
52. Hair Jr. JF, Black WC, Babin BJ, Anderson RE. *Multivariate Data Analysis*, *7th edn.* Upper Saddle River: Prentice Hall (2010).
53. Bagozzi RP Yi Y. Specification, evaluation, and interpretation of structural equation models. *J Acad Mark Sci.* (2012) 40:8–34. doi: 10.1007/s11747-011-0278-x
54. Schreiber J, Nora A. Reporting structural equation modeling and confirmatory factor analysis results: a review. *J Educ Res.* (2006) 6:323–38. doi: 10.3200/JOER.99.6.323-338
55. Marôco, J. *Análise de Equações Estruturais: fundamentos teóricos, software & aplicações*. 2 ed. Pêro Pinheiro: Soluções Gráficas (2014).
56. Watkins MW. The reliability of multidimensional neuropsychological measures : from alpha to omega. *Clin Neuropsychol.* (2017) 31:1–14. doi: 10.1080/13854046.2017.1317364
57. Fornell C, Larcker DF, Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and.pdf. *J Mark Res.* (1981) XVIII:39–50. doi: 10.1177/002224378101800104
58. Henseler J, Ringle CM, Sarstedt M. A new criterion for assessing discriminant validity in variance-based structural equation modeling. *J Acad Mark Sci.* (2015) 43:115–35. doi: 10.1007/s11747-014-0403-8
59. Leal GVdS, Philippi ST, Matsudo SMM, Toassa EC. Consumo alimentar e padrão de refeições de adolescentes, São Paulo, Brasil Food intake and meal patterns of adolescents, São Paulo, Brazil. *Rev Bras Epidemiol.* (2010) 13:457–67. doi: 10.1590/S1415-790X2010000300009
60. Blanchard CM, Fisher J, Sparling PB, Shanks TH, Nehl E, Rhodes RE, et al. Understanding adherence to 5 servings of fruits and vegetables per day:

a theory of planned behavior perspective. *J Nutr Educ Behav.* (2009) 41:3–10. doi: 10.1016/j.jneb.2007.12.006
61. John DR. Consumer socialization of children: a retrospective look at twenty-five years of research. *J Consum Res.* (1999) 26:183–213. doi: 10.1086/209559
62. Avery A, Anderson C, McCullough F. Associations between children's diet quality and watching television during meal or snack consumption: a systematic review. *Matern Child Nutr.* (2017) 13:12428. doi: 10.1111/mcn.12428
63. Lipsky LM, Iannotti RJ. Associations of television viewing with eating behaviors in the 2009 health behaviour in school-aged children study. *Arch Pediatr Adolesc Med.* (2012) 166:465–72. doi: 10.1001/archpediatrics.2011.1407
64. Chapman CD, Nilsson VC, Thune HA, Cedernaes J, Le Greves M, Hogenkamp PS, et al. Watching TV and food intake: the role of content. *PLoS ONE.* (2014) 9:e100602. doi: 10.1371/journal.pone.0100602
65. Ares G, Machín L, Girona A, Curutchet MR, Giménez A. Uma comparação dos motivos subjacentes às escolhas alimentares e das barreiras contra a alimentação saudável entre consumidores de renda baixa e média no Uruguai. *Cad Saude Publica.* (2017) 33:1–12. doi: 10.1590/0102-311x00213315
66. Garvey W, Mechanick J. Proposal for a scientifically correct and medically actionable disease classification system (ICD) for obesity. *Obesity.* (2020) 28:484–92. doi: 10.1002/oby.22727
67. Appelhans BM, Whited MC, Schneider KL, Pagoto SL. Time to abandon the notion of personal choice in dietary counseling for obesity? *J Am Diet Assoc.* (2011) 111:1130–113. doi: 10.1016/j.jada.2011.05.014
68. Wharton S, Lau DCW, Vallis M, Sharma AM, Biertho L, Campbell-Scherer D, et al. Obesity in adults: a clinical practice guideline. *CMAJ.* (2020) 192:E875–91. doi: 10.1503/cmaj.191707
69. Krølner R, Rasmussen M, Brug J, Klepp K-I, Wind M, Due P. Determinants of fruit and vegetable consumption among children and adolescents: a review of the literature. Part II: qualitative studies. *Int J Behav Nutr Phys Act.* (2011) 8:112. doi: 10.1186/1479-5868-8-112
70. Sharps M, Robinson E. Encouraging children to eat more fruit and vegetables: Health vs. descriptive social norm-based messages. *Appetite.* (2016) 100:18–25. doi: 10.1016/j.appet.2016.01.031
71. Robinson E, Fleming A, Higgs S. Prompting healthier eating: testing the use of health and social norm based messages. *Health Psychol.* (2014) 33:1057–64. doi: 10.1037/a0034213
72. Higgs S, Liu J, Collins EIM, Thomas JM. Using social norms to encourage healthier eating. *Nutr Bull.* (2019) 44:43–52. doi: 10.1111/nbu.12371
73. Luszczynska A, Horodyska K, Zarychta K, Liszewska N, Knoll N, Scholz U. Planning and self-efficacy interventions encouraging replacing energy-dense foods intake with fruit and vegetable: a longitudinal experimental study. *Psychol Heal.* (2016) 31:40–64. doi: 10.1080/08870446.2015.1070156

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

POLICY AND PRACTICE REVIEWS
published: 25 March 2022
doi: 10.3389/fnut.2022.861526

The 2018 Revision of Italian Dietary Guidelines: Development Process, Novelties, Main Recommendations, and Policy Implications

Laura Rossi, Sibilla Berni Canani, Laura Censi, Laura Gennaro, Catherine Leclercq, Umberto Scognamiglio, Stefania Sette and Andrea Ghiselli*

Council for Agricultural Research and Economics - Research Center for Food and Nutrition (CREA – Food and Nutrition), Rome, Italy

The fourth edition of the Italian Dietary Guidelines (IDGs) for Healthy Eating was published in 2019. The objective of this paper is to describe the developmental process of IDGs, the main recommendations, the differences with previous revisions, and the concordance and differences with international guidance on a healthy diet. A National Commission oversaw IDG development. A Scientific Dossier (SD), including analysis on nutrition, health, and risk factors status in Italy, was the reference for IDGs preparation. The IDGs are based on the principles of the Mediterranean Diet and are mainly aimed to prevent obesity and nutrition-related non-communicable diseases. The IDGs included 13 directives that were divided into four conceptual blocks: i) how to balance weight; ii) foods to be promoted; iii) foods to be limited; and iv) how to ensure a varied and sustainable diet. Each directive has a box summarizing the key recommendation, myths lists, and false beliefs to be dispelled. The topics of sustainability and the correct approach to food supplementation and weight-loss diet were introduced in the present edition of IDGs. This paper contributes to the debate on the complexity of derivation of Dietary Guidelines and their adaptation to the national context.

Keywords: dietary guidelines, nutritional recommendations, food policy, consumer behavior, household food safety, sustainability, Italy

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brasilia, Brazil

Reviewed by:
Adriano Decarli, University of Milan, Italy
Rita Akutsu, Rita de Cássia Coelho de Almeida Akutsu, Brazil

****Correspondence:***
Laura Rossi
laura.rossi@crea.gov.it

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

Received: *24 January 2022*
Accepted: *15 February 2022*
Published: *25 March 2022*

Citation:
Rossi L, Berni Canani S, Censi L, Gennaro L, Leclercq C, Scognamiglio U, Sette S and Ghiselli A (2022) The 2018 Revision of Italian Dietary Guidelines: Development Process, Novelties, Main Recommendations, and Policy Implications. Front. Nutr. 9:861526. doi: 10.3389/fnut.2022.861526

INTRODUCTION

The Research Center for Food and Nutrition of CREA (Council for Agricultural Research and Economics) in 2019 released the fourth edition of the Italian Dietary Guidelines for Healthy Eating–Revision 2018 (1). In **Figure 1**, the history of the Italian Dietary Guidelines (IDGs) is shown. The first exercise of the development of food-based nutritional recommendations in Italy was carried out in 1979 as a joint effort of the former National Institute of Nutrition and the Ministry of Health. This document defined the portion size to be guaranteed to a population that is still suffering from nutritional deficiencies (2). Proper dietary guidelines were first published in Italy in 1986 (3), followed by a second edition in 1997 (4), and the third one in 2003 (5). The IDGs have undergone these important revisions in terms of content, length, presentation style, and language, while maintaining relevancy and representing current scientific evidence regarding nutrition and health.

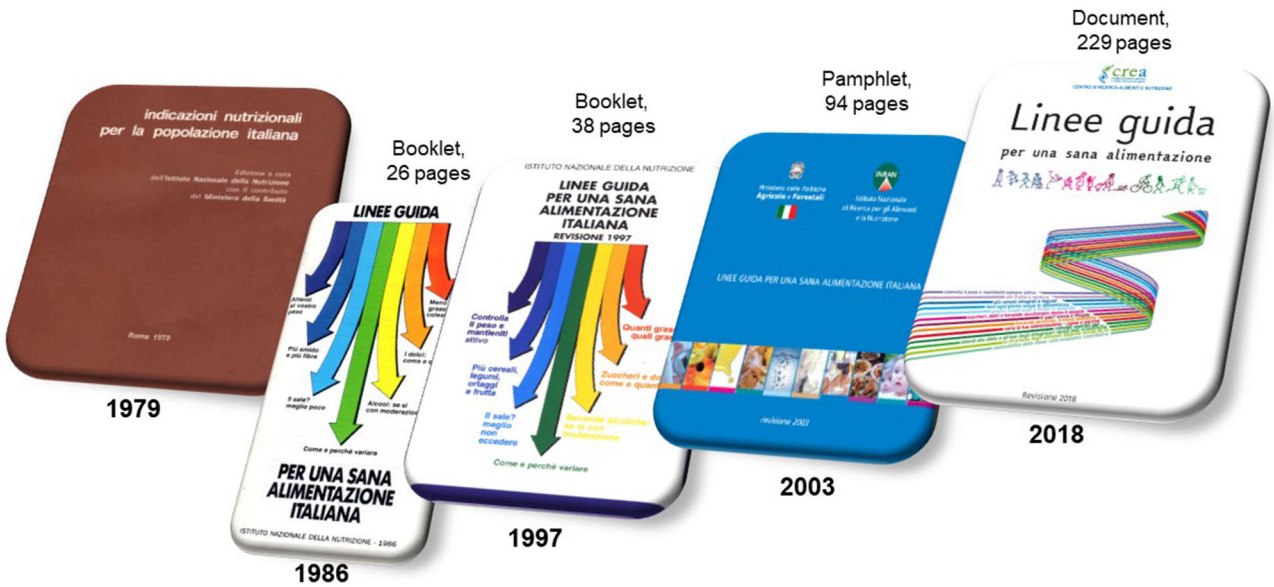


FIGURE 1 | History of Italian Dietary Guidelines (IDGs).

In Italy, the development, periodic revision, and implementation of the IDGs are an institutional task (defined by Law n.258/63; Law n.70/75; Legislative Decree 454/99) of CREA Research Center for Food and Nutrition (formerly National Institute of Nutrition). It is a consensus document accepted and endorsed by the scientific community and civil society stakeholders. As stated by DeSalvo et al. (6), the Dietary Guidelines are an important part of a complex and multifaceted solution to promote health and prevent diet-related chronic diseases, including cardiovascular disease, type 2 diabetes, some cancers, and obesity. Consequently, the IDGs are a public health document based on the health and nutrition epidemiological situation in Italy that proposes prevention strategies for the main critical diet-related public health problems. The IDGs were conceived to improve the nutritional quality of the diet, by modulating the quantities of food to be consumed and promoting lifestyle changes. As new topics of the last revision of IDGs, the improvement of the sustainability and environmental impact of the diet, and a specific chapter on food supplementation and correct approach to dieting was introduced.

The objective of this paper is to describe the developmental process of IDGs Revision 2018, the main recommendations, the novelties, the differences with previous revisions, and the concordance and differences with international guidance on a healthy diet as articulated by International Organizations, such as WHO and Food and Agriculture Organization (FAO) (7). This paper contributes to the research discussion related to the IDGs' evolving pathway and explains how the international recommendations were adapted to the Italian context. The research questions underlying this work are: i) to what extent is it possible to translate evidence from nutrient-based, food-based, and dietary patterns research in dietary guidelines? ii) to what extent is it possible to propose behavioral changes towards the desired recommendations, considering that the acceptance of new inputs in the diet require time? and iii) is it possible to evaluate the impact of dietary guidelines and what methodology could be proposed?

THE IDGs' DEVELOPMENT PROCESS AND POLICY ACTIONS IMPLICATIONS

The steps of preparation of IDGs (**Figure 2**) started in 2013 with the appointment of the Commission of Revision of IDGs, a National Task Force, having the assignment to elaborate the Scientific Dossier (SD) (8). The IDGs' Commission of Revision composition is reported in the **Supplementary Material**. The nature of the commission, which included competencies in food and nutrition sciences from Academia and National Research Institutions, representatives of Scientific Societies (medical, nutrition, physical activity, obesity, and nutritional disorders), psychologists, consumers associations, representatives from Ministries of Health, Ministry of Environment, and Ministry of Education, is a guarantee of the consensual nature of IDGs. The work was coordinated by the Editorial Coordination Board that was responsible for SD evidence adaptation/translation in the IDGs for amending the document, and for preparing and editing the IDGs final version. An official endorsement from FAO and WHO was provided and was included as a preface of the final IDGs document. In 2017, the first version of the IDGs was released by the Editorial Coordination Board and revised by the IDGs Commission of Revision. The amended final versions of the documents [SD (8), IDGs (1)] were officially launched in 2019.

The SD (8) analyzed and evaluated the health and nutrition situation in Italy, the prioritization and determining strategies for

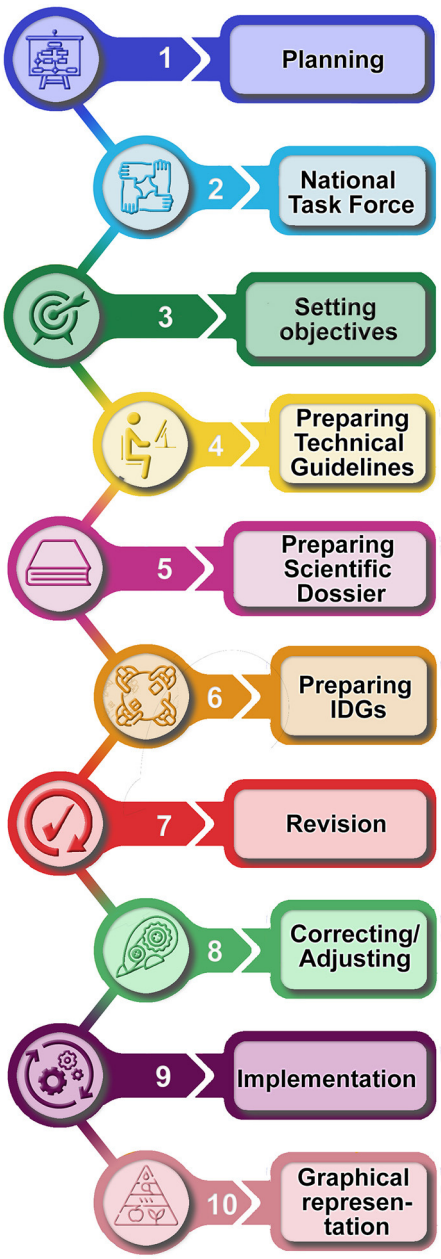


FIGURE 2 | Steps of preparing the IDGs.

alleviating public health problems, and the national goals to be reached through the IDGs. In addition to that, a description of Italian food consumption patterns and eating habits was carried out. In the SD, the key points to be included in the IDGs were identified as a general framework for the preparation of the policy document. The methodology used for SD was functional to the objectives of IDGs and was shaped accordingly. The study of the bibliography was focused on peer-reviewed papers, and complemented by the technical reports of scientific and governmental bodies that were included in the review based on the Authors' decision. The Commission of Revision decided that the so-called "grey literature," i.e., papers under potential conflicts of interest or works published in reports or journals not subject to the external review procedure or private sector reports, was consulted and cited if the conclusions were also substantiated by the official literature. The literature review of the 13 chapters of the SD corresponding to the 13 directives of the IDGs was carried out using a set of keywords specifically reported for the different topics in a dedicated paragraph in each chapter of the SD (8). This work was based on consultation of the literature databases of the authors, combined with the search for published works using Medline, ScienceDirect, and Ingenta. The main inclusion criteria for bibliography selection were temporal with the consideration of papers published in the period 2000–2018. The older bibliographies were reported only in case of very consensual and generally accepted results. The focus of the literature review was on human studies rather than animal studies, metanalysis, and systematic reviews, to provide a robust statement as much as possible. The articles on animal and cellular models and case studies have been critically reviewed for the scope of the work and cited only if relevant. Approximately 5,000 references are cited in the whole SD (8). The construction of IDGs was based on the overall SD literature analysis, allowing a holistic approach to food and nutrition that included epidemiological and biomedical aspects together with sociocultural habits, behavioral attitude, and sustainability aspects.

The Health and the Nutritional Situation in Italy

Italy, according to official OECD statistics (9), is ranked 25th (out of the 37 OECD member states in 2017) for the prevalence of overweight and obesity, with a worryingly high prevalence in childhood (10, 11). The poor adherence of the Italian population to the Mediterranean Diet, as well as the high level of sedentary lifestyle (12, 13), could both be among the main factors to explain the rise in the prevalence of obesity in Italy (14). According to the data reported by DaSilva et al. (15), further confirmed by Vilarnau et al. (16), many countries in the Mediterranean basin were drifting away from the Mediterranean dietary pattern. A recent review (17) has shown a high prevalence of children and adolescents living in southern European countries (Italy, Spain, and Greece) with poor adherence to the Mediterranean diet. The dietary shift of Mediterranean basin countries could have influenced nutritional outcomes, considering the higher prevalence rates of childhood overweight and obesity in the Mediterranean countries (i.e., Cyprus, Greece, Malta, Italy, and Spain), compared to other countries (18).

According to a study carried out by the Global Burden of Disease (GBD) Italy Collaborators (19), in 2017, the Italian life expectancy was among the highest globally, with life expectancy at birth reaching 85.3 years for females and 80.8 years for males. Among nutritionally related disorders, cardiovascular diseases decreased by 53.7% and neoplasms decreased by 28.2% in terms of age-standardized death rates in 1990 and 2017. Behavioral nutritional risk factors, which are potentially modifiable, still have a strong effect, particularly on the mentioned diseases,

and considering the aging of the population. For instance, in 2017 in Italy, 12,000 deaths were attributed to alcohol use, and 9,500 to high body mass index (BMI), while 47,000 deaths due to cardiovascular diseases could be attributed to high Low Density Lipoprotein (LDL) cholesterol, 28,700 to low whole grains consumption, and 15,900 to low physical activity. On the other hand, a high intake of sodium, low intake of whole grains, and low intake of fruits were the leading dietary risk factors for deaths and disability-adjusted life-years (DALYs) globally and in many countries (20).

We mentioned the importance of IDGs as public health documents, but IDGs are also used as food policy documents aimed to improve the food behaviors of populations. According to FAO (21), dietary guidelines are intended to establish a basis for public food and nutrition, health and agricultural policies, and nutrition education programs to foster healthy eating habits and health-protecting lifestyles. They provide advice on foods, food groups, and dietary patterns to assure the coverage of nutrient requirements for the public to promote overall health and to prevent chronic diseases. The healthy food consumption patterns accomplishing these characteristics can be promoted through the development of Food-based Dietary Guidelines (21), which helps to maintain the high consumption of local and culture-specific foods (22).

The food consumption data at the national level (23, 24) provided information on dietary risk factors that required intervention for modification and correction. The observation of current Italian food consumption patterns showed that an improvement of the healthiness of the diet could be obtained through an increase in consumption of vegetable source foods, such as pulses, fruits, and vegetables, and through a decrease in consumption of red and processed meat. Italian diet nutrient intake excesses are related to fats (37% of total energy intake), saturated fatty acids (12% of total energy intake), free sugars (15% of total energy intake), and salt (10 g/die).

The 13 Directives of IDGs

The working approach of IDGs was based on a three-phase process (**Figure 3**). The SD was used as the benchmark for the development of each chapter of IDGs, providing the emerging issues, and the identification of the main topics to be included in the 13 directives of IDGs. The second phase was characterized by broad discussions of the SD content by the Editorial Coordination Board to define the outlines of each guideline and how to convey messages and recommendations. The third phase was the final drafting of the IDGs and their approval by the Commission of Revision.

The IDGs are based on the principles of the Mediterranean Diet (MD), a model that has gained fame and honor, being the dietary pattern that combines prevention of non-communicable chronic diseases, longevity, and health, with consumers' acceptability and sustainability (25). The MD-related food products and eating habits can vary from country to country. The IDGs were developed to declinate the principles of the MD adapting them to the most recent international recommendations. The challenge of this adaptation is the identification of a local healthy food consumption pattern as part of the healthy lifestyle that the IDGs need to recommend.

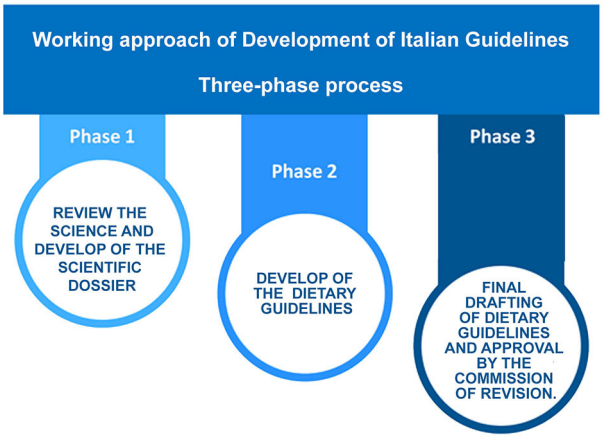


FIGURE 3 | Working approach of development of the IDGs.

The IDGs recommendations cover all age groups, from infants to the elderly, including the special needs of physiological conditions, such as pregnancy and lactation. There is also a focus on the requirements of people who practice sports, as well as recommendations for people at increased risk of obesity and most common non-communicable chronic diseases, such as cardiovascular and cerebrovascular diseases, diabetes, and cancers.

Table 1 reports the titles, the summary of the content, and the main recommendations of the 13 directives that were divided into four conceptual blocks. The first block is related to balancing weight, food intake, and physical activity (Directive 1). The second block is dedicated to food categories that need to be promoted to increase consumption, such as fruits and vegetables, legumes, whole grain cereals, water (Directives 2–4). The third block concerns critical food components in the current diet that need to be reduced, such as fat, salt, sugar, and alcohol (Directives 5–8). The last block is dedicated to "How to" ensure a varied, safe, healthy, and sustainable diet (Directives 9–13).

Each directive, as incipit provided "key recommendations" and practical and simple application behaviors that help consumers to put in place the advice. In addition to that, at the end of each directive, a list of "myths" and false beliefs was provided with the purpose to fight against fake news common in nutrition (26).

In terms of content, the overall philosophy of IDGs is the promotion of a plant-based diet that includes a large proportion of fruit and vegetable, whole grain cereals, and vegetable sources of proteins (legumes). Reduction of consumption of salt and sugar, and selection of animal source foods that combine health and environmental protection, such as milk, eggs, fish, and white meat, was also recommended. The importance of considering the whole dietary pattern, as protection for health and environment concerning single food or ingredient, was the key point of the present revision of IDGs. The bad/good dichotomy of

TABLE 1 | The 4 conceptual blocks, the 13 directives, and the main recommendations of each directive.

Conceptual block	Directive	Main recommendations
Balance	D1. Keep your weight under control and always be active	• In the case of overweight reduce food intake and increase physical activity. • Avoid very restrictive diets that exclude entire food groups. • Be careful to extreme food behavior that could be symptoms of eating disorders.
Increase consumption	D2. Eat more fruits and vegetables	• Increase fruit and vegetable consumption limiting the adding of added fats and salt. • Choose seasonal fruit and vegetables in varying colors. • Fruit juice cannot replace a portion of fresh fruit.
	D3. Eat whole grains and legumes	• Increase consumption of fiber by choosing whole grain products. • Increase legume intake as an alternative to animal source food. • Remember the importance of whole grains as protective factors for non-communicable diseases.
	D4. Drink abundant water every day	• Water must be the preferred fluid for rehydration. • Drinks at least 8 glasses of water a day, more is better. • Increase water intake during physical activity.
Reduce consumption	D5. Fats: select which ones and limit the quantity	• Reduce intake of saturated fat choosing foods containing unsaturated fatty acid for cardiovascular prevention. • Remember that all fats have the same caloric content. • Remember that in Italy trans-fatty acids are no more used in industrial products.
	D6. Sugar, sweets, and sugar-sweetened beverages: less is better	• Reduce intake of sugar in favor of starchy foods. • A high intake of sweetened beverages is a risk factor for non-communicable diseases, including diabetes and obesity. • Remember that brown sugar, honey, and fructose are not healthy alternatives to sugar.
	D7. Salt: less is better (but iodized)	• Reduce intake of salt and choose iodine-fortified products. • Remember that several industrial products are hidden sources of salt (e.g., breakfast cereals). • Remember that salt intake is an important risk factor for non-communicable diseases in particular heart disorders.
	D8. Alcoholic beverages: the least possible	• Avoidance of alcohol from any source, including wine and beer, is the best for health. • If you decide to drink alcohol it is for your pleasure not for health; limit the quantities: no more than 1 alcoholic unit (e.g., a glass of wine) per day for females and elderly and 2 alcoholic units per day for males. • No alcohol of any type to children, adolescents, pregnant and lactating women.
How to do	D9. Enjoy a variety of food choices	• Remember that choosing a variety of foods is a way to guarantee nutritional adequacy. • Variety does not mean more foods. Portions and frequencies must be adequate to energy consumption at different ages and physiological statuses. • Mediterranean Diet is the dietary pattern that inspires the Italian Dietary Guidelines.
	D10. Follow special recommendations for target groups	• Remember that children have special needs during infancy: select foods of high quality in adequate quantity. • Pregnancy and breastfeeding are physiological periods that require attention: best to think about that before, to arrive at these moments in good health and put in place all preventive actions needed (e.g., folic acid supplementation). • The elderly need to eat a little less because the energy metabolism slows down, but the quality of the food must be higher, without forgetting to maintain an active lifestyle.
	D11. Be careful of dieting and misuse of dietary supplements	• Dieting is a therapeutic act that requires trained professionals; consumers should avoid referring to non-qualified people. • Losing weight requires time and constancy, "everything and immediately" is not compatible with dieting. • Dietary supplements could be important in case of deficiency but never substitute a healthy diet.
	D12. Food safety depends also on you	• At home, be careful to adequately store food in the refrigerator. • At the supermarket, in the grocery cart and bags separate fruit and vegetables from meat, poultry, and fish to avoid cross-contamination. • Prepare the kitchen, clean the sink before and after washing and preparing fresh fruit and vegetables, use different cutting boards and preparation areas for meat/poultry/fish and fresh fruits and vegetables. Wash especially well between preparation of meat/poultry/fish and preparation of food that will be eaten without cooking.
	D13. Select a sustainable diet	• Avoid processed meat and reduce red meat consumption in favor of poultry or vegetal source of protein. Select fish from sustainable stocks, e.g., small fish from the Mediterranean Sea (anchovies, sardines, mackerel, etc.); do not demonize aquaculture. • Increase consumption of plant food avoiding the selection of products that require large use of external inputs for growing (e.g., high fertilizing, artificial light, and heating or overseas products). • Planning, preparing, and storing food can help consumers to waste less food, save money, and eat healthier food. Re-use old ingredients or leftovers in new dishes.

food classification was avoided since it is considered too much reductive and simplistic.

The IDGs Recommendations: What and How Has Changed From the Previous Version

Comparing the present IDGs with the version published in 2003, it is possible to identify, among others, a general change of the structure, starting with the directive's numbers that increased from 10 to 13. The 3 additional directives are: i) Directive 2 on fruit and vegetables; ii) Directive 11 on diet and supplements; iii) Directive 13 on sustainability. In addition to that, the IDGs document was overall updated, considering the new scientific data and the emerging aspects of public health nutrition. Each directive changed accordingly, providing updated recommendations. The newest aspects of the present version in comparison with the 2003 edition are: i) the recommendation on red and processed meat; ii) the position on alcoholic beverages; iii) the definition of portions size for the different classes of ages (infants, children, adolescents, and adults). In addition to these major changes, several other aspects of novelty were introduced in this revision of IDGs. As non-exhaustive examples, we can report the division in conceptual blocks that were never used before: the introduction of the concept of "discretionary foods" or "non-necessary foods". The recommendations for people practicing sport were added in the present revision of IDGs. Each directive included recommendations for the prevention of obesity, cardiovascular disease, diabetes, and cancers, and these subjects were newer approached in this form in the previous revisions of IDGs. Also, the provision of "key recommendations" at the start of each chapter was a change introduced in the present revision of IDGs, as well as several other modifications that would be difficult to list in detail.

Directive 2 – Fruit and Vegetable Promotion

In the published IDGs in 2003, fruit and vegetable recommendations were included in a unique directive promoting cereals, legumes, and other plant-based foods. Considering the growing evidence on the specific role of fruit and vegetable consumption in health promotion (27), in the present version of IDGs, a directive was specifically dedicated to these foods. The purpose of Directive 2 on fruit and vegetables was to stimulate their consumption, with the recommendation of multiplying the occasion of consumption to increase the quantity, to reduce the caloric density of the meals, and to increase the intake of health-protective components. Identifying any products better than others was avoided (e.g., red fruits or green vegetables), with the message that all fruits and vegetables are protective of health. It was clearly stated that the single component of fruits and vegetables, in pills or as extracts, do not have the same actions of eating these foods as part of a healthy diet. The fruit juices topic was treated in Directive 2 reporting the non-equivalence with fresh fruits and adding a table explaining the differences among the various commercial drinking-fruit products. Another concept of Directive 2 was that the ready-to-use and minimally processed products could be an option to increase the consumption of fruits and vegetables by the consumers who considered the preparation of these foods time-consuming.

Directive 11 – Losing Weight Diets and Dietary Supplements

The introduction of Directive 11 was an absolute novelty in the IDGs, and the Commission of Revision discussed extensively the opportunity to include this directive since dieting is a therapeutic approach for overweight and obese people, while the IDGs refer to the general healthy population. However, it was considered important to approach this aspect in a public health document that would potentially reach a very large audience. The purpose of this directive was to counteract the growing myths and fake news that the so-called "diet industry" contributes to spreading out. The Editorial Coordination Board considered it important to address the topic of dieting in a policy document as IDGs in consideration of the possible fragility of the consumers that need to lose weight and could be exposed to the persuasion of non-scientific methods. The most common losing weight diets (low fats, low carbohydrates, ketogenic, Paleolithic, vegan, vegetarian, etc.) were analyzed showing the strengths and weaknesses of the different dietetic patterns. The final messages were that short-cuts and miracle diets do not exist and that to lose weight, it is necessary to reduce food intake and to increase physical activity. The topic of dietary supplements was also addressed; either considering the slimming products or other dietary pharmaceutical and herbal products. The final messages were that a supplement could not replace a healthy and balanced diet and that supplementation with natural products or with vitamins and minerals is not necessarily always safe, considering that excesses of ingestion could be not exempt from risks.

Directive 13 – Sustainability of Food Choices

In line with the international indications (28), the issue of the environmental impact of food consumption and dietary choices was addressed in Directive 13. Existing food systems are dysfunctional and do not ensure access to healthy diets, being focused on providing abundant and cheap calories *via* mass production of staple commodities. Therefore, unhealthy dietary patterns and obesity spread up together with increased diffusion of socio-economic inequalities. Food system-related policies, such as agriculture, trade, food safety, environment, development, research, education, fiscal and social policies, market regulation, food waste management, and more, have been developed independently over decades, with minimal attention to dietary impacts (29). With Directive 13, the IDGs intended to contribute to bridging the cultural distance between nutrition and environmental aspects. The objective of the sustainability of the Directive of IDGs was the promotion of healthy food choices for the environment and social protection, and to counteract the food access and distribution inequities. Food waste was largely addressed in Directive 13, in consideration of the fact that since 2016, Italy endorsed the international commitment on this aspect with regulatory efforts (30) for the establishment of the National Observatory on Food Surplus, Recovery, and Waste (OERSA),

aiming to collect data and carry out educational programs and awareness campaigns (31). In Directive 13, recommendations were provided for planning, preparing, and storing food that can help consumers to waste less food, to eat healthy and safe food, and save money. Re-use of leftovers in new dishes was suggested, also providing practical examples. An important message of Directive 13 was that a healthy diet is not necessarily a costly diet. Examples of simple, cheap ingredients with high nutritional values, such as eggs, poultry, beans, milk, and seasonal fruit and vegetables, were provided to guide consumers with limited income.

Another important difference with the previous versions of the IDGs was the introduction of the concept of "discretionary foods" or "non-necessary foods" that is different from the "basic foods". The "discretionary foods" are commonly used foods, but not essential to meet macro and micronutrient needs. For most of them, it was not possible to define consumption frequencies in line with health-promoting aspects. In most cases, the IDGs recommended an occasional consumption that is limited to particular events as a pleasurable, social, and tasty moment. Included in this group, among others, are sweetened beverages, chips, ice cream, creamy tarts, processed meat, and alcoholic beverages.

Recommendation on Red and Processed Meat

The development of recommendations on red and processed meat was based on the World Cancer Research Fund (WCRF) (32) recommendations that claimed for a limitation of the intake of red meat (no more than three portions per week of red meat corresponding to 350–500 g cooked weight) and consumption of very little, if any, processed meat. The importance of such recommendation was reinforced by the publication of the Monograph of the International Agency for Research on Cancer (IARC) (33), where processed meat is classified as "carcinogenic to humans" (Group 1) since sufficient evidence is available for colorectal cancer risk. In the same monograph, the red meat was classified as "probably carcinogenic to humans" (Group 2A) (34). In consideration of the IARC data solidity, which is also confirmed in Italian consumers cohorts (35–37), the recommendation of IDGs was to limit the consumption of red meat to one portion (100 g) per week, with the suggestion of replacing it with poultry that should be the preferred typology of meat (up to three portions per week). The processed meat was considered among the "discretionary foods", and the recommendation was an occasional consumption in the quantity that is as little as possible. In Italy, at the disseminative level, the pork is frequently not considered red meat, while it was necessary for the IDGs to define the term "red meat" that, following IARC (33), refers to beef, pork, horse, lamb, and goat from domesticated animals.

The Position on Alcoholic Beverages

The position on alcoholic beverages drastically changed in the last 20 years. The work carried out by the GBD 2016 Alcohol Collaborators (38) estimates the alcohol use and alcohol-attributable deaths and DALYs for 195 locations from 1990 to 2016. It provided very strong recommendations reporting zero standard drinks per week, as the level of alcohol consumption minimized harms across health outcomes. In addition to that, the WCFR/IARC (32) positioned alcoholic beverages within Group 1 of carcinogens, which is the group that specifically contains substances (and food items) "known to cause cancer in humans". Considering these solid positions, the IDGs "shifted" from the previous suggested/recommended low-to-moderate alcohol consumption, to discouraging any level. This shift is mainly driven by epidemiological observations on alcohol intake-cancer association. The present IDGs considered that the evidence regarding the protective effects of low alcohol intake on cardiovascular diseases in specific segments of the population have been progressively considered less relevant and are negatively counterbalanced by the carcinogenic risks, at any level of consumption, when applied to the whole population as reported by WHO (39), with the consequent strong recommendation of avoidance of alcohol consumption to prevent cancers (40). This novel position has been endorsed by the panel of experts who drafted the IDGs intending to achieve the maximum protection of the population from risk factors. This position is common in the Food-based Dietary Guidelines in Europe (41), in which the messages related to alcohol consumption are very restrictive in large parts of the countries. The recommendation is "do not drink alcohol" without any orientation to healthy quantities. Similarly, when tolerated quantities are provided, it is specified that this "should not be taken as an encouragement to regularly consume alcohol".

The IDGs considered alcoholic beverages in the group of non-necessary foods, stressing the harms of their consumption, and, consequently, with the indication of non-recommended food. However, we considered the role of this product in the Italian cultural background. Stressing the message that "There is not a quantity of alcohol exempt from harm" and "you better not drink", it was also said that "If you want to drink, do it in strictly controlled quantities, and do it occasionally". This indication may appear not sufficiently strong, as it leaves to consumers the decision to drink alcohol or not. Indeed, this is a compromise justified by the context of recommendations that address the population, avoiding being too strong taking into account the generalized traditional consumer habits.

The Definition of Portions' Size for the Different Classes of Ages (Infants, Children, Adolescents, and Adults)

The IDGs contain diet plans, including low-calorie patterns, which include foods from all food groups using the Italian standard portions as a reference. The concept of portions and the importance of their knowledge by consumers is of fundamental importance for a balanced diet and was also present in the 2003 revision. In the present IDGs edition, the topic was broadened by defining the entity of the portions of the different foods, as well as their frequency of consumption to have a complete and balanced diet with foods of common use that are easily available and adhered to Italian culture and tradition. Completely new in this revision is the introduction

of practical recommendations of consumption profiles that is also for infants, children, and adolescents, to help families organize a varied and balanced daily diet for these age groups. The Editorial Coordination Board considered it important to address this topic that was not present in the 2003 revision and is largely requested by technical operators (e.g., school canteens), consumers, and communicators. The quantities of different foods were adapted to make them suitable for children and teenagers starting from the portions defined for adults. Weekly menus differentiated by age range of three years where provided for the age groups from infancy to adolescence, to facilitate parents' food choices either in terms of quantity or quality.

Considering the above-reported modifications of the present version of IDGs, it is evident that the effort of the commission to align the directives with international recommendations also regarding traditional foods. For some directives, an equilibrium had to be found between the current Italian traditional food habits and the international guidelines. This effort led to some discussion within the commission, in which some members claimed a certain autonomy of a Member State in the development of its guidance, especially in the case of international recommendations, which appeared to be too far from the consumers' habits. In the IDGs' development, this criticism emerged for processed meat recommendations that some members considered too strong for Italian dietary habits. Another aspect that created discussion by some members was related to wine that the commission considered a source of alcohol, which is independent of its composition in terms of polyphenols, as well as independently from its consideration as food characterizing the Mediterranean diet. Another point that was discussed by some components was related to the fact that no mention was carried out to local branded products, such as the food with Protected Designation of Origin (PDO) or Protected Geographic Indication (PGI), while the position of the commission was to avoid the promotion of specific products or food chains. Considering the size of the commission, it was physiological to have different positions in the light of the backgrounds of the commission members that include agricultural sciences, nutritional sciences, epidemiology, and public health. The role of the coordination board was to synthesize the positions and, in some cases, to take decisions.

ACTIONABLE RECOMMENDATIONS

The IDGs are intended to be used by health professionals who deal with nutrition, the private sector, and, in general, by the world of communication, generalist, and scientific. In addition to that, the main messages could represent the basis for school nutrition education programs.

The IDGs are used as the starting point to create training and message dissemination. Since the IDGs publication, participation in congresses, thematic conferences, bilateral informative meetings with the private sector, and training courses for nutritionists were carried out to disseminate IDGs concept, development process, general philosophy, novelties, and main recommendations.

Training

Training packages for university students were structured and introduced in the nutritional science academic courses (42–47). All these academic efforts cover the nutritional education of more than 600 students per year but only in the areas of Rome (Italy). The IDGs were transformed into online training courses for nutritionists, medical doctors, and other health professionals providing formative credits (48, 49).

The IDGs are also used in-school educational programs as discussion material and information tools in teachers' training, and as the base to create playful and experiential laboratories targeted to children (50–52).

Dissemination to the Public

For the general population, the IDGs were translated into short videos (3–4 min for each directive) published on a dedicated channel of the CREA's YouTube section (53). In addition to that, either as videos or as printable downloading text, the IDGs are included as informative material in the institutional website *sapermangiare.mobi* (54).

As a further simplification, Directive 2 became a "Decalogue for promotion of the consumption of fruit and vegetable" (**Figure 4**), targeted to children and families, distributed in all fairs and events, where pupils and parents are present, and added to the textbook for teachers (55).

With the same purpose from Directive 13, it was developed as "Decalogue against food waste", which is a set of 10 recommendations (56) addressed to consumers that could be disseminated in schools, events, and information sessions. The 10 recommendations summarize the messages of Directive 13 simply and practically, pointing out the importance of: (1) reading labels by being aware of the difference between "best before" and "use by" date on the planning of food purchases and storing especially for fresh products, use of leftovers; (2) avoiding the stigma of asking for a doggy bag in restaurants and food catering; (3) offering foods that were left-over to guests, especially in the occasions that involve children to pass the message of not wasting food to youngest (**Figure 5**).

Further implementations of IDGs will be carried out according to the availability of resources. Starting from the published policy document, the extracts and synthetic information brochures will be structured for different targets, adults, adolescents, and children. The communication professionals will be used to the productions of leaflets to translate the scientific language into highly usable messages addressed to non-specialistic audiences that include consumers, as well as other interested stakeholders. These dissemination documents need to be graphically attractive, e.g., using infographics duly conceived by specialistic graphics service. The translation of the main recommendations of the IDGs in English may be considered for the dissemination of the document through international channels.

FIGURE 4 | The decalogue for promotion of fruit and vegetable consumption.

Professional short films (e.g., 100 s of guidelines) will be structured with infographics intended for the web to further disseminate the messages of the IDGs.

Monitoring and Impact

Based on the available resources, the monitoring and impact evaluation will be carried out. The evaluation of dietary

FIGURE 5 | The decalogue against food waste.

quality indices will be considered especially in terms of longitudinal adherence to the Mediterranean diet considering that Italian IDGs are based on Mediterranean Diet principles. The impact assessment of the nutritional education actions based on IDGs will be carried out through the development of the Nutrition Knowledge tool (57) that could be applied to different age groups through adaptation of the international questionnaires to the Italian context, comparison with eating habits, creation of indexes of adherence to recommendations, and evaluation of nutrition literacy in the general population and selected groups. This will allow the in-house data flow to monitor trends and to evaluate changes regarding the effects of IDGs implementation.

DISCUSSION

Dietary guidelines in general, and IDGs in particular, established a basis for public food and nutrition, health, and agricultural policies, and for nutrition education programs to promote healthy eating and lifestyles in the general population (58). In this paper, we described the process of development of IDGs to share with the scientific community the processes leading to its release, its adaptation to the national context, and the compromises that, in some cases, the commission accepted to pursue what was considered reachable to consumers' behavioral changes.

The Evolution of IDG

IDGs key messages are aligned with recommendations of the WHO Healthy Diet Fact Sheet (58, 59) in terms of promotion of consumption of fruits and vegetables, legumes, whole grains, nuts; and limiting free sugars, salt, and fat, use of iodized salt. The recommendations of limiting red meat and avoiding processed meat and the consideration of alcoholic beverages as a harmful component of the diet were introduced in the present revision of IDGs to be in line with international recommendations. In fact, despite different geographical, socio-economic, and cultural contexts among countries, most of the pivotal nutritional recommendations are similar.

Since the first edition, IDGs changes reflected the best of nutritional science's available evidence. Without necessarily going through the text of the different revisions (in Italian), the idea of the changes is provided by the evolution of the titles of the directives of the IDGs across the years (**Table 2**). In the directive on bodyweight in 2003 and 2018, the physical activity recommendation was introduced in response to its increasing importance in the framework of bodyweight management (First line of **Table 2**). The number of directives was 7 in the 1986 and 1997 revisions and was increased to 10 Directives in 2003. The 3 directives added to the 2003 revision were related to the importance of water as a nutrient, and the correct hydration as an element of healthy eating. A directive on food safety in

response to the momentum of the outbreak of several food safety emergencies (e.g., mad cow, dioxin chicken, etc.), and a directive aimed to provide specific recommendations for groups, such as pregnant and lactating women, infants and children, and the elderly, were introduced. In 2018, the overall number of directives further increased to 13 with the inclusion of directives on fruit and vegetables, which, in the previous revisions, were treated in a unique directive with whole grains and legumes, slimming diet and supplements, and sustainability, as presented in this paper. The language of the different IDG revisions evolved across the years. In the 1986 and 1997 editions, the prescriptive language was more common than in the 2003 revision and was further attenuated in IDGs published in 2018. For example, the directive on fats (Third line of **Table 2**) progressively become more qualitative, as the focus on cholesterol was eliminated in response to the literature evidence, and the combinations of qualitative and quantitative aspects were further added in recent years.

A consumption pattern in line with IDGs reduces the risk of major chronic diseases by supplying adequate amounts of energy and nutrients, compared with the current food consumption intakes. The process of development of IDGs described in the present paper combined evidence-based elements with expert knowledge and common sense, as well as adaptation to local food consumption habits.

IDGs Policy Implications

Aligning the dietary guidelines with the latest evidence, not just on healthy eating but also on the wider social and environmental implications of dietary choices is, therefore, an important starting point for enabling a policy coherence and building a food environment that contributes to good public and personal health, as well as to local and global environmental sustainability (60–62). The inclusion of sustainability in dietary guidelines is an open exercise that is still in progress in several countries. According to Springmann et al. (63), the inclusion of sustainability aspects into the national dietary guidelines, as well as in the WHO guidelines, could be beneficial not only from a health perspective but is also necessary for meeting global sustainability goals (64) and staying within the environmental limits of the food system. In IDGs, we demonstrated that it is possible to translate for consumers, the practical recommendations aimed to improve their behaviors in terms of environmental and social protection other than health. Probably, the strategy of prioritizing recommendations for health protection and combining them with environmental aspects avoided the confusion by being the most coherent public health nutrition document as IDGs. Considering that the IDGs' targets are families and individuals, even a few selected sustainability recommendations could have a large population impact. Limitations of this approach were largely discussed during the coordination meetings, along with the process of IDGs' development. The sustainability of diet is an aspect of the environmental impact of food production that is still not completely exploited, in which the risk of bias and "personal" interpretation is still high. At the time of IDGs preparation, the sources of information were limited, and the consensus documents were almost absent. As reported by Rosi et al. (65), the dietary recommendations, in terms of environmental impacts, should also consider the aspects related to the choice of locally grown and seasonal products, as well as agricultural and processing techniques, to approach globally the sustainability of the food system. However, it should be pointed out that the overall estimation of the different aspects of sustainability of the food system is still lacking.

The policy implications of IGDs are not different from other countries' nutritional guidance. A particularly relevant issue in this sense is how to properly communicate the information to the public in the current era of widespread and largely uncontrolled dissemination of information *via* an almost limitless variety of media outlets. Indeed, the nutritional issues, which are often intrinsically complex, are difficult to report comprehensively and, even when truly balanced, frequently fail in general communication and online communication (66). The long process of IDGs' development required cooperation among different Italian stakeholders, such as scientists, clinicians, and policymakers, who have an active part in the process. After the IDGs publication, to be maximally effective in terms of policy, the involvement of other society segments, such as the food private sectors, the communications areas, and the education sector, was carried out with different approaches such as evidence briefs, policy dialogues, and benchmarking. The Authors are conscious that these steps are just at the initial phases and that much more needs to be put in place.

IDGs for Developmental Ages

According to Herforth et al. (67), the worldwide available Food-based Dietary Guidelines state that they apply to the general population: 46% qualify this statement with a "healthy" population and 13% refer to the general "adult" population. Over half (52%) specify an age above which the guidelines apply: almost all of these refer to age 2 years and older, although two countries, instead, specify 1 year, one country says 3 years, and three countries say 5 years. Forty percent of countries have separate messages or guidelines for specific subpopulations, which include infants under 2 years of age, school-aged children, adolescents, pregnant and lactating women, the elderly, and others. The IDGs' recommendations cover all age groups from infants to the elderly, including physiological conditions, such as pregnancy and lactation, to stay healthy during different periods of life. In this overall approach to all classes of ages, the Editorial Coordination Board decided to have a specific focus on infants, children, and adolescents providing practical recommendations with indicative serving sizes for consumption, expressed either as food items or food groups for developmental ages, to create menus coherent with the principle of a healthy and balanced diet. Another similar exercise was carried out by Kastorini et al. (68), that starting from Dietary Guidelines addressed to the general population, the developed food-based nutritional and physical activity recommendations for promoting healthy dietary habits in Greek infants, children, and adolescents proposed menus based on traditional Greek diet. Montagnese et al. (69) analyzed and compared the different European food-based dietary guidelines and reported that specific recommendations

TABLE 2 | Language, length, and recommendation changes of Italian Dietary Guidelines (IDGs) revisions since 1986.

1986 edition 7 directives	1997 revision 7 directives	2003 revision 10 directives	2018 revision 13 directives
Beware of your weight	Control your weight and stay active	Check your weight and always be active	Check your weight and always be active
More starch and more fiber	More cereals, legumes, vegetables, and fruits	More cereals, legumes, vegetables, and fruits	Eat more fruits and vegetables
			Eat whole grains and legumes
Less fat and cholesterol	How many fats, which fats	Fats: choose the quality and limit the quantity	Fats: select which ones and limit the quantity
Sweets: how and how many	Sugars and sweets: how and how many	Sugars, sweets, and sugar-sweetened beverages: within the right limits	Sugar, sweets, and sugar-sweetened beverages: sweets: less is better
Salt? Less is better	Salt? better not too much	Salt? Less is better	Salt? Less is better …(but iodized)
Alcohol: if yes with moderation	Alcoholic drinks: if yes with moderation	Alcoholic beverages: if yes, only in controlled quantities	Alcoholic beverages: the least possible
How and why to vary	How and why to vary	Often vary your choices	Enjoy a variety of food choices
		Drink abundant water every day	Drink abundant water every day
		Special recommendations for special people	Follow special recommendations for target groups
		Food safety depends also on you	Food safety depends also on you
			Be careful of dieting and misuse of dietary supplements
			Select a sustainable diet

regarding children were provided in 21 countries (59%), while recommendations for adolescents were provided in 17 countries (50%). They pointed out that more emphasis should be given to some subgroups of the total population that currently represent a clear prevention target such as adolescents. Schwartz et al. (70) also evaluated the extended coverage of the international and national dietary guidelines of the themes of infants and children feeding habits. They concluded that guidelines, in general, cover most of the themes, but some of the national guidelines are incomplete. However, guidelines could be an occasion to give more practical tips to parents, especially to help them establish an appropriate feeding behavior for their children. According to UNICEF (71), only some of the guidance for specific groups are developed and disseminated as part of the national guidelines. The level of specificity in guidance for developmental ages varies greatly. For example, some countries provide very detailed guidance on how to initiate and maintain breastfeeding, how to choose and safely use infant formula, and how to introduce complementary foods. Relatedly, some newer DGs, including IDGs, also focus on the social role of meals in the family and the community, on the transmission of food skills to children and adolescents, and on the role of marketing and the need to limit the exposure of children to marketing, but also to educate children and adolescents on this issue. Some countries' DGs have also begun to address a wider range of behavioral issues around food and diets, including responsive feeding, parenting to help children develop healthy habits and healthy relationship to foods and eating, and addressing the developmental stage of adolescence. A specific chapter on adolescence was also included in the IDGs. The reasons for these differences are related to the fact that, especially in high-income countries, the government's guidance for specific groups (most commonly, infants, young children, and pregnant and lactating women) is developed through parallel processes and by specialized scientific societies, such as pediatrics, gynecologists, etc.

The Limits of IDGs

The philosophy of IDGs is that the more plant-based a diet is, the more it is health-promoting and sustainable and that, among the different sources of proteins, red meat presence in the menu represents a critical issue both in terms of sustainability of the food choices and occurrence of non-communicable diseases. The IDGs consider that to promote human health and to reach an environmentally sustainable solution, the animal-based foodstuffs should be partially replaced with fruits, vegetables, legumes, and cereals, and among animal source foods, a selection of milk, eggs, fish, and white meat leads to better health promotion and environmental outcome in addition to being most in line with nutritional recommendations. However, such changes are hard to achieve at the population level considering that the diet to be promoted does not only depend on nutritional recommendations, but also needs to consider the social and practical aspects, cultural factors, and consolidated behaviors. The starting point of changes needs to be the current food consumption pattern of the population considering that large behavioral changes are difficult to be achieved. Indeed, advice towards drastic changes risks being ineffective. Instead, modulating the current consumption to achieve the nutritional and environmental goals step by step would result in a better outcome. The IDGs are important tools to inform policies and

promote public health. To facilitate and improve adherence to IDGs and to have a real effect on food consumption, recommendations need to have clear links to Italian food policies.

It is widely recognized that even in high-income countries with a long history of developing, communicating, and otherwise implementing evidence-based DGs, the dietary patterns are far from ideal. It is important to acknowledge that while the development of DGs is necessary, which is to inform consumers and to program food and nutrition policy, their implementation is very far from sufficient (71). The main limitation of the IDGs is related to the existing gap between dietary recommendations and actual consumer behavior indicating the generally poor compliance of IDGs. An IDGs' implementation strategy is as equally important as the development of the evidence-based document. The need for effective communication to assist in translating the recommendations into practical and actionable advice is widely acknowledged and has been included as part of the global release of guidelines (72), even though in Italy, an articulated plan of developing strategies to assist behavior change is still lacking. The length of the process in developing and publishing the documents was another relevant limitation of IDGs. The question of whether a better compromise could be found remains open; for example, reducing the number of consultations. For example, discussions at the level of scientists that better know the literature could be reduced. On the other hand, probably, we should prioritize the consultations with stakeholders other than researchers to speed up the process.

Conclusive Remarks

With this paper, we got the challenges of Bechthold et al. (73) that claimed efforts to have a common concept for the future derivation of European Food-based Dietary Guidelines. With the description of the Italian experience, we would contribute to the debate on the complexity of derivation of Dietary Guidelines, and their adaptation to the national context. We fully agree with the idea that a common European concept could serve as a starting point for the derivation of the national dietary guidelines that, however, need to be adapted to each country-specific condition. But to develop the common concept, we think that it is important to analyze the different experiences to get the lessons learned and to find cross-cutting recommendations to share, as well as valorize local peculiarities.

AUTHOR CONTRIBUTIONS

AG is the President and LR is the General Coordinator of the Commission of Revision of IDGs. SBC, LC, LG, CL, US, and SS are members of the IDGs' Editorial Coordination Board. The paper was conceptualized and writing and original draft preparation were carried out by LR. Writing, review, and editing were done by SBC, LC, LG, CL, US, SS, and AG. All authors have read and agreed to the published version of the manuscript.

ACKNOWLEDGMENTS

The authors thank all colleagues that, out of the Commission of Revision, provided suggestions and inputs on the IDGs document.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fnut.2022.861526/full#supplementary-material

REFERENCES

1. CREA. Centro di ricerca Alimenti e la nutrizione. Linee Guida per una sana alimentazione. (2018) December 2019. Available online at: https://www.crea.gov.it/en/web/alimenti-e-nutrizione/-/linee-guida-per-una-sana-alimentazione-2018 (accessed January 24, 2022).
2. *Indicazioni nutrizionali per la popolazione italiana*. Edizione a cura dell'Istituto Nazionale della Nutrizione con il contributo del Ministero della Salute ed. Roma: Edizione a cura dell'Istituto Nazionale della Nutrizione con il contributo del Ministero della Salute (1979). p. 45.
3. *Linee Guida per una sana alimentazione italiana*: Istituto Nazionale della Nutrizione (1986) Rome.
4. *Linee Guida per una sana alimentazione italiana*: Istituto Nazionale della Nutrizione (1997) Rome.
5. *Linee Guida per una sana alimentazione italiana*: Istituto Nazionale della Nutrizione (2003) Rome.
6. DeSalvo KB, Olson R, Casavale KO. Dietary Guidelines for Americans. *Jama.* (2016) 315:457–8. doi: 10.1001/jama.2015.18396
7. Conference Outcome Document: Framework for Action. *FAO, WHO Second International Conference on Nutrition.* (2014) Rome, Italy.
8. CREA. *Dossier Scientifico Linee Guida per una sana alimentazione*. Roma (2018). p. 1570. Available online at: https://www.crea.gov.it/web/alimenti-e-nutrizione/-/dossier-scientifico-linee-guida-per-una-sana-alimentazione-2018 (accessed January 24, 2022).
9. Obesity Update 2017 [Internet]. Organisation for economic co-operation and development. Available online at: https://www.oecd.org/els/health-systems/Obesity-Update-2017.pdf (accessed January 24, 2022).
10. Epicentro I. Indagine nazionale 2019 OKkio alla Salute: i dati nazionali. (2019). Available online at: https://www.epicentro.iss.it/okkioallasalute/indagine-2019-nazionale (accessed January 24, 2022)
11. WHO. *Fact sheet - Severe obesity among children aged 6–9 years*. Available online at: https://www.euro.who.int/en/media-centre/sections/fact-sheets/2019/fact-sheet-severe-obesity-among-children-aged-6-9-years (accessed January 24, 2022)
12. Soric M, Meh K, Rocha P, Wendel-Vos W, de Hollander E, Jurak G. An inventory of national surveillance systems assessing physical activity, sedentary behaviour and sport participation of adults in the European Union. *BMC Public Health.* (2021) 21:1797. doi: 10.1186/s12889-021-11842-1
13. Verloigne M, Loyen A, Van Hecke L, Lakerveld J, Hendriksen I, De Bourdheaudhuij I, et al. Variation in population levels of sedentary time in European children and adolescents according to cross-European studies: a systematic literature review within DEDIPAC. *Int J Behav Nutr Phys Act.* (2016) 13:69. doi: 10.1186/s12966-016-0395-5
14. Popkin BM, Gordon-Larsen P. The nutrition transition: worldwide obesity dynamics and their determinants. *Int J Obes Relat Metab Disord.* (2004) 28(Suppl 3):S2–9. doi: 10.1038/sj.ijo.0802804
15. da Silva R, Bach-Faig A, Raidó Quintana B, Buckland G, Vaz de Almeida MD, Serra-Majem L. Worldwide variation of adherence to the Mediterranean diet, in 1961–1965 and 2000–2003. *Public Health Nutr.* (2009) 12:1676–84. doi: 10.1017/s1368980009990541

16. 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
17. Grosso G, Galvano F. Mediterranean diet adherence in children and adolescents in southern European countries. *NFS Journal.* (2016) 3:13–9. doi: 10.1016/j.nfs.2016.02.004
18. WHO European Childhood Obesity Surveillance Initiative (COSI). *Report on the Fourth Round of Data Collection, 2015–2017*. Copenhagen: WHO Regional Office for Europe (2021).
19. Monasta L, Abbafati C, Logroscino G, Remuzzi G, Perico N, Bikbov B, et al. Italy's health performance, 1990–2013, 2017: findings from the global burden of disease study 2017. *Lancet Pub Hea.* (2019) 4:e645–57. doi: 10.1016/S2468-2667(19)30189-6
20. Afshin A, Sur PJ, Fay KA, Cornaby L, Ferrara G, Salama JS, et al. Health effects of dietary risks in 195 countries, 1990–2013, 2017: a systematic analysis for the global burden of disease study 2017. *Lancet.* (2019) 393:1958–72. doi: 10.1016/S0140-6736(19)30041-8
21. FAO. Food-based dietary guidelines. Available online at: https://www.fao.org/nutrition/nutrition-education/food-dietary-guidelines/en/ (accessed January 24, 2022).
22. Ferrari M, Benvenuti L, Rossi L, De Santis A, Sette S, Martone D, et al. Could dietary goals and climate change mitigation be achieved through optimized diet? *the experience of modeling the national food consumption data in Italy. Front Nutr.* (2020) 7:48. doi: 10.3389/fnut.2020.00048
23. Sette S, Le Donne C, Piccinelli R, Arcella D, Turrini A, Leclercq C, et al. The third Italian national food consumption survey, INRAN-SCAI 2005-06–part 1: nutrient intakes in Italy. *Nutr Metab Cardiovasc Dis.* (2011) 21:922–32. doi: 10.1016/j.numecd.2010.03.001
24. Leclercq C, Arcella D, Piccinelli R, Sette S, Le Donne C, Turrini A, et al. The Italian national food consumption survey INRAN-SCAI 2005-06: main results in terms of food consumption. *Public Health Nutr.* (2009) 12:2504–32. doi: 10.1017/S1368980009005035
25. Berry EM. Sustainable food systems and the mediterranean diet. *Nutrients.* (2019) 11:2229. doi: 10.3390/nu11092229
26. Moreno-Rodríguez VP, Sánchez-Cabrero R, Abad-Mancheño A, Juanes-García A, Martínez-López F. Food and nutrition myths among future secondary school teachers: a problem of trust in inadequate sources of information. *Soc Sci.* (2021) 10:325. doi: 10.3390/socsci10090325
27. Wang X, Ouyang Y, Liu J, Zhu M, Zhao G, Bao W, et al. Fruit and vegetable consumption and mortality from all causes, cardiovascular disease, and cancer: systematic review and dose-response meta-analysis of prospective cohort studies. *BMJ.* (2014) 349:g4490. doi: 10.1136/bmj.g4490
28. Willett W, Rockstrom 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
29. Egal F, Berry EM. Moving towards sustainability—bringing the threads together. *Front Sustain Food Sys.* (2020) 4:9. doi: 10.3389/fsufs.2020.00009
30. Gazzetta Ufficiale. LEGGE 19 agosto 2016, n. 166. Available online at: https://www.gazzettaufficiale.it/eli/id/2016/08/30/16G00179/sg (accessed January 24, 2022)
31. CREA. Osservatorio sugli sprechi alimentari. Available online at: https://www.crea.gov.it/web/alimenti-e-nutrizione/-/osservatorio-sugli-sprechi-alimentari (accessed January 24, 2022).
32. *World Cancer Research Fund/American Institute for Cancer Research. Diet, Nutrition, Physical Activity and Cancer: a Global Perspective. Continuous Update Project Expert Report 2018*. Available online: https://www.iarc.who.int/wp-content/uploads/2018/07/pr240_E.pdf (accessed January 24, 2022).
33. *International Agency for Research on Cancer. Red Meat and Processed Meat. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans Volume 114*. Available online: https://www.iarc.who.int/wp-content/uploads/2018/07/pr240_E.pdf (accessed January 24, 2022).
34. Bouvard V, Loomis D, Guyton KZ, Grosse Y, Ghissassi FE, Benbrahim-Tallaa L, et al. Carcinogenicity of consumption of red and processed meat. *Lancet Oncol.* (2015) 16:1599–600. doi: 10.1016/S1470-2045(15)00444-1
35. Rosato V, Kawakita D, Negri E, Serraino D, Garavello W, Montella M, et al. Processed meat and risk of selected digestive tract and laryngeal cancers. *Eur J Clin Nutr.* (2019) 73:141–9. doi: 10.1038/s41430-018-0153-7
36. Rosato V, Negri E, Parazzini F, Serraino D, Montella M, Ferraroni M, et al. Processed meat and selected hormone-related cancers. *Nutrition.* (2018) 49:17–23. doi: 10.1016/j.nut.2017.10.025
37. Rosato V, Tavani A, Negri E, Serraino D, Montella M, Decarli A, et al. Processed meat and colorectal cancer risk: a pooled analysis of three italian case-control studies. *Nutr Cancer.* (2017) 69:732–8. doi: 10.1080/01635581.2017.1310259
38. Griswold MG, Fullman N, Hawley C, Arian N, Zimsen SRM, Tymeson HD, et al. Alcohol use and burden for 195 countries and territories, 1990–2013, 2016: a systematic analysis for the global burden of disease study 2016. *Lancet.* (2018) 392:1015–35. doi: 10.1016/S0140-6736(18)31310-2
39. WHO??. Global status report on alcohol and health 2018. World Health Organization. Available online at: https://apps.who.int/iris/handle/10665/274603 (accessed on January 24, 2022) License: CC BY-NC-SA 3.0 IGO.
40. Schuz J, Espina C, Villain P, Herrero R, Leon ME, Minozzi S, et al. European code against cancer 4th edition: 12 ways to reduce your cancer risk. *Cancer Epidemiol.* (2015) 39(Suppl 1):S1–10. doi: 10.1016/j.canep.2015.05.009
41. WHO. Food-Based Dietary Guidelines in Europe - table 17. Available online at: https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/food-based-dietary-guidelines-europe-table-17_en (accessed on January 24, 2022).
42. *Università Roma Tre Corso di Scienza della Alimentazione, Facoltà di Scienze e Culture Enogastronomiche*. Available online at: https://www.uniroma3.it/insegnamento-erogato/dipartimento-di-scienze/l/2020-2021/scienze-e-culture-enogastronomiche-0580706202600001/d39edc4f-1928-4e7e-a4b2-b742489811ee$-$20402443/ (accessed January 24, 2022).
43. *Università di Roma Tor Vergata. Corso di Laurea in Scienze Motorie*. Available online at: https://web.uniroma2.it/it/percorso/didattica/sezione/scienze_motorie (accessed January 24, 2022).
44. *Università di Roma Tor Vergata. Corso di Laurea in Turismo Enogastronomico*. Available online at: https://web.uniroma2.it/it/percorso/didattica/sezione/turismo_enogastronomico (accessed January 24, 2022).
45. *Università Roma Tor Vergata. Master in nutrizione*. Available online at: http://masternutrizione-2018.uniroma2.it/ (accessed January 24, 2022)
46. *Università di Roma Tor Vergata. Corso di Laurea in Scienze della Nutrizione Umana*. Available online at: https://www-2021.scienzenutrizione.uniroma2.it/ (accessed January 24, 2022)
47. *Università Campus Bio-medico di Roma. Corso di Laurea in Scienze della Alimentazione e della Nutrizione Umana*. Available online at: https://www.unicampus.it/scienze-alimentazione-e-nutrizione (accessed January 24, 2022)
48. *SINU/CREA Le nuove Linee Guida Nutrizionali per una sana alimentazione*. Available online at: https://eng.sinu.it/2021/03/05/corso-fad-nuove-linee-guida-nutrizionali-per-la-sana-alimentazione/ (accessed January 24, 2022)
49. *ClioEDU. Presentazione nuove Linee Guida per una sana Alimentazione*. Available online at: https://elearning.clioedu.it/course/view.php?id=263 (accessed January 24, 2022)
50. Frutta e verdura nelle scuole. Misure di accompagnamento. Available online at: http://www.fruttanellescuole.gov.it/misure-di-accompagnamento/formazione-insegnanti (accessed January 24, 2022)
51. CREAre consapevolezza per una alimentazione sana e sostenibile. L'educazione alimentare nella scuola con ANP-Lazio e CREA – Alimenti e Nutrizione. Corso di Formazione per Insegnanti della Scuola Primaria del Lazio. Available online at: https://www.crea.gov.it/documents/59764/0/Programma$+$.pdf/879cde4f-884c-cd8f-431f-f06fa60e43b9?t=1631701580555 (accessed January 24, 2022)
52. Buono per te, buono per il pianeta? Frascati scienza 21-21 Settembre 2021. Available online at: https://www.frascatiscienza.it/pagine/notte-europea-dei-ricercatori-2021/programma-scuole-2/evs=3100&bytarget=&bycategory=&bytown=&byday=&byorgs= (accessed January 24, 2022)
53. Introduzione alle nuove linee guida per una sana alimentazione. Available online at: https://www.youtube.com/watch?v=1Dt5orwK3qk&list=PLuHR_wWt4GLUYlvismpEMEyQnmmA_ZnLS (accessed January 24, 2022)
54. sapermangiare.mobi. Available online at: http://sapermangiare.mobi/ (accessed January 24, 2022).
55. *Scopri le meraviglie di Frutta e Verdura. CREA, gioca e impara*. Gennaro L, Berni Canani S, Maccati F, Peñalosa Barbero A, editors (2020). Available online at: https://www.crea.gov.it/documents/59764/20200727_

QuardernoDidatticoEasyRead_DEFweb_LR.pdf/e4e49f5d-fcf2-c6b2-a32d-b916cefa0b02?t=1626437456532 (accessed January 24, 2022)
56. Il decalogo antispreco. Available online at: https://www.crea.gov.it/documents/59764/0/decalogo$+$antispreco.pdf/f065e8eb-2a2a-e920-0a51-30334b57da06?t=1588069084394 (accessed January 24, 2022)
57. Scalvedi ML, Gennaro L, Saba A, Rossi L. Relationship between nutrition knowledge and dietary intake: an assessment among a sample of italian adults. *Front Nutr.* (2021) 8:714493. doi: 10.3389/fnut.2021.714493
58. WHO. Regional Office for the Eastern M, editor. *Report on the FAO/WHO technical consultation on national food-based dietary guidelines, Cairo, Egypt, 6–9 December 2004*. (2006). Cairo: World Health Organization. Regional Office for the Eastern Mediterranean.
59. WHO. Fact sheets: healthy diets. Available online at: https://www.who.int/news-room/fact-sheets/detail/healthy-diet (accessed January 24, 2022).
60. Behrens P, Kiefte-de Jong JC, Bosker T, Rodrigues JFD, de Koning A, Tukker A. Evaluating the environmental impacts of dietary recommendations. *Proc Natl Acad Sci USA.* (2017) 114:13412–7. doi: 10.1073/pnas.1711889114
61. Springmann M, Clark M. Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L, et al. Options for keeping the food system within environmental limits. *Nature.* (2018) 562:519–25. doi: 10.1038/s41586-018-0594-0
62. Springmann M, Wiebe K. Mason-D'Croz D, Sulser TB, Rayner M, Scarborough P. Health and nutritional aspects of sustainable diet strategies and their association with environmental impacts: a global modelling analysis with country-level detail. *Lancet Planet Health.* (2018) 2:e451–e61. doi: 10.1016/s2542-5196(18)30206-7
63. Springmann M, Spajic L, Clark MA, Poore J, Herforth A, Webb P, et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. *BMJ.* (2020) 370:m2322. doi: 10.1136/bmj.m2322
64. UN. Transforming our world: the 2030 Agenda for Sustainable Development (2015). Available online at: http://www.un.org/ga/search/view_doc.asp?symbol=A/RES/70/1&Lang=E (accessed January 24, 2022).
65. Rosi A, Mena P, Pellegrini N, Turroni S, Neviani E, Ferrocino I, et al. Environmental impact of omnivorous, ovo-lacto-vegetarian, and vegan diet. *Sci Rep.* (2017) 7:6105. doi: 10.1038/s41598-017-06466-8
66. Magni P, Bier DM, Pecorelli S, Agostoni C, Astrup A, Brighenti F, et al. Perspective: improving nutritional guidelines for sustainable health policies: current status and perspectives. *Adv Nutr.* (2017) 8:532–45. doi: 10.3945/an.116.014738
67. Herforth A, Arimond M, Álvarez-Sánchez C, Coates J, Christianson K, Muehlhoff E, et al. Global review of food-based dietary guidelines. *Adv Nutr.* (2019) 10:590–605. doi: 10.1093/advances/nmy130
68. Kastorini CM, Critselis E, Zota D, Coritsidis AL, Nagarajan MK, Papadimitriou E, et al. National dietary guidelines of greece for children and adolescents: a tool for promoting healthy eating habits. *Public Health Nutr.* (2019) 22:2688–99. doi: 10.1017/S1368980019001034
69. Montagnese C, Santarpia L, Buonifacio M, Nardelli A, Caldara AR, Silvestri E, et al. European food-based dietary guidelines: a comparison and update. *Nutrition.* (2015) 31:908–15. doi: 10.1016/j.nut.2015.01.002
70. Schwartz C, Scholtens PA, Lalanne A, Weenen H, Nicklaus S. Development of healthy eating habits early in life. Review of recent evidence and selected guidelines. *Appetite.* (2011) 57:796–807. doi: 10.1016/j.appet.2011.05.316
71. United Nations Children's Fund (UNICEF). Review of national Food-Based Dietary Guidelines and associated guidance for infants, children, adolescents, and pregnant and lactating women. New York: UNICEF, (2020) Available online at: https://www.unicef.org/media/102761/file/2021-Food-based-Dietary-Guidelines-final.pdf (accessed on 14 February, 2022)
72. Fayet-Moore F, Pearson S. Interpreting the Australian dietary guideline to "limit" into practical and personalised advice. *Nutrients.* (2015) 7:2026–43. doi: 10.3390/nu7032026
73. Bechthold A, Boeing H, Tetens I, Schwingshackl L, Nöthlings U. Perspective: food-based dietary guidelines in europe-scientific concepts, current status, and perspectives. *Adv Nutr.* (2018) 9:544–60. doi: 10.1093/advances/nmy033

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 Sustainable Food Systems

ORIGINAL RESEARCH
published: 29 March 2022
doi: 10.3389/fsufs.2022.794533

Exploring Purchasing Determinants for a Low Fat Content Salami: Are Consumers Willing to Pay for an Additional Premium?

Giuseppe Di Vita[1], *Raffaele Zanchini*[1], *Daniela Spina*[2]*, *Giulia Maesano*[2], *Giovanni La Via*[2] *and Mario D'Amico*[2]

[1] Department of Agricultural, Forest and Food Sciences (DISAFA), University of Turin, Turin, Italy, [2] Department of Agricultural, Food and Environment (Di3A), University of Catania, Catania, Italy

Consumers today are increasingly moving toward healthier lifestyles and food purchasing habits. This new awareness has also prompted the meat industry, usually indicted for the use of harmful compounds and ingredients such as additives, salt, and fat, to introduce innovative measures to meet demand. This study aims to assess consumer willingness to pay an additional price premium (APP) for a healthy salami by identifying which factors are more likely to have an effect on the willingness to purchase, such as socio-demographic and product and market-related attributes. An Ordered Logit model has been applied to define factors influencing consumers' willingness to pay for a low-fat salami. Results show a favorable consumer acceptance of reduced-fat salami conveyed by the willingness of consumers to pay an additional price for this product and confirm that the health awareness of consumers is an important driving force in cured meat marketing strategies.

Keywords: food choice, consumer behavior, salami, cured meat, fat content, healthy diet, ordered logit

OPEN ACCESS

Edited by:
Ana Lúcia De Saccol, UFN - Universidade Franciscana, Brazil

Reviewed by:
Stefano Corsi, University of Milan, Italy
Laís Mariano Zanin, Senac University Center, Brazil

***Correspondence:**
Daniela Spina
danispina@gmail.com

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

Received: *13 October 2021*
Accepted: *09 February 2022*
Published: *29 March 2022*

Citation:
Di Vita G, Zanchini R, Spina D, Maesano G, La Via G and D'Amico M (2022) Exploring Purchasing Determinants for a Low Fat Content Salami: Are Consumers Willing to Pay for an Additional Premium? Front. Sustain. Food Syst. 6:794533. doi: 10.3389/fsufs.2022.794533

HIGHLIGHTS

- A consumer acceptance of reduced-fat salami was shown by the willingness of consumers to pay an additional price for this product.
- Significant differences between different price thresholds were found.
- Socio-demographics characteristics of consumers (Gender, Monthly Income, Regular Sport Activity) have a positive impact on willingness to purchase.
- Consumers who engage in regular physical activity are the most willing to pay for low-fat salami.
- A negative correlation between traditional productive process and healthier salami was found.

INTRODUCTION

Over the last few years, the consumption of meat has been subject to much debate. Concerns include those regarding sustainability, health, and ethics (Dreher et al., 2021). Food safety is becoming increasingly important to consumers, and its ramifications for their health are becoming more apparent (Spina et al., 2021). As a result, researchers are more and more fascinated by the economic potential of healthier meat products to suit the expanding and complex consumer

demand. Consumer acceptance of these novel foods will determine whether this potential is achievable and how quickly it can be attained (Barone et al., 2021). Meat products are considered rich in B vitamins, minerals, trace elements, and protein with a high biological value, but also some other bioactive components (Sharma et al., 2013; Bohrer, 2017). However, they have a rather negative consumer image due to their connection to diseases prevalent in Western societies such as cardiovascular disease, cancer, and obesity (Micha et al., 2010; Van Wezemael et al., 2010; Toldrá and Reig, 2011). The relationship between a proper diet and good health cannot be denied, and food companies could be playing a more significant role (Annunziata and Pascale, 2011). Just consider industrial food production, often to blame for using unhealthy compounds or excessive amounts of fat, sugar, and salt. To this end, the World Health Organization has proposed the following, to open up a closer dialogue with the food industry: fewer saturated fats, more fruit and vegetables, and incentives for the marketing and production of healthier products (WHO, 2020).

The meat industry has to face contemporary lifestyle changes, adopting adaptive and innovative measures to meet the expectations of demand and develop the production of healthier processed meats (Hathwar et al., 2012; Di Vita et al., 2019). The major innovations and approaches are aimed at either reducing the fat and salt content, as well as making use of less nitrate and nitrite, or improving the health benefits of the contents, like the inclusion of functional ingredients (Toldrá and Reig, 2011). The challenge is keeping the consumer satisfied (Hoppu et al., 2017). Consumer preferences and perceptions of quality when purchasing meat products are influenced by a variety of factors that relate to the senses; however, psychological and marketing factors also play an important role (Caracciolo et al., 2010; Lanfranchi and Giannetto, 2021).

As indicated in the literature (Hung et al., 2016; Shan et al., 2017; Merlino et al., 2018), we should analyse consumer behavior when purchasing healthy cured meats from different perspectives as it is affected by socio-demographic factors as well as extrinsic and intrinsic product attributes.

Even though research on the willingness to pay for healthy food products has been carried out worldwide (Wu et al., 2015; Ali and Ali, 2020), and several studies have shown empirical evidence on willingness to pay (WTP) for cured meats (Balogh et al., 2016; Garavaglia and Mariani, 2017; Schnettler et al., 2019; Teixeira and Rodrigues, 2020), there is still a lack of insights into the price related determinants for cured meats regarding the willingness to pay an additional price premium, particularly for salami.

The novelty of this paper resides in the first-time assessment of consumers' attitude toward low-fat salami by analyzing their willingness to pay an additional price. We investigated in depth whether and to what extent salami characteristics and consumer beliefs influence additional (different) price threshold, thereby filling a gap in the literature. By reviewing the existing scientific literature on cured meat and salami consumption, we investigated the willingness to pay an additional price premium for a low-fat salami, in relation to socio-demographic and product and market-related attributes.

THE MAIN DETERMINANTS OF CURED MEAT AND SALAMI CONSUMPTION

This section presents a literature review on the determinants of consumption included in our study that affect directly or indirectly the additional premium price of cured meat and salami.

Cured meats are consumed all over the world and appreciated for their full flavor, but also for their price and convenience (Brunner et al., 2010; Gaviglio and Pirani, 2016). For these kinds of products, consumers seem to pay particular attention to health and fat content during the purchase compared to others (Grunert, 2006). Despite some research stating that pricing has a significant impact on consumer purchase intentions for processed meat (Resurreccion, 2004), price is not always the main determining factor. Indeed, quality, production method, and origin often hold more weight (Bernabéu and Tendero, 2005; Realini et al., 2013; Font-i-Furnols and Guerrero, 2014). Taste, and other sensory characteristics, remain decisive indicators for product approval and repeat purchases (Sindelar et al., 2007; Saeed et al., 2013). Prices, especially of traditional foods, have been observed to enhance the level of tradition and naturalness shown on the labeling (McEachern and Willock, 2004; Honeyman et al., 2006; Abrams et al., 2010; Gifford and Bernard, 2011; Chamhuri and Batt, 2013; Risius and Hamm, 2017). Price preferences are also related to the socio-demographic characteristics of consumers (Font-i-Furnols et al., 2011).

Fat and Other Unhealthy Attributes

It is the high fat content in meat products that is noticeable when we compare them to other categories of processed foods (Alves et al., 2016). They impact a population's diet greatly, firstly due to this high fat content, ranging from 15 to 35%, and secondly because they are consumed in large quantities (Bis-Souza et al., 2020). Italian-type salami can be full of saturated fat (up to 32%) according to physicochemical parameters, and high in salt, poor in fiber, and lack bioactive molecules (Pérez-Burillo et al., 2020).

Salami products are an important source of both high biological value proteins and animal fats, rich in saturated fatty acids and cholesterol. The outcome of lessening the fat content in a meat product is usually undesirable because this affects both texture and taste (Campagnol et al., 2011; Henning et al., 2016), as well as causing a reduction in the amount produced (Han and Bertram, 2017). Djinovic-Stojanovic et al. (2019) established that healthier dry sausages (with lower salt and fat content) may be produced with no negative effects on the physicochemical and biochemical properties of the end product. Many attempts to manufacture emulsified meat products with a lower fat content have been made. Several studies have shown that replacing animal fat with dietary fiber is one of the most successful techniques (Tomaschunas et al., 2013; Ktari et al., 2014; Petersson et al., 2014; Zhuang et al., 2016). In addition, consumer preference for meat products with physiological and nutritional benefits has grown considerably (Han and Bertram, 2017).

The food industry has been motivated to limit and reduce the quantities of trans fatty acids (FA) and saturated FA, salt, and free sugars in foods currently available and acceptable to consumers.

Ansorena et al. (2019) in a study on the labeling of processed meat products argued that fat is the nutrient most frequently mentioned in the nutrition claims and the expression "low-fat" the most used.

Severini et al. (2003) highlighted that by partially substituting pork backfat with extra-virgin olive oil, the chemical, physical, and sensory features of the product remained largely unchanged with the exception of water activity and firmness. Dudinskaya et al. (2021) in their study analyzed European consumers' preferences regarding fat, concluding that there is no homogeneity between countries. In France and Italy, for example, consumers appreciate the lack of visible fat more, and for this reason they choose leaner meat cuts with less visible fat content.

As for the consumption of salt, its intake in developed economies is extremely high (Burnier, 2021). In the Western world, almost 70% of salt intake derives from foods that have been processed, and 20% of that from meat products (Ruusunen and Puolanne, 2005). There is a small, natural amount of salt present in fresh foods, but this amount rises staggeringly when processed (Inguglia et al., 2017). For instance, fresh pork normally has 70 mg of sodium/100 g, while bacon contains around 1,480 mg sodium/100 g (Henney et al., 2010).

Excessive dietary salt intake relates to an increased risk of hypertension affecting more than 25% of the world adult population (Adrogué and Madias, 2007), which results in a major risk factor for stroke and other cardiovascular disorders, as well as diabetes and kidney disease (Doyle and Glass, 2010). Too much salt is also the driving force of obesity (Allison, 2018). There is strong evidence to support that a reduction in salt intake worldwide would lead to improved public health (He and MacGregor, 2009). In order to lessen current salt intake significantly, a shift in both the production of commercial foods and consumer behavior is required (Bryła, 2020). Among processed foods, meat products are one of the most common sources of sodium (Desmond, 2006). There are researchers who have evaluated the acceptance of lower salt meat products (Guàrdia et al., 2006), and they have shown that replacing sodium chloride with potassium chloride (resulting in 50% less salt) is a motivating factor, particularly among women, and that they are more receptive to dry sausages. Other research on sensory characteristics of low-sodium salami has highlighted that salami prepared with a 64% reduction of Na was received highly by consumers (De Almeida et al., 2016).

Nitrate and nitrite salts are important, widely used food additives in cured meats. They convey a better flavor and aroma, retain the typical red-pinkish color of the meat, slow down the process of oxidation, and have antimicrobial properties (Govari and Pexara, 2018; Ferysiuk and Wójciak, 2020). However, despite the advantages of these additives, the presence of nitrites in processed meat and their long-term intake may have major human health consequences (Sebranek and Bacus, 2007; Aoki et al., 2010). The European Union regulates the use of nitrite (Reg. No. 1333/2008), asking that greater attention be paid not only to the finished product but also to the presence of these preservatives throughout the production process (Haouet et al., 2016). Producers must protect the typicality of their products and, at the same time, ensure food safety. They are particularly interested in developing technologies aimed at the production of cured meats without nitrites and nitrates. For this reason, the use of starter cultures has become commonplace in the salami industry, consisting of strains of lactic bacteria and micro-staphylococci chosen according to desired characteristics (Cenci-Goga et al., 2012; Aquilanti et al., 2016).

The idea of replacing sodium nitrite with various plant extracts has also been the focus of research, since fruits and vegetables are made up by different kinds of phenolic compounds, which have a favorable effect on human health (Alahakoon et al., 2015; Munekata et al., 2020).

Sensory Attributes

In recent years consumer demand for low-fat and low-sodium meat products have been on the rise (Ruusunen and Puolanne, 2005), and there has been a growing interest in creating meat products with better health benefits, such as dry fermented sausages reformulated (Beriain et al., 2011; Aaslyng et al., 2014). However, consumer behavior and expectations regarding the sensory assessment of traditional meat products are becoming less predictable. Research on low-fat and salt in fermented sausages has produced contradicting results in sensory characteristics. According to Tuorila et al. (1994), sensory expectations concerning lower fat products are often minimal. Mendoza et al. (2001), Olivares et al. (2010), and Henning et al. (2016) achieved higher aroma, flavor, color, texture scores, and greater acceptability in high-fat dry fermented sausages than lean sausages. Barone et al. (2021) claim that consumers are usually wary of meat products that are healthier since they are unfamiliar. However, they noted that the partial replacement of meat with plant-based ingredients and the resulting reduction in fat and salt was accepted. Consumer perception and the favorable reception of chicken and beef salami with regard to the fat and salt content was also investigated by Djinovic-Stojanovic et al. (2019). Their results highlighted how Serbian consumers find healthy meat products more appealing. These findings have been confirmed also by other studies, which have shown that consumers are willing to pay a higher price for cured meats or sausages with limited sodium and fat content (Lee et al., 2015; Romagny et al., 2017). Moreover, other authors have shown an improvement in odorous volatile compounds in lean sausages (Chevance et al., 2000; Muguerza et al., 2002). Reducing salt may also have negative effects on sensory characteristics, leading fermented sausages to have a lighter tone, a less salty flavor, a minor distinctive taste, and less microbial stability (Corral et al., 2013; Laranjo et al., 2017). In addition, the sensory properties of the sausage with regards to consumer satisfaction in terms of taste, flavor, and texture are not affected by the addition of preservatives, while there are differences in color attributes, with a preference for the appearance of sausages containing preservatives (Braghieri et al., 2016).

Animal Welfare

Recent studies on the consumption of meat and meat derivatives have brought to the attention the possibility of agricultural production processes affecting consumer attitudes and their wish

to purchase meat products from farms that are environmentally friendly (Migliore et al., 2015; Caracciolo et al., 2016; Stampa et al., 2020; Burnier et al., 2021).

Consumer concerns for the consequences of animal breeding related to human health, environmental impacts, and animal welfare have led to preferences for sustainably farmed meat (Aiking et al., 2006; Stampa et al., 2020). Consumer WTP and preference are significantly greater when information is provided to consumers (Napolitano et al., 2010). Even though previous research has suggested the possibility of a positive correlation between consumer behavior and sustainable products, studies on consumer behavior and sustainable farming methods are limited (Hwang et al., 2020).

Furthermore, not only do ethical concerns influence purchasing behaviors for sustainable products, but so do diverse cognitions of sensory perceptions. Hwang et al. (2021) assess the impact of information of sustainability on sensory assessments and consumer purchasing behaviors for three kinds of sustainable agricultural production: free of antibiotics, animal welfare, and grazing livestock. They discovered that consumers are generally willing to pay more for salami in all three informed conditions, and in particular for animal welfare.

Packaging

Consumers, overall, prefer packaged over-the-counter pork rather than that purchased from a butcher (Špička and Náglová, 2022). Regarding the satisfaction of the packaging format in dry cured ham, in the study of Mesías et al. (2013), just one of the clusters, identified as a traditional consumer, attributed very low importance to this attribute, while for the other two clusters it was the most or the second most important attribute for consumers. The study by Ortiz et al. (2020) investigates consumer preference for the two types of ham packaging formats, vacuum packaging and modified atmosphere packaging, showing a greater preference for vacuum-packed products capable of preserving their sensory characteristics.

Indication of Origin

The information on the origin for consumers is a strong element of preference in purchasing a food product (Pilato et al., 2015). The geographical origin is assumed as a quality concept, and European quality schemes that guarantee the link with the territory positively influence the WTP of consumers in the case of Parma ham (Mancini et al., 2019). However, although the protected designation of origin (PDO) regime for dry cured ham appeals to a certain segment of costumers, the region of origin is a powerful instrument, even more than the country of origin (Van Ittersum et al., 2003) and a stronger quality evaluation than EU certification schemes (Resano et al., 2012). In consumer preference for Iberian PDO ham, the most influential attributes are the price, type of ham (Mesías et al., 2010), cured ham breed, and its regional origin, while a foreign origin is penalized by consumers (Resano et al., 2007). The WTP estimates for meat products are related to the attributes considered, the country of origin where the analysis is conducted (Cicia and Colantuoni, 2010), and the geographic location of the consumers involved in the survey (Resano-Ezcaray et al., 2010). Moreover, consumer WTP estimates for GI labels differ due to certain features of product and market or political institutions that affect the premium price consumers are willing to pay for such GI labels (Deselnicu et al., 2013).

METHODOLOGY

Data Collection

We carried out a qualitative and quantitative analysis over a sample of 484 Italian consumers to assess which drivers move consumers toward salami with 30% less fat. This percentage was identified according to research on frankfurter cooked sausage, whereby a 25–30% reduction of fat levels does not affect significantly texture and other sensory properties (National Research Council., 1988).

Data were collected by trained interviewers on the topics of the questionnaire by direct interviewing consumers after a random walk recruitment (Di Vita et al., 2020, 2021a). The survey was based on a multi-section questionnaire and, to improve the reliability of the answers, only regular consumers of processed meat who were responsible for purchasing such products were selected. The study assessed consumer attitudes in relation to a convenience sample, which may produce unbalanced frequency classes compared to the general population, limiting to some extent the possibility of inference. However, this sampling method has proven to be quite consistent, considering that the reliability of the results is not compromised (Etikan et al., 2016; Testa et al., 2019; Di Vita et al., 2021a,b). The administration of the final version of the questionnaire was preceded by 2 main steps: the focus group and a pilot survey.

Concerning the focus group, a range of specialists such as academics, entrepreneurs, and food technologists were invited to discuss main determinants of salami consumption. Subsequently they were asked to select which attributes could influence the willingness to pay (WTP) for a reduced-fat salami: thematic nodes and consequent questions were included in the preliminary questionnaire employed for the pilot survey. It was conducted on 40 consumers before administering the final questionnaire to test the effectiveness and degree of understanding of the questions. The final version of the survey, derived from the focus group and the pilot survey, consisted in four sections: (1) General characteristics of salami consumption; (2) Importance of intrinsic and extrinsic attributes of salami consumption; (3) WTP for different salami categories, including reduced-fat salami; (4) socio-demographic characteristics of the sample.

The questions in the survey were organized as binary (yes/no answer) and multiple-choice answers in the case of sections Introduction and Results and as seven-point Likert scale in section The Main Determinants of Cured Meat and Salami Consumption. For example, the importance of the different attributes in section The Main Determinants of Cured Meat and Salami Consumption concerning intrinsic and extrinsic characteristics was explored as perceived importance by consumers as follows:

"How important do you think the following intrinsic characteristics are for defining the quality of a salami? "

Once the list of characteristics was provided, consumers expressed their opinion on the Likert scale by indicating 1 = *not important* and 7 = *very important*.

Data and information were collected by trained interviewers in Sicily in large-scale retail trade shops via face-to-face methods and resulted in 484 valid observations whose consumer characteristics are shown in **Table 1**. Regarding the categorization of age groups, some aspects should be described in more detail. In fact, age was transformed from a continuous variable into an ordinal variable, namely age cohort; to this aim, the classification proposed by Brosdahl and Carpenter (2011) was employed. The classification divides the generations as follows: Millennials: those born between 1982 and 2000; Generation X: people born between 1961 and 1981; the Older Generation group finally collected those born before 1961, i.e., the cohorts of Baby Boomers and the Silent Generation.

TABLE 1 | Socio-demographic characteristics and consumption habits of the sample (n = 484).

Group of Variables	Items	Frequency	Percent
Age cohort	Millennials	300	61.98
	Generation X	145	29.96
	Older generations	39	8.06
Gender	Male	254	52.48
	Female	230	47.52
Body Mass Index	Underweight	37	7.64
(BMI)	Normal weight	293	60.54
	Overweight	118	24.38
	Obese	36	7.44
Family members (n)	1	22	4.54
	2	72	14.88
	3	124	25.62
	4	196	40.50
	5	58	11.98
	6	12	2.48
Education	Elementary and middle schools	130	26.86
	High school	175	36.16
	Bachelor's and master's degrees	151	31.20
	Higher education	28	5.78
Monthly family income	No answer	93	19.21
	Up to 1,500 €/month	230	47.52
	Between 1,501 and 3,000 €/month	117	24.17
	Between 3,001 and 4,000 €/month	28	5.79
	Over 4,000 €/month	16	3.31
Regular sport activity	No	272	56.20
	Yes	212	43.80
	Salami consumption (hg/week) Mean–SD	1.12 (0.94)	
Habits	Price paid for salami (€/hg) Mean–SD	1.28 (0.72)	

Data Analysis

The assessment of willingness to pay for a reduced-fat salami was performed by means of an ordinal scale representing discrete alternatives of increasing additional premium (AP). Specifically, the alternatives were: not willing to pay an AP; willing to pay up to 10%; between 10 and 20%, between 20 and 30%; more than 30%. Considering that the dependent variables were expressed in a categorical dimension, an ordered logit model was performed to assess which predictors affect the willingness to pay for the product. The model laid on the structural model for ordinal outcomes with a single continuous latent variable (Rabe-Hesketh and Skrondal, 2008; D'Amico et al., 2016).

The latent variable AP_i^* is employed to model the discrete alternatives of the dependent variable, and consequently the model can be expressed as follows:

$$AP_i^* = X_i^{'}\beta + \varepsilon_i \quad (1)$$

where AP_i^* is latent and continuous ranging from -∞ and +∞; $X_i^{'}$ represent the vector of regressors; β is the vector of model coefficient; and ε_i represent the vector of error terms.

The model also includes the estimation of a set of coefficients or intercept terms as cut-points in the latent variable AP_i^*distribution as follows: $(\alpha_1 < \alpha_2 \ldots < \alpha_{j-1})$ with (J−1). The cut-points are considered threshold values for switching from one category of the observed variable AP to another. Cut points are typically considered as nuisance parameters needed for estimation purposes, although having no intrinsic meaning (Greene and Hensher, 2010).

Thus, the ordinal variable AP is linked to the latent variable AP_i^* as shown below:

$$AP_i = j \ \ if \ \ \alpha_{j-1} < AP_i^* \leq \alpha_j \quad (2)$$

where j = 1 to J and $\alpha_0 = -\infty$ and $\alpha_J + \infty$.

Once the model was obtained, the problem of correlation between the regressors or multicollinearity arose. Multicollinearity can be a relevant issue in regression due to the undesired correlation among predictors reducing the capacity of the model to recognize significant variables (Daoud, 2017). To check the reliability of the model in terms of multicollinearity phenomena, the Variance Inflation Factor (VIF) analysis was employed. Based on the current literature, the interpretation of the analysis should be performed on the 1/VIF ratio, which should be >0.2 to indicate that the model is not affected by multicollinearity problems that could lead to invalid results (Mehmetoglu and Jakobsen, 2016).

The last step of the model implied the study of marginal effects since the information provided by the coefficients of the ordered logistic regression are not directly interpretable in terms of probability (Greene and Hensher, 2010). To overcome this

TABLE 2 | Descriptive statistics of the variables used in the Ordered Logit model.

Variables	Mean	SD
Overall taste	4.67	1.22
Color	5.32	1.24
Texture	5.38	1.15
Nitrites content	2.46	1.80
Packaging	4.72	1.71
Italian origin	6.48	0.67
PDO/PGI	5.91	0.77
Animal welfare	6.33	1.16

problem, the estimation of probability changes was carried out by means of the average marginal coefficients. This assessment allows the estimation of how a marginal variation in the value of a regressor impacts the probability of the result, holding the other predictors at their mean values (Boes and Winkelmann, 2006).

RESULTS

Our research aim was to analyse what variables influence consumers' willingness to pay an additional price premium for a healthy salami with low-fat content. To this purpose, different socio-demographic characteristics shown in **Table 1** and intrinsic/extrinsic salami attributes in **Table 2** were tested in the econometric model.

Starting from the summary statistics, some first insights can be drawn from **Table 2** where the mean value and standard deviation of the tested characteristics are shown. Animal welfare and Italian Origin ranked the most popular followed by PDO/PGI and texture. Nitrites content, overall taste, and packaging ranked lower with a mean average between 2.46 and 4.72, which underlines a certain degree of interest in these attributes. The low importance attached to the nitrite content in salami suggests that consumers prefer to avoid this substance in the final product. Regarding the willingness to pay an additional price/extra for reduced-fat salami, the distribution of frequencies among the different classes was the following: 7.44% of the sample were not willing to pay extra; 33.26% of the sample were willing to pay up to 10%; 50.83% were willing to pay between 10 and 20%; 7.02% were willing to pay between 20 and 30%; and 1.45% of the sample were willing to pay more than 30%.

Moving on to the core of the paper, i.e., the estimation of the effects of attributes and socio-demographic characteristics on consumers' willingness to pay an "additional price for healthy salami," **Table 3** shows the results of the regression model. In the estimated model, the pseudo R^2 (McFadden, 1973) was calculated to assess the goodness of fit; the obtained value of 0.136 is acceptable based on current literature (Liu et al., 2015; Yano et al., 2021).

Table 3 shows that only 7 out of the 17 regressors are statistically significant at 5%, and 1 variable is significant at 10%. The four categories of cut points are also reported in the table.

Starting with texture as an intrinsic attribute, the model suggests that consumers who value this characteristic are less willing to pay for a low-fat salami. A similar result was obtained for nitrite content, with consumers who considered this attribute important being less interested in a reduced-fat salami. Considering the extrinsic attributes, only the PDO/PGI label, reflecting the quality and regional specificity of salami, was significant. The coefficient obtained suggests that respondents interested in this quality certification are less inclined to pay an additional price for a reduced-fat salami.

TABLE 3 | Ordered logit model results on WTP for reduced fat salami ($n = 484$).

Variables	Coef.	*p*-value
Overall taste	0.024	0.823
Color	0.149	0.197
Texture	−0.217	0.042
Nitrites content	−0.288	0.000
Packaging	−0.044	0.490
Italian origin	0.211	0.281
PDO/PGI	−0.416	0.004
Animal welfare	0.174	0.102
Age cohort	0.179	0.256
Gender	−0.534	0.007
Body Mass Index (BMI)	−0.181	0.163
Family members	−0.065	0.457
Education	0.140	0.266
Monthly family income	0.332	0.002
Regular sport activity	0.420	0.036
Salami consumption	−0.249	0.071
Price paid for salami	0.698	0.000
Cut 1	−3.388	
Cut 2	−0.673	
Cut 3	2.671	
Cut 4	4.531	
Goodness of fit	Mc Fadden *r* square	0.136
	Log likelihood	−481.483

The table also highlights the role of socio-demographic characteristics that were found to be significant. The coefficient of gender suggests that males are more interested in this product and households with a high income as well. Finally, the variable sport activity was also significant, and the model implies that people who have a regular sporting activity are more willing to pay an additional price premium for this type of salami.

The negative coefficient concerning consumer habits, measured with the variable "Salami consumption," indicates that consumers who consume large amounts of product are less willing to pay an additional price for a reduced fat salami, suggesting an opposite relationship between product quantity and quality. The other variable, "Price paid for salami," indicates the actual price at which the sample purchases salami. The model suggests respondents that consume expensive products are more willing to pay for a healthier product.

The validation of the model in terms of multicollinearity is shown in **Table 4**. The table presents the outcome of the variance inflation factor (VIF) analysis and emphasizes the absence of multicollinearity among the variables included in the model. This

TABLE 4 | Variance Inflation Factor (VIF) analysis of the model.

Variables	VIF	1/VIF
Overall taste	2.08	0.48
Color	2.28	0.44
Consistency	1.63	0.62
Nitrites content	2.41	0.42
Packaging	1.46	0.68
Italian origin	2.06	0.49
PDO/PGI	1.38	0.73
Animal welfare	1.77	0.57
Age cohort	1.18	0.85
Gender	1.12	0.89
Body Mass Index (BMI)	1.09	0.92
Family members	1.09	0.92
Education	1.49	0.67
Monthly family income	1.12	0.89
Regular sport activity	1.14	0.88
Salami consumption	1.90	0.53
Price paid for salami	2.09	0.48
Mean VIF	1.60	

information is given by the 1/VIF ratio. In truth, when the ratio is >0.2, multicollinearity cannot be considered relevant as the stability of the coefficients provided by the logistic regression is satisfactory.

Since direct interpretation of the coefficients in an ordered response model is uncertain (Greene and Hensher, 2010), further investigation of the outcomes may be needed. Therefore, the findings of the model, shown in **Table 3**, have been further elaborated to assess predicted probabilities and marginal effects. Indeed, the coefficients of logistic models only indicate the magnitude of impacts, positive or negative, on the probability of a certain result for the dependent variable (Smith et al., 2009). In addition, the marginal effects applied to the ordered logistic model permit us to observe probability variation across the discrete alternatives of the dependent variable (D'Amico et al., 2016). Furthermore, since the predicted probabilities from the logistic regression shown in **Table 3** can change over the categories of the dependent variable, we can use the marginal effects to quantitatively assess how much they increase or decrease the probability of the outcome. **Table 5** provides insights for the significant variables.

Analyzing the interpretation of socio-demographic characteristics on the willingness to pay an additional price on a reduced-fat salami, we focus on significant marginal effects related to gender, monthly family income, and regular sport activity. Indeed, since the ordered logistic regression allows evaluating the probability variation across each level of the ordinal scale, in this second step, more coefficient is provided for the covariates. The interpretation of marginal effects should be focused on significant coefficients that indicate that the probability of the change provided within the level assessed on the ordinal scale is distinguishable from zero (Esarey and Sumner, 2018). Starting with gender, the study of marginal effects provides deeper insight than the mere interpretation of the coefficient in the logistic regression. In fact, the general effect indicates that men are more interested in reduced-fat salami. The general trend can be deeply explored by the marginal coefficient, which indicates that women are more willing to pay an additional price premium to 10% (6.5% in terms of probability). Instead, males are more willing to pay an additional price premium: between 10 and 20% (6.2%), between 20 and 30 (2.9%), and more than 30% (around 1%). Turning to the variable "Monthly family income," the marginal coefficients suggest that the probability of an additional price premium increases for higher incomes in the case of premium prices of 10–20% (3.8%), 20–30% (1.8%), and more than 30% (around 1%). People with lower incomes, on the other hand, can be more willing to pay up to 10% (4%). Finally, people who practice sport regularly are more willing to pay an additional price premium for the alternatives 10–20% (4.8%), 20–30% (2.3%), and more than 30% (around 1%).

DISCUSSION

The results of our work generally confirm the initial assumption that there is a higher willingness to pay for low-fat salami on the basis of certain variables that have been investigated. Moreover, the distribution of frequency of the responses shows that respondents were willing to pay an additional price premium mainly up to 10% and between 10 and 20 for reduced-fat salami. This fact confirms consumers' ever-growing attention to food products perceived as "healthy" and that healthier meat products are a well-established market that could be further developed (Guàrdia et al., 2006; Schnettler et al., 2019). Therefore, these research findings could have a direct influence on the meat industry since it has to understand the attributes that consumers feel are relevant.

In our study, the variables that most affect the consumption of low-fat cured meats relate to intrinsic characteristics (Texture, Nitrites), extrinsic characteristics (PDO/PGI), and socio-demographic and consumption characteristics (Gender, Monthly Income, Regular Sport Activity, Price paid for salami). In particular, variables within the "socio-demographic" group have a positive impact on WTP.

In detail, the texture variable appears relevant, but as the importance attached by consumers to this attribute increases, the WTP for low-fat salami decreases. On the other hand, tenderness, fragrance, and texture have always been among the most important sensory attributes, especially for pork that has been cooked (Miller, 2020). Válková et al. (2007) had already highlighted these results, emphasizing that texture is one of the most significant factors that affects consumers' opinion of ham quality. Ordóñez et al. (2001), in their research, found that higher fat frankfurters were considered more satisfactory by consumers than experimental lower fat frankfurters, precisely because of their consistency, while other studies found that a frankfurter with a low fat content was more likely to be consumed than conventional ones (Rocha et al., 2019). Similarly, Shan et al. (2017) examined consumers' judgment on reducing fat in meat

TABLE 5 | Average marginal effects for significant variables derived from the ordered logit model.

Variables	Not willing to pay	Up to 10%	Between 10 and 20%	Between 20 and 30%	More than 30%
Texture	0.015	0.026	−0.025	−0.012	−0.003
p-value	0.046**	0.040**	0.039**	0.053*	0.101
Nitrites content	0.018	0.035	−0.033	−0.016	−0.004
p-value	0.001***	0.000***	0.000***	0.001***	0.029**
PDO/PGI	0.026	0.050	−0.048	−0.023	−0.006
p-value	0.007***	0.004***	0.005***	0.008***	0.049**
Gender	0.033	0.065	−0.062	−0.029	−0.007
p-value	0.010***	0.006***	0.007***	0.011**	0.053*
Monthly family income	−0.021	−0.040	0.038	0.018	0.005
p-value	0.003***	0.002***	0.002***	0.005***	0.039**
Regular sport activity	−0.026	−0.051	0.048	0.023	0.006
p-value	0.042**	0.035**	0.036**	0.044**	0.096*
Salami consumption	0.016	0.030	−0.029	−0.014	−0.003
p-value	0.078*	0.068*	0.069*	0.080*	0.133
Price paid for salami	−0.043	−0.085	0.082	0.038	0.009
p-value	0.001***	0.000***	0.000***	0.001***	0.028**

*,**,***Indicate significant marginal effects at p-values 0.1, 0.05, and 0.01, respectively.*

products, confirming that survey participants did not mention any significant changes regarding the flavor of either product.

The same can be said for nitrite content. This reinforces the hypothesis that consumers who are particularly attentive to intrinsic variables (therefore related to the naturalness of the product) are less willing to pay for products perceived as modified (Galati et al., 2019). A recent study (Di Vita et al., 2019) has in fact highlighted the relevance of variables linked to properties such as being nitrite-free and salt reduction in consumer choices, underlining the significant consumer propensity for paying extra for salami with such characteristics. Hung et al. (2016) reached the same conclusions when he studied consumer attitudes and purchase intent toward processed meat products containing the addition of natural compounds and reduction of nitrites.

Concerning the analysis of the incidence of the PDO/PGI variable, again, people who are sensitive to the traditional productive process of the meat products are less used to paying more for low-fat salami. This finding is consistent with the previous literature on the role of PDO certifications in food products, whereby the consumer values more the typicality than industrialized food (Garavaglia and Mariani, 2017).

Considering the attitude based on gender literature, concerning healthy food products and attributes, have provided divergent results. The role of gender could be non-significant (Bruschi et al., 2015); however, several researchers reported that woman find nutritional labels more important than men when selecting meat products and are more willing to pay for healthy food (Rimal, 2005; Timpanaro et al., 2020), while other studies reveal that males are more satisfied with healthy characteristics in some products, such as dry-cured ham (Resano et al., 2011).

In our case, women are interested in reduced-fat salami but are willing to pay an additional price premium only for the lowest alternative (up to 10%). This result suggests that the gender effect may be influenced by the product evaluated in the study or the origin of the consumers.

In addition, the respondents actively doing regular physical exercise were more inclined to pay a higher price for health and wellness food products, consistent with both expectations and other studies carried out on processed meats. In particular, the consumers surveyed who do sports seem to be more in favor of paying an additional price for a healthy salami (Di Vita et al., 2019). That physical activity variables also positively influence WTP was also found in a study on salty bread (Di Vita et al., 2016).

Interestingly, the subjects who do regular physical exercise are those who, by far, are the most willing to pay for low-fat salami, even more so than those in the high-income bracket. This finding is consistent with existing literature that highlight how healthy eating motivation is associated with healthy lifestyles. This research is in line with prior studies which have examined the link between healthy motivation, consumption, and lifestyle behavior like sport and exercise (Wardle and Steptoe, 2003; Hearty et al., 2007).

As far as income is concerned, the previous studies are confirmed where low family income is associated with a poor-quality dietary intake (Wolfson et al., 2019), along with a limited consumption of fruit and vegetables in favor of more sugar-sweetened beverages and a general consumption of high-fat foods. Indeed, Naughton et al. (2015) illustrated how social class status influences diets, with higher classes being linked to diets of better quality and lower classes tending to have diets that are nutrient poor and rich in energy. These findings, then, are consistent with other research stating that healthier food options are more often bought by consumers with higher education levels and incomes (Sajdakowska et al., 2018); furthermore, they are willing to pay an additional price for foods with lower fat and salt (Nordström and Thunström, 2015).

Ortega et al. (2011) and Wu et al. (2015) have determined that consumers' pork meat preferences are influenced by factors such as gender, education, and level of income. Moreover, Balogh

et al. (2016), who investigated the WTP for a traditional food product like Hungarian mangalitza salami, revealed how income and education may affect consumer preference and WTP. In line with previous studies, a preference for meat consumption was also found to be correlated to family economic status (de Boer and Aiking, 2018; Milford et al., 2019).

It goes without saying that WTP decreases as salami consumption increases, since the higher price would affect substantial amounts of consumption. Finally, consumers who are already used to paying higher prices show a greater willingness to pay because the marginal price increase is less significant for them.

CONCLUDING REMARKS

Several factors, such as product attributes, socio-demographics, and habits that move consumers toward the consumption of reduced-fat salami, have been detected. Through the econometric model adopted in the study, a general trend influencing the likelihood of the price premium was described and further insights were obtained through the study of marginal effects. Concerning the product attributes consistency, nitrites content and PDO/PGI were significant, suggesting the prominent role of sensory attributes, additives content, and regional specificity. Among the socio-demographic characteristics, gender, income, and sporting activity were highly significant. Finally, consumers' habits highlighted the importance of the quantities consumed which negatively affects the willingness to pay.

This paper has several implications for both marketers and producers. As for producers, our study suggests the feasibility for the reduction of fat in cured meat by producing foods that are less harmful to health. Healthier products are appreciated by different consumer segments, so by including information on the label in different forms, such as nutritional claims, these products can be differentiated. Product differentiation can also allow both small producers and large companies to extend the range of interested consumers, improving sales and hence increasing revenues.

The main limitation of this study mainly relies on the sample method adopted, namely convenience sampling. Even though this sampling approach has been largely used in the literature, and the reliability of results is accepted, the results should be interpreted with care as the potential for inference in the wider population is lower than the stratified method.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

GD: conceptualization, methodology, writing—original draft, writing—review and editing, and supervision. RZ: methodology, writing—original draft, writing—review and editing, formal analysis, data curation, and validation. DS: writing—original draft, writing—review and editing, formal analysis, data curation, and validation. GM: writing—original draft, writing—review and editing, and data curation. GL: methodology and supervision. MD'A: conceptualization, supervision, project administration, and resources. All authors contributed to the article and approved the submitted version.

FUNDING

This work was supported by the project PIAno di inCEntivi per la Ricerca di Ateneo (PIACERI) UNICT 2020/22 line 2, University of Catania (5A722192154).

REFERENCES

Aaslyng, M. D., Vestergaard, C., and Koch, A. G. (2014). The effect of salt reduction on sensory quality and microbial growth in hotdog sausages, bacon, ham and salami. *Meat Sci.* 96, 47–55. doi: 10.1016/j.meatsci.2013.06.004

Abrams, K. M., Meyers, C. A., and Irani, T. A. (2010). Naturally confused: consumers' perceptions of all-natural and organic pork products. *Agric. Hum. Values* 27, 365–374. doi: 10.1007/s10460-009-9234-5

Adrogué, H. J., and Madias, N. E. (2007). Sodium and potassium in the pathogenesis of hypertension. *N. Engl. J. Med.* 356, 1966–1978. doi: 10.1056/NEJMra064486

Aiking, H., de Boer, J., and Vereijken, J. M. (eds.). (2006). *Sustainable Protein Production and Consumption: Pigs or Peas?* Dordrecht: Springer. doi: 10.1007/1-4020-4842-4

Alahakoon, A. U., Jayasena, D. D., Ramachandra, S., and Jo, C. (2015). Alternatives to nitrite in processed meat: up to date. *Trends Food Sci. Technol.* 45, 37–49. doi: 10.1016/j.tifs.2015.05.008

Ali, T., and Ali, J. (2020). Factors affecting the consumers' willingness to pay for health and wellness food products. *J. Agric. Food Res.* 2, 2666–1543, doi: 10.1016/j.jafr.2020.100076

Allison, S. (2018). High salt intake as a driver of obesity. *Nat. Rev. Nephrol.* 14, 285. doi: 10.1038/nrneph.2018.23

Alves, L. A. A. D. S., Lorenzo, J. M., Gonçalves, C. A. A., Santos, B. A. D., Heck, R. T., Cichoski, A. J., et al. (2016). Production of healthier bologna type sausages using pork skin and green banana flour as a fat replacer. *Meat Sci.* 121, 73–78. doi: 10.1016/j.meatsci.2016.06.001

Annunziata, A., and Pascale, P. (2011). "Consumer behaviour and attitudes towards healthy food products: Organic and functional foods," in *A Resilient European Food Industry in a Challenging World*, eds G. Baourakis, K. Mattas, C. Zopounidis, C., G. van Dijk (Nova Publishers), 17–36. doi: 10.1080/10454446.2011.618790

Ansorena, D., Cama, S., Alejandre, M., and Astiasarán, I. (2019). Health-related messages in the labeling of processed meat products: a market evaluation. *Food Nutr. Res.* 63, 1–7. doi: 10.29219/fnr.v63.3358

Aoki, K., Shen, J., and Saijo, T. (2010). Consumer reaction to information on food additives: evidence from an eating experiment and a field survey. *J. Econ. Behav. Organiz.* 73, 433–438. doi: 10.1016/j.jebo.2009.11.007

Aquilanti, L., Garofalo, C., Osimani, A., and Clementi, F. (2016). Ecology of lactic acid bacteria and coagulase negative cocci in fermented dry sausages manufactured in Italy and other Mediterranean countries: an overview. *Int. Food Res. J.* 23, 429–445.

Balogh, P., Békési, D., Gorton, M., Popp, J., and Lengyel, P. (2016). Consumer willingness to pay for traditional food products. *Food Policy* 61, 176–184. doi: 10.1016/j.foodpol.2016.03.005

Barone, A. M., Banovic, M., Asioli, D., Wallace, E., Ruiz-Capillas, C., and Grasso, S. (2021). The usual suspect: how to co-create healthier meat products. *Food Res. Int.* 143, 110304. doi: 10.1016/j.foodres.2021.110304

Beriain, M. J., Gómez, I., Petri, E., Insausti, K., and Sarriés, M. V. (2011). The effects of olive oil emulsified alginate on the physico-chemical, sensory, microbial, and fatty acid profiles of low-salt, inulin-enriched sausages. *Meat Sci.* 88, 189–197. doi: 10.1016/j.meatsci.2010.12.024

Bernabéu, R., and Tendero, A. (2005). Preference structure for lamb meat consumers. A Spanish case study. *Meat Sci.* 71, 464–470, doi: 10.1016/j.meatsci.2005.04.027

Bis-Souza, C. V., Ozaki, M. M., Vidal, V. A. S., Pollonio, M. A. R., Penna, A. L. B., and Barretto, A. C. S. (2020). Can dietary fiber improve the technological characteristics and sensory acceptance of low-fat Italian type salami? *Int. J. Food Sci. Technol.* 57, 1003–1012. doi: 10.1007/s13197-019-04133-6

Boes, S., and Winkelmann, R. (2006). Ordered response models. *Allgem. Statist. Arch.* 90, 167–181. doi: 10.1007/s10182-006-0228-y

Bohrer, B. M. (2017). Review: nutrient density and nutritional value of meat products and non-meat foods high in protein. *Trends Food Sci. Technol.* 65, 103–112 doi: 10.1016/j.tifs.2017.04.016

Braghieri, A., Piazzolla, N., Galgano, F., Condelli, N., De Rosa, G., and Napolitano, F. (2016). Effect of preservative addition on sensory and dynamic profile of Lucanian dry-sausages as assessed by quantitative descriptive analysis and temporal dominance of sensations. *Meat Sci.* 122, 68–75. doi: 10.1016/j.meatsci.2016.07.020

Brosdahl, D. J., and Carpenter, J. M. (2011). Shopping orientations of US males: a generational cohort comparison. *J. Retail. Consumer Serv.* 18, 548–554. doi: 10.1016/j.jretconser.2011.07.005

Brunner, T. A., van der Horst, K., and Siegrist, M. (2010). Convenience food products. Drivers for consumption. *Appetite* 55, 498–506. doi: 10.1016/j.appet.2010.08.017

Bruschi, V., Teuber, R., and Dolgopolova, I. (2015). Acceptance and willingness to pay for health-enhancing bakery products–Empirical evidence for young urban Russian consumers. *Food Qual. Pref.* 46, 79–91. doi: 10.1016/j.foodqual.2015.07.008

Bryła, P. (2020). Selected predictors of the importance attached to salt content information on the food packaging (a study among polish consumers). *Nutrients* 22;12:293. doi: 10.3390/nu12020293

Burnier, M. (2021). Is modifying salt intake an effective treatment strategy for hypertension control? *Nephrol Dial Transplant*. 37, 31–32. doi: 10.1093/ndt/gfaa108

Burnier, P. C., Spers, E. E., and de Barcellos, M. D. (2021). Role of sustainability attributes and occasion matters in determining consumers' beef choice. *Food Qual. Prefer*. 88:104075. doi: 10.1016/j.foodqual.2020.104075

Campagnol, P. C., Dos Santos, B. A., Wagner, R., Terra, N. N., and Pollonio, M. A. (2011). Amorphous cellulose gel as a fat substitute in fermented sausages. *Meat Sci.* 90, 36–42. doi: 10.1016/j.meatsci.2011.05.026

Caracciolo, F., Cembalo, L., Cicia, G., and Del Giudice, T. (2010). "European preferences for pork product and process attributes: a generalized random utility model for ranked outcome," in *Proceedings in Food System Dynamics*, 161–173. Avaiilable online at: http://centmapress.ilb.uni-bonn.de/ojs/index.php/proceedings/article/view/1012/45

Caracciolo, F., Cicia, G., Del Giudice, T., Cembalo, L., Krystallis, A., Grunert, K. G., et al. (2016). Human values and preferences for cleaner livestock production. *J. Clean. Prod.* 112, 121–130. doi: 10.1016/j.jclepro.2015.06.045

Cenci-Goga, B. T., Rossitto, P. V., Sechi, P., Parmegiani, S., Cambiotti, V., and Cullor, J. S. (2012). Effect of selected dairy starter cultures on microbiological, chemical and sensory characteristics of swine and venison (Dama dama) nitrite-free dry-cured sausages. *Meat Sci.* 90, 599–606. doi: 10.1016/j.meatsci.2011.09.022

Chamhuri, N., and Batt, P. J. (2013). Exploring the factors influencing consumers' choice of retail store when purchasing fresh meat in Malaysia. *Int. Food Agribusiness Manag. Rev.* 16, 99–122.

Chevance, F. F., Farmer, L. J., Desmond, E. M., Novelli, E., Troy, D. J., and Chizzolini, R. (2000). Effect of some fat replacers on the release of volatile aroma compounds from low-fat meat products. *J. Agric. Food Chem.* 48, 3476–3484. doi: 10.1021/jf991211u

Cicia, G., and Colantuoni, F. (2010). Willingness to pay for traceable meat attributes: a meta-analysis. *Int. J. Food Syst. Dyn.* 1, 252–263. doi: 10.18461/ijfsd.v1i3.138

Corral, S., Salvador, A., and Flores, M. (2013). Salt reduction in slow fermented sausages affects the generation of aroma active compounds. *Meat Sci.* 93, 776–785. doi: 10.1016/j.meatsci.2012.11.040

D'Amico, M., Di Vita, G., and Monaco, L. (2016). Exploring environmental consciousness and consumer preferences for organic wines without sulfites. *J. Clean. Prod.* 120, 64–71. doi: 10.1016/j.jclepro.2016.02.014

Daoud, J. I. (2017). Multicollinearity and regression analysis. *J. Phys. Conf. Ser.* 949, 012009). doi: 10.1088/1742-6596/949/1/012009

De Almeida, M. A., de, Villanueva, N. D. M., Pinto, J. S., da, S., Saldaña, E., and Contreras-Castillo, C.J. (2016). Sensory and physicochemical characteristics of low sodium salami. *Scientia Agricola* 73, 347–355. doi: 10.1590/0103-9016-2015-0096

de Boer, J., and Aiking, H. (2018). Prospects for pro-environmental protein consumption in Europe: cultural, culinary, economic and psychological factors. *Appetite* 121, 29–40. doi: 10.1016/j.appet.2017.10.042

Deselnicu, O. C., Costanigro, M., Souza-Monteiro, D. M., and McFadden, D. T. (2013). A meta-analysis of geographical indication food valuation studies: What drives the premium for origin-based labels? *J. Agric. Resour. Econ.* 38, 204–219.

Desmond, E. (2006). Reducing salt: a challenge for the meat industry. *Meat Sci.* 74, 188–196. doi: 10.1016/j.meatsci.2006.04.014

Di Vita, G., Blanc, S., Mancuso, T., Massaglia, S., La Via, G., and D'Amico, M. (2019). Harmful compounds and willingness to buy for reduced-additives salami. An outlook on Italian consumers. *Int. J. Environ. Res. Public Health* 16, 2605. doi: 10.3390/ijerph16142605

Di Vita, G., D'Amico, M., Lombardi, A., and Pecorino, B. (2016). Evaluating trends of low sodium content in food: the willingness to pay for salt-reduced bread, a case study. *Agric. Econ. Rev.* 17, 82–99. doi: 10.22004/ag.econ.262442

Di Vita, G., Pippinato, L., Blanc, S., Zanchini, R., Mosso, A., and Brun, F. (2021b). Understanding the role of purchasing predictors in the consumer's preferences for PDO labelled honey. *J. Food Products Market.* 27 , 42–56. doi: 10.1080/10454446.2021.1884161

Di Vita, G., Strano, A., Maesano, G., La Via, G., and D'Amico, M. (2020). The role of individual knowledge in functional olive oil preferences: does self-coherence lead to different health attributes perception? *Foods* 9, 1428. doi: 10.3390/foods9101428

Di Vita, G., Zanchini, R., Falcone, G., D'Amico, M., Brun, F., and Gulisano, G. (2021a). Local, organic or protected? Detecting the role of different quality signals among Italian olive oil consumers through a hierarchical cluster analysis. *J. Clean. Prod.* 290, 125795. doi: 10.1016/j.jclepro.2021.125795

Djinovic-Stojanovic, J., Ristic, M., and Troeger, K. (2019). Eating habits of Serbian consumers regarding content of fat and salt in meat products. *IOP Conf. Ser. Earth Environ. Sci.* 333, 012056. doi: 10.1088/1755-1315/333/1/012056

Doyle, M. E., and Glass, K. A. (2010). Sodium reduction and its effect on food safety, food quality, and human health. *Compreh. Rev. Food Sci. Food Saf.* 9, 44–56. doi: 10.1111/j.1541-4337.2009.00096.x

Dreher, J., Weißmüller, M., Herrmann, K., Terjung, N., Gibis, M., and Weiss, J. (2021). Influence of protein and solid fat content on mechanical properties and comminution behavior of structured plant-based lipids. *Food Res. Int.* 145, 110416. doi: 10.1016/j.foodres.2021.110416

Dudinskaya, E., Naspetti, S., Arsenos, G., Caramelle-Holtz, E., Latvala, T., Martin-Collado, D., et al. (2021). European consumers' willingness to pay for red meat labelling attributes. *Animals* 11, 556. doi: 10.3390/ani11020556

Esarey, J., and Sumner, J. L. (2018). Marginal effects in interaction models: determining and controlling the false positive rate. *Compar. Polit. Stud.* 51, 1144–1176. doi: 10.1177/0010414017730080

Etikan, I., Musa, S. A., and Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *Am. J. Theor. Appl. Stat.* 5, 1–4. doi: 10.11648/j.ajtas.20160501.11

Ferysiuk, K., and Wójciak, K. M. (2020). Reduction of nitrite in meat products through the application of various plant-based ingredients. *Antioxidants* 9, 711. doi: 10.3390/antiox9080711

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

Font-i-Furnols, M., Realini, C., Montossi, F., Sañudo, C., Campo, M. M., Oliver, M. A., et al. (2011). Consumer's purchasing intention for lamb meat

affected by country of origin, feeding system and meat price: a conjoint study in Spain, France and United Kingdom. *Food Qual. Pref.* 22, 443–441. doi: 10.1016/j.foodqual.2011.02.007

Galati, A., Schifani, G., Crescimanno, M., and Migliore, G. (2019). "Natural wine" consumers and interest in label information: an analysis of willingness to pay in a new Italian wine market segment. *J. Clean. Prod.* 227, 405–413. doi: 10.1016/j.jclepro.2019.04.219

Garavaglia, C., and Mariani, P. (2017). How much do consumers value protected designation of origin certifications? Estimates of willingness to Pay for PDO Dry-Cured Ham in Italy. *Agribusiness* 33, 403–423. doi: 10.1002/agr.21494

Gaviglio, A., and Pirani, A. (2016). Consumer perception of cured pork meats: the added value of the organic attribute. *Czech J. Food Sci.* 33, 32–36. doi: 10.17221/233/2014-CJFS

Gifford, K., and Bernard, J. C. (2011). The effect of information on consumers' willingness to pay for natural and organic chicken. *Int. J. Consumer Stud.* 35, 282–289. doi: 10.1111/j.1470-6431.2010.00929.x

Govari, M., and Pexara, A. (2018). Nitrates and Nitrites in meat products. *J. Hellenic Vet. Med. Soc.* 66, 127–140. doi: 10.12681/jhvms.15856

Greene, W. H., and Hensher, D. A. (2010). *Modeling Ordered Choices: A Primer*. Cambridge: Cambridge University Press. doi: 10.1017/CBO9780511845062

Grunert, K. G. (2006). Future trends and consumer lifestyles with regard to meat consumption. *Meat Sci.* 74 149–160. doi: 10.1016/j.meatsci.2006.04.016

Guàrdia, M. D., Guerrero, L., Gelabert, J., Gou, P., and Arnau, J. (2006). Consumer attitude towards sodium reduction in meat products and acceptability of fermented sausages with reduced sodium content. *Meat Sci.* 73, 484–490. doi: 10.1016/j.meatsci.2006.01.009

Han, M., and Bertram, H. C. (2017). Designing healthier comminuted meat products: effect of dietary fibers on water distribution and texture of a fat-reduced meat model system. *Meat Sci.* 133, 159–165. doi: 10.1016/j.meatsci.2017.07.001

Haouet, N., Pistolese, S., Ortenzi, R., Schiavo, M. R., Clementi, F., and Altissimi, S. (2016). *Uso o abuso di additivi nei prodotti a base di carne: valutazione e interpretazione dei fattori che intervengono nella trasformazione dei nitriti e dei nitrati*. Sanità Pubblica Veterinaria. Perugia, 99.

Hathwar, S. C., Rai, A. K., Modi, V. K., and Narayan, B. (2012). Characteristics and consumer acceptance of healthier meat and meat product formulations—a review. *J. Food Sci. Technol.* 49 653–664. doi: 10.1007/s13197-011-0476-z

He, F. J., and MacGregor, G. A. (2009). A comprehensive review on salt and health and current experience of worldwide salt reduction programmes. *J. Hum. Hypertens.* 23, 363–384. doi: 10.1038/jhh.2008.144

Hearty, Á. P., McCarthy, S. N., Kearney, J. M., and Gibney, M. J. (2007). Relationship between attitudes towards healthy eating and dietary behaviour, lifestyle and demographic factors in a representative sample of Irish adults. *Appetite* 48, 1–11. doi: 10.1016/j.appet.2006.03.329

Henney, J. E., Taylor, C. L., and Boon, C. S. (2010). *Strategies to Reduce Sodium Intake in the United States*. Institute of Medicine (US) Committee on Strategies to Reduce Sodium Intake, editors. Washington, DC: National Academies Press.

Henning, S. S. C., Tshalibe, P., and Hoffman, L. C. (2016). Physico-chemical properties of reduced-fat beef species sausage with pork back fat replaced by pineapple dietary fibres and water. *LWT Food Sci. Technol.* 74, 92–98. doi: 10.1016/j.lwt.2016.07.007

Honeyman, M. S., Pirog, R. S., Huber, G. H., Lammers, P. J., and Hermann, J. R. (2006). The United States pork niche market phenomenon. *J. Anim. Sci.* 84, 2269–2275. doi: 10.2527/jas.2005-680

Hoppu, U., Hopia, A., Pohjanheimo, T., Rotola-Pukkila, M., Mäkinen, S., Pihlanto, A., et al. (2017). Effect of salt reduction on consumer acceptance and sensory quality of food. *Foods* 6, 103. doi: 10.3390/foods6120103

Hung, Y., de Kok, T. M., and Verbeke, W. (2016). Consumer attitude and purchase intention towards processed meat products with natural compounds and a reduced level of nitrite. *Meat Sci.* 121, 119–126. doi: 10.1016/j.meatsci.2016.06.002

Hwang, J., Lee, S., Jo, M., Cho, W., and Moon, J. (2021). The effect of sustainability-related information on the sensory evaluation and purchase behavior towards salami products. *Food Sci. Anim. Resour.* 41, 95. doi: 10.5851/kosfa.2020.e83

Hwang, J., You, J., Moon, J., and Jeong, J. (2020). Factors affecting consumers' alternative meats buying intentions: plant-based meat alternative and cultured meat. *Sustainability* 12, 5662. doi: 10.3390/su12145662

Inguglia, E. S., Zhang, Z., Tiwari, B. K., Kerry, J. P., and Burgess, C. M. (2017). Salt reduction strategies in processed meat products–A review. *Trends Food Sci. Technol.* 59, 70–78. doi: 10.1016/j.tifs.2016.10.016

Ktari, N., Smaoui, S., Trabelsi, I., Nasri, M., and Salah, R. B. (2014). Chemical composition, techno-functional and sensory properties and effects of three dietary fibers on the quality characteristics of Tunisian beef sausage. *Meat Sci.* 96, 521–525. doi: 10.1016/j.meatsci.2013.07.038

Lanfranchi, M., and Giannetto, C. (2021). Meat consumption trend in Sicily (Italy): an analysis of consumer preferences. *Calitatea* 22, 136–138.

Laranjo, M., Gomes, A., Agulheiro-Santos, A. C., Potes, M. E., Cabrita, M. J., Garcia, R., et al. (2017). Impact of salt reduction on biogenic amines, fatty acids, microbiota, texture and sensory profile in traditional blood dry-cured sausages. *Food Chem.* 218, 129–136. doi: 10.1016/j.foodchem.2016.09.056

Lee, S. H., Han, D. B., Caputo, V., and Nayga Jr, R. M. (2015). Consumers' valuation for a reduced salt product: a nonhypothetical choice experiment. *Can. J. Agric. Econ.* 63, 563–582. doi: 10.1111/cjag.12081

Liu, R., Hoefkens, C., and Verbeke, W. (2015). Chinese consumers' understanding and use of a food nutrition label and their determinants. *Food Qual. Pref.* 41, 103–111. doi: 10.1016/j.foodqual.2014.11.007

Mancini, M. C., Arfini, F., and Guareschi, M. (2019). Innovation and typicality in localised agri-food systems: the case of PDO Parmigiano Reggiano. *Br. Food J.* 121, 3043–3061. doi: 10.1108/BFJ-10-2018-0662

McEachern, M. G., and Willock, J. (2004). Producers and consumers of organic meat: a focus on attitudes and motivations. *Br. Food J.* 106, 34–552. doi: 10.1108/00070700410545737

McFadden, D. (1973). "Conditional logit analysis of qualitative choice be," in *Frontiers in Econometrics*, ed P. Zarembka (New York, NY: Academic Press), 105–142.

Mehmetoglu, M., and Jakobsen, T. G. (2016). *Applied statistics using* Stata: a guide for the social sciences. Sage.

Mendoza, E., Garcia, M. L., Casas, C., and Selgas, M. D. (2001). Inulin as fat substitute in low fat, dry fermented sausages. *Meat Sci.* 57, 387–393. doi: 10.1016/S0309-1740(00)00116-9

Merlino, V. M., Borra, D., Girgenti, V., Dal Vecchio, A., and Massaglia, S. (2018). Beef meat preferences of consumers from Northwest Italy: analysis of choice attributes. *Meat Sci.* 143:119–128. doi: 10.1016/j.meatsci.2018.04.023

Mesías, F. J., Gaspar, P., Escribano, M., and Pulido, F. (2010). The role of protected designation of origin in consumer preference for Iberian dry-cured ham in Spain. *Ital. J. Food Sci.* 22, 367.

Mesías, F. J., Pulido, F., Escribano, M., Gaspar, P., Pulido, Á. F., Escribano, A., et al. (2013). Evaluation of new packaging formats for dry-cured meat products using conjoint analysis: an application to Dry-Cured I berian Ham. *J. Sensory Stud.* 28, 238–247. doi: 10.1111/joss.12040

Micha, R., Wallace, S. K., and Mozaffarian, D. (2010). Red and processed meat consumption and risk of incident coronary heart disease, stroke, and diabetes mellitus: a systematic review and meta-analysis. *Circulation* 121, 2271–2283. doi: 10.1161/CIRCULATIONAHA.109.924977

Migliore, G., Di Gesaro, M., Borsellino, V., Asciuto, A., and Schimmenti, E. (2015). Understanding consumer demand for sustainable beef production in rural communities. *Qual. Access Success* 16, 75–79.

Milford, A. B., Le Mouël, C., Bodirsky, B. L., and Rolinski, S. (2019). Drivers of meat consumption. *Appetite* 141, 104313. doi: 10.1016/j.appet.2019.06.005

Miller, R. (2020). Drivers of consumer liking for beef, pork, and lamb: a review. *Foods (Basel, Switzerland)* 9, 428. doi: 10.3390/foods9040428

Muguerza, E., Fista, G., Ansorena, D., Astiasarán, I., and Bloukas, J. G. (2002). Effect of fat level and partial replacement of pork backfat with olive oil on processing and quality characteristics of fermented sausages. *Meat Sci.* 61, 397–404. doi: 10.1016/S0309-1740(01)00210-8

Munekata, P. E. S., Rocchetti, G., Pateiro, M., Lucini, L., Domínguez, R., and Lorenzo, J. M. (2020). Addition of plant extracts to meat and meat products to extend shelf-life and health-promoting attributes: an overview. *Curr. Opin. Food Sci.* 31, 81–87. doi: 10.1016/j.cofs.2020.03.003

Napolitano, F., Braghieri, A., Piasentier, E., Favotto, S., Naspetti, S., and Zanoli, R. (2010). Effect of information about organic production on beef liking and consumer willingness to pay. *Food Qual. Pref.* 21, 207–212. doi: 10.1016/j.foodqual.2009.08.007

National Research Council. (1988). "Processing options for improving the nutritional value of poultry meat and egg products," in *Designing Foods: Animal Product Options in the Marketplace* (Washington, DC: National Academies Press).

Naughton, P., McCarthy, S. N., and McCarthy, M. B. (2015). The creation of a healthy eating motivation score and its association with food choice and physical activity in a cross sectional sample of Irish adults. *Int. J. Behav. Nutr. Phys. Activity* 12, 1–10. doi: 10.1186/s12966-015-0234-0

Nordström, J., and Thunström, L. (2015). The impact of price reductions on individuals' choice of healthy meals away from home. *Appetite* 89, 103–111. doi: 10.1016/j.appet.2015.01.023

Olivares, A., Navarro, J. L., Salvador, A., and Flores, M. (2010). Sensory acceptability of slow fermented sausages based on fat content and ripening time. *Meat Sci.* 86, 251–257. doi: 10.1016/j.meatsci.2010.04.005

Ordóñez, M., Rovira, J., and Jaime, I. (2001). The relationship between the composition and texture of conventional and low-fat frankfurters. *Int. J. Food Sci. Technol.* 36, 749–758. doi: 10.1046/j.1365-2621.2001.00525.x

Ortega, D. L., Wang, H. H., Wu, L., and Olynk, N. J. (2011). Modeling heterogeneity in consumer preferences for select food safety attributes in China. *Food Policy* 36, 318–324. doi: 10.1016/j.foodpol.2010.11.030

Ortiz, A., Tejerina, D., Díaz-Caro, C., Elghannam, A., García-Torres, S., Mesías, F. J., et al. (2020). Is packaging affecting consumers' preferences for meat products? A study of modified atmosphere packaging and vacuum packaging in Iberian dry-cured ham. *J. Sensory Stud.* 35, e12575. doi: 10.1111/joss.12575

Pérez-Burillo, S., Pastoriza, S., Gironés, A., Avellaneda, A., Francino, M. P., and Rufián-Henares, J. A. (2020). Potential probiotic salami with dietary fiber modulates metabolism and gut microbiota in a human intervention study. *J. Funct. Foods* 66, 103790. doi: 10.1016/j.jff.2020.103790

Petersson, K., Godard, O., Eliasson, A. C., and Tornberg, E. (2014). The effects of cereal additives in low-fat sausages and meatballs. Part 2: Rye bran, oat bran and barley fibre. *Meat Sci.* 96, 503–508. doi: 10.1016/j.meatsci.2013.08.019

Pilato, M., Platania, M., and Rizzo, M. (2015). The value of country of origin in the consumption. Results of a survey on Sicilian products. *Qual. Access Success* 16, 382–387.

Rabe-Hesketh, S., and Skrondal, A. (2008). *Multilevel and Longitudinal Modeling Using Stata*. College Station, TX: STATA Press.

Realini, C. E., i Furnols, M. F., Sañudo, C., Montossi, F., Oliver, M. A., and Guerrero, L. (2013). Spanish, French and British consumers' acceptability of Uruguayan beef, and consumers' beef choice associated with country of origin, finishing diet and meat price. *Meat Sci.* 95, 14–21. doi: 10.1016/j.meatsci.2013.04.004

Resano, H., Pérez-Cueto, F. J. A., Sanjuán, A. I., de Barcellos, M. D., Grunert, K. G., and Verbeke, W. (2011). Consumer satisfaction with dry-cured ham in five European countries. *Meat Science* 87, 336–343. doi: 10.1016/j.meatsci.2010.11.008

Resano, H., Sanjuán, A. I., and Albisu, L. M. (2007). Consumers' acceptability of cured ham in Spain and the influence of information. *Food Qual. Pref.* 18, 1064–1076. doi: 10.1016/j.foodqual.2007.05.002

Resano, H., Sanjuán, A. I., and Albisu, L. M. (2012). Consumers' response to the EU Quality policy allowing for heterogeneous preferences. *Food Policy* 37, 355–365. doi: 10.1016/j.foodpol.2012.03.006

Resano-Ezcaray, H., Sanjuán-López, A. I., and Albisu-Aguado, L. M. (2010). Combining stated and revealed preferences on typical food products: the case of dry-cured ham in Spain. *J. Agric. Econ.* 61, 480–498. doi: 10.1111/j.1477-9552.2010.00250.x

Resurreccion, A. V. A. (2004). Sensory aspects of consumer choices for meat and meat products. *Meat Sci.* 66, 11–20. doi: 10.1016/S0309-1740(03)00021-4

Rimal, A. (2005). Meat labels: consumer attitude and meat consumption pattern. *Int. J. Consumer Stud.* 29, 47–54. doi: 10.1111/j.1470-6431.2005.00374.x

Risius, A., and Hamm, U. (2017). The effect of information on beef husbandry systems on consumers' preferences and willingness to pay. *Meat Sci.* 124, 9–14. doi: 10.1016/j.meatsci.2016.10.008

Rocha, Y. J. P., de Noronha, R. L. F., and Trindade, M. A. (2019). Understanding the consumer's perception of traditional frankfurters and frankfurters with healthy attributes through sorting task and hard laddering techniques. *Meat Sci.* 149, 70–78. doi: 10.1016/j.meatsci.2018.11.004

Romagny, S., Ginon, E., and Salles, C. (2017). Impact of reducing fat, salt and sugar in commercial foods on consumer acceptability and willingness to pay in real tasting conditions: a home experiment. *Food Qual. Pref.* 56, 164–172. doi: 10.1016/j.foodqual.2016.10.009

Ruusunen, M., and Puolanne, E. (2005). Reducing sodium intake from meat products. *Meat Sci.* 70, 531–541. doi: 10.1016/j.meatsci.2004.07.016

Saeed, F., Grunert, K. G., and Therkildsen, M. (2013). How product trial changes quality perception of four new processed beef products. *Meat Sci.* 93, 119–127. doi: 10.1016/j.meatsci.2012.08.014

Sajdakowska, M., Jankowski, P., Gutkowska, K., Guzek, D., Zakowska-Biemans, S., and Ozimek, I. (2018). Consumer acceptance of innovations in food: a survey among Polish consumers. *J. Consumer Behav.* 17, 253–267. doi: 10.1002/cb.1708

Schnettler, B., Ares, G., Sepúlveda, N., Bravo, S., Villalobos, B., Hueche, C., et al. (2019). Are consumers willing to pay more for reformulated processed meat products in the context of the implementation of nutritional warnings? Case study with frankfurters in Chile. *Meat Sci.* 152, 104–108. doi: 10.1016/j.meatsci.2019.02.007

Sebranek, J. G., and Bacus, J. N. (2007). Cured meat products without direct addition of nitrate or nitrite: what are the issues? *Meat Sci.* 77, 136–147. doi: 10.1016/j.meatsci.2007.03.025

Severini, C., De Pilli, T., and Baiano, A. (2003). Partial substitution of pork backfat with extra-virgin olive oil in 'salami' products: effects on chemical, physical and sensorial quality. *Meat Sci.* 64, 323–331. doi: 10.1016/S0309-1740(02)00204-8

Shan, L. C., De Brún, A., Henchion, M., Li, C., Murrin, C., Wall, P. G., et al. (2017). Consumer evaluations of processed meat products reformulated to be healthier–a conjoint analysis study. *Meat Sci.* 131, 82–89. doi: 10.1016/j.meatsci.2017.04.239

Sharma, S., Sheehy, T., and Kolonel, L. N. (2013). Contribution of meat to vitamin B 12, iron and zinc intakes in five ethnic groups in the USA: implications for developing food-based dietary guidelines. *J. Hum. Nutr. Dietetics* 26, 156–168. doi: 10.1111/jhn.12035

Sindelar, J. J., Cordray, J. C., Sebranek, J. G., Love, J. A., and Ahn, D. U. (2007). Effects of varying levels of vegetable juice powder and incubation time on color, residual nitrate and nitrite, pigment, pH, and trained sensory attributes of ready-to-eat uncured ham. *J. Food Sci.* 72, S388–S395. doi: 10.1111/j.1750-3841.2007.00404.x

Smith, T. A., Huang, C. L., and Lin, B. H. (2009). Does price or income affect organic choice? Analysis of US fresh produce users. *J. Agric. Appl. Econ.* 41, 731–744. doi: 10.1017/S1074070800003187

Špička, J., and Náglová, Z. (2022). Consumer segmentation in the meat market - The case study of Czech Republic. *Agric. Econ. - Czech.* 68, 68–77. Available online at: https://www.agriculturejournals.cz/publicFiles/334_2021-AGRICECON.pdf

Spina, D., Vindigni, G., Pecorino, B., Pappalardo, G., D'Amico, M., and Chinnici, G. (2021). Identifying themes and patterns on management of horticultural innovations with an automated text analysis. *Agronomy* 11, 1103. doi: 10.3390/agronomy11061103

Stampa, E., Schipmann-Schwarze, C., and Hamm, U. (2020). Consumer perceptions, preferences, and behavior regarding pasture-raised livestock products: a review. *Food Qual. Pref.* 82, 103872. doi: 10.1016/j.foodqual.2020.103872

Teixeira, A., and Rodrigues, S. (2020). Consumer perceptions towards healthier meat products. *Curr. Opin. Food Sci.* 38, 147–154. doi: 10.1016/j.cofs.2020.12.004

Testa, R., Asciuto, A., Schifani, G., Schimmenti, E., and Migliore, G. (2019). Quality determinants and effect of therapeutic properties in honey consumption. An exploratory study on Italian consumers. *Agriculture* 9, 174. doi: 10.3390/agriculture9080174

Timpanaro, G., Bellia, C., Foti, V. T., and Scuderi, A. (2020). Consumer behaviour of purchasing biofortified food products. *Sustainability* 12, 6297. doi: 10.3390/su12166297

Toldrá, F., and Reig, M. (2011). Innovations for healthier processed meats. *Trends Food Sci. Technol.* 22, 517–522. doi: 10.1016/j.tifs.2011.08.007

Tomaschunas, M., Zörb, R., Fischer, J., Köhn, E., Hinrichs, J., and Busch-Stockfisch, M. (2013). Changes in sensory properties and consumer acceptance of reduced fat pork Lyon-style and liver sausages containing inulin and citrus fiber as fat replacers. *Meat Sci.* 95, 629–640. doi: 10.1016/j.meatsci.2013.06.002

Tuorila, H., Cardello, A. V., and Lesher, L. L. (1994). Antecedents and consequences of expectations related to fat-free and regular-fat foods. *Appetite* 23, 247–263. doi: 10.1006/appe.1994.1057

Válková, V., Saláková, A., Buchtová, H., and Tremlová, B. (2007). chemical, instrumental and sensory characteristics of cooked pork ham. *Meat Sci.* 77, 608–615. doi: 10.1016/j.meatsci.2007.05.013

Van Ittersum, K., Candel, M. J., and Meulenberg, M. T. (2003). The influence of the image of a product's region of origin on product evaluation. *J. Bus. Res.* 56, 215–226. doi: 10.1016/S0148-2963(01)00223-5

Van Wezemael, 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

Wardle, J., and Steptoe, A. (2003). Socioeconomic differences in attitudes and beliefs about healthy lifestyles. *J. Epidemiol. Commun. Health* 57, 440–443. doi: 10.1136/jech.57.6.440

WHO (2020). *Healthy Diet*. Geneva: WHO. Available online at: www.who.int/news-room/fact-sheets/detail/healthy-diet (accessed October 7, 2021).

Wolfson, J. A., Ramsing, R., Richardson, C. R., and Palmer, A. (2019). Barriers to healthy food access: associations with household income and cooking behavior. *Prev. Med. Rep.* 13, 298–305. doi: 10.1016/j.pmedr.2019.01.023

Wu, L., Wang, S., Zhu, D., Hu, W., and Wang, H. (2015). Chinese consumers' preferences and willingness to pay for traceable food quality and safety attributes: the case of pork. *China Econ. Rev.* 35, 121–136. doi: 10.1016/j.chieco.2015.07.001

Yano, Y., Nakamura, T., Ishitsuka, S., and Maruyama, A. (2021). Consumer attitudes toward vertically farmed produce in russia: a study using ordered logit and co-occurrence network analysis. *Foods* 10, 638. doi: 10.3390/foods10030638

Zhuang, X., Han, M., Kang, Z. L., Wang, K., Bai, Y., Xu, X. L., et al. (2016). Effects of the sugarcane dietary fiber and pre-emulsified sesame oil on low-fat meat batter physicochemical property, texture, and microstructure. *Meat Sci.* 113, 107–115. doi: 10.1016/j.meatsci.2015.11.007

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

ORIGINAL RESEARCH
published: 05 April 2022
doi: 10.3389/fsufs.2022.853692

Consumers' Expectations on Transparency of Sustainable Food Chains

Renata Pozelli Sabio[1] *and Eduardo Eugênio Spers*[2]*

[1] Department of Health Management, Evaluation and Policy, Université de Montréal, Montréal, QC, Canada, [2] Department of Economics, Administration and Sociology, School of Agriculture "Luiz de Queiróz" (ESALQ), University of São Paulo (USP), Piracicaba, Brazil

The search for food products from sustainable chains has increased in the past years, motivated by consumers' interest in reducing the negative environmental, economic, and health impacts of their food choices. However, it is not yet clear whether transparency expectations of sustainable food chains influence in consumers' perception of this food products. The literature shows that there are gaps in the growth of sustainable product consumption is the transparency of production and the provision of more information to consumers. In this paper, we aimed to better understand what is the role of transparency expectations and how they influence consumers' decision to consume sustainable food products. Based on scales already validated in the literature, a theoretical model with nine hypotheses was proposed. A questionnaire was structured and empirically tested through a survey with 136 consumers of food from alternative networks. Six hypotheses were validated. Three segments of consumers target were identified from an exploratory factor analysis and cluster. Based on the results some marketing actions were suggested for the participants of alternative food networks. Other studies may validate the model proposed here.

Keywords: sustainable consumption, food chain transparency, sustainability, consumer behavior, alternative food system

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brasilia, Brazil

Reviewed by:
Virgílio Strasburg, Federal University of Rio Grande do Sul, Brazil
Dayanne Maynard, University of Brasilia, Brazil

***Correspondence:**
Eduardo Eugênio Spers
edespers@usp.br

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

Received: *12 January 2022*
Accepted: *11 February 2022*
Published: *05 April 2022*

Citation:
Pozelli Sabio R and Spers EE (2022) Consumers' Expectations on Transparency of Sustainable Food Chains. Front. Sustain. Food Syst. 6:853692. doi: 10.3389/fsufs.2022.853692

INTRODUCTION

Consumers' desire to eat food products from sustainable chains, such as alternative food networks has been increasing in the past years (De Bernardi and Tirabeni, 2018; Fourat et al., 2020). One of the main reasons for that is the fact that consumers expect such food products to have lower environmental impacts and greater positive impacts for local economies, the environment and for the health of individuals, including workers and consumers (Maier et al., 2020). The alternative food networks are "very diverse," including short commercialization circuits, such as fresh produce fairs, delivery of weekly baskets, small producer stores, agrotourism, and institutional sales for school meals (Brandenburg et al., 2015). One of the most recognized examples of alternative food networks is the Community Supported Agriculture (CSA), which consists of a partnership between producers and consumers, in that consumers can have access to local and organic food, and producers have the certainty that their production will be sold at a fair price. The pandemic of COVID-19 has accelerated this movement toward sustainable food chains (Ricker and Kardas-Nelson, 2020; Chiche and Lachapelle, 2021; Futemma et al., 2021). This increasing interest for

sustainable food products is aligned with today's critical and ethical consumerism, highly concerned with environmental impacts and effects on health and food consumption (Grunert et al., 2014).

Brazil is a big country, with a dimension of more than 8 million km² and more than 212 million inhabitants. From the one side, the country counts with the presence of large agri-food chains, such as soybeans, corn, wheat, and sugar. From the other side, data from the 2017 to 2018 Agricultural Census, conducted by the Brazilian Institute of Geography and Statistics (IBGE), reveal that almost 80% of Brazil's rural establishments were characterized as belonging to family farming. While not all family farms can be characterized as alternative food networks, they are more likely to participate in such actions, including short circuit commercialization, organic production practices, etc. Even though the availability of data concerning alternative food networks is still limited, we can infer that they are especially present in the state of São Paulo. One of the arguments that gives support to this is the fact that organic production in São Paulo is higher than the Brazilian average (2.6% of all agricultural establishments in the state, while the Brazilian average is 1.3%; IBGE, 2019).

In Brazil, alternative network foods have also been the focus of some studies. The following are some of them: the role of transaction costs in the intensity of organic food consumption in Brazil (Cechin et al., 2021), an evaluation Brazilian cocoa production chain from the perspective of sustainable rural development (Gontijo, 2020), short food supply chains (Queiroz, 2021), the proposal of a theoretical model for the diagnosis of transparency in the food sector (Nicastro and dos Santos, 2021), and finally, how to contribute to sustainability being economically from cases of alternative food systems (Fialho, 2020). However, no study focusing on consumers' expectations on the transparency of sustainable food chains.

It is already supported by the literature that environmental values and concerns about supporting local communities are among the reasons why people join sustainable food chains, such as CSAs (Brehm and Eisenhauer, 2008). Concerns about food quality and how food is produced have also been recognized as one of the most relevant motivating factors for participating in such initiatives (Brehm and Eisenhauer, 2008). Questions about quality and food practices have played an important role in increasing demands on transparency in the food supply chain. However, little is known about the role of transparency of the food chain in consumer behavior. Nevertheless, "the growing popularity of transparency in supply chains and networks" are not "accidents or fads that are soon to be replaced" (Mol, 2015). Rather, "transparency in value chains is there to stay" (Mol, 2015). Also, although "generally assumed to empower the powerless, transparency in sustainable chains can as well empower the powerful" (Mol, 2015).

"Transparency might be perceived differently between individuals because its perception is mainly determined by the limited ability of individuals to collect, process and transfer information, as well as by subjective feelings and experiences in the past" (Deimel et al., 2008). Karg (1990) describes perceived transparency as the feeling of being informed about something and defines it as the availability of relevant information as experienced by the individual that makes processes subjectively distinct and clear. Deimel et al. (2008) compared the transparency of the pork and dairy chains of production as experienced by farmers. They found that transparency was higher in the dairy than in the pork business, influenced by a lower number of transaction partners and a tendency toward a longer-term governance structure. Also, "the explicitness and clearness of information exchanged and the levels of trust and commitment were higher in the dairy sector" (Deimel et al., 2008). The authors call for further research on the transparency of food chains.

In their study (Bhaduri and Ha-Brookshire, 2011), found that consumers "questioned the legitimacy of the claims made by the businesses with regard to their transparent supply chain practices." In this sense, they required a "standard seal" or "seal of approval" which would certify businesses' transparency efforts to ensure the businesses are "living up to a particular standard of operations and, thereby, giving consumers the confidence to make an educated decision." They demand a "standard authorizing agency to verify the claims of the transparent businesses."

Grunert (2011) proposes six gaps that hinder the consumption of food with sustainable characteristics. They are: (1) exposure does not lead to perception, i.e., consumers simply do not notice the label, because they are in a hurry to buy and most shopping is done habitually; (2) perception leads only to peripheral processing, i.e., consumers see the label, but do not bother to make the effort to understand what it means; (3) the consumer makes "wrong" inferences, i.e., he looks at the label, however he relies on "wrong" reasons; (4) eco-information is offered with other criteria, i.e., the price may be higher, but the taste is not good and the family may prefer something else; (5) lack of environmental awareness and/or credibility, i.e., consumers who want to make sustainable choices may find it difficult to do so in practice, and finally, (6) lack of motivation at the moment of choice, i.e., although consumers have a positive attitude toward sustainability, this attitude is not so strong as to affect behavior in all situations where sustainability may be a relevant criterion. We can say that consumers "forget" their positive attitude toward sustainability when making their food choices. These "latent" attitudes are an important factor in explaining the discrepancies between attitude and behavior.

In this paper, we aim to understand the importance of transparency of the chain in consumers' perception, including both the lack of information, and the gaps involving the motivation and decision to consume food from sustainable chains. Thus, we aim to answer the following research question: What is the role of transparency expectations in consumers' decision to buy food from sustainable chains?

METHODOLOGY

Research Hypotheses

Based on the literature review, nine hypotheses were formulated and are presented in **Figure 1**. We used the database Web of Science and the criteria for keywords and the literature

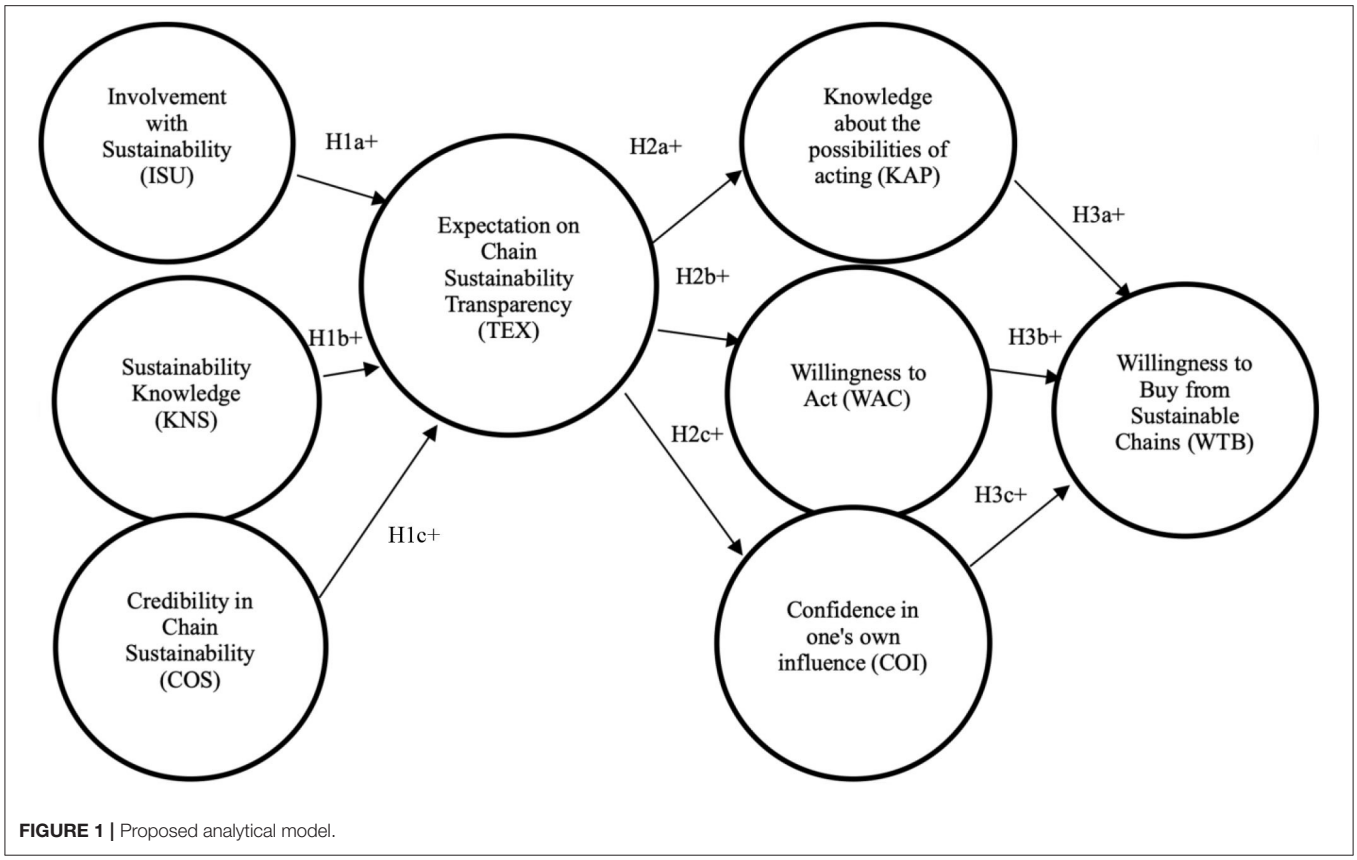


FIGURE 1 | Proposed analytical model.

review was based on the terms "transparency of the chain" and "alternative food and networks." The first group of hypotheses are related to the expectation of chain sustainability transparency (TEX). As antecedents of this expectation, we have involvement with sustainability (ISU), knowledge about sustainability (KNS), and credibility in chain sustainability (COS). Therefore, we formulated the following hypotheses:

H1a: Engagement with sustainability (ISU) is directly related to expectations about the transparency of the chain's sustainability (TEX).
H1b: Knowledge about sustainability (KNS) is directly related to expectations about the transparency of the chain's sustainability (TEX).
H1c: Credibility in chain sustainability (COS) is directly related to expectations about transparency of the chain's sustainability (TEX).

The second set of hypotheses is related to the consequences of the expectation of transparency of the sustainability of the chain (TEX). These consequences would be related to attitudes such as knowledge of the possibilities for action (KAP), willingness to act (WAC), and confidence in one's own influence (COI).

According to Mol (2015), consumer transparency involves the disclosure of production and product information related to claims of sustainable production processes and products through public or private labeling and certification. Organic, green, fair trade, and all types of other sustainability products and processes are articulated in standards, disclosed in certifications, labels, and information systems can be called consumer transparency (Mol, 2015). It is expected that these behaviors will happen with more intensity or likelihood when the expectation about the transparency of the sustainability chain is also higher:

H2a: Expectation about the transparency of the chain's sustainability (TEX) is directly related to knowledge of the possibilities for action (KAP).
H2b: Expectation about transparency of chain sustainability (TEX) is directly related to willingness to act (WAC).
H2c: Expectation about transparency of chain sustainability (TEX) is directly related to trust in one's own influence (COI).

Finally, the third group of hypotheses relates the three attitudes of the previous hypotheses to the willingness to buy from sustainable chains (WTB). The attitudes are: knowledge about the possibilities to act (KAP), willingness to act (WAC), and confidence in one's own influence (COI). Similarly to the previous hypotheses, it is expected that the higher the intensity of these attitudes the more likely will be the desire to buy from transparent and sustainable chains. Therefore, we formulated the following hypotheses:

H3a: Knowledge about the possibilities of action (KAP) is directly related to the desire to buy from transparent and sustainable chains (WTB).

H3b: Willingness to act (WAC) is directly related to the desire to buy from transparent and sustainable chains (WTB).
H3c: Confidence in one's own influence (COI) is directly related to the desire to buy from transparent and sustainable chains (WTB).

Design of the Study and Data Collection

To achieve the aim of this paper we applied a quantitative study design. A field survey was carried out to test the hypotheses elaborated in our proposed model. The population was defined as any consumer of food from alternative networks from the state of São Paulo. We focused on this state because it concentrates most Brazilian consumers of food from alternative networks. The sample was defined as non-probabilistic, and the questionnaire was structured in the Google Forms platform and distributed randomly through snowballs on social networks such as Facebook and LinkedIn, as well as message applications such as e-mail and WhatsApp. As there is no official data regarding the population consuming this type of food, it was not possible to stratify the sample for statistical inference. The main focus was to ensure that the respondents were consumers of alternative food and, therefore, able to answer the questions with confidence. The minimum number of individuals necessary for the analysis of the proposed model (**Figure 1**) was 127 and was calculated using the GPower software (Kang, 2021). The collection period was from August 18 to 30, 2021. We collected 145 responses, 11 individuals being discarded from the analysis of variance and outliers. To analyze the results, we used univariate and multivariate analysis (Malhotra et al., 2017). Part of the research was causal type, with hypothesis testing conducted using the Confirmatory Factor Analysis method. Another part of the research was descriptive, with the use of quantitative methods, but without the presence of a dependent variable: Exploratory Factor Analysis and the Cluster Analysis (Hair et al., 2009b).

Even though the research included consumers from all over Brazil, the survey covered mainly the state of São Paulo because it has the highest level of urbanization and concentrates most of the country's higher income and higher education level population (IBGE, 2010). These characteristics make this state the main target audience of alternative food network initiatives.

To ensure the validity of the data collection instrument, the original scales used in the questionnaire were translated from English into Portuguese and the final version was approved by three researchers specialized in the marketing area. The objective of this translation and linguistic survey process was to ensure that the meaning of the applied statements was consistent with the references used in English and that the questions were not ambiguous, which could affect the integrity of the results. These conditions are recommended by Brislin (1980). In addition, a pre-test was conducted with 30 participants to avoid problems with the understanding of the respondents, to adjust some terms, as well as to identify problems regarding the completion of the questionnaire. The pre-test was applied 30 days before the data collection, using the same criteria for the selection of the final sample.

The final questionnaire applied included 37 questions, with five questions characterizing the respondent and 32 in a seven-point Likert scale format, ranging from 1 (strongly disagree) to 7 (strongly agree). These questions represent dimensions validated in the literature and the respective articles of these scales can be found in the **Appendix 1**.

TABLE 1 | Discriminant validity of the constructs.

Latent variable	IOC	COS	ISU	KAP	KNS	TEX	WAC	WTB
IOC	**0.828**							
COS	0.404	**0.808**						
ISU	0.487	0.365	**0.879**					
KAP	0.556	0.380	0.341	**0.870**				
KNS	0.315	0.078	0.458	0.425	**0.907**			
TEX	0.444	0.574	0.434	0.420	0.420	**0.684**		
WAC	0.794	0.501	0.614	0.527	0.280	0.488	**0.925**	
WTB	0.625	0.464	0.635	0.326	0.259	0.451	0.751	**0.893**
CR*	0.897	0.904	0.931	0.925	0.933	0.777	0.946	0.940
CA**	0.845	0.867	0.901	0.889	0.893	0.642	0.915	0.915
AVE***	0.686	0.653	0.772	0.758	0.823	0.468	0.855	0.798

Source: Original research data.
**CR, Composite Reliability.*
***CA, Cronbach's Alpha.*
****AVE, Average Variance Extracted.*

With the intention of verifying the measurement quality of the proposed theoretical model, a confirmatory factor analysis (CFA) was performed using variance-based structural equation modeling. This evaluative method allows to verify the fit of the collected data structure to the theoretical model (Hair et al., 2009a), through a combination of dependence (factor analysis) and interdependence (multiple regression analysis) techniques (Hair et al., 2016). Data were analyzed using SmartPLS software version 3.3. The reliability of the proposed scales was tested, as well as their convergent and discriminant validations (**Table 1**). To identify the validity of the constructs, it was verified if the variables really belong to the construct to be measured, being that the more abstract the construct, the greater the difficulty in establishing its validity (Souza et al., 2017). The hypotheses raised in this study, described in the model presented in **Figure 1**, were tested using the same SmartPLS software, followed by a set of multiple regression equations.

In order to group the questions into dimensions based on consumer perception and then group them among consumers, an exploratory factor analysis was performed using the Principal Components extraction method and rotated using the Varimax method with Kaiser normalization (**Appendix 4**). To perform the cluster analysis or segmentation the K-means method was used. Three clusters were previously chosen and the factor loadings obtained in the exploratory factor analysis were used as a source of information.

RESULTS

Regarding monthly family income, the average value was concentrated in 14,400 Reais (∼US$2,880.00). The average age of

TABLE 2 | Evaluation of the structural model.

	Original sample (O)	VIF	Sample mean (M)	Standard deviation (STDEV)	*T* statistics (|O/STDEV|)	*P*-values
H1a: ISU -> TEX	0.092	1.467	0.104	0.083	1.104	0.270
H1b: KNS -> TEX	0.338	1.297	0.340	0.080	4.238	0.000**
H1c: COS -> TEX	0.514	1.167	0.509	0.083	6.170	0.000**
H2a: TEX -> KAP	0.420	1.000	0.426	0.084	5.018	0.000**
H2b: TEX -> WAC	0.488	1.000	0.494	0.079	6.140	0.000**
H2c: TEX -> COI	0.444	1.000	0.453	0.082	5.380	0.000**
H3a: KAP -> WTB	−0.120	1.490	−0.113	0.093	1.298	0.195
H3b: WAC -> WTB	0.717	1.000	0.678	0.130	5.505	0.000**
H3c: COI -> WTB	0.122	2.909	0.155	0.124	0.989	0.323

Source: Original research data.
N = 134.
***Mean significance level at p < 0.01.*

the participants was ∼39 years old, with a standard deviation of 12.82. Regarding gender, the sample was equally distributed, with 50% of the participants being female and 50% male. Most of the interviewees, 47.01%, had a graduate degree. The general profile of the sample is described in **Appendix 2**.

Regarding the Likert-type questions, the ones with the highest agreement were "I believe that what each person does is important for sustainable development" (Mean = 8.93, Standard Deviation 1.67), "I would buy food from transparent and sustainable chains if it is available where I shop" (M = 8.75, SD = 1.82), and "There is a high probability that I will buy food from transparent and sustainable chains in the future" (M = 8.69, SD = 1.95) (**Appendix 3**).

In relation to the affirmations that consumers most disagreed, they were: "Alternative food producers use registered workers to produce their products" (M = 5.66, DP = 1.93), "I wanted/ I could easily find out about the working conditions on farms that produce alternative foods" (M = 5.16, DP = 2.82), and "People who know me, consider me an expert in the area of food sustainability" (M = 3.97, DP = 2.69). The results show that even though the respondents are involved with alternative foods, they demonstrate little knowledge regarding technical issues about their production and food sustainability.

Confirmatory Factor Analysis

Although the variables were taken from the literature, their subsequent adaptation for the purposes of the present study warranted validation. The validation process was carried out using the total sample of 134 participants. The results of this confirmatory analysis are summarized in **Table 1**.

It was observed that the assumptions of reliability and convergent and discriminant validity were met for all scales. Through the Average Variance Extracted (AVE), we obtained a value >0.500 (acceptable load) for all the constructs, with the exception of the latent variable TEX (0.468). Although the latter does not meet the stipulated value, the theoretical complexity presented in the paper is reasonable justification to consider this value acceptable in these circumstances.

The composite reliability (CR) for all constructs was considered to be above 0.700, which is an acceptable load for this variable (Fornell and Larcker, 1981; Hair et al., 2009a). Even with an AVE of <0.5, it is noted that TEX also showed a CR above 0.7, a characteristic also obtained for other authors' valid constructs (Lam, 2012). Finally, the effectiveness analysis of the discriminant validity tests, according to the precepts of Fornel and Larcker (1981), evaluated possible construct relationships with the other variables and did so, successively, in all cases. The square root values of the AVE, on the diagonal of the **Table 1** (highlighted in bold), confirm that the constructs are indeed valid. Therefore, the results of the confirmatory analysis of the constructs show that the adaptations made to categorize and measure the dimensions of interest in this paper were effective.

Hypothesis Validation

The results applicable to the structural model analysis show that six out of the nine hypotheses tested were supported at a significance level of $p \leq 0.01$, as shown in **Table 2**. It can be noted that all significant relationships between the constructs proposed in the hypotheses were positive, as expected. Contrary to expectations, hypotheses H1a, H3a, and H3c were not significant.

The inflation variance factor (VIF) values were >1,000 for all the hypotheses, indicating no multicollinearity (Bowerman and O'Connell, 1990). All VIF values are acceptable, since they are below 3,000, as explained by Ringle et al. (2015).

When it comes to the first group of hypotheses (H1a, H1b, H1c), we wanted to understand consumers sustainability transparency expectations. As H1b and H1c were supported by our data, we confirmed that as consumers show a greater knowledge about sustainability, their expectation of transparency of the sustainability of the chain also increases. Also, the greater the credibility in the sustainability of the chain, the greater the expectation of transparency. Contrary to what we expected, our results do not support the affirmation that engagement with sustainability is directly related to the expectation about the transparency of the chain's sustainability (H1a).

The results indicate that higher expectations about the sustainability and transparency of the chain generate three types

of attitudes: a desire for greater knowledge of the possibilities of action (H2a), a greater willingness to act (H2b) and, greater confidence in one's own influence (H2c). All of these were confirmed, including their positive relationship, which indicates greater engagement and proactivity about food from alternative networks. This is an indication that transparence may play an important role in generating action toward food from alternative networks. The three hypotheses were confirmed, including their positive relationship, which indicates greater engagement and proactivity about food from alternative networks.

Finally, from the third group of hypotheses, only H3b was supported by our data, confirming the affirmation that willingness to act is directly related to the desire to buy transparent and sustainable chains. On the other hand, we found that knowledge about the possibilities of action (H3a) and confidence in one's own influence are not directly related to the willingness to buy from transparent and sustainable chains. One of the explanations for that may be the low self-confidence derived from the still low knowledge of consumers about the production process of these foods. As evidenced earlier, the questions about knowledge about food from alternative networks were the ones with the lowest average agreement. These results suggest, therefore, the need for communication actions to generate an active attitude from the consumer in searching for this type of product. More engaged, with more knowledge and confidence, these consumers can become influencers of other consumers.

Cluster Analysis

We performed an exploratory factor analysis using the Principal Components extraction method and rotated using the Varimax method with Kaiser normalization (**Appendix 4**). Based on the 23 Likert-type questions, six factors were obtained, which explained 72.53% of the variance (**Appendix 5**). The factors were: (1) Action and likelihood of sustainable food consumption (15.84%); (2) Credibility and expectations of chain transparency and sustainability (13.12%); (3) Confidence in own influence (12.38%); (4) Action on sustainable development (11.54%); (5) Concern about sustainable food (9.86%) and finally; (6) Knowledge about food sustainability (9.80%). The total variance explained is generally not 100%. This metric indicates how well the questions asked evaluate the entire variance. The values of each factor above 3% demonstrate that the data were aggregated consistently and the explained variance above 60% demonstrates that the set of questions measure what we aimed to analyze (Fabrigar and Wegener, 2011). The remaining factors have eigenvalues smaller than 1 and are, therefore, considered to be unexplained variance.

The cluster analysis revealed the existence of three clusters (**Appendix 6** brings more information about each cluster or segment). Cluster 1, called Acting, is composed of consumers that are active in relation to sustainable food and are more likely to consume this type of product. This cluster is made up of 54.05% females, single (64.86%), aged 18–37 years (46.27%), complete college education (32.43%), living in a family of three people (29.73%), family income from R$1,001.00 to R$10,000.00 (49.97%) and residing in the state of São Paulo (83.78%).

Cluster 2, called Confident, is formed by consumers that are confident in their own influence, as they show preoccupation about sustainable development worry. The profile of consumers is majority of females (52.33%), married (51.16%), between 18 and 37 years old (62.16%), with a complete post-graduation course (53.49%), living in a family of four people (29.07%), with a family income of R$1,001.00 to R$10,000.00 (50%), and living in the state of São Paulo (83.72%).

Cluster 3, called Indifferent, is made up by consumers that are less active when it comes to acquiring food from sustainable networks. This cluster is formed by 81.82% of males, married (54.55%), between 38 and 57 years old (69.64%), with complete post-graduation (54.55%), living in a 3-person family (54.55%), with a family income of R$1,001.00 to R$10,000.00 (60%), and living in the state of São Paulo (63.64%).

CONCLUSION

The results confirm the existence of gaps mitigating the consumption of sustainable products are also present in the research's target audience. Therefore, more effective communication strategies focused on both increasing consumer understanding and increasing motivation for action regarding sustainable food chains are suggested. Both positioning and tactical marketing actions, i.e., price, product, promotion and place, should be tailored to the three identified segments: Active, Confident, and Indifferent.

Our results on the first group of hypotheses indicate credibility and knowledge about sustainability generate the expectation of transparency of alternative food networks (hypothesis H1b and H1c). In managerial terms, the results indicate that the actors belonging to sustainable food chains should invest in knowledge and increase credibility to consequently increase expectations about the transparency of their products and practices. Campaigns focused on credibility and transparency with the endorsement of digital influencers can be an effective motivation to intention-to-buy action. Also, actions in social media with the generation of informational content can raise awareness about sustainability. However, we observed that consumers need to be encouraged and communicated about the transparency of alternative food networks, once being involved with sustainability was not enough to generate the expectation of transparency. Perhaps one of the explanations is the fact that the involved consumer is more skeptical about the capacity of chains to be sustainable or even that their expectation level is already high and, therefore, no longer subject to change (hypothesis H1a). Therefore, there is a need to improve the perception of transparency for consumers involved with alternative network foods. This could be solved through a direct engagement with the alternative food network initiative. For example, the research conducted by Savarese et al. (2020) explored the consumer-farmer relationship in Community Supported Agriculture (a type of alternative food network) an found that consumers felt really engaged whenever they had a "strong and direct relation with the farmers," including, for instance, sharing the production fees or participating in educational activities. These authors

concluded that engagement is "a key element for the creation of an environment for consumer education and behavior change" toward sustainable consumption practices (Savarese et al., 2020).

Regarding the second group of hypotheses, the results show that transparency is a good antecedent and promoter of action intention about alternative foods (hypothesis H2a, H2b, and H2c). The results suggest that short alternative food chains invest in transparency about the production processes of these foods as well as the benefits they provide (put a reference). For instance, the use of labels that externalize and make tangible the transparency of the practices are interesting actions to culminate in consumer action on this chain. This finding is aligned with the study conducted by De Bernardi et al. (2020), which found that "higher levels of transparency lead to higher levels of quantity and frequency of purchases" from alternative food networks. The authors suggest that farmers "keep their consumers informed about the characteristics of their products" (De Bernardi et al., 2020).

Finally, the third group of hypotheses shows that, although there is a positive availability in relation to the action, it is possible that the intention of buying this type of product does not occur in practice. The results indicate that the purchase of these foods is a more impulsive purchase, based on the willingness to act (hypothesis H3b) and not a more conscious purchase based on knowledge about the possibilities of action and confidence (hypothesis H3a and H3c). Actions in the decision process, as suggested by Grunert (2011) are necessary.

In terms of validity of the research and the collection instrument, although several procedures have been adopted to mitigate possible errors and the metrics of adjustment and statistical tests of the proposed model, some limitations regarding the measurement of the constructs may have occurred, as well as possible biases of the respondents regarding the interpretation of the questions formulated. In terms of sample reliability and possible statistical inference, it is suggested that the research can be replicated to other types of target audiences and different contexts or even countries, so that the cultural aspect can be evaluated and the proposed model widely validated. The hypotheses that were not validated in this study can be validated in countries where the consumption of foods from alternative networks is more established, such as countries of mature economy.

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

AUTHOR CONTRIBUTIONS

ES was responsible for collecting data, performing data analyses, and revised critically preliminary versions of the paper. RP wrote the first draft of the manuscript. Both authors contributed substantially to the design of the study. Both authors contributed to the interpretation of the findings and contributed important intellectual content. Both authors reviewed and edited the manuscript and approved the final version.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2022.853692/full#supplementary-material

REFERENCES

Bhaduri, G., and Ha-Brookshire, J. E. (2011). Do transparent business practices pay? Exploration of transparency and consumer purchase intention. *Cloth. Textiles Res. J.* 29, 135–149. doi: 10.1177/0887302X11407910

Bowerman, B. L., and O'Connell, R. T. (1990). *Linear Statistical Models: An Applied Approach*. Boston, MA: PWS-Kent Pub. Co.

Brandenburg, A., Billaud, J.-P., and Lamine, C. (2015). *Redes de Agroecologias: Experiências No Brasil e na França*. Curitiba: Kairos Edições, 248. ISBN 978-85-63806-30-7.

Brehm, J. M., and Eisenhauer, B. W. (2008). Motivations for participating in community-supported agriculture and their relationship with community attachment and social capital. *J. Rural Soc. Sci.* 23, 94–115. Available online at: https://egrove.olemiss.edu/cgi/viewcontent.cgi?article=1319&context=jrss

Brislin, R. W. (1980). Expanding the role of the interpreter to include multiple facets of intercultural communication. *Int. J. Intercult. Relat.* 4, 137–148. doi: 10.1016/0147-1767(80)90025-5

Cechin, A., Medaets, J. P. P., Fornazier, A., and Zoghbi, A. C. P. (2021). Exploring the role of transaction costs in the intensity of organic food consumption in Brazil. *Br. Food J.* 123, 3760–3775. doi: 10.1108/BFJ-07-2020-0579

Chiche, A., and Lachapelle, U. (2021). *Du fermier au citadin : la pandémie accélère l'agriculture soutenue par la communauté*. The Conversation. Available online at: https://theconversation.com/du-fermier-au-citadin-la-pandemie-accelere-lagriculture-soutenue-par-la-communaute-153607 (accessed February 24, 2022).

De Bernardi, P., Bertello, A., Venutti, F., and Foscolo, E. (2020). How to avoid the tragedy of alternative food networks (AFNs)? the impact of social capital and transparency on AFN performance. *Br. Food J.* 122, 2171–2186. doi: 10.1108/BFJ-07-2019-0537

De Bernardi, P., and Tirabeni, L. (2018). Alternative food networks: sustainable business models for anti-consumption food cultures. *Br. Food J.* 120, 1776–1791. doi: 10.1108/BFJ-12-2017-0731

Deimel, M., Frentrup, M., and Theuvsen, L. (2008). Transparency in food supply chains: empirical results from German pig and dairy production. *J. Chain Netw. Sci.* 8, 21–32. doi: 10.3920/JCNS2008.x086

Fabrigar, L. R., and Wegener, D. T. (2011). *Exploratory Factor Analysis*. Oxford: Oxford University Press. doi: 10.1093/acprof:osobl/9780199734177.001.0001

Fialho, L. P. S. (2020). *How to Contribute to Sustainability Being Economically Viable: Case Study of Alternative Food Systems*. (Doctoral Dissertation), ISCTE-IUL, Lisbon, Portugal.

Fornell, C., and Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *J. Market. Res.* 18, 39–50. doi: 10.2307/3151312

Fourat, E., Closson, C., Holzemer, L., and Hudon, M. (2020). Social inclusion in an alternative food network: values, practices and tensions. *J. Rural Stud.* 76, 49–57. doi: 10.1016/j.jrurstud.2020.03.009

Futemma, C., Tourne, D. C. M., Andrade, F. A. V., Santos, N. M., Macedo, G. S. S. R., and Pereira, M. E. (2021). The Covid-19 pandemic and small-scale farmers: surpassing or falling? *Boletim do Museu Paraense Emílio Goeldi. Ciências Humanas* 16:e20200143. doi: 10.1590/2178-2547-bgoeldi-2020-0143

Gontijo, F. J. C. (2020). *The Productive Chain of Brazilian Cocoa From the Perspective of Sustainable Rural Development. Specialization in Public Policies in Agriculture and Livestock*. Brasília, DF: National School of Public Administration.

Grunert, K. G. (2011). Sustainability in the food sector: A consumer behaviour perspective. *Int. J. Food Syst. Dyn.* 2, 207–218. doi: 10.22004/ag.econ.121943

Grunert, K. G., Hieke, S., and Wills, J. (2014). Sustainability labels on food products: consumer motivation, understanding and use. *Food Policy* 44, 177–189. doi: 10.1016/j.foodpol.2013.12.001

Hair, J. F., Black, W. C., Babin, B. J., Anderson, R. E., and Tatham, R. L. (2009a). *Multivariate Data Analysis*. Porto Alegre: Bookman Editora.

Hair, J. F., Hult, G. T. M., Ringle, C., and Sarstedt, M. (2016). *A Primer on Partial Least Squares Structural Equation Modeling (PLS-SEM)*. London: Sage Publications.

Hair, J. F. Jr., Black, W. C., Babin, B. J., and Anderson, R. E. (2009b). *Multivariate Data Analysis, 7th Edn*. Upper Saddle River, NJ: Prentice Hall.

IBGE (2019). *Censo Agropecuário 2017-2018. Resultados definitivos*. Rio de Janeiro: Instituto brasileiro de geografia e estatística, 105.

IBGE, I. (2010). *Censo demográfico 2010*. IBGE: Insituto Brasileiro de Geografia.

Kang, H. (2021). Sample size determination and power analysis using the G* Power software. *J. Educ. Eval. Health Professions* 18:17. doi: 10.3352/jeehp.2021.18.17

Karg, K. R. (1990). *Transparenz in Organisationen aus der Sichtihrer Mitglieder* (Ph.D. thesis). University of Erlangen-Nuremberg, Erlangen, Germany

Lam, L. W. (2012). Impact of competitiveness on salespeople's commitment and performance. *J. Bus. Res.* 65, 1328–1334. doi: 10.1016/j.jbusres.2011.10.026

Maier, P., Klein, O., and Schumacher, K. P. (2020). Ecological benefits through alternative food networks? Prospects of regional barley-malt-beer value chains in Bavaria, Germany. *J. Clean. Product.* 265:121848. doi: 10.1016/j.jclepro.2020.121848

Malhotra, N., Nunan, D., and Birks, D. (2017). *Marketing Research: An Applied Approach*. London: Pearson. doi: 10.4324/9781315088754

Mol, A. P. J. (2015). Transparency and value chain sustainability. *J. Clean. Product.* 107, 154–161. doi: 10.1016/j.jclepro.2013.11.012

Nicastro, M. L., and dos Santos, A. (2021). Modelo teórico para diagnóstico da transpareência em serviços: uma proposta para o setor de alimentos. *Estudos em Design*. 29, 65–81.

Queiroz, S. S. D. (2021). *Short Food Supply Chains: An Analysis of Embeddedness in Family Farming and Its Interaction in Local Markets*. (PhD in Sustainable Rural Development), Universidade Estadual do Oeste do Paraná, Marechal Cândido Rondon, PR, Brazil.

Ricker, H., and Kardas-Nelson, M. (2020). *Community Supported Agriculture Is Surging Amid de Pandemic*. Civil Eats. Available online at: https://civileats.com/2020/04/09/community-supported-agriculture-is-surging-amid-the-pandemic/ (accessed February 24, 2022).

Ringle, C. M., Sven, W., and Becker, J.-M. (2015). *SmartPLS 3*. Bönningstedt: SmartPLS.

Savarese, M., Chamberlain, K., and Graffigna, G. (2020). Co-creating value in sustainable and alternative food networks: the case of community supported agriculture in New Zealand. *Sustainability* 12:1252. doi: 10.3390/su12031252

Souza, A. C. D., Alexandre, N. M. C., and Guirardello, E. D. B. (2017). Psychometric properties in instrument evaluation: assessing reliability and validity. *Epidemiol. Health Serv.* 26, 649–659. doi: 10.5123/S1679-49742017000300022

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

ORIGINAL RESEARCH
published: 01 June 2022
doi: 10.3389/fsufs.2022.853564

Assessing Institutional Support From Dietetics Associations Toward Integration of Sustainable Food Concepts in Dietetics Practice

Edith G. Callaghan[1]*, *Rachael Powell*[2] and *Liesel Carlsson*[3]

[1] F.C. Manning School of Business, Acadia University, Wolfville, NS, Canada, [2] Memorial University of Newfoundland and Labrador, Eastern Health, St. John's, NL, Canada, [3] School of Nutrition and Dietetics, Acadia University, Wolfville, NS, Canada

The degrees to which diets are consistent with food system sustainability, are the result of influences across scales of social interaction. This study considers the importance and limitations of institutional influence over integration of sustainable food systems ideas and concepts in dietetics practice. Working with the International Confederation of Dietetics Associations (ICDA) and their Member Country Associations our objectives are to (a) understand ways by which ICDA could contribute to global sustainable food systems, (b) develop a method for assessing ICDA's contribution to sustainable food systems and (c) test initial data collection options for this assessment. Assessment of institutional support for sustainable food system integration to practice was conducted by examining usage data (from Google Analytics) of the ICDA sponsored online sustainable food system Toolkit, and website content analysis. Study results establish baseline data and indicate initially modest support for backing integration of sustainable food system concepts within the dietetics profession.

Keywords: sustainable food system, dietetics, practice, behavior change, institutional change, institutional influence

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brazilia, Brazil

Reviewed by:
Larissa Seabra, Federal University of Rio Grande do Norte, Brazil
Lorena Angela Filip, Iuliu Haţieganu University of Medicine and Pharmacy, Romania

***Correspondence:**
Edith G. Callaghan
edith.callaghan@acadiau.ca

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

Received: *12 January 2022*
Accepted: *24 February 2022*
Published: *01 June 2022*

Citation:
Callaghan EG, Powell R and Carlsson L (2022) Assessing Institutional Support From Dietetics Associations Toward Integration of Sustainable Food Concepts in Dietetics Practice. Front. Sustain. Food Syst. 6:853564. doi: 10.3389/fsufs.2022.853564

INTRODUCTION

Contributions of our global food systems to an unsustainable world are clear (Mason and Lang, 2017; Mosby et al., 2020), and the need for food system participants to make positive change toward sustainable food systems (SFS) and to be able to assess progress is increasingly pressing. Among the vast network of actors within the food system who can make contributions toward SFS, dietitians and nutritionists are often overlooked. Dietitians work in various roles across the food system that are well-positioned to support pro-SFS behavior change across their communities (Vogliano et al., 2015; Dietitians Canada, 2020; Spiker et al., 2020). For this study, researchers worked with a global body of registered dietitians, and their representative association, the International Confederation of Dietetics Associations (ICDA), to (a) understand ways by which ICDA and member affiliates could contribute to SFS, (b) develop a method for assessing ICDA and member affiliates' contributions to SFS, and (c) test initial data collection options for this assessment.

The following sections introduce concepts of institutional influence for behavior change as they relate to ICDA, dietitians, and sustainable food systems. We continue by exploring the importance of addressing barriers to behavior change, and the possibility of assessing the extent to which barriers to change are being reduced or removed. This is followed by presentation of the methods used to develop and select assessment measures, as well as the

data collection process. The final sections present results and a discussion of the findings.

ICDA, Institutions, and Behavioral Influence

Organizational and institutional theorists have long explored the interplay of influence between institutions and their members (Meyer and Rowan, 1977). Institutions directly influence individual behaviors and group norms through "shared rules and typifications that identify categories of social actors and their appropriate activities or relationships" (Barley and Tolbert, 1997). Likewise, individuals, as organizational participants, both enact and influence the rules and norms of legitimate behavior for and within institutions. As an international confederation, the ICDA has no direct influence over the daily routines of registered dietitians-nutritionists (RDNs), yet they play an important role in setting the global context of standards and expectations for RDNs. Further, ICDA must also work to ensure that the management of the organization and replication of norms are not overly reliant on, or expressive of, one region of the world or cultural identity. Within this context, the ICDA governing Board of Directors supports and promotes international standards of practice that are derived by and for RDNs across the globe. Through communications via their newsletter, website, and member conferences, basic professional standards of practice and norms for activities and patterns of behavior are shared and reproduced. Given that RDNs occupy various roles of influence across the food system (Dietitians Canada, 2020), the ICDA is in a powerful position to support standards, norms and expectations for RDNs to be a positive influence toward global sustainable food systems.

The relationship between institutions and individual sustainability related values and behavior has been observed in several different industries. Velasco and Harder (2014) examined an education for sustainable development (ESD) intervention enacted by the International Federation of Red Cross and Red Crescent Societies with their Youth as Agents of Behavior Change program. Their study highlights the importance of an institutional and societal context that supports behavior change for sustainability. Without institutional and broader contextual support, people can *learn* about the need for sustainability, but transfer to behavior change will be inhibited (Velasco and Harder, 2014). Another study exploring the influence of small and medium business owners in New Zealand showed that appropriate institutional support can foster the development of sustainability-related identities, which as a result, can lead to behavior, organizational, and cultural change toward sustainability (Kiefhaber et al., 2020).

Similar to these organizational settings, the ICDA can leverage change toward SFS within the dietetic profession by setting a broader institutional context that highlights the importance of sustainable food and understanding sustainable food systems. As an international association that reaches a large audience the ICDA can facilitate learning and leverage behavior change that supports SFS (Carlsson and Callaghan, 2022). **Figure 1** illustrates domains of influence across four concentric rings of scale within the dietetics profession: populations of focus (individual people) for RDNs, practicing RDNs who work with individual people and institutions of various nations, national level Associations of RDNs, and finally the International Confederation of Dietetic Associations (ICDA).

Reducing Barriers for Behavior Change

Setting a positive context and expectations is often not enough to illicit behavior change. When people are interested in learning or doing something new, such as adopting a new hobby or habit, or in some significant way changing their behavior pattern, barriers often arise. Because barriers to change can slow or completely block drivers that promote a desired change, identifying barriers and creating and implementing strategies that support the removal of barriers can be productive in facilitating individual, organizational and social change. The need to address barriers to change has been seen in a variety of contexts, including: corporate shifts toward sustainability (Lozano, 2007), sustainable consumer behavior (Rizzi et al., 2020; Chwialkowska and Flicinska-Turkiewicz, 2021), public health promotion and programming (Ljungqvist et al., 2014), and programs to enhance effectiveness in workplace settings (Mohajer and Singh, 2018; Maltinsky and Swanson, 2020).

In a study of Registered Dietitians of Canadian (Carlsson et al., 2020), participants were asked what barriers they saw for achieving SFS. Four high-level barriers were identified: (1) competing food-health messages that lack scientific evidence, (2) inadequate opportunities for developing understanding of interactions between food, people, and the environment, (3) cultural expectations of stable access to a variety of imported foods year-round, and (4) cultural de-prioritization of food. While this study took a comprehensive approach to understanding barriers to SFS as perceived by dietitians, the context was limited to Canada, a high-income country. It is reasonable to assume that barriers may differ between countries of different income levels and cultural contexts.

Building on the Canadian research, another study explored perceived barriers to SFS from an international audience of dietitians (Carlsson et al., 2019). Working with the ICDA, researchers found that the ICDA membership perceived seven high-level barriers to moving toward SFS globally: (1) professional culture that is reluctant to embrace sustainability related research and practice, (2) lack of common ground for understanding the scope and complexity the SFS challenges, (3) the food price paradox (high food prices inhibit access, low food prices can incentivize unhealthy diet patterns), (4) profits as priority, (5) food safety/waste trade-offs, (6) access to adequate infrastructure and technology, (7) environmental degradation. As a loosely coupled global association of national dietetics associations, there is a relatively low degree of dependence among the organizations of which the ICDA is comprised. Thus, the ICDA is limited in its ability to address some of these barriers directly. Many are tied to social and economic policies at the country or international level. However, of these high-level barriers identified, the first two barriers were within ICDA's purview. Within these two ICDA relevant barriers, seven

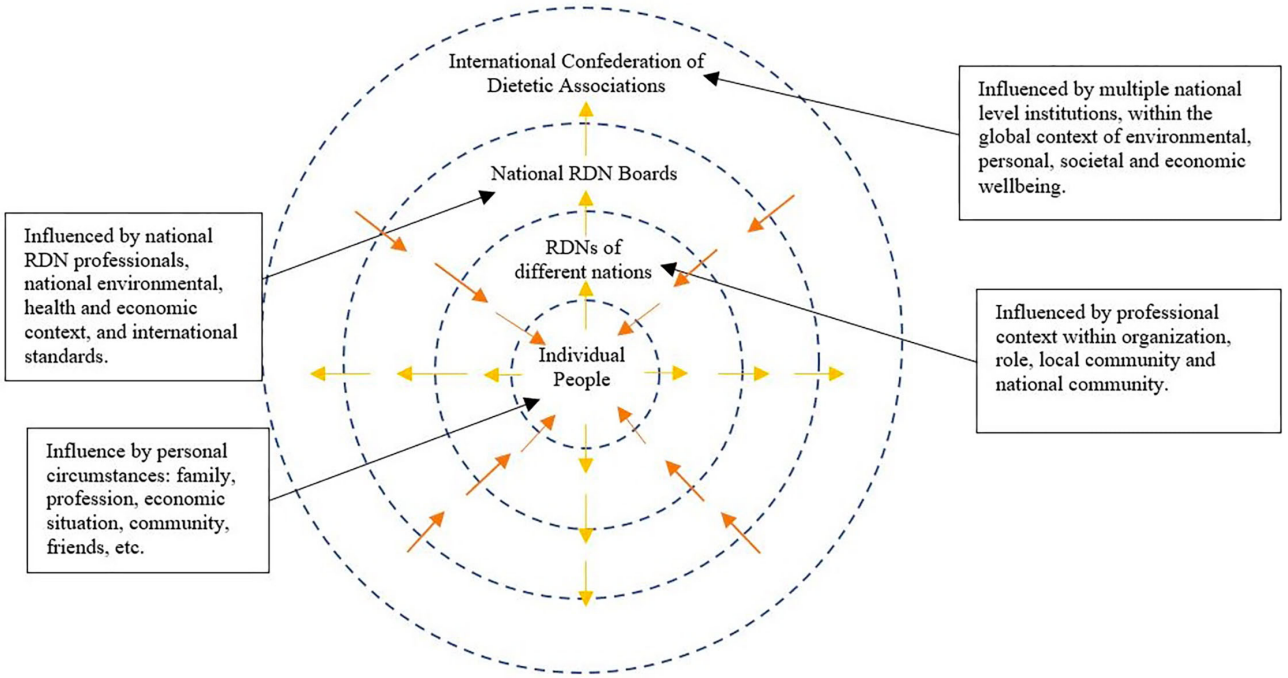


FIGURE 1 | Influence across scales of the dietetics profession.

additional sub-barriers were identified (Carlsson and Callaghan, 2022):

Reluctance within Professional Culture:

Inability to influence peers on relevance of SFS to practice.
Cultural norms in the workplace impedes N-D SFS work.
Lack of a clear, collective vision of success.

Lack of Common Ground borne from Complexity:

Complexity of food systems issues is overwhelming.
Rapid emergence of new research and developments, difficult to keep up with.
Lack of common language for SFS-Food-Nutrition.
Lack of multidisciplinary thinking for collective understanding.

Process as Indication of Progress

In order to assess progress toward significant objectives (such as sustainable diets, or climate adaptation) within a complex system (such as the food system, or the earth's climate), evaluators of programs are encouraged to use a mix of both outcome and process indicators (Bagheri and Hjorth, 2007; Niemann et al., 2017). Outcome indicators demonstrate that a specific objective has been achieved and are most useful when assessing progress toward a specific, clearly defined end goal. Process indicators are more suitable for contexts and problems that are constantly changing, where the time horizon for achievement of the objective is difficult to determine, and the exact measure of *success* is fuzzy due (in part) to the many voices of stakeholders who can influence the outcome. Process indicators "measure progression toward the achievement of an outcome (e.g. 'resilience to drought'), but do not guarantee or measure the final outcome itself" (Bours et al., 2014).

Like adaptation to a changing climate, or supporting society in reducing its reliance on plastics, the evolution toward food systems sustainability is wickedly complex (Hull et al., 2018; Lehtonen et al., 2018). In relation to sustainable food systems, the influence of ICDA allows them to provide professionally relevant information and support activities designed to enable dietetic associations and their members to incorporate SFS framing into their practice. Ideally, this will assist in promoting dietary patterns that are consistent with SFS on local and global levels. Within this context, process indicators are a more useful tool than outcome indicators for assessing contribution toward SFS.

The operationalization of process indicators are actions (processes). The previous study of ICDA membership presented above, also explored what types of supports/actions RDNs felt would be useful to them in their efforts to integrate SFS within their practice (Carlsson and Callaghan, 2022). Three high-level action areas were identified. These action areas are shown in **Table 1**, with each associated barrier to SFS that could potentially be addressed by the action/process.

The identification of these three clear areas of action, and associated barriers that could be addressed by ICDA, led ICDA to invest in development of an online SFS Toolkit[1] for global dietitians (Carlsson et al., 2019). The SFS Toolkit was designed to demonstrate SFS leadership by ICDA, assist others in taking

[1]Please see ICDA Sustainable Food Systems Toolkit: https://icdasustainability.org.

TABLE 1 | Actions for addressing barriers to integration of SFS work in dietetics practice.

Action Area 1: Provide strong leadership for sustainable food systems in practice	
Barrier 1	Inability to influence peers on relevance of SFS to practice
Barrier 2	Cultural norms in the workplace impedes RDN SFS work
Barrier 3	Lack of a clear, collective vision of success
Action Area 2: Facilitate learning and collaboration among ICDA members	
Barrier 4	Complexity of food systems issues is overwhelming
Barrier 5	Rapid emergence of new research and developments, difficult to keep up with
Barrier 6	Lack of common language for SFS-Food-Nutrition
Action Area 3: Identify and engage global partners in this work	
Barrier 7	Lack of multidisciplinary thinking for collective understanding

SFS leadership, and to facilitate learning and collaboration (the first two action areas). Identifying and engaging global partners in SFS work was beyond the initial scope for the SFS Toolkit. In existence since September 1, 2020, the SFS Toolkit contains three main sections: Resources, Community of Practice, and Professional Development. The Resources section includes various types of literature, reports and case studies. The Community of Practice section provides a number of opportunities for users to share their own stories, and interact with one another in a way that could build community around SFS. Finally, the Professional Development section provides a curated set of learning opportunities regarding SFS related webinars, podcasts, etc. Refer to **Table 4** for more details regarding the various Toolkit elements.

Development of the SFS Toolkit is a strong indication of ICDA's intention to make positive contributions toward integrating SFS into dietetic practice. Of course, the mere existence of a toolkit is not enough. Building the toolkit was a step in the right direction, further actions must be taken, however, before barriers to change will diminish. Assessment of toolkit usage, through Google Analytics and a user Self-Assessment survey, allowed for initial consideration of contributions made by ICDA and member affiliates toward supporting a shift within the profession toward sustainable food systems.

METHODS

Data Collection

This study is one component of a larger body of work, and builds directly from earlier publications (Carlsson et al., 2019; Carlsson and Callaghan, 2022). As with the earlier work, the population for this study was dietitians who are registered with their country's ICDA Member Association. Initial invitation to participate was sent from the ICDA Board *via* email to member country ICDA representatives. At the time of this work, there were 43 ICDA member countries, each with one or two elected ICDA representatives, elected by numerous registered dietitians within each country. Participant recruitment, and inclusion criteria, are fully discussed in a previously published paper (Carlsson and Callaghan, 2022). Ethical approval for the methods used was granted by Acadia University, Research Ethics Board.

TABLE 2 | Questions from the ICDA member Delphi Inquiry process.

1	What does a sustainable food system look like to you?
2	What are the major barriers to achieving the sustainable food system you describe above?
3	What types of support do you believe are most needed to move toward a sustainable food system?
4	What types of supports could ICDA provide to support movement toward a sustainable food system?
5	What do you think is the role of nutritionists and dietitians in promoting sustainable food systems?
6	Identify specific measures (or indicators) you believe are important for monitoring progress toward your vision of a sustainable food system?

Initial data collection was done through a Delphi Inquiry Method (administered through an online survey system, Lime Surveys © 2017), where participants were asked a set of the same questions in three consecutive rounds. For each consecutive round, participants were given a composite summary of responses from the prior round and asked to respond to the questions again considering what their colleagues have expressed. This method of data collection allowed us to facilitate a quasi-dialogue with members, over time, and across the globe. In the first round, 72 ICDA members participated from 30 countries (including all continents except Antarctica). In round two, 61 members participated, and 50 participants completed round three. Australia had the highest level of participation, followed by Portugal and Greece.

Data and analysis presented for this publication is one component of a larger study. Six questions were asked in the Delphi Inquiry, as shown in **Table 2**. Results and analysis for the first five questions are the subject of another paper (Carlsson and Callaghan, 2022). Initial ideas for how to monitor progress were taken from participants responses to questions 6 below, and further framed by responses to questions 2 and 4 as presented in other published work (Carlsson and Callaghan, 2022).

The vast majority of respondents' answers to question 6 spoke to broad scale societal, human health, infrastructure, and ecological indicators that are beyond the bounds of this study, such as: affordability of local food, food type intake, energy production, and fish stocks. When data collection of the Delphi Inquiry process was complete, respondents had suggested over 500 possible indicators of progress toward SFS. Of the indicators suggested, the researchers zoomed in on those relevant to the barriers identified and the action areas highlighted in **Table 1**. Indicators were culled according to the following criteria:

1) Relevance to ICDA
2) Suggested by participants
3) Availability of data
4) Feasibility of data collection (measurable, time, cost)

In total, 16 indicators to assess progress toward dismantling barriers that impede integration of SFS into RDN practice were identified. Of these, 12 were feasible to research within the constraints of this study. The full list of indicators are provided

TABLE 3 | (a) Barrier 1 – Inability to influence peers on relevance of SFS to practice; **(b)** Barrier 2 – Cultural norms in the workplace impede RDN SFS work; **(c)** Barrier 3 – Lack of a clear, collective vision of success; **(d)** Barrier 4 – Complexity of food systems issues is overwhelming; **(e)** Barrier 5 – Rapid emergence of new research and developments, difficult to keep up with; **(f)** Barrier 6 – Lack of common language for SFS-food-nutrition; **(g)** Barrier 7 – Lack of multidisciplinary thinking for collective understanding.

Process indicators	Indicator data source	Data results
(a) Existence of ICDA strategic plan to guide SFS work*	**IDS-1** ICDA website content analysis for policy integration ofSFS	Analysis revealed no specific strategic plan focused on sustainability/SFS. However, in the general ICDA Strategic Plan 2017-2020, "Decision makers in health, agriculture and food have readily available advice from dietitian-nutritionists on sustainable food systems that promote healthy diets" is included in their "goals". No further supporting action was mentioned (as of June 30, 2021)
Existence of an ICDA position statement on inclusion of SFS in dietetic scope of practice (or,ICDA-led support finding other members who have one)*	**IDS-2** ICDA SFS website content analysis for position statement of ICDA, OR examples of other member associations	Analysis of ICDA website revealed no existing position statement on the inclusion in dietetic scope of practice from the ICDA. There was also no ICDA-led support finding other members who have one (as of April 6, 2021). Analysis of content on the ICDA-SFS Toolkit, revealed no position statements from other (ICDA) members on the Toolkit. There are three SFS related role statement/papers from Canada, Australia, and Italy (as of April 6, 2021)
Member associations with a position, role or policy statement	**IDS-3** Search each member association website for position/role statements and collate	Analysis uncovered a total of 6 (of 45) member-country associations (Canada, Australia, Italy, United Kingdom, Portugal, and Norway) with an SFS related position, role or policy statement (as of June 11, 2021)
	IDS-4 Search dietetic literature for position/role statements,collate	The cost and time for researching this indicator was deemed not practical, beyond the ability of this research project. No data was collected for this indicator.
Member associations with a link to the ICDA toolkit	**IDS-5** Content analysis of memberwebsites	There were two associations (Spain and Sweden), out of a possible 45, member country websites that have posted a link to the Toolkit (as of June 11, 2021)
Inclusion/amount of relevance-related support material in the SFS Toolkit	**IDS-6** Y/N indicator assessed by content analysis of the SFS website/inclusion of this topic on thewebsite	Analysis revealed relevance-related support material is included in multiple sections: the SDG briefs, the resource database, the self-assessment, and the webinars, workshops & podcasts pages (as of June 11, 2021)
	IDS-7 Self-Assessment data, percentage interested in understanding relevance of topic topractice	Reported in Self-Assessment: 32% of respondents (RDN's & Trainees) selected that they want to understand the relevance of this topic (SFS) to their practice area
	IDS-8 Traffic to the SDG Briefs and Learning Modules	Page: SDG Briefs; Views: 167; Avg time: 3 min, 20 sec; Bounce rate: 51%; Date range M/D/Y: 9/1/20-6/24/21; Other notes: None.
		Page: Learning module homepage; Views: 201; Avg time: 1 min, 13 sec; Bounce rate: 47%; Date range M/D/Y: 9/1/20-6/24/21; Other notes: Navigation summary shows that 90 users clicked on one of the 3 learning modules after visiting this page.
		Page: Learning module 1; Views: 231; Avg time: 3 min, 51 sec; Bounce rate: 82.5%; Date range M/D/Y: 9/1/20-6/24/21; Other notes: Navigation summary shows that 15 users clicked on one of the other learning modules after this page.
		Page: Learning module 2; Views: 69; Avg time: 2 min, 34 sec; Bounce rate: 77%; Date range M/D/Y: 9/1/20-6/24/21; Other notes: Navigation summary shows that 11 users clicked on one of the other learning modules after this page.
		Page: Learning module 3; Views: 53; Avg time: 1 min, 24 sec; Bounce rate: 83%; Date range M/D/Y: 9/1/20-6/24/21; Other notes: Navigation summary shows that 5 users clicked on one of the other learning modules after this page.

(Continued)

TABLE 3 | Continued

Process indicators	Indicator data source	Data results
(b) Existence of ICDA-led Standards of Practice for integrating SFS into various practice areas*	**IDS-9** ICDA SFS Website(content analysis)	Analysis of the ICDA SFS Website revealed no relevant resources/attachments/links related to ICDA-led standards of practice for integration of SFS into practice areas (as of May 27, 2021)
ICDA Supports finding practice standards examples that can be adapted (e.g., through examples made available online)	**IDS-10** ICDA website, and SFS Website(content analysis)	Analysis of the ICDA website and ICDA-SFS website found no examples of practice standards (as of May 27, 2021)
Recognitions for SFS leaders*	**IDS-11** Content analysis of the ICDA website and newsletter; Content analysis of ICDA-SFS website and ICDA SFS newsletter	Analysis of 13 ICDA newsletters (between 2017 and April 2021) were analyzed for any grants/awards/news highlights related to SFS work completed by/involving an RDN. In total, 6 newsletter issues recognized/contained SFS-work by RDNs. One issue contained 2 recognitions, and the rest contained 1 each, for a total of 7recognitions. The webinars, workshops & podcasts page on the SFS-Toolkit was analyzed for any resources that related to the process indicator (i.e., recognized SFS-work by RDs) in April 2021. Out of 21 resources on this page, 10 fit the criteria—recognizing SFS-work by RDNs. Analysis of ICDA-SFS newsletters (March, April, May – 2021) found a total of 4 recognitions (out of 9 potential opportunities) of SFS-work by RDs in the ICDA-SFS newsletter.
	IDS-12 Association level promotion of SFS and/or D-N role in SFS (media promotion or other, e.g., social media,advocacy work)	The cost and time for researching this indicator was deemed not practical, beyond the ability of this research project. No data was collected for this indicator.

Process indicators	Indicator data source	Data results
(c) Vision of success posted and integrated into ICDA work, and member countries*	**IDS-13** Content analysis of ICDA website	The vision of success is not posted on the ICDA website (as of May 19, 2021)
	IDS-14 Content analysis of Member Association websites	The vision of success is not posted on Member Associations websites (as of May 19, 2021)

Process indicators	Indicator data source	Data results					
(d) Toolkit existence and usage*	**IDS-15** Usage stats (hits, downloads, time) for learning modules	Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
		Learning module homepage	201	1 min, 13 sec	47%	9/1/20-6/24/21	Navigation summary shows 90 users clicked on one of 3 learning modules after visiting this page.
		Learning module 1	231	3 min, 51 sec	82.5%	9/1/20-6/24/21	Navigation summary shows 15 users clicked on one of the other learning modules after this page.
		Learning module 2	69	2 min, 34 sec	77%	9/1/20-6/24/21	Navigation summary shows 11 users clicked on one of the other learning modules after this page.
		Learning module 3	53	1 min, 24 sec	83%	9/1/20-6/24/21	Navigation summary shows 5 users clicked on one of the other learning modules after this page.

(Continued)

TABLE 3 | Continued

	IDS-16 Usage stats (hits, downloads, time on webinars, podcasts and emerging research, these three are all designed to facilitate peer-to-peer learning)	Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
		Workshops webinars podcasts	346	2 min, 25 sec	67.69%	9/1/20-4/22/21	None
		Resource database	511	2 min, 19 sec	41.68%	9/1/20-4/22/21	Navigation summary shows 204 users (or ∼40%) clicked on one of the resources provided after visiting this page.
		Emerging research	94	1 min, 3 sec	60%	3/1/21-5/10/21	Navigation summary shows 37 users clicked on one of the research reports from the emerging research main page.
		Mailchimp analytics show the number of clicks on the emerging research section of the newsletters. From the three newsletters released (March, April, and May), there were a total of 15 clicks on this section.					
		Newsletter	Total opens	Total click throughs	Specific clicks on an emerging research report		
		March, 2021	185	26	6		
		April, 2021	105	25	5		
		May, 2021	214	31	4		
	IDS-17 Content analysis of discussion forum for Toolkit peer-to-peer support content	Currently, there is little use of the discussion forum, not enough content for analysis (as of June 30, 2021)					
Toolkit usage to seek information regarding broad understanding of SFS	**IDS-18** Self-assessment data, percentage of people who "select all" when asked what type of sustainability information they were seeking, and # of RDNs completing the SAoverall.	A total of 104 people completed the Self-Assessment survey between September 1, 2020 and January 13 2021. Of these, 84 indicated they were RDNs or Trainees. When asked what sustainability issues they were interested in learning more about, 14 of the 84 (17%) chose "all". The five additional users (non-RDN and not Trainee) also selected "all" in response to this question (or just over 18% of total respondents).					
Process indicators	**Indicator data source**	**Data results**					
(e) Existence of/Use of a toolkit section dedicated to knowledge translation of new and emerging research	**IDS-19** Y/N to if it exists	There is an existing webpage on the Toolkit dedicated to emerging research, which launched on March 1, 2021.					
	IDS-20 Google Analytics (# hits, time on page)	Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
		Emerging research	94	1 min, 3 sec	60%	3/1/21-5/10/21	Navigation summary shows 37 users clicked on one of the annotated research reports from the emerging research main page.

(Continued)

TABLE 3 | Continued

		Mailchimp analytics show the number of clicks on the emerging research section of the newsletters. From the three newsletters released (March, April, and May), there were a total of 15 clicks on this section.

Newsletter	Total opens	Total click throughs	Specific clicks on an emerging research report
March	185	26	6
April	105	25	5
May	214	31	4

	IDS-21 Content analysis of forum (number of shares new data/research, discussion of relevance for practice)	Currently, there is little use of the discussion forum, not enough content for analysis (as of June 30, 2021)

Process indicators	**Indicator data source**	**Data results**
(f) Toolkit Usage to support development of common language	**IDS-22** Percentage of people completing self-assessments looking for sustainable informed curriculum	Of 84 RDNs/Trainees who completed the Toolkit Self-Assessment (September 1, 2020 and January 13 2021), 38 (45%) of them selected "sustainable informed curriculum" as a topic of interest.
	IDS-23 Google analytics stats on the learning modulespage(s)	

Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
Learning module homepage	201	1 min, 13 sec	47%	9/1/20-6/24/21	Navigation summary shows 90 users clicked on one of 3 learning modules after visiting this page.
Learning module 1	231	3 min, 51 sec	82.5%	9/1/20-6/24/21	Navigation summary shows 15 users clicked on one of the other learning modules after this page.
Learning module 2	69	2 min, 34 sec	77%	9/1/20-6/24/21	Navigation summary shows 11 users clicked on one of the other learning modules after this page.
Learning module 3	53	1 min, 24 sec	83%	9/1/20-6/24/21	Navigation summary shows 5 users clicked on one of the other learning modules after this page.

(Continued)

TABLE 3 | Continued

	IDS-24 Google analytics stats on the webinars/workshops/podcastspage	Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
		Workshops webinars podcasts	346	2 min, 25 sec	67.69%	9/1/20-4/22/21	None
	IDS-25 Google analytics stats on the glossarypage	Page	Views	Avg time	Bounce rate	Date range M/D/Y	Other notes
		Glossary	59	2 min, 59 sec	66.67%	9/1/20-4/22/21	None
RDNs participating in working groups/Task Forces*	**IDS-26** Interviews and/or surveys with directors of member associations; Surveys of ICDA members	The cost of researching this indicator was beyond the ability of this research project. No data was collected for this indicator.					
Process indicators	**Indicator data source**	**Data results**					
(g) Number of member associations/RDNs collaborating with other food interests (farmers, retailers, etc.)*	**IDS-27** Interviews and/or surveys with directors of member associations; Surveys of ICDA members	The cost and time for researching this indicator was deemed not practical, beyond the ability of this research project. No data was collected for this indicator.					
Number of ICDA or Member association SFS specific events (workshops, conferences, etc.) where cross pollination and collaboration with other food interests are intentional.	**IDS-28** Content analysis of ICDA website and member country websites	The cost and time for researching this indicator was deemed not practical, beyond the ability of this research project. No data was collected for this indicator.					

NOTE: the asterisk next to some process indicator items indicates that these were identified by the ICDA membership as possible indicators for assessing SFS.

TABLE 4 | Elements of the ICDA SFS toolkit, overview of features/elements used in data collection.

SFS toolkit feature	Brief description
Resources	Existing Resources Database: Compilation of mostly gray literature reports released by external organizations, annotated by the ICDA SFS team. Case Studies: Stories of SFS challenges addressed by initiatives, programs and organizations from across the world. *SDG Briefs*: Eight of the 17 UN Sustainable Development Goals (SDGs) are explained, along with their relevance to RDN practice. *Glossary*: A number of terms relevant to SFS are defined. References provided. Emerging Research: Summarizing of recent scholarly research articles that are relevant to SFS and the Dietetics/Nutrition profession. Relevance to practice is explained for all reports.
Professional development	Learning Modules: A curated series of SFS learning modules with introductory text and reflective question written by the Toolkit designers, and direct links to relevant articles, reports, videos and podcasts. The learning modules are structured to support three levels of knowledge: • Understanding foundational concepts of sustainability and food systems • Understanding the relevance of SFS to nutrition and dietetic practice • Being able to apply SFS concepts in practice Podcasts and Webinars: These cover a wide variety of topics. Some curated from other sources, others are produced by the ICDA SFS Team. Topics range from basic sustainability theory, to in depth consideration of complex aspects of sustainable food systems.
Community of practice	This section of the Toolkit includes, *Examples of Sustainability in Practice*, *Share Your Story*, and *Discussion Forum*. It was designed to encourage interaction among practitioners and other users through shared stories, and a discussion forum board. In addition to the ICDA SFS Project Team, a further 10 RDNs are listed on the site as regional contacts to support usage in ways appropriate to the local context.

in **Tables 3a–g**, along with data sources and results of data collection. For each barrier, there are two or more potential indicators of progress, and for each indicator, there are often multiple sources of data identified. Indicators with an asterisk are those suggested by Delphi participants.

As illustrated in **Tables 3a–g**, data collection for the identified indicators involved several different methods, including website content analysis, descriptive statistics, and google analytics. In addition to the websites of ICDA, and Member Associations, the ICDA SFS Toolkit was used extensively in this research. A detailed description of the various aspects of the Toolkit relevant to this research is provided in **Table 4**.

To assess the pages within Resources and Professional Development a variety of analytical tools were used. Many of the pages were assessed for content of key terms that were relevant to the barrier being assessed. Researchers also used Google Analytics to understand user interaction with the SFS Toolkit [Google Analytics, (n.d)]. The bounce rate for pages was also examined along with the average time spent per page, and exits per page. Bounce rate is a metric which refers to the percentage of single-page sessions in which there was no interaction with the page (i.e., that a person exits the page without page interaction). A higher bounce rate (e.g., 100%) indicates that on average, users interacted less with the page. A lower bounce rate (e.g., 0%) indicates higher interaction with the page. Exits include moving to another page on the site, or clicking a link on the page which leads to an external website (e.g., some resources on the workshops and webinars page lead to other websites).

In addition to analysis of specific page use within the Toolkit, the ICDA SFS Toolkit includes an anonymous, voluntary Self-Assessment Tool. This Self-Assessment asked users a number of questions designed to help them navigate the Toolkit, quickly identifying information relevant to their interests. This also gave researchers insight into the learning needs of users. The 100 Self-Assessments (from 21 countries) competed between September 1, 2020–January 13, 2021, were used as a source of data for this study. The data collection period varied slightly among the different elements of the Toolkit. Date ranges for each analysis and detailed descriptions of data collection method for each indicator is presented in **Table 3**.

RESULTS

Tables 3a–g report the findings for each of the indicators, the indicator data sources (IDS), and their associated barrier. In the text below, the data are discussed.

Action Area 1: Provide Strong Leadership for Sustainable Food Systems in Practice

Barrier 1: Inability to Influence Peers on Relevance of SFS to Practice

Results for IDS-1, IDS-2 and IDS-3 reveals that ICDA and the majority of Member Associations have not yet documented actionable commitments to integrating SFS into dietetics practice. With no SFS focus in their strategic plan, no existing position statement for practice, and just over a handful of Member Associations with an SFS related policy statement, there was no documented evidence that SFS has penetrated to the core of institutional planning and policy making. Usage stats from the other indicator data sources however, counter this second possibility. The results of IDS-7 show that of the 100 respondents to the Toolkit Self-Assessment, 32% indicated that they were interested in learning more about all aspects of sustainability in relation to food systems.

With respect to traffic on the SDG briefs and learning modules pages (IDS-8), is appears that users spent adequate time on each page to review and consider what was presented, and interact with the material provided. Almost half of the users who examined the SDG briefs page (167) explored the page interactively by clicking through to the SDG briefings

as indicated by the 51% bounce rate. Similarly, just over half of the users who accessed the Learning Modules main page, clicked into one of the three modules offered on that page (bounce rate 47%). The analytics from the learning modules is more difficult to interpret. Each Learning Module includes explanatory text, reflection questions, references, and links to other websites for further information. As shown in the Data Results table, people spent the most time, on average, on Learning Module 1 (3 min, 51 s/231 pageviews), a bit less on Learning Module 2 (2 min, 34 s/69 pageviews), and the least time on Learning Module 3 (1 min, 24 s/53 pageviews). The text on the Learning Module pages is more generally contextual, with the more rigorous explanations and learning coming from the downloadable files and the video links from other websites. It could be that users downloaded the files that they wanted, then exited the site to examine the detailed more closely. Further, each click through to a different website would count as an exit of the site, rather than interaction with the material. Thus, while the data shows that people are using the various pages, limitations of the data inhibit our ability fully understand the extent to which they are interacting with, and learning from, the material provided.

Barrier 2: Cultural Norms in the Workplace Impede RND SFS Work

Results from IDS-9 and IDS-10 reveal that ICDA has not promoted standards for practice relevant to SFS in dietetics practice. For IDS-11, content analysis of ICDA and ICDA-SFS newsletters was conducted to find recognition of SFS work by RDNs. Between January 2017 and April 2021, analysis of 13 ICDA newsletters, which are sent to all registered members of ICDA, revealed seven recognitions of RDN SFS work; analysis of four ICDA-SFS newsletters, which is sent to people who explicitly sign-up for the newsletter on the SFS Toolkit, found four recognitions of this type of recognition out of nine recognition opportunities.

Barrier 3: Lack of a Clear, Collective Vision of Success

For both IDS-13 and IDS-14, content analysis was conducted for the ICDA and Member Association website to see if the ICDA member generated Vision of Success for SFS was posted or referenced. No such references or postings were found.

Action Area 2: Facilitate Learning and Collaboration Among ICDA Members

Barrier 4: Complexity of Food Systems Issues Is Overwhelming

Data for examining means by which IDCA is addressing this barrier were taken entirely from usage data of the ICDS SFS Toolkit. The data from IDS-15 are summarized above (IDS-8), however it is worth noting that the process indicator suggested for IDS-15 was toolkit usage.

IDS-16 examines usage stats from specific pages of the Toolkit. During the 8 month date range of data collection, there were almost 350 visits to the Workshops, Webinars and Podcast page of the Toolkit, as well as the Resource Database page. There was more traffic on the Resources Database, and the bounce rate for this page was lower than for other pages (41.68%). The bounce rate for the Workshops Webinars and Podcasts page was higher relative to some other pages (67.69%). It is important to note that direct comparison between bounce rate numbers is misleading. All of the items on the Resource Database page keep users within the website, but most of the items on the Workshops Webinars and Podcasts take users to other website. Thus, the bounce rate away from the Resources Database page is an accurate reflection of people leaving without further explorations of the material on the page, whereas the bounce rate for Workshops Webinars and Podcasts likely includes interactions with the page that took users to other websites. Emerging research had significantly fewer visits, but data collection only occurred over ∼2.5 months. Analysis of clicks from the ICDA SFS newsletters onto specific articles on the Emerging Research page showed moderate interest.

Data from ISD-18 shows that during the period of data collection 104 people filled in the Self-Assessment form. When asked what type of sustainability issues they would like to learn more about, just over 18% chose "select all."

Barrier 5: Rapid Emergence of New Research and Developments, Difficult to Keep Up With

The Emerging Research section was not part of the initial Toolkit design. In early 2021, however, funding to support this became available. Therefore, the relatively lower number of page views (94) needs to be understood with this in mind.

With IDS-21, the intention was to assess discussions of research in the Toolkit's Discussion Forum. Unfortunately, there was insufficient traffic on the Discussion Forum to allow for analysis.

Barrier 6: Lack of Common Language for SFS-Food-Nutrition

Of the RDNs/Trainees who completed the Self-Assessment, IDS-22 shows that 45% of them were interested in sustainable informed curriculum.

The data results for IDS-23 and IDS-24 have been summarized above (IDS-8 and IDS-16 respectively). To understand Toolkit usage to support development of a common language for SFS, we also examined Google Analytics from the Glossary page. Results showed that relatively few people (59 views) reviewed the glossary page, but those that did spend time to review the material, and interact with it.

Action Area 3: Identify and Engage Global Partners in This Work

Barrier 7: Lack of Multidisciplinary Thinking for Collective Understanding

Both process indicator sources of data collection were deemed not practical, and beyond the project capacity for current collection (IDS-27, IDS-28). No data were collected to assess progress toward addressing this barrier.

DISCUSSION

Tracking and analysis of data collected over 9 months during the first year of the Toolkit's existence provides a baseline for

understanding how the website is being used. Two types of data were collected: contiguous and binary. The intent with this data is not to arrive at a single score, nor are we are able to provide conclusive answers regarding progress toward or away from the dismantling of barriers to the integration of SFS in RDN practice. We do, however, provide an initial narrative regarding the contribution made by ICDA and Member Associations, toward promoting integration of SFS to dietetic practice. Progressive tracking over years, and further development of the ICDA SFS Toolkit, will allow researchers to provide a more nuanced understanding of these indicators as well as possibly identify and develop additional indicators. This discussion is organized around *Action Areas* identified as important by RDNs toward supporting SFS, and consideration is given to both actions taken and potential action to be taken by ICDA, National/Regional Dietetics Associations, and RDNs themselves. Actions and future opportunities across scales of the profession are illustrated in **Figure 2**.

Action Area 1: Provide Strong Leadership for Sustainable Food Systems in Practice

ICDA has demonstrated leadership in supporting SFS as relevant to RDN practice by providing a free, accessible, online Toolkit with relevance-related support material in multiple sections (i.e., SDG briefs, learning modules, resource database, self-assessment tool, webinars and workshops, emerging research). This resource provides RDNs with tools and information that, theoretically, can provide grounding in SFS and its relevance to practice. Strong grounding in the relevance of SFS to dietetics practice will help RDNs facilitate the shift of cultural norms within workplace environments toward greater acceptance of SFS. This shift can also be supported by establishment of SFS certifications and acknowledgment and promotion of SFS leadership by dietetics institutions. Results illustrate that minimal institutional level efforts have been dedicated toward this type of support. We are unsure if this is because standards of practice or certifications have not developed, or if documentation of such standards have not yet been posted to their website and/or the Toolkit.

Leadership can also be demonstrated by articulating and promoting a clear vision of success in relation to a particular goal. The ICDA membership has generated such a vision for SFS in the dietetics profession, however more can be done to use the vision to its potential as a guide to orient action. Public promotion and acknowledgment, and inclusion of the vision in strategic documents, are two ways to more fully leverage the potential of the Vision of Success. Finally, that only two Member Associations provide a link to the ICDA SFS Toolkit on their own member country websites (ISD-5) is either: further indication that SFS remains a peripheral concern for most Member Association, or that the SFS Toolkit has been found to not be relevant (additional research is required to determine this).

The data collected demonstrates that the ICDA and the Member Associations have initiated leadership in supporting integration of SFS in dietetics practice. However, given the urgency of global sustainability challenges, much more must be done and more quickly. While these early steps of leadership are good, a more proactive approach would strengthen the field in this area (see recommendations for practice below).

Action Area 2: Facilitate Learning and Collaboration

Active use of the ICDA SFS Toolkit can make strong contributions toward SFS learning and collaboration. Further, frustration stemming from the overwhelming complexity of SFS issues coupled with the daunting task of keeping pace with rapidly emerging new research can be calmed by systematic and consistent support in learning and application to practice. Usage statistics from Emerging Research and Learning Modules pages indicate that RDNs are seeking these types of learning materials and activities. Building the mechanisms for learning is necessary for progress in this area, however, it is not sufficient. It is possible that SFS learning and collaboration is strongly inhibited by lack of time and institutional support. This brings the discussion back to the need for strong leadership. Once SFS learning for RDNs is legitimized through certification, and collaboration is rewarded through strong institutional support, uptake in this area will likely gain pace.

Action Area 3: Identify and Engage Global Partners in This Work

Unfortunately, as noted earlier, the research team did not have capacity to investigate activities in this area. Nevertheless, it is our belief that action by RDNs toward engaging global partners will be facilitated by strong leadership. Further, without strong institutional support in this area, the energy and time required to initiate and sustain such partnerships will be impede progress. Investigation of activities designed to promote multidisciplinary thinking is an opportunity for future research.

LIMITATIONS

The authors acknowledge challenges and limitations of website usage data. Two significant challenges stand-out. First, simply because someone looks at a page, we cannot know what is gleaned from their examination of the resource. A proxy for the relative utility of a page or Toolkit resource can be estimated by tracking usage over time. Alternatively, a more accurate measure of utility can be assessed by interviewing and/or surveying users of the Toolkit. The second limitation of website usage data is that if interest in certain aspects of the Toolkit wain, without further research it is impossible to interpret why such a drop-off occurred. Perhaps, for example, if users no longer show interest in a specific set of resources it could be because their need for knowledge provided by that resource has been satisfied, or perhaps the recourse is no longer seen as adequate or relevant. As this field progresses, a broader reading of the socio-ecological and institutional contexts will be required to further ground website usage data. Additionally, data collection for this study was limited to a seven to 8 month period, and Self-Assessment data were only obtained for a 4 month period. Longer periods of data collection for future assessments will grant additional depth to this study.

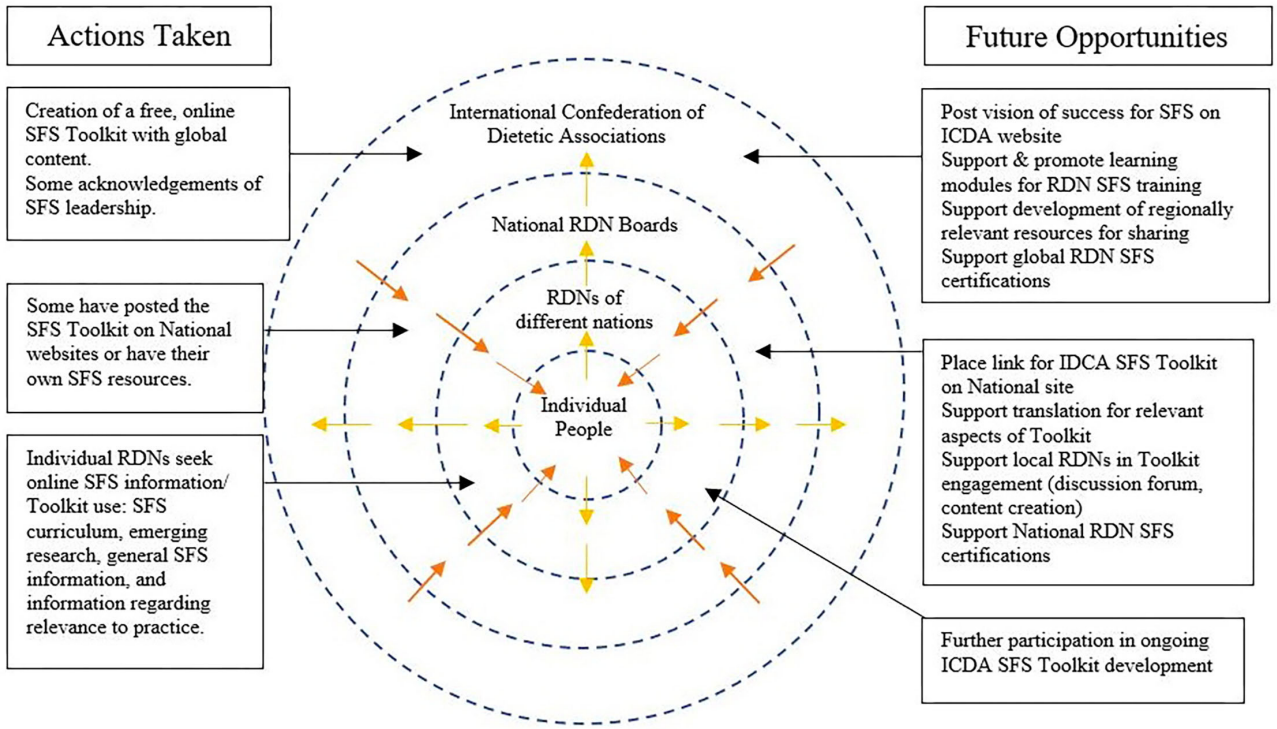


FIGURE 2 | Actions and opportunities across scales of the dietetics profession.

CONCLUDING REFLECTIONS

This paper has argued the importance of institutional leadership for integrating SFS into dietetics practice. In concert with our initial objectives we have identified ways by which ICDA can contribute to SFS through addressing barriers RDNs experience toward integration of SFS in dietetics practice. We have developed and tested a method for assessing ICDA's contribution toward addressing these barriers, and established a baseline regarding current ICDA and Member Association actions aimed at addressing barriers. Results show that ICDA, and some ICDA Member Associations, have taken initial steps toward demonstrating leadership for SFS, and supporting learning and collaboration for SFS. Further, results from Google Analytics indicate that RDNs from around the globe are interested in learning more about SFS. Our results also show that there remain several relatively easy and low cost steps that could be taken by the institutions to further reduce barriers to SFS experienced by RDNs. Finally, additional research is needed to identify ways dietetics institutions can support productive partnerships of diverse expertise designed to enhance collaboration on SFS.

Even with the forementioned limitations, we believe that this research has made a contribution toward understanding the importance of institutional support for SFS in the field of dietetics, and we have provided suggestions to enhance this support on into the future.

RECOMMENDATIONS FOR PRACTICE

In order for RDNs to reach a tipping point, where SFS integration into practice is a norm, stronger and more proactive leadership from institutions is required. The commitment of time, energy, and financial resources to development and maintenance of the ICDA SFS Toolkit has been positive. However, for the Toolkit to have maximum benefit RDNs must know about the resource, be encouraged to use it, and have time to use/integrate it. ICDA could promote the toolkit, and/or various aspects of it, to member associations through the ICDA newsletter. This may influence these associations to use it in their own work or share it on their own websites in the future. Additional potential promotion and outreach options include: learning modules that steer learners to emerging research and discussion the forum, promotion of new emerging research papers and discussions on Twitter, and national/international workshops that introduce these aspects of toolkit to participants.

Finally, greater efforts need to be put toward creating incentives for Toolkit usage, and integration of ideas into practice. Positive incentives for usage will likely be motivated by: (1) social media promotion of emerging research and debates, (2) recognition and promotion of individual RDN SFS leadership in their practice, (3) development of a SFS certification, and (4) development of SFS curriculum modules for Dietetics education.

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 Acadia University, Ethics Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

EC was primary contributor to the framing of the study. RP was primarily responsible for website usage and content data collection, analysis, and writing. LC contributed toward study conceptualization and editing. EC and LC contributed in paper writing. All authors approved the final submitted version.

REFERENCES

Bagheri, A., and Hjorth, P. (2007). A framework for process indicators to monitor for sustainable development: practice to an urban water system. *Environ. Dev. Sustain.* 9, 143–61. doi: 10.1007/s10668-005-9009-0

Barley, S. R., and Tolbert, P. S. (1997). Institutionalization and structuration: studying the links between action and institution. *Organ. Stud.* 18, 93–117 doi: 10.1177/017084069701800106

Bours, D., McGinn, C., and Pringle, P. (2014). *Guidance Note 2: Selecting Indicators for Climate Change Adaptation Programming*. Guidance for MandE of Climate Change Interventions Sea Change, UKCIP, 10. Available online at: https://www.ukcip.org.uk/wp-content/PDFs/MandE-Guidance-Note2.pdf (accessed December 20, 2021).

Carlsson, L., and Callaghan, E. (2022). The social license to practice sustainability: concepts, barriers and actions to support nutrition and dietetics practitioners in contributing to sustainable food systems. *J. Hunger Environ. Nutr.* doi: 10.1080/19320248.2022.2034559. [Epub ahead of print].

Carlsson, L., Callaghan, E., and Broman, G. (2020). Assessing community contributions to sustainable food systems: dietitians leverage practice, process and paradigms. *Syst. Pract. Action Res.* 2020, 1–27. doi: 10.1007/s11213-020-09547-4

Carlsson, L., Callaghan, E., and Laycock Pedersen, R. (2019). *Building Common Ground for Sustainable Food Systems in Nutrition and Dietetics.* International Confederation of Dietetics Associations. Available online at: https://icdasustainability.org/ (accessed October 18, 2021).

Chwialkowska, A., and Flicinska-Turkiewicz, J. (2021). Overcoming perceived sacrifice as a barrier to the adoption of green non-purchase behaviours. *Int. J. Consumer Stud.* 45, 205–20. doi: 10.1111/ijcs.12615

Dietitians Canada. (2020). *The Role of Dietitians in Sustainable Food Systems and Sustainable Diets*. Toronto, ON: Dietitians of Canada, 40. Available online at: https://www.dietitians.ca/Advocacy/Toolkits-and-Resources?n=The%20Role%20of%20Dietitians%20in%20Sustainable%20Food%20Systems%20and%20Sustainable%20Diets%20(role%20paper)andPage=1# (accessed January 15, 2022).

Google Analytics (n.d.) *Behavior*. Available online at: analytics.google.com/ (accessed September 10, 2021).

Hull, R. B., Robertson, D., and Mortimer, M. (2018). Wicked leadership competencies for sustainability professionals: definition, pedagogy, and assessment. *Sustainability* 11, 171–77. doi: 10.1089/sus.2018.0008

Kiefhaber, E., Pavlovich, K., and Spraul, K. (2020). Sustainability-related identities and the institutional environment: the case of new zealand owner–managers of small- and medium-sized hospitality businesses. *J. Bus. Ethics* 163, 37–51. doi: 10.1007/s10551-018-3990-3

Lehtonen, A., Salonen, A., Cantell, H., and Riuttanen, L. (2018). A pedagogy of interconnectedness for encountering climate change as a wicked sustainability problem. *J. Clean. Prod.* 199, 860–867. doi: 10.1016/j.jclepro.2018.07.186

Ljungqvist, I., French, J., and Apfel, F. (2014). *Social Marketing Guide for Public Health Programme Managers and Practitioners.* Glasgow: European Centre for Disease Prevention and Control, 105.

Lozano, R. (2007). Orchestrating organisational changes for corporate sustainability: overcoming barriers to change. *Greener Manag. Int.* 57, 43–64.

Maltinsky, W., and Swanson, V. (2020). Behavior change in diabetes practitioners: an intervention using motivation, action planning and prompts. *Patient Educ. Counsel.* 103, 2312–19. doi: 10.1016/j.pec.2020.04.013

Mason, P., and Lang, T. (2017). *Sustainable Diets: How Ecological Nutrition Can Transform Consumption and the Food System,* 1 edition. London, New York: Routledge.

Meyer, J. W., and Rowan, B. (1977). Institutionalized organizations: formal structure as myth and ceremony. *Am. J. Sociol.* 83, 340–363.

Mohajer, N., and Singh, D. (2018). Factors enabling community health workers and volunteers to overcome socio-cultural barriers to behaviour change: meta-synthesis using the concept of social capital. *Human Resourc. Health* 16, N.PAG. doi: 10.1186/s12960-018-0331-7

Mosby, I., Rotz, S., and Fraser, E. D. G. (2020). *Uncertain Harvest: The Future of Food on a Warming Planet.* Saskatchewan, Canada: University of Regina Press.

Niemann, L., Hoppe, T., and Coenen, F. (2017). On the benefits of using process indicators in local sustainability monitoring: lessons from a Dutch Municipal Ranking (1999–2014). *Environ. Policy Govern.* 27, 28–44. doi: 10.1002/eet.1733

Rizzi, F., Annunziata, E., Contini, M., and Frey, M. (2020). On the effect of exposure to information and self-benefit appeals on consumer's intention to perform pro-environmental behaviours: a focus on energy conservation behaviours. *J. Cleaner Prod.* 270, 122039. doi: 10.1016/j.jclepro.2020.122039

Spiker, M. L., Knoblock-Hahn, A., Brown, K., Giddens, J., Hege, A. S., and Sauer, K. (2020). Cultivating sustainable, resilient, and healthy food and water systems: a nutrition-focused framework for action. *J. Acad. Nutr. Diet.* 120, 1057–67. doi: 10.1016/jand.2020.02.018

Velasco, I., and Harder, M. K. (2014). From attitude change to behaviour change: institutional mediators of education for sustainable development effectiveness. *Sustainability* 6, 6553–6575. doi: 10.3390/su6106553

Vogliano, C., Steiber, A., and Brown, K. (2015). Linking agriculture, nutrition, and health: the role of the registered dietitian nutritionist. *J. Acad. Nutr. Diet.* 115, 1710–1714. doi: 10.1016/jand.2015.06.009

Conflict of Interest: LC was a Registered Dietitian. RP was a Dietetics Intern in Canada. EC was not a dietitian, but a scholar of business and sustainability. Generous support for student research was provided by the International Confederation of Dietetics Associations and the Harrison McCain Emerging Scholars Fund.

frontiers | Frontiers in Public Health

SYSTEMATIC REVIEW
published: 03 June 2022
doi: 10.3389/fpubh.2022.892153

The Relationship Between Plant-Based Diet and Risk of Digestive System Cancers: A Meta-Analysis Based on 3,059,009 Subjects

Yujie Zhao[1†], *Junyi Zhan*[2†], *Yongsen Wang*[1] *and Dongli Wang*[1*]

[1] *Department of Gastroenterology, Affiliated Hospital of Shandong University of Traditional Chinese Medicine, Jinan, China,*
[2] *Graduate School, Shandong University of Traditional Chinese Medicine, Jinan, China*

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brasilia, Brazil

Reviewed by:
Hossein Shahinfar, Iran University of Medical Sciences, Iran
Alireza Jafari, Kerman Medical University, Iran
Nathalia Pizato, University of Brasilia, Brazil

***Correspondence:**
Dongli Wang
zyjwww920@sina.com

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

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

Received: *08 March 2022*
Accepted: *09 May 2022*
Published: *03 June 2022*

Citation:
Zhao Y, Zhan J, Wang Y and Wang D (2022) The Relationship Between Plant-Based Diet and Risk of Digestive System Cancers: A Meta-Analysis Based on 3,059,009 Subjects. Front. Public Health 10:892153. doi: 10.3389/fpubh.2022.892153

Background and Objectives: Diets containing red or processed meat are associated with a growing risk of digestive system cancers. Whether a plant-based diet is protective against cancer needs a high level of statistical evidence.

Methods: We performed a meta-analysis of five English databases, including PubMed, Medline, Embase, Web of Science databases, and Scopus, on October 24, 2021 to identify published papers. Cohort studies or case-control studies that reported a relationship between plant-based diets and cancers of the digestive system were included. Summary effect-size estimates are expressed as Risk ratios (RRs) or Odds ratios (ORs) with 95% confidence intervals and were evaluated using random-effect models. The inconsistency index (I^2) and τ^2 (Tau^2) index were used to quantify the magnitude of heterogeneity derived from the random-effects Mantel-Haenszel model.

Results: The same results were found in cohort (adjusted RR = 0.82, 95% CI: 0.78–0.86, $P < 0.001$, $I^2 = 46.4\%$, $Tau^2 = 0.017$) and case-control (adjusted OR = 0.70, 95% CI: 0.64–0.77, $P < 0.001$, $I^2 = 83.8\%$, $Tau^2 = 0.160$) studies. The overall analysis concluded that plant-based diets played a protective role in the risk of digestive system neoplasms. Subgroup analyses demonstrated that the plant-based diets reduced the risk of cancers, especially pancreatic (adjusted RR = 0.71, 95% CI: 0.59–0.86, $P < 0.001$, $I^2 = 55.1\%$, $Tau^2 = 0.028$), colorectal (adjusted RR = 0.76, 95% CI: 0.69–0.83, $P < 0.001$, $I^2 = 53.4\%$, $Tau^2 = 0.023$), rectal (adjusted RR = 0.84, 95% CI: 0.78–0.91, $P < 0.001$, $I^2 = 1.6\%$, $Tau^2 = 0.005$) and colon (adjusted RR = 0.88, 95% CI: 0.82–0.95, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$) cancers, in cohort studies. The correlation between vegan and other plant-based diets was compared using Z-tests, and the results showed no difference.

Conclusions: Plant-based diets were protective against cancers of the digestive system, with no significant differences between different types of cancer.

Systematic Review Registration: https://www.crd.york.ac.uk/prospero/display_record.php?ID=CRD42022322276, Identifier: CRD42022322276.

Keywords: plant-based diet, meta-analysis, digestive system, eating habits, cancer

INTRODUCTION

Common digestive system cancers include liver, esophageal, gastric, and colorectal tumors, which are among the 10 most significant healthcare issues worldwide (1). According to the latest statistics in the 2020 GLOBOCAN database, more than 1.9 million new colorectal cancer (including anus) cases and 935,000 deaths occurred (2), and the cancer burden could rise to 27.5 million new cases annually by 2040. Gastric tumors were responsible for over one million new cases and an estimated 769,000 deaths, ranking fifth for incidence and fourth for mortality globally. Liver cancer was the sixth most commonly diagnosed cancer and the third leading cause of cancer death worldwide (906,000 new cases and 830,000 deaths), and esophageal cancer ranked seventh in incidence (604,000 new cases) and sixth in mortality overall (544,000 deaths). Therefore, it is urgent and essential to establish primary prevention programs for digestive system cancers (3). Because 30–50% of all cancer cases are preventable, the World Cancer Research Fund (WCRF) and American Institute for Cancer Research (AICR) published 10 cancer prevention recommendations that set the benchmark for evidence-based guidance, and diet was particularly important (4).

Diet is an inseparable part of people's daily lives, and it has attracted much attention. High quality evidence investigated that red meat, especially the consumption of processed meat, was associated with a growing risk of digestive system cancers (5, 6). Increasing emphasis has been placed on the tumor-preventing function of plant-based diets (7). However, a recent meta-analysis (8) suggested that vegetarian diets were not significantly associated with a lower risk of breast, colorectal or prostate cancer compared to non-vegetarian diets. This study systematically searched two databases and included six cohort studies included with limited types of digestive system cancers. Therefore, the evidence is not sufficiently strong to evaluate the relationship between digestive system cancers and plant-based diets. Comprehensive evaluations are scarce, especially for various digestive system cancers and multiple dietary patterns.

Several styles of vegetarian diets are defined based on the specific animal products consumed (9). Vegetarian diets are classified into six different types according to food selection (10, 11). The vegetarian diets (12) include vegan (eats only plant-based foods but no red meat, poultry, fish, dairy or eggs), pesco-lacto-ovo-vegetarian (eats fish, dairy and eggs without red meat or poultry), lacto-ovo-vegetarian (eats dairy and eggs without red meat, poultry or fish), pesco-vegetarian (eats fish, but no red meat, poultry, dairy or eggs), ovo-vegetarian (eats eggs but no red meat, poultry, fish or dairy), lacto-vegetarian(eats dairy, but no red meat, poultry, fish or eggs) and semi vegetarian (eats dairy, eggs and some red meat, poultry and fish $\geq$1 time/month but only 1 time/week).

Other classified dietary patterns, such as the Mediterranean diet (13), prudent diet (14) and dietary approaches to stop hypertension (DASH) (15), are widely defined and followed. Because these three diets also focus on vegetables, fruits, and cereals, they were considered plant-based diets. In summary, plant-based diets were defined as follows: (1) a diet excluding any meat, meat products, seafood, or food of animal origin (i.e., vegetarian and vegan diets, respectively); and (2) a diet characterized by a higher consumption of fruits, vegetables, legumes, and nuts rather than animal products (16).

With these complicated classifications, the dietary patterns and subtypes of cancer require further detailed grouping. Therefore, we did this meta-analysis to better assess the association between plant-based diets and gastrointestinal cancers to provide evidence for dietary guidance.

METHODS

Registration and Reporting Format

The performance of the meta-analysis adhered to the guidelines in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) statement (17) and Meta-analysis of Observational Studies in Epidemiology (MOOSE) statement (18). The PRISMA and MOOSE checklists are presented in **Supplementary Tables 1**, **2**. The study protocol was registered with the International Prospective Register of Systematic Reviews (PROSPERO), and the registration number is CRD42022322276.

Search Strategy

A literature search was performed in the PubMed, Medline, Embase, Web of Science and Scopus databases before October 24, 2021. The PICOS tool was used to guide the search strategy: (P) Population: patient with digestive system cancers; (I) Intervention: plant-based diet; (C) Comparator: other diet patterns; (O) Outcomes: gastrointestinal system cancers; (S) Study type: case-control and cohort studies. A complete list of the search terms is available in the additional materials section (**Supplementary Table 3**).

Eligibility Criteria

Our analysis was restricted to articles that met the following criteria: (1) study participants: population with plant-based diets; (2) endpoints: all kinds of digestive system cancers; (3) study type: cohort studies or case-control studies; (4) follow-up rate: at least 70%; and (5) the dietary patterns in the articles included specific food components. Case reports or case series, editorials, narrative reviews, non-English articles,and literature with unqualified data and not available were excluded.

Study Selection

Endnote 20 literature management software was used to manage the literature search records. The selection process covered three sections. Two reviewers (Y.Z. and Y.W.) independently reviewed articles based on their titles, and duplicates were removed. Articles with questionable titles were included in the abstract review phase. The same two independent reviewers screened and evaluated the abstracts of all articles selected from the first section for eligibility. Meanwhile, they assessed full-text articles that warranted further investigation using the eligibility criteria. Disagreements in each phase were resolved by a third independent reviewer (D.W.) from our group.

Data Extraction

Two investigators (Y.Z. and Y.W.) independently extracted data from each qualified article, including the first author, year of publication, country where study was performed, sex, sample size, study type, follow-up years, the age of study subjects, cancer type, definition of the vegetarian dietary pattern, menstrual status and other confounding risk factors, when available. The divergence was resolved via joint re-evaluations of original articles, and by a third author (D.W.) when necessary.

Risk of Bias of Individual Studies

Two authors (Y.Z. and Y.W.) independently assessed the risk of bias of all eligible studies using the Risk of Bias in Non-randomized Studies-of Interventions (ROBINS-I) assessment tool (19). The following seven domains were considered: (i) bias due to confounding; (ii) bias in selection of participants into the study; (iii) bias in classification of interventions; (iv) bias due to deviations from intended interventions; (v) bias due to missing data; (vi) bias in measurement of outcomes; (vii) bias in selection of the reported result. Each part were categorized into five levels of ROB: low risk of bias (the study is comparable to a well-performed randomized trial with regard to this domain); moderate risk of bias (the study is sound for a non-randomized study with regard to this domain but cannot be considered comparable to a well- performed randomized trial); serious risk of bias (the study has some important problems); critical risk of bias (the study is too problematic to provide any useful evidence on the effects of intervention); no information (no information is reported about the methods of outcome assessment). Trials were divided into three levels of ROB by the number of components for which high ROB potentially existed: high risk (five or more), moderate risk (three or four) and low risk (two or less).

Statistical Analyses

Data management and analyses were handled using STATA software version 14.1 for Windows (Stata Corp, College Station, TX, USA). Effect size was estimated as risk ratios (RRs) or hazard ratios (HRs) with 95% confidence intervals (CIs) in cohort studies and as odds ratios (ORs) with 95% CIs in case-control studies. To make the statistical results more accurate, we transformed the HRs into RRs using the formula RR = (1–expHR*ln (1–r))/r. Pooled effect-size estimates were derived under the random-effects model, regardless of the magnitude of between-study heterogeneity. Differences between two estimates were tested using the Z-test proposed by Altman and Bland (20).

The inconsistency index (I^2) statistic, which represents the percent of diversity due to heterogeneity rather than chance, was used to quantify the magnitude of heterogeneity derived from the random-effects Mantel-Haenszel model. An $I^2 > 50\%$ indicated the presence of significant heterogeneity, and a higher percent corresponded to a higher degree of heterogeneity. Another index, τ^2 (Tau^2), was used to examine the sensitivity of the results to different levels of between-study heterogeneity. To account for possible sources of between-study heterogeneity from clinical and methodological aspects, a large number of pre-specified subgroup analyses were performed according to geographic region, study design, age, sex, cancer type, definition of plant-based dietary pattern, and follow-up interval. To avoid giving large weight to relatively small studies, we fitted the fixed effect models using sensitivity analyses.

The probability of publication bias was evaluated using Begg's funnel plots and Egger regression asymmetry tests at a significance level of 10%. The trim-and-fill method was used to estimate the number of theoretically missing studies.

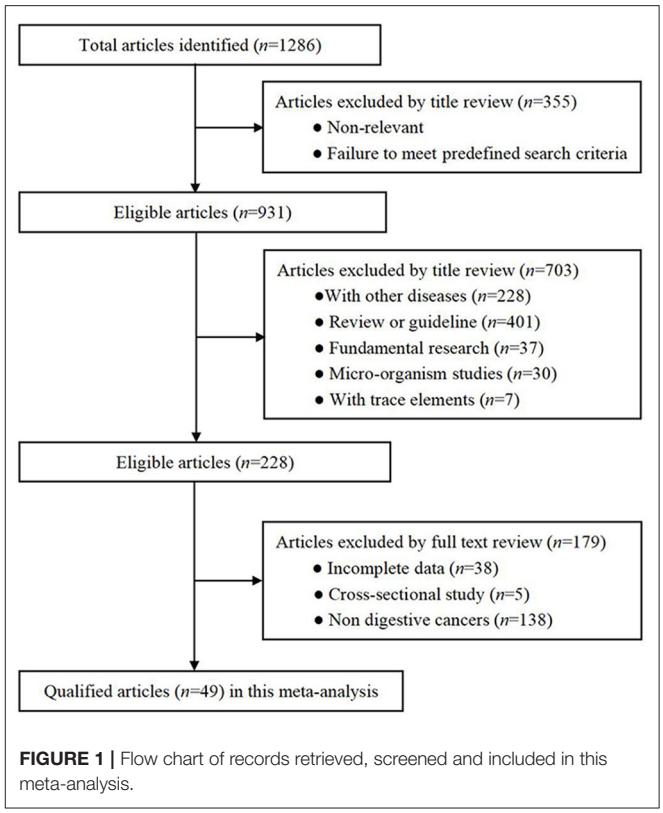


FIGURE 1 | Flow chart of records retrieved, screened and included in this meta-analysis.

RESULTS

Eligible Studies

A total of 5,232 articles were initially identified using predefined medical subject words to search the predefined public database, and 49 of studies met the criteria for eventual inclusion, including 3,059,009 subjects. The detailed selection process is shown in **Figure 1**.

Study Characteristics

Supplementary Table 4 shows the baseline characteristics of the 49 articles (21–69) included in this meta-analysis. Eighteen of these articles were cohort studies (21, 24–27, 32, 33, 36, 40, 41, 47, 51, 55, 57, 59, 61, 62, 69), and 31 were case-control studies (22, 23, 28–31, 34, 35, 37–39, 42–46, 48–50, 52–54, 56–58, 60, 63–68). Sixteen articles were performed in Europe (22, 24, 29, 33, 37, 40, 42, 43, 45, 48–50, 52, 59–61), 15 articles were attributed to North America (21, 23, 26, 28, 30, 32, 35, 36, 38, 41, 44, 54, 56, 57, 68), 16 articles were Asian (25, 27, 31, 34, 46, 47,

51, 53, 58, 62–67, 69) and the remaining 2 articles were from Oceania (39, 55). Depending on the study endpoints, 6 articles focused on pancreatic cancer (21, 28, 41–44), 23 articles focused on colorectal cancer (22, 24, 27, 29, 34–37, 40, 45, 46, 50, 51, 53–56, 58, 59, 61–64), 12 studies examined colon cancer (23, 24, 26, 27, 37, 51, 55–57, 59, 61, 62), 12 studies were performed on rectal cancer (24, 27, 32, 37, 51, 55–59, 61, 62), 9 studies investigated gastric cancer (25, 30, 33, 48, 52, 60, 65–67), 3 studies focused on esophageal cancer (31, 39, 69), 2 studies examined pharyngolaryngeal cancer (38, 49), and 2 articles were on liver cancer (47, 68). Fifteen of the included articles used female groups (24, 27, 28, 30, 32, 36, 40, 41, 44, 47, 56, 58–60, 66) and 16 studies examined male subjects (25–28, 30, 32, 35, 36, 40, 41, 44, 47, 56, 58, 60, 66). We created a detailed classification of the dietary patterns involved according to the principles mentioned in the incorporated eligible article (**Supplementary Table 5**). Classification resulted in 14 articles on vegan diets (21, 22, 25, 28, 29, 31, 35, 36, 39, 43, 47, 51, 54, 57), 8 articles contained semi-vegetarian diets (24, 32, 37, 38, 41, 48, 61, 63), 1 article was on pesco-vegetarians (27), 1 study mentioned lacto-ovo-vegetarians (55), 2 studies reported on pesco-laco-ovo-vegetarians (46, 53), 1 study involved lacto-vegetarians (68), 10 articles were on prudent diets (23, 26, 27, 30, 34, 44, 56, 58, 60, 62), 3 studies referred to the DASH diet (56, 65, 66) and 11 articles were on the Mediterranean diet (33, 40, 42, 45, 49, 50, 52, 59, 60, 64, 69).

Results of ROB Assessment

The details of the ROB assessment in each study we included was showed in **Supplementary Table 6**. Overall, 32 articles were judged to be of low ROB, 14 articles were rated to be of moderate risk and 2 were of high risk. In the box of confounding bias, 31 articles showed low ROB and 2 were rated as serious. In the box of selection bias, 16 studies were judged to be of low risk and the remaining 32 were of moderate risk. For the bias of missing data, 25 articles presented the low ROB and for bias due to deviations from intended interventions, 24 studies didn't show the detail information.

Overall Analyses

After summarizing the results of all qualified cohort and case-control studies, the pattern of plant-based diets was statistically associated with the risk of digestive system cancer. The results suggested that a plant-based diet pattern played a protective factor for the risk of digestive system cancer in the cohort studies (adjusted RR = 0.82, 95% CI: 0.78–0.86, $P < 0.001$, $I^2 = 46.4\%$, $Tau^2 = 0.017$) and case-control studies (adjusted OR = 0.70, 95% CI: 0.64–0.77, $P < 0.001$, $I^2 = 83.8\%$, $Tau^2 = 0.160$).

Plant-based diets were statistically significant for pancreas cancer (adjusted RR = 0.71, 95% CI: 0.59–0.86, $P < 0.001$, $I^2 = 55.1\%$, $Tau^2 = 0.028$), colorectal cancer (adjusted RR = 0.76, 95% CI: 0.69–0.83, $P < 0.001$, $I^2 = 53.4\%$, $Tau^2 = 0.023$), colon cancer (adjusted RR = 0.88, 95% CI: 0.82–0.95, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$), rectal cancer (adjusted RR = 0.84, 95% CI: 0.78–0.91, $P < 0.001$, $I^2 = 1.6\%$, $Tau^2 = 0.005$), gastric cancer (adjusted RR = 0.81, 95% CI: 0.68–0.97, $P = 0.021$, $I^2 = 0.0\%$, $Tau^2 = 0.000$), liver cancer (adjusted RR = 0.61, 95% CI: 0.47–0.80, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$), and esophageal cancer (adjusted RR = 1.08, 95% CI: 1.00–1.16, $P = 0.04$, $I^2 = 3.7\%$, $Tau^2 = 0.001$) in the cohort studies, and equivalent connections were found in case-control studies for pancreatic cancer (adjusted OR = 0.65, 95% CI: 0.55–0.77, $P < 0.001$, $I^2 = 47.4\%$, $Tau^2 = 0.035$), colorectal cancer (adjusted OR = 0.67, 95% CI: 0.56–0.80, $P < 0.001$, $I^2 = 88.3\%$, $Tau^2 = 0.177$), gastric cancer (adjusted OR = 0.58, 95% CI: 0.44–0.77, $P < 0.001$, $I^2 = 86.1\%$, $Tau^2 = 0.252$), pharyngolaryngeal cancer (adjusted OR = 0.44, 95% CI: 0.32–0.61, $P < 0.001$, $I^2 = 81.6\%$, $Tau^2 = 0.135$) and liver cancer (adjusted OR = 0.61, 95% CI: 0.48–0.79, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$). No statistically significant relationship was found between plant-based diets and colon cancer (adjusted OR = 0.93, 95% CI: 0.80–1.06, $P = 0.280$, $I^2 = 53.9\%$, $Tau^2 = 0.045$) or rectal cancer (adjusted OR = 0.91, 95% CI: 0.71–1.17, $P = 0.469$, $I^2 = 82.1\%$, $Tau^2 = 0.204$) (**Figure 2**).

Cumulative and Sensitivity Analyses

Cumulative analysis of the included studies obtained completely similar conclusions, and the trend tended to be stable. Sensitivity analyses revealed no significant impact on any single study on overall effect-size estimates.

Publication Bias

Figure 3 shows Begg's funnel plot of publication bias for the association of plant-based diets with digestive system cancers. Evidence of asymmetry of study effects was found using Eggers's test in the cohort (Coef. = −1.43, 95%CI: −1.94 to −0.93, $P = 0.000$) and case-control studies (Coef. = −1.23, 95%CI: −2.08 to −0.38, $P = 0.005$). The "trim and fill" method was used and no correction was made to the original estimates.

Subgroup Analyses

Because of between-study heterogeneity, we performed a series of pre-specified analyses to further explore the relationship between plant-based diets and digestive system cancer risk. Notably, the protective effect of plant-based diet patterns was accordant in all subgroup analyses (**Table 1**). We did not find a consistent pattern of difference or heterogeneity in the results by sex, or any other study characteristics examined in the selected cohort studies. However, significant heterogeneity was found in the results of the included case-control studies, including sex, geographic region, type of digestive cancers, classification of plant-based diets, and follow-up intervals.

Plant-based diets were statistically associated with digestive system cancer risk in males (adjusted RR = 0.85, 95% CI: 0.81–0.90, $P < 0.001$, $I^2 = 46.4\%$, $Tau^2 = 0.017$) and females (adjusted RR = 0.77, 95% CI: 0.69–0.87, $P < 0.001$, $I^2 = 45.8\%$, $Tau^2 = 0.031$) in the cohort studies (two-sample Z-test $P = 0.128$).

The included cohort and case-control studies were divided into North America, Europe, and Asia. In the cohort studies, subgroup analysis demonstrated statistical significance of plant-based dietary patterns for digestive cancers in Europe (adjusted RR = 0.67, 95% CI: 0.59–0.76, $P < 0.001$, $I^2 = 49.8\%$, $Tau^2 = 0.039$), Asia (adjusted RR = 0.90, 95% CI: 0.85–0.96, $P = 0.001$, $I^2 = 24.1\%$, $Tau^2 = 0.007$) or North America (adjusted RR = 0.84, 95% CI: 0.80–0.89, $P < 0.001$, $I^2 = 13.4\%$, $Tau^2 = 0.002$). In the case-control studies, subgroup analysis proved statistical

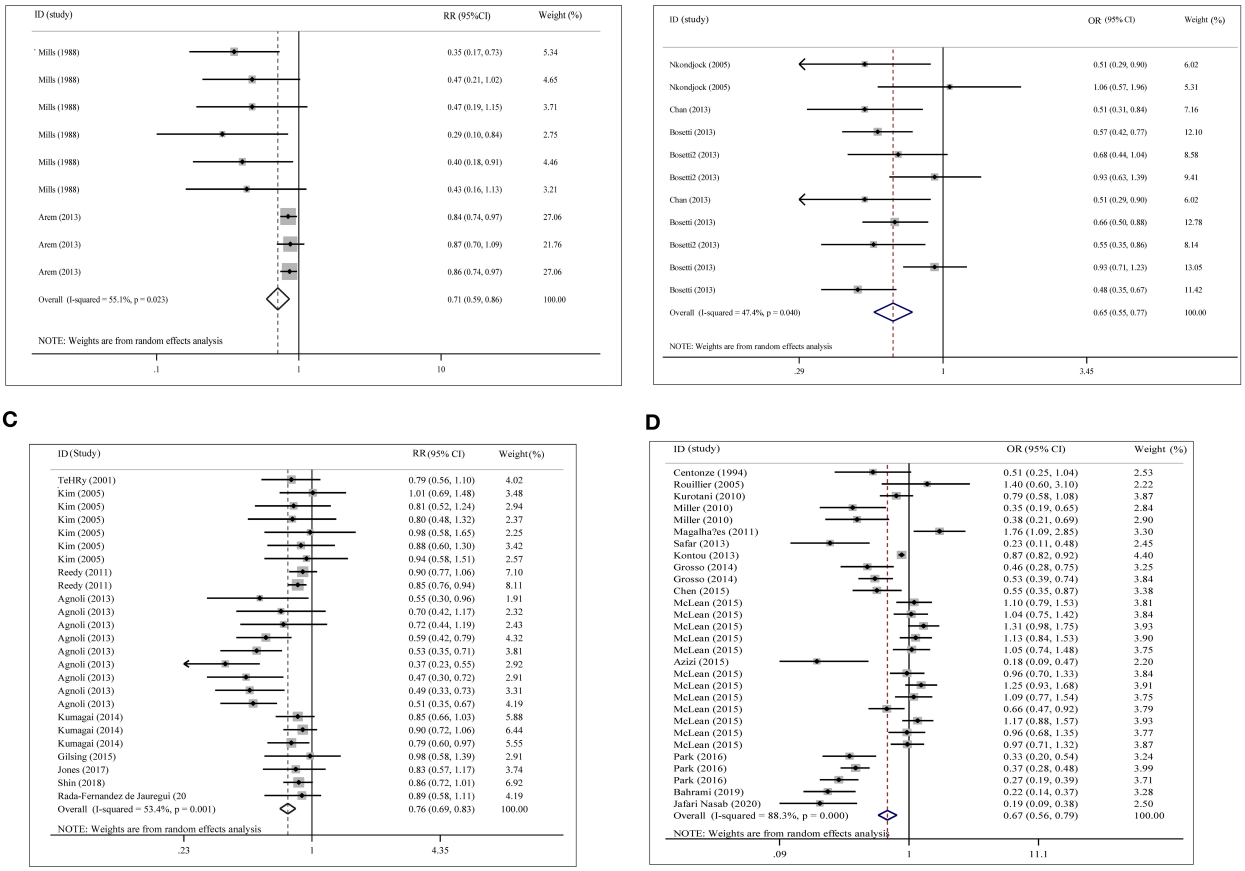


FIGURE 2 | Continued.

significance of plant-based dietary patterns for digestive cancers in Europe (adjusted OR = 0.72, 95% CI: 0.61–0.84, $P < 0.001$, $I^2 = 86.0\%$, $Tau^2 = 0.135$), Asia (adjusted OR = 0.30, 95% CI: 0.23–0.40, $P < 0.001$, $I^2 = 79.3\%$, $Tau^2 = 0.281$) or North America (adjusted OR = 0.88, 95% CI: 0.80–0.96, $P = 0.004$, $I^2 = 65.7\%$, $Tau^2 = 0.070$).

We found a significant difference between the vegan pattern (adjusted RR = 0.80, 95% CI: 0.74–0.86, $P < 0.001$, $I^2 = 27.2\%$, $Tau^2 = 0.008$) and digestive system cancers in the cohort studies, and this relationship also existed in the prudent dietary pattern (adjusted RR = 0.85, 95% CI: 0.77–0.92, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$), semi vegetarian pattern (adjusted RR = 0.87, 95% CI: 0.82–0.92, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$), and Mediterranean pattern (adjusted RR = 0.69, 95% CI: 0.59–0.82, $P < 0.001$, $I^2 = 84.3\%$, $Tau^2 = 0.091$). However, there were no significant difference between pesco-vegetarians (adjusted RR = 0.90, 95% CI: 0.80–1.03, P =0.118, $I^2 = 0.0\%$, $Tau^2 = 0.000$) and lacto-ovo-vegetarians (adjusted RR = 0.97, 95% CI: 0.71–1.33, P =0.871, $I^2 = 0.0\%$, $Tau^2 = 0.000$). Vegan (adjusted OR = 0.62, 95% CI: 0.52–0.75, $P < 0.001$, $I^2 = 43.2\%$, $Tau^2 = 0.067$), prudent (adjusted OR = 0.59, 95% CI: 0.46–0.75, $P < 0.001$, $I^2 = 84.6\%$, $Tau^2 = 0.220$), Mediterranean (adjusted OR = 0.55, 95% CI: 0.46–0.67, $P < 0.001$, $I^2 = 89.5\%$, $Tau^2 = 0.136$), pesco-laco-ovo-vegetarian (adjusted OR = 0.21, 95% CI: 0.12–0.36, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$) and lacto-vegetarian (adjusted OR = 0.61, 95% CI: 0.48–0.79, $P < 0.001$, $I^2 = 0.0\%$, $Tau^2 = 0.000$) diets had robust correlations with digestive tract cancers in case-control studies, but not semi-vegetarian (adjusted OR = 0.73, 95% CI: 0.45–1.18, $P = 0.195$, $I^2 = 89.0\%$, $Tau^2 = 0.421$) or DASH diets (adjusted OR = 0.96, 95% CI: 0.86–1.08, $P = 0.499$, $I^2 = 68.9\%$, $Tau^2 = 0.082$).

We combined plant-based diets other than the vegan pattern into the non-vegan diet and found that vegan and non-vegan diets were statistically significant for digestive cancers, but no significant difference was found between the two diets in cohort studies (two-sample Z-test $P = 0.617$) or case-control studies (two-sample Z-test $P = 0.158$).

Prominent differences were found in people of the Adventists faith (adjusted RR = 0.54, 95% CI: 0.39–0.74, $P < 0.001$, $I^2 = 48.4\%$, $Tau^2 = 0.085$) and normal populations (adjusted RR = 0.83, 95% CI: 0.79–0.87, $P < 0.001$, $I^2 = 43.9\%$, $Tau^2 = 0.015$) in cohort studies.

For the median value (10 years) of the follow-up period, the protective effect of plant-based diets for digestive cancers was

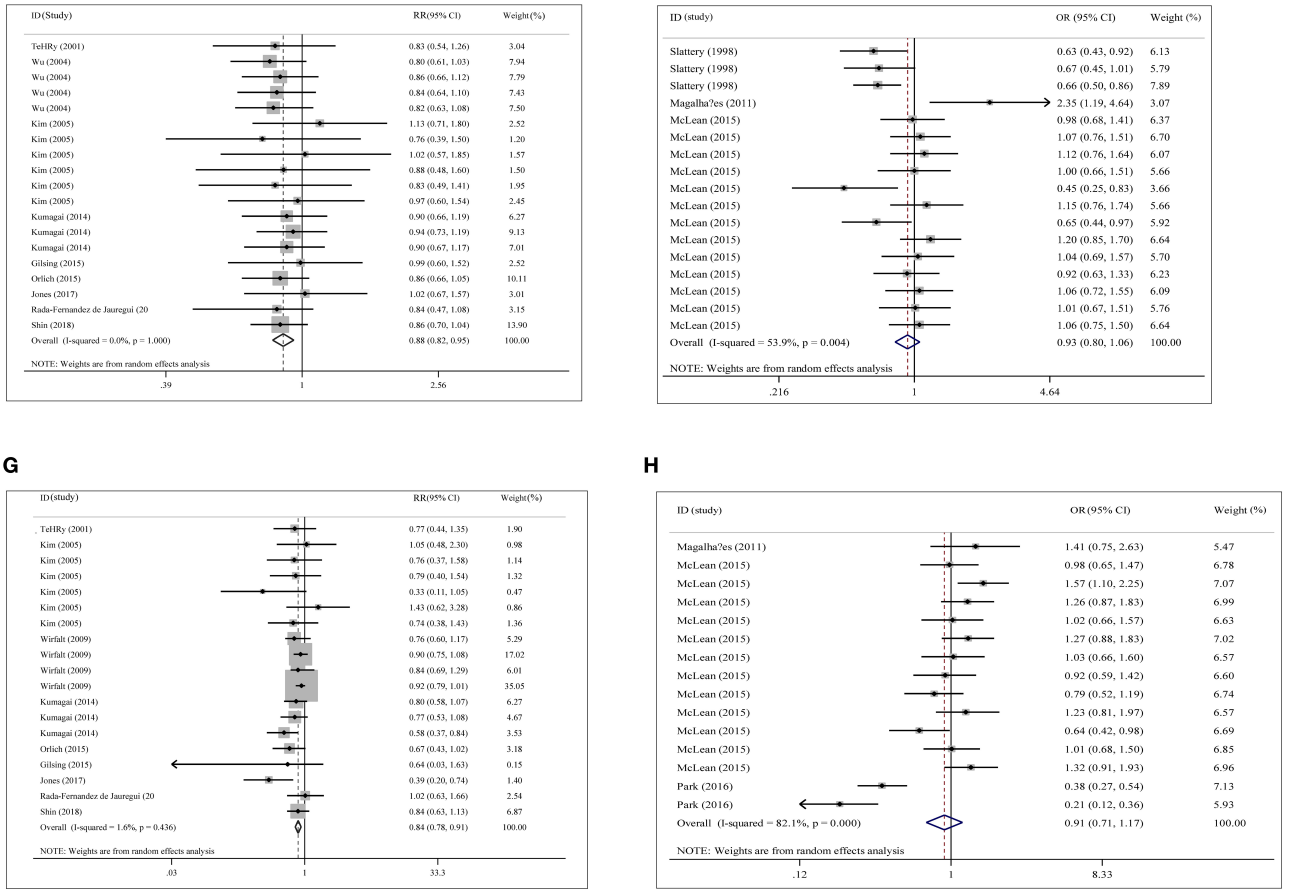


FIGURE 2 | Continued.

consistent and significant regardless of the length of follow-up in cohort studies (≤ 10 years: adjusted RR = 0.83, 95% CI: 0.78–0.88, $P < 0.001$, $I^2 = 31.4\%$, $Tau^2 = 0.008$; >10 years: adjusted RR = 0.79, 95% CI: 0.73–0.86, $P < 0.001$, $I^2 = 49.9\%$, $Tau^2 = 0.021$).

DISCUSSION

To the best of our knowledge, this study is the first comprehensive examination of meta-analyses between plant-based diets and digestive system tumors. Our key findings suggest protective effects of a plant-based diet on digestive cancer risk in cohort and case-control studies. Our adjunctive analysis showed that geographic region, type of digestive cancer, classification of plant-based diets, and follow-up intervals may be sources of inter-study heterogeneity. The implication of this study is a call for action to pay special attention to plant-based diets to reduce the risk of digestive system cancers.

Our findings are biologically plausible. Inflammation, oxidative stress, and the mediating effect of insulin all affect the development of tumors (70). Oxidative stress causes DNA damage and the risk of cancer if not repaired (71). The process by which insulin and insulin-like growth factors regulate carbohydrate and energy metabolism is associated with cancer risk (72). Inflammation is also a recognized marker of cancer that affects the development and progression of malignant tumors (73).

Plant foods (e.g., fruits, vegetables, grains, nuts and seeds, legumes and vegetable oils) are primary sources of fiber and other bioactive compounds in the diet (16, 74). A well-planned plant-based diet promotes a high intake of vitamins, minerals, and phytochemicals, which regulate antioxidant and anti-inflammatory prcoesses (9, 75). Notably, plant bioactive substances, including fiber, sulfur compounds, carotenoids, and polyphenols, are rich in foods such as cruciferous vegetables, allium vegetables, tomatoes, green tea, and whole grain grains (74), which are beneficial against cancer. Carotenoids promote good health due to their special physiological efficacy as provitamins and antioxidant reactions, especially in the clearance of singlet oxygen, which reduce the risk of cancers (76). Vitamin C, vitamin E, and other natural antioxidants of plants, such as polyphenols, alfalfa, anthocyanins, flavonoids, lignans,

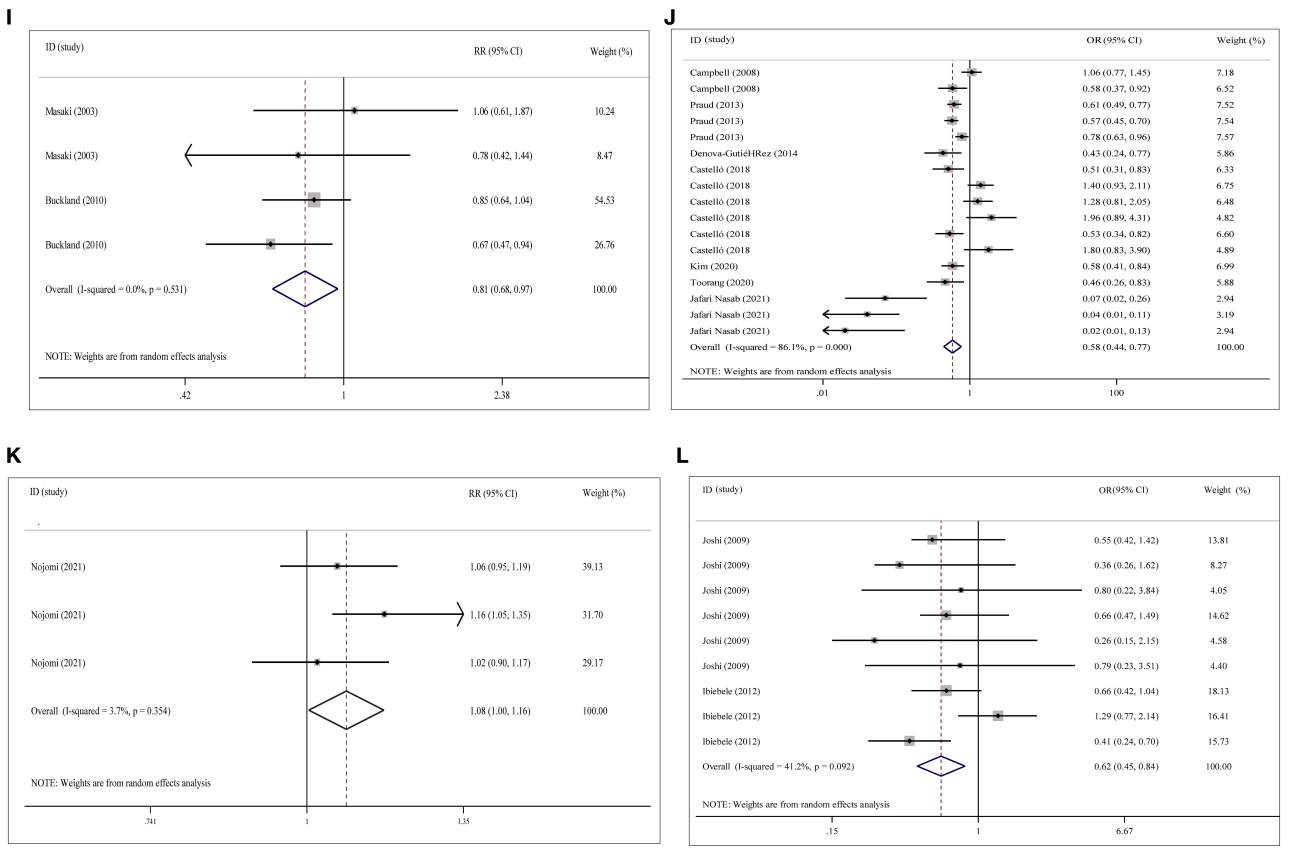


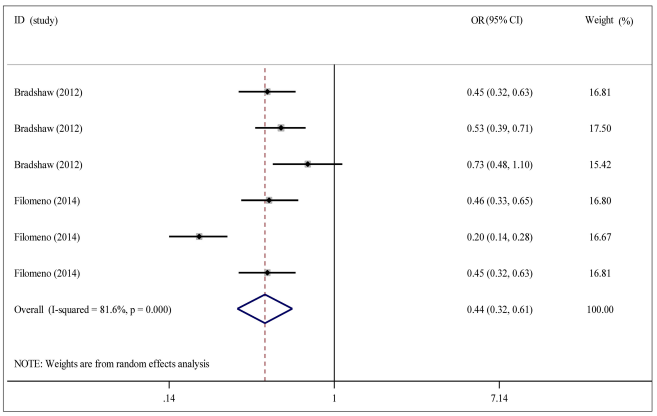
FIGURE 2 | Continued.

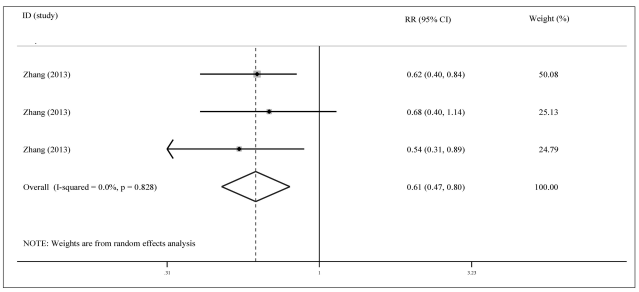
and phenolic acids, have a variety of biological properties, such as anti-inflammatory and anti-cancer properties (77–79). More interestingly, Afshari et al. (80) evaluated the anti-cancer properties of eggplant extract on human gastric cancer cell lines. They concluded that eggplant was rich in phenolic components and had powerful antioxidant properties that effectively scavenged free radicals. Therefore, eggplant may be a protective food to reduce the incidence of cancer (81).

Evidences suggests that the effect of a plant-based diet on intestinal flora is inextricably linked to digestive tract tumors. Daily consumption of nuts reduces the risk of cancers of the digestive system. High levels of dietary fiber, polyphenols and unsaturated fats are rich nutrients in nuts, and dietary fiber increases anaerobic fermentation and reduces intestinal transit time, which may reduce the exposure of colorectal mucosa to carcinogens (82). Polyphenols and unsaturated fats increase the abundance of Bifidobacterium and Lactobacillus in the intestine, which inhibit gastrointestinal inflammation and carcinogenic effects by promoting the production of short-chain fatty acids (83). The present study found that vegetarian diets were more protective in Asians. With fast economic growth and rapid industrialization, the thriving middle class in developing countries is adopting a Westernized lifestyle that is characterized by a high-fat, high-protein diet, which may change the community of microbes living in the humans to increase the risk of cancer (84, 85). Notably, the latest data show that East Asia was the worst-affected region, with 637,096 new cases and 275,604 deaths due to colorectal cancer (85).

Due to the protective effect of vegetarian dietary patterns on tumors, we examined whether people needed to ensure a pure vegan diet. For further research, we divided the plant-based dietary patterns into two categories, including a pure vegan diet and other types of primarily vegetarian diets and found that these two diet types produced equivalent protective roles against digestive system cancers. This conclusion means people do not need to adopt a pure plant-based diet. These results provide a more robust understanding of healthy eating guidance. According to WCRF dietary recommendations, people do not need to completely avoid eating meat but should limit consumption to no more than approximately three portions per week. People should consume a diet that provides at least 30 g per day of fiber and five portions or servings (at least 400 g or 15 oz in total) of a variety of non-starchy vegetables and fruit every day (4). These results are consistent with the pant-based diet advocated in the present study.

Our review was systematic and exhaustive and concluded the most different types of digestive cancers and various plant-based diets. A considerable sample size of 3,059,009 subjects and adults





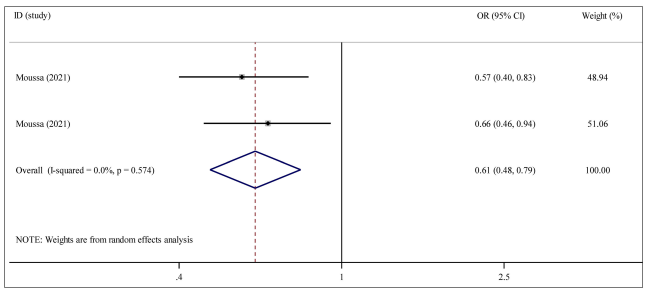
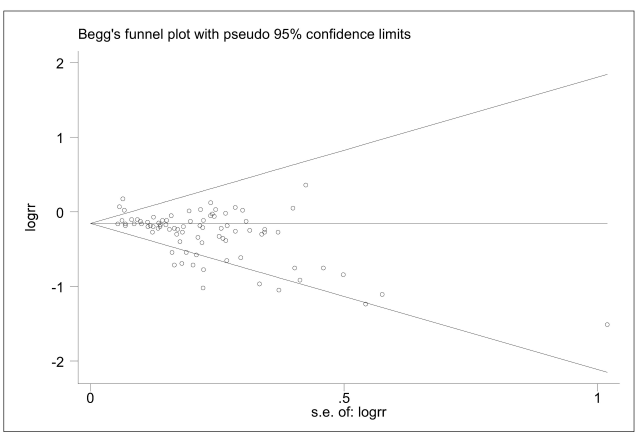


FIGURE 2 | Overall analysis of plant-based diets and cancer risk in cohort studies and case-control studies with risk ratio (RR), odds ratio (OR) and 95% confidence interval (CI). **(A)** Pancreas cancer with cohort study in overall analysis (adjusted). **(B)** Pancreas cancer with case- control study in overall analysis (adjusted). **(C)** Colorectal cancer with cohort study in overall analysis (adjusted). **(D)** Colorectal cancer with case-control study in overall analysis (adjusted). **(E)** Colon cancer with cohort study in overall analysis (adjusted). **(F)** Colon cancer with case- control study in overall analysis (adjusted). **(G)** Rectal cancer with cohort study in overall analysis (adjusted). **(H)** Rectal cancer with case-control study in overall analysis (adjusted). **(I)** Gastric cancer with cohort study in overall analysis (adjusted). **(J)** Gastric cancer with case-control study in overall analysis (adjusted). **(K)** esophagus cancer with cohort study in overall analysis (adjusted). **(L)** esophagus cancer with case-control study in overall analysis (adjusted). **(M)** Pharyngolaryngeal cancer with case-control study in overall analysis (adjusted). **(N)** Liver cancer with cohort study in overall analysis (adjusted). **(O)** Liver cancer with case- control study in overall analysis (adjusted).



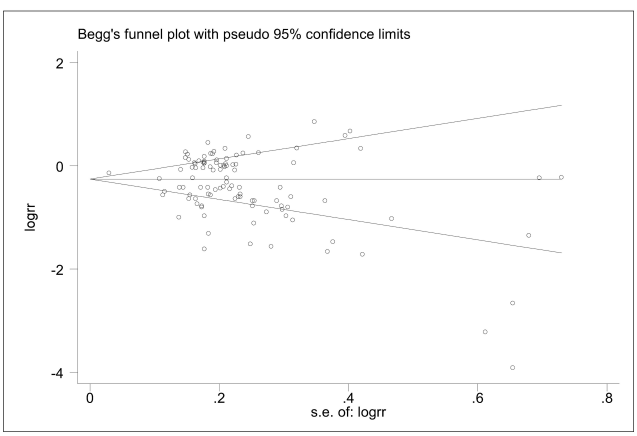


FIGURE 3 | The Begg's funnel plots for plant-based diets and cancer risk. **(A)**, Plant-based diets and cancer risk in cohort studies. **(B)**, Plant-based diets and cancer risk in case-control studies.

TABLE 1 | Overall and subgroup analyses of plant-based diets and digestive cancer risk.

Groups	Number of qualified observations	Plant-based diets (cohort study)			Plant-based diets (case-control study)		
		RR (95% CI); *P*	I^2	Tau^2	OR (95% CI); *P*	I^2	Tau^2
Overall analyses							
Digestive system cancer (adjusted)	82/106	0.82 (0.78–0.86); <0.001	46.4%	0.017	0.70 (0.64–0.77); <0.001	83.8%	0.160
Subgroup analyses based on Cancer							
By cancer type							
Pancreas cancer	9/11	0.71 (0.59–0.86); <0.001	55.1%	0.028	0.65 (0.55–0.77); <0.001	47.4%	0.035
Colorectal cancer	25/29	0.76 (0.69–0.83); <0.001	53.4%	0.023	0.67 (0.56–0.80); <0.001	88.3%	0.177
Colon cancer	19/17	0.88 (0.82–0.95); 0.001	0.0%	0.000	0.93 (0.80–1.06); 0.277	53.9%	0.045
Rectal cancer	19/15	0.84 (0.78–0.91); <0.001	1.6%	0.005	0.91 (0.71–1.17); 0.469	82.1%	0.204
Gastric cancer	4/17	0.81 (0.68–0.97); 0.021	0.0%	0.000	0.58 (0.44–0.77); <0.001	86.1%	0.252
Esophagus cancer	3/9	1.08 (1.00–1.16); 0.040	3.7%	0.001	0.62 (0.45–0.84); 0.002	41.2%	0.084
Pharyngolaryngeal cancer	*/6	*	*	*	0.44 (0.32–0.61); <0.001	81.6%	0.135
Liver cancer	3/2	0.61 (0.47–0.80); <0.001	0.0%	0.000	0.61 (0.48–0.79); <0.001	0.0%	0.000
By sex							
Male	23/28	0.85 (0.81–0.90); <0.001	46.4%	0.017	0.79 (0.65–0.95); 0.015	85.6%	0.223
Female	23/26	0.77 (0.69–0.87); <0.001	45.8%	0.031	0.92 (0.81–1.05); 0.236	58.9%	0.068
Both	34/49	0.81 (0.75–0.88); <0.001	63.7%	0.029	0.57 (0.50–0.65); <0.001	85.5%	0.161
By region							
North America	21/54	0.84 (0.80–0.89); <0.001	13.4%	0.002	0.88 (0.80–0.96); 0.004	65.7%	0.070
Europe	20/28	0.67 (0.59–0.76); <0.001	49.8%	0.039	0.72 (0.61–0.84); <0.001	86.0%	0.135
Asia	38/21	0.90 (0.85–0.96); 0.001	24.1%	0.007	0.30 (0.23–0.40); < 0.001	79.3%	0.281
Oceania	3/3	0.97 (0.71–1.33); 0.871	0.0%	0.000	0.71 (0.38–1.32); 0.274	78.7%	0.239
By population							
Adventist	8/*	0.54 (0.39–0.74); <0.001	48.4%	0.085	*	*	*
Normal person	74/106	0.83 (0.79–0.87); <0.001	43.9%	0.015	0.70 (0.64–0.77); <0.001	83.8%	0.160
By plant-based diets							
Vegan	24/19	0.80 (0.74–0.86); <0.001	27.2%	0.008	0.62 (0.52–0.75); <0.001	43.2%	0.067
Semi vegetarian	13/8	0.87 (0.82–0.92); <0.001	0.0%	0.000	0.73 (0.45–1.18); 0.195	89.0%	0.421
Lacto-vegetarian	*/2	*	*	*	0.61 (0.48–0.79); <0.001	0.0%	0.000
Pesco-vegetarian	18/*	0.90 (0.80–1.03); 0.118	0.0%	0.000	*	*	*
Lacto-ovo-vegetarian	3/*	0.97 (0.71–1.33); 0.871	0.0%	0.000	*	*	*
Pesco-laco-ovo-vegetarian	*/2	*	*	*	0.21 (0.12–0.36); <0.001	0.0%	0.000
DASH diets	*/40	*	*	*	0.96 (0.86–1.08); 0.499	68.9%	0.082
Prudent diets	7/18	0.85 (0.77–0.92); <0.001	0.0%	0.000	0.59 (0.46–0.75); <0.001	84.6%	0.220
Mediterranean diet	17/17	0.69 (0.59–0.82); <0.001	84.3%	0.091	0.55 (0.46–0.67); <0.001	89.5%	0.136
Non-vegan	58/87	0.82 (0.77–0.87); <0.001	56.2%	0.026	0.72 (0.65–0.79); <0.001	85.8%	0.165
By follow-up years							
≤10 years	39/*	0.83 (0.78–0.88); <0.001	31.4%	0.008	*	*	*
>10 years	40/*	0.79 (0.73–0.86); <0.001	49.9%	0.021	*	*	*

*RR, risk ratio; OR, odds ratio; 95% CI, 95% confidence interval; DASH, Dietary Approaches to Stop Hypertension; *, data not available.*

living with digestive cancers ($n = 34{,}009$) were included, which provided the power to detect a statistically significant relationship between plant-based diets and digestive cancers. However, the possible limitations of our meta-analysis must be considered. First, the present meta-analysis involved sufficient sample sizes for overall analyses, but the number of qualified studies in some subgroups was very limited. For example, the number of original articles involving pesco-vegetarian, lacto-vegetarian, and lacto-ovo-vegetarian diets was too small, which results in bias in the results to some extent. Second, although all studies used validated questionnaires to collect dietary data, most studies did not provide repeated measurements during the follow-up periods and did not register possible change in diet over time. Third, several of the analyses involved comparing the highest vs.

lowest exposure categories, which may exaggerate associations by focusing on the extremes of the distribution. However, with the relative paucity of studies referring to different exposure levels of plant-based diets, we were not able to perform a dose-response analysis to obtain more detailed guideline results. Although all the selected original articles were detailed in their investigation of food, they differentiated between meat from common poultry and red meat and foods with higher fat content and assessed the definition of plant-based diets using specialized scales. However, we cannot completely exclude the consumption of a mixture of red meat and other meats. The World Health Organization classified processed meat as a Class 1 carcinogen and red meat as a Class 2A carcinogen (86). However, there is no evidence that natural poultry meats have a significant effect on digestive cancers. Finally, the food industry provides a wide variety of vegan foods, which are classified as ultra-processed food due to the degree of processing. Whether vegans are harmed and have an increased risk for digestive system cancers is not clear because they may consume these foods more than non-vegan people. This aspect should be investigated in future studies.

In summary, it is important to understand and reveal eating habits that make our lives healthier and the important role these habits play in the management and prevention of oncological diseases. Our study propose that a plant-based diet is promising to prevent the development of cancer.

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.

AUTHOR CONTRIBUTIONS

DW and YZ: conceived and designed the experiments. YZ and JZ: performed the experiments and wrote the paper. JZ and YW: analyzed the data. YW: contributed materials and analysis tools. All authors read and approved the final manuscript prior to submission.

FUNDING

Taishan Scholar Foundation of Shandong Province (Award number(s): 2018–35).

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.892153/full#supplementary-material

REFERENCES

1. Global Burden of Disease Cancer C, Fitzmaurice C, Allen C, et al. Global, regional, and national cancer incidence, mortality, years of life lost, years lived with disability, and disability-adjusted life-years for 32 cancer groups, 1990 to 2015: a systematic analysis for the global burden of disease study. *JAMA Oncol.* (2017) 3:524–48. doi: 10.1001/jamaoncol.2016.5688
2. 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
3. Clinton SK, Giovannucci EL, Hursting SD. The world cancer research fund/american institute for cancer research third expert report on diet, nutrition, physical activity, and cancer: impact and future directions. *J Nutr.* (2020) 150:663–71. doi: 10.1093/jn/nxz268
4. World Cancer Research Fund/American Institute for Cancer Research Diet, Nutrition, Physical Activity and Cancer: A Global Perspective. *Continuous Update Project Expert Report.* (2018). Available online at: http://dietandcancerreport.org (accessed on April 19, 2022).
5. Yiannakou I, Barber LE, Li S, Adams-Campbell LL, Palmer JR, Rosenberg L, et al. A prospective analysis of red and processed meat intake in relation to colorectal cancer in the black women's health study. *J Nutr.* (2021) 52:1254–62. doi: 10.1093/cdn/nzab036_030
6. Cross AJ, Ferrucci LM, Risch A, Graubard BI, Ward MH, Park Y, et al. A large prospective study of meat consumption and colorectal cancer risk: an investigation of potential mechanisms underlying this association. *Cancer Res.* (2010) 70:2406–14. doi: 10.1158/0008-5472.CAN-09-3929
7. Oussalah A, Levy J, Berthezene C, Alpers DH, Gueant JL. Health outcomes associated with vegetarian diets: an umbrella review of systematic reviews and meta-analyses. *Clin Nutr.* (2020) 39:3283–307. doi: 10.1016/j.clnu.2020.02.037
8. Godos J, Bella F, Sciacca S, Galvano F, Grosso G. Vegetarianism and breast, colorectal and prostate cancer risk: an overview and meta-analysis of cohort studies. *J Hum Nutr Diet.* (2017) 30:349–59. doi: 10.1111/jhn.12426
9. Bye ZL, Keshavarz P, Lane GL, Vatanparast H. What role do plant-based diets play in supporting the optimal health and well-being of canadians? a scoping review. *Adv Nutr.* (2021) 12:2132–46. doi: 10.1093/advances/nmab061
10. Rizzo NS, Jaceldo-Siegl K, Sabate J, Fraser GE. Nutrient profiles of vegetarian and nonvegetarian dietary patterns. *J Acad Nutr Diet.* (2013) 113:1610–9. doi: 10.1016/j.jand.2013.06.349
11. Craddock JC, Probst YC, Peoples GE. Vegetarian and omnivorous nutrition - comparing physical performance. *Int J Sport Nutr Exerc Metab.* (2016) 26:212–20. doi: 10.1123/ijsnem.2015-0231
12. Pohl A, Schunemann F, Bersiner K, Gehlert S. The impact of vegan and vegetarian diets on physical performance and molecular signaling in skeletal muscle. *Nutrients.* (2021) 13:3884. doi: 10.3390/nu13113884
13. Kushi LH, Lenart EB, Willett WC. Health implications of mediterranean diets in light of contemporary knowledge. 1. Plant foods dairy products. *Am J Clin Nutr.* (1995) 61(6 Suppl):1407S−1415S. doi: 10.1093/ajcn/61.6.1407S
14. Chandler PD, Balasubramanian R, Paynter N, Giulianini F, Fung T, Tinker LF, et al. Metabolic signatures associated with western and Prudent dietary patterns in women. *Am J Clin Nutr.* (2020) 112:268–83. doi: 10.1093/ajcn/nqaa131
15. Mohseni R, Mohseni F, Alizadeh S, Abbasi S. The association of dietary approaches to stop hypertension (DASH) diet with the risk of colorectal cancer: a meta-analysis of observational studies. *Nutr Cancer.* (2020) 72:778–90. doi: 10.1080/01635581.2019.1651880
16. Molina-Montes E, Salamanca-Fernandez E, Garcia-Villanova B, Sanchez MJ. The Impact of plant-based dietary patterns on cancer-related outcomes: a rapid review and meta-analysis. *Nutrients.* (2020) 12:2010. doi: 10.3390/nu12072010
17. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ.* (2021) 372:n71. doi: 10.1136/bmj.n71
18. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D, et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis of observational studies in epidemiology (MOOSE) group. *JAMA.* (2000) 283:2008–12. doi: 10.1001/jama.283.15.2008

19. Sterne JA, Hernan MA, Reeves BC, Savovic J, Berkman ND, Viswanathan M, et al. ROBINS-I: a tool for assessing risk of bias in non-randomised studies of interventions. *BMJ.* (2016) 355:i4919. doi: 10.1136/bmj.i4919
20. Altman DG, Bland JM. Interaction revisited: the difference between two estimates. *BMJ.* (2003) 326:219. doi: 10.1136/bmj.326.7382.219
21. Mills PK, Beeson WL, Abbey DE, Fraser GE, Phillips RL. Dietary habits and past medical history as related to fatal pancreas cancer risk among Adventists. *Cancer.* (1988) 61:2578–85.3.doi: 10.1002/1097-0142(19880615)61:12<2578::AID-CNCR2820611232>3.0.CO;2-0
22. Centonze S, Boeing H, Leoci C, Guerra V, Misciagna G. Dietary habits and colorectal cancer in a low-risk area. Results from a population-based case-control study in southern Italy. *Nutr Cancer.* (1994) 21:233–46. doi: 10.1080/01635589409514322
23. Slattery ML, Boucher KM, Caan BJ, Potter JD, Ma KN. Eating patterns and risk of colon cancer. *Am J Epidemiol.* (1998) 148:4–16. doi: 10.1093/aje/148.1.4-a
24. Terry P, Hu FB, Hansen H, Wolk A. Prospective study of major dietary patterns and colorectal cancer risk in women. *Am J Epidemiol.* (2001) 154:1143–9. doi: 10.1093/aje/154.12.1143
25. Masaki M, Sugimori H, Nakamura K, Tadera M. Dietary patterns and stomach cancer among middle-aged male workers in Tokyo. *Asian Pac J Cancer Prev.* (2003) 4:61–6.
26. Wu K, Hu FB, Fuchs C, Rimm EB, Willett WC, Giovannucci E. Dietary patterns and risk of colon cancer and adenoma in a cohort of men (United States). *Cancer Causes Control.* (2004) 15:853–62. doi: 10.1007/s10552-004-1809-2
27. Kim MK, Sasaki S, Otani T, Tsugane S. Dietary patterns and subsequent colorectal cancer risk by subsite: a prospective cohort study. *Int J Cancer.* (2005) 115:790–8. doi: 10.1002/ijc.20943
28. Nkondjock A, Ghadirian P. Associated nutritional risk of breast and colon cancers: a population-based case-control study in Montreal, Canada. *Cancer Lett.* (2005) 223:85–91. doi: 10.1016/j.canlet.2004.11.034
29. Rouillier P, Senesse P, Cottet V, Valléau A, Faivre J, Boutron-Ruault MC. Dietary patterns and the adenomacarcinoma sequence of colorectal cancer. *Eur J Nutr.* (2005) 44:311–8. doi: 10.1007/s00394-004-0525-8
30. Campbell PT, Sloan M, Kreiger N. Dietary patterns and risk of incident gastric adenocarcinoma. *Am J Epidemiol.* (2008) 167:295–304. doi: 10.1093/aje/kwm294
31. Joshi SC, Saxena SR, Satyawali VN, Joshi A, Nigam P, Singh VK, et al. Oesophageal carcinoma–a study of risk factors (emphasis on nutrition) in a teaching hospital of Kumaon region of Uttarakhand. *J Assoc Phys India.* (2009) 57:631–5.
32. Wirfält E, Midthune D, Reedy J, Mitrou P, Flood A, Subar AF, et al. Associations between food patterns defined by cluster analysis and colorectal cancer incidence in the NIH-AARP diet and health study. *Eur J Clin Nutr.* (2009) 63:707–17. doi: 10.1038/ejcn.2008.40
33. Buckland G, Agudo A, Luján L, Jakszyn P, Bueno-de-Mesquita HB, Palli D, et al. Adherence to a Mediterranean diet and risk of gastric adenocarcinoma within the European Prospective Investigation into Cancer and Nutrition (EPIC) cohort study. *Am J Clin Nutr.* (2010) 91:381–90. doi: 10.3945/ajcn.2009.28209
34. Kurotani K, Budhathoki S, Joshi AM, Yin G, Toyomura K, Kono S, et al. Dietary patterns and colorectal cancer in a Japanese population: the Fukuoka Colorectal Cancer Study. *Br J Nutr.* (2010) 104:1703–11. doi: 10.1017/S0007114510002606
35. Miller PE, Lazarus P, Lesko SM, Muscat JE, Harper G, Cross AJ, et al. Diet index-based and empirically derived dietary patterns are associated with colorectal cancer risk. *J Nutr.* (2010) 140:1267–73. doi: 10.3945/jn.110.121780
36. Reedy J, Wirfält E, Flood A, Mitrou PN, Krebs-Smith SM, Kipnis V, et al. Comparing 3 dietary pattern methods–cluster analysis, factor analysis, and index analysis–With colorectal cancer risk: the NIH-AARP Diet and Health Study. *Am J Epidemiol.* (2010) 171:479–87. doi: 10.1093/aje/kwp393
37. Magalhães B, Bastos J, Lunet N. Dietary patterns and colorectal cancer: a case-control study from Portugal. *Eur J Cancer Prev.* (2011) 20:389–95. doi: 10.1097/CEJ.0b013e328347220a
38. Bradshaw PT, Siega-Riz AM, Campbell M, Weissler MC, Funkhouser WK, Olshan AF. Associations between dietary patterns and head and neck cancer: the Carolina head and neck cancer epidemiology study. *Am J Epidemiol.* (2012) 175:1225–33. doi: 10.1093/aje/kwr468
39. Ibiebele TI, Hughes MC, Whiteman DC, Webb PM. Dietary patterns and risk of oesophageal cancers: a population-based case-control study. *Br J Nutr.* (2012) 107:1207–16. doi: 10.1017/S0007114511004247
40. Agnoli C, Grioni S, Sieri S, Palli D, Masala G, Sacerdote C, et al. Italian Mediterranean Index and risk of colorectal cancer in the Italian section of the EPIC cohort. *Int J Cancer.* (2013) 132:1404–11. doi: 10.1002/ijc.27740
41. Arem H, Reedy J, Sampson J, Jiao L, Hollenbeck AR, Risch H, et al. The Healthy Eating Index 2005 and risk for pancreatic cancer in the NIH-AARP study. *J Natl Cancer Inst.* (2013) 105:1298–305. doi: 10.1093/jnci/djt185
42. Bosetti C, Bravi F, Turati F, Edefonti V, Polesel J, Decarli A, et al. Nutrient-based dietary patterns and pancreatic cancer risk. *Ann Epidemiol.* (2013) 23:124–8. doi: 10.1016/j.annepidem.2012.12.005
43. Bosetti C, Turati F, Dal Pont A, Ferraroni M, Polesel J, Negri E, et al. The role of Mediterranean diet on the risk of pancreatic cancer. *Br J Cancer.* (2013) 109:1360–6. doi: 10.1038/bjc.2013.345
44. Chan JM, Gong Z, Holly EA, Bracci PM. Dietary patterns and risk of pancreatic cancer in a large population-based case-control study in the San Francisco Bay Area. *Nutr Cancer.* (2013) 65:157–64. doi: 10.1080/01635581.2012.725502
45. Kontou N, Psaltopoulou T, Soupos N, Polychronopoulos E, Xinopoulos D, Linos A, et al. The mediating effect of Mediterranean diet on the relation between smoking and colorectal cancer: a case-control study. *Eur J Public Health.* (2013) 23:742–6. doi: 10.1093/eurpub/cks109
46. Safari A, Shariff ZM, Kandiah M, Rashidkhani B, Fereidooni F. Dietary patterns and risk of colorectal cancer in Tehran Province: a case-control study. *BMC Public Health.* (2013) 13:222. doi: 10.1186/1471-2458-13-222
47. Zhang W, Xiang YB, Li HL, Yang G, Cai H, Ji BT, et al. Vegetable-based dietary pattern and liver cancer risk: results from the Shanghai women's and men's health studies. *Cancer Sci.* (2013) 104:1353–61. doi: 10.1111/cas.12231
48. Denova-Gutiérrez E, Hernández-Ramírez RU, López-Carrillo L. Dietary patterns and gastric cancer risk in Mexico. *Nutr Cancer.* (2014) 66:369–76. doi: 10.1080/01635581.2014.884237
49. Filomeno M, Bosetti C, Garavello W, Levi F, Galeone C, Negri E, et al. The role of a Mediterranean diet on the risk of oral and pharyngeal cancer. *Br J Cancer.* (2014) 111:981–6. doi: 10.1038/bjc.2014.329
50. Grosso G, Biondi A, Galvano F, Mistretta A, Marventano S, Buscemi S, et al. Factors associated with colorectal cancer in the context of the mediterranean diet: a case-control study. *Nutr Cancer.* (2014) 66:558–65. doi: 10.1080/01635581.2014.902975
51. Kumagai Y, Chou WT, Tomata Y, Sugawara Y, Kakizaki M, Nishino Y, et al. Dietary patterns and colorectal cancer risk in Japan: the ohsaki cohort study. *Cancer Causes Control.* (2014) 25:727–36. doi: 10.1007/s10552-014-0375-5
52. Praud D, Bertuccio P, Bosetti C, Turati F, Ferraroni M, La Vecchia C. Adherence to the Mediterranean diet and gastric cancer risk in Italy. *Int J Cancer.* (2014) 134:2935–41. doi: 10.1002/ijc.28620
53. Azizi H, Asadollahi K, Davtalab Esmaeili E, Mirzapoor M. Iranian dietary patterns and risk of colorectal cancer. *Health Promot Perspect.* (2015) 5:72–80. doi: 10.15171/hpp.2015.009
54. Chen Z, Wang PP, Woodrow J, Zhu Y, Roebothan B, McLaughlin JR, et al. Dietary patterns and colorectal cancer: results from a Canadian population-based study. *Nutr J.* (2015) 14:8. doi: 10.1186/1475-2891-14-8
55. Gilsing AM, Schouten LJ, Goldbohm RA, Dagnelie PC, van den Brandt PA, Weijenberg MP. Vegetarianism, low meat consumption and the risk of colorectal cancer in a population based cohort study. *Sci Rep.* (2015) 5:13484. doi: 10.1038/srep13484
56. Jones-McLean E, Hu J, Greene-Finestone LS, de Groh M. A DASH dietary pattern and the risk of colorectal cancer in Canadian adults. *Health Promot Chronic Dis Prev Can.* (2015) 35:12–20. doi: 10.24095/hpcdp.35.1.03
57. Orlich MJ, Singh PN, Sabaté J, Fan J, Sveen L, Bennett H, et al. Vegetarian dietary patterns and the risk of colorectal cancers. *JAMA Internal Med.* (2015) 175:767–76. doi: 10.1001/jamainternmed.2015.59
58. Park Y, Lee J, Oh JH, Shin A, Kim J. Dietary patterns and colorectal cancer risk in a Korean population: a case-control study. *Medicine.* (2016) 95:e3759. doi: 10.1097/MD.0000000000003759

59. Jones P, Cade JE, Evans CEL, Hancock N, Greenwood DC. The Mediterranean diet and risk of colorectal cancer in the UK Women's Cohort Study. *Int J Epidemiol.* (2017) 46:1786–1796. doi: 10.1093/ije/dyx155
60. Castelló A, Fernández de Larrea N, Martín V. High adherence to the Western, Prudent, and Mediterranean dietary patterns and risk of gastric adenocarcinoma: MCC-Spain study. *Gastric Cancer.* (2018) 21:372–82. doi: 10.1007/s10120-017-0774-x
61. Rada-Fernandez de Jauregui D, Evans CEL, Jones P, Greenwood DC, Hancock N, Cade JE. Common dietary patterns and risk of cancers of the colon and rectum: analysis from the United Kingdom Women's Cohort Study (UKWCS). *Int J Cancer.* (2018) 143:773–81. doi: 10.1002/ijc.31362
62. Shin S, Saito E, Sawada N, Ishihara J, Takachi R, Nanri A, et al. Dietary patterns and colorectal cancer risk in middle-aged adults: a large population-based prospective cohort study. *Clin Nutr.* (2018) 37:1019–26. doi: 10.1016/j.clnu.2017.04.015
63. Bahrami A, Houshyari M, Jafari S, Rafiei P, Mazandaranian M, Hekmatdoost A, et al. Dietary patterns and the risk of colorectal cancer and adenoma: a case control study in Iran. *Gastroenterol Hepatol Bed Bench.* (2019) 12:217–25.
64. Jafari Nasab S, Bahrami A, Rafiee P, Hekmatdoust A, Ghanavati M, Rashidkhani B, et al. Healthy Eating Index-2010 and mediterranean-style dietary pattern score and the risk of colorectal cancer and adenoma: a case-control study. *Nutr Cancer.* (2020) 72:1326–35. doi: 10.1080/01635581.2019.1683212
65. Toorang F, Sasanfar B, Hadji M, Esmaillzadeh A, Zendehdel K. Adherence to "dietary approaches to stop hypertension" eating plan in relation to gastric cancer. *Nutr J.* (2020) 19:40. doi: 10.1186/s12937-020-00560-w
66. Jafari Nasab S, Ghanavati M, Rafiee P, Bahrami A, Majidi N, Clark CCT, et al. A case-control study of Dietary Approaches to stop hypertension (DASH) diets, colorectal cancer and adenomas among Iranian population. *BMC Cancer.* (2021) 21:1050. doi: 10.1186/s12885-021-08786-5
67. Kim JH, Lee J, Choi IJ, Kim YI, Kim J. Dietary patterns and gastric cancer risk in a Korean population: a case-control study. *Eur J Nutr.* (2021) 60:389–97. doi: 10.1007/s00394-020-02253-w
68. Moussa I, Day RS, Li R, Du XL, Kaseb AO, Jalal PK, et al. Dietary patterns and hepatocellular carcinoma risk among US adults. *Nutrients.* (2021) 13:2011 doi: 10.3390/nu13062011
69. Nojomi M, Tehrani Banihashemi A, Niksima H, Hashemian M, Mottaghi A, Malekzaddeh R. The relationship between dietary patterns, dietary quality index, and dietary inflammatory index with the risk of all types of cancer: golestan cohort study. *Med J Islamic Repub Iran.* (2021) 35:48. doi: 10.47176/mjiri.35.48
70. Steck SE, Murphy EA. Dietary patterns and cancer risk. *Nat Rev Cancer.* (2020) 20:125–38. doi: 10.1038/s41568-019-0227-4
71. Halliwell B. The antioxidant paradox: less paradoxical now? *Br J Clin Pharmacol.* (2013) 75:637–44. doi: 10.1111/j.1365-2125.2012.04272.x
72. Pollak M. Insulin and insulin-like growth factor signalling in neoplasia. *Nature Rev Cancer.* (2008) 8:915–28. doi: 10.1038/nrc2536
73. Diakos CI, Charles KA, McMillan DC, Clarke SJ. Cancer-related inflammation and treatment effectiveness. *Lancet Oncol.* (2014) 15:e493–503. doi: 10.1016/S1470-2045(14)70263-3
74. Subramaniam S, Selvaduray KR, Radhakrishnan AK. bioactive compounds: natural defense against cancer? *Biomolecules.* (2019) 9:758. doi: 10.3390/biom9120758
75. Hever J, Cronise RJ. Plant-based nutrition for healthcare professionals: implementing diet as a primary modality in the prevention and treatment of chronic disease. *J Geriatr Cardiol.* (2017) 14:355–68. doi: 10.11909/j.issn.1671-5411.2017.05.012
76. Singh B, Singh JP, Kaur A, Singh N. Bioactive compounds in banana and their associated health benefits - a review. *Food Chem.* (2016) 206:1–11. doi: 10.1016/j.foodchem.2016.03.033
77. Li Y, Zhang JJ, Xu DP, Zhou T, Zhou Y, Li S, et al. Bioactivities and health benefits of wild fruits. *Int J Mol Sci.* (2016) 17:1258. doi: 10.3390/ijms17081258
78. Zhang JJ, Li Y, Zhou T, Xu DP, Zhang P, Li S, et al. Bioactivities and health benefits of mushrooms mainly from China. *Molecules.* (2016) 21:938 doi: 10.3390/molecules21070938
79. Xu DP, Li Y, Meng X, Zhou T, Zhou Y, Zheng J, et al. Natural antioxidants in foods and medicinal plants: extraction, assessment and resources. *Int J Mol Sci.* (2017) 18:96. doi: 10.3390/ijms18010096
80. Afshari F, Seraj H, Hashemi ZS, Timajchi M, Ensiyeh O, Ladan G, et al. The cytotoxic effects of eggplant peel extract on human gastric adenocarcinoma cells and normal cells. *Mod Med Lab J.* (2017) 1:77–83. doi: 10.30699/mmlj17.1.2.77
81. Samtiya M, Aluko RE, Dhewa T, Moreno-Rojas JM. Potential health benefits of plant food-derived bioactive components: an overview. *Foods.* (2021) 10:839. doi: 10.3390/foods10040839
82. Gonzalez CA, Salas-Salvado J. The potential of nuts in the prevention of cancer. *Br J Nutr.* (2006) 96(Suppl. 2), S87–94. doi: 10.1017/BJN20061868
83. Singh RK, Chang HW, Yan D, Lee M, Ucmak D, Wong K, et al. Influence of diet on the gut microbiome and implications for human health. *J Transl Med.* (2017) 15:73. doi: 10.1186/s12967-017-1175-y
84. Ang QY, Alba DL, Upadhyay V, Bisanz JE, Cai J, Lee HL, et al. The East Asian gut microbiome is distinct from colocalized white subjects and connected to metabolic health. *Elife.* (2021) 10:e70349. doi: 10.7554/eLife.70349
85. Collaborators GBDCC. Global, regional, and national burden of colorectal cancer and its risk factors, 1990-2019: a systematic analysis for the global burden of disease study 2019. *Lancet Gastroenterol Hepatol.* (2022). doi: 10.1016/S2468-1253(22)00044-9. [Epub ahead of print].
86. 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

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: 13 June 2022
doi: 10.3389/fnut.2022.902498

Can Multiple Attributes of Vegan Restaurants Affect the Behavioral Intentions by Customer Psychological Factors?

Junghyun Park[1], *Yunmi Park*[2] *and Jongsik Yu*[3]*

[1] College of Hospitality and Tourism Management, Sejong University, Seoul, South Korea, [2] Department of Aviation Service, Cheongju University, Cheongju-si, South Korea, [3] College of Business Division of Tourism and Hotel Management, Cheongju University, Cheongju-si, South Korea

Over the past decade, there has been an increased interest in veganism in several nations across the world. In 2021, there were around 79 million vegans. While veganism is growing, it still covers only 1% of the global population. But if the diet keeps its steady growth rate, it's predicted to increase to one in 10 people within the next 10 years. However, in addition to the traditional, though poorly studied, multiple attributes ascribed to vegan restaurants, there may be other factors influencing the approach intentions of vegan restaurant customers. Within this context, this study investigated the psychological resilience associated with customer engagement (identification, enthusiasm, attention, absorption, and interaction) with the vegan movement for Korean vegan customers. The analysis was conducted using SPSS 22.0 and AMOS 22.0. The results revealed that numerous attributes ascribed to vegan restaurants positively affected customer engagement, especially identification, and strongly influenced psychological resilience as well. However, the identification customer engagement factor did not significantly affect the approach intentions of vegan restaurant customers. The study results suggested that when eliciting customer engagement to increase approach intentions toward vegan restaurants, it is necessary to emphasize customer psychological resilience, enthusiasm, attention, absorption, and interaction. This study contributes to food and consumer behavior literature on the approach intentions toward vegan restaurants.

Keywords: vegan restaurants, multiple attributes, consumer engagement, psychological resilience, approach intentions

OPEN ACCESS

Edited by:
Renata Puppin Zandonadi, University of Brasilia, Brazil

Reviewed by:
Kisang Ryu, Sejong University, South Korea
Sunghyup Hyun, Hanyang University, South Korea

***Correspondence:**
Jongsik Yu
andyjs.yu@gmail.com

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

Received: *03 April 2022*
Accepted: *11 May 2022*
Published: *13 June 2022*

Citation:
Park J, Park Y and Yu J (2022) Can Multiple Attributes of Vegan Restaurants Affect the Behavioral Intentions by Customer Psychological Factors? Front. Nutr. 9:902498. doi: 10.3389/fnut.2022.902498

INTRODUCTION

Food has long been a major social issue and has taken on an even more critical role in recent years owing to its close associations with people's lives (1). Vegan foods, in particular, have lately shown exceptional stability and development in both sales and consumption (2). Expert Market Research (3) reported that the worldwide vegan food market reached USD 15.4 billion in 2020 and was expected to reach USD 26.1 billion by 2026. Reflecting this trend, one of the most noticeable foodservice trends in the recent decade has been the increase in the number of vegan restaurants (4). Although vegans constitute a very small percentage of the population, their influence on the food industry and general consumption habits is expected to continue to expand (5, 6).

Customers typically select the product or service at a restaurant based on multiple attributes, such as food quality, location convenience, price, hygiene, design and layout, taste, and nutritional value. However, vegan restaurants are different from general restaurants. There are numerous reasons why consumers switch to veganism (7). The 2019 Global Vegan Survey reported that 68.1% of the participants had switched to a vegan diet owing to concerns about ethics and animal welfare. Of those surveyed, 17.4% claimed that they had switched to a vegan diet owing to health and beauty reasons, 9.7% reported that they were motivated by environmental concerns, and 4.8% switched for religious or personal reasons (8). Several academic studies found that people had switched to vegan diets owing to ethical considerations (guilt), curiosity, environmental concerns, and health and beauty benefits (5, 9, 10). Therefore, the attributes that can be ascribed to vegan restaurants are health and beauty, guilt, curiosity, and environmental concerns (7).

As individuals' beliefs and values influence their choice to follow a vegan diet, their particular psychology affects the vegan restaurant attributes they perceive as valuable (11–13). Particularly, their preference for vegan eateries is associated with their psychological resilience to specific ways of eating. Von Essen and Mårtensson (14) highlighted that internalized food memories are connected with positive feelings that help people adjust and better manage their developmental stress, which, in turn, can assist in building psychological resilience. In addition, vegan diets are more meaningful psychologically than physical in that they have fewer symptoms of eating disorders, lower eating intentions, less stress, and less motivation for weight control compared to other diets (15).

These customer psychological factors also affect restaurant customer engagement (16). attracting and retaining customers is one of the top priorities of running a restaurant, and customer engagement can significantly influence a restaurant's success (17). As customer engagement is the ability to keep customers happy at every stage and interaction with the business (18), the multiple attributes ascribed to vegan restaurants drive customer engagement (19). As engaged customers become more involved in the service process, they share the absorption, identification, and enthusiasm for the service outcomes and develop social bonds (17, 20).

Despite its psychological importance, numerous studies on vegan choices focus on health and physical benefits (21–24), so research on individual psychological aspects has been lacking. In addition, there is a lack of an empirical approach to which factor has the most important influence on the selection of vegan restaurants. Specifically, it is unclear how the identified attributes of vegan restaurants, such as health and beauty, guilt, curiosity, and environmental concerns, are associated with psychological resilience and customer engagement, and little is known of the particular psychological beliefs that motivate customers to choose vegan restaurants. Thus, the need for further research on customer engagement in the choice and approach of vegan restaurants in the psychological and emotional context of customers is critical and timely. Consequently, this study sought to fill these research gaps by investigating the influence of engagement on the formation of consumer approach intentions toward vegan restaurants and presenting significant implications for the importance of psychological and emotional parts in vegan restaurant selection and approach intention.

This study had three primary objectives: (1) to understand and determine the influence of the multiple consumer attributes on vegan restaurant selection, (2) to verify the effect of these multiple consumer attributes of vegan restaurants on customer engagement and psychological resilience, and (3) to determine whether psychological factors, such as psychological resilience and engagement, encourage consumers to approach vegan restaurants. Thus, this study used a mixed-method of qualitative and quantitative research that has not been attempted before in a vegan-related study and it will help a clear understanding of the vegan restaurant choices of growing Korean customers. In addition, the result can present practical measures to increase customer accessibility to Korean vegan restaurants.

LITERATURE REVIEW

Multiple Attributes of Vegan Restaurants

Many people follow vegan diets that has led to the emergence of vegan restaurants (25, 26), which are restaurants that do not serve animal products in their dishes or drinks (27); that is, all menu items are dairy- and meat-free, and no animal or animal by-products are used in the kitchen. However, veganism is a "life endeavor" or a series of "catalytic encounters" (10, 28). Hirschler (29) found that social rejection and prejudicial interactions caused psychological distress to vegans. Vegans are often viewed as judgmental, are frequently confronted about their meat-free lifestyles, and are unable to eat at most establishments (30). Nevertheless, as people have specific reasons to adopt veganism, they tend to prefer to visit vegan restaurants for health, nutrition, socializing, and to have a positive experience (31). Previous research found that the main motivations for choosing to eat at vegan restaurants were health and beauty (32–34), guilt (10, 28, 35), curiosity (10), and environmental concerns (36, 37).

Health and Beauty

Craig (32) reported that vegan diets have numerous health benefits. For example, these diets can increase the intake of protective nutrients and phytochemicals and minimize the dietary factors associated with several chronic diseases (32, 38–41). In addition, it can help us achieve the highest levels of fitness while also lowering our risk of developing chronic diseases (41). Vegans generally consume more fruit, legumes, vegetables, and fiber than omnivores (38–40), all of which have been found to protect against some cancers, metabolic syndromes, mortality, and obesity (42). A study by Cruwys et al. (43) and Ryan (44) found that people were slimmer and attempted to lose weight more frequently than those who did not cut their meat intake, and that the societal ideals of slimness and beauty led them to choose a vegan diet (45, 46). In addition, Lim et al. (47) found that vegans preferred foods that were rich in vitamins and mineral content, had nutritional value, and had hair, nail, and skin beauty benefits, which indicated that health and beauty were important factors for vegans and their preference to dine in vegan restaurants.

Guilt

Guilt is associated with the breaking of internal moral or religious rules (28, 48) and can also be defined as the feelings of a person who has violated a moral standard and must bear the sanctions imposed by the breaking of that standard (49). Greenebum (37) found that some people had a sense of discomfort, guilt, and anxiety about animals being slaughtered for their food. Ghaffari et al.'s (50) study of consumer motivations for adopting the vegan diet suggests that eco- and animal-friendly components have connected to emotional outcomes, such as feeling less guilty, implying that eco- and animal-friendly vegan diets allow people to feel less guilty when eating vegan meals. Therefore, vegan restaurants' eco- and animal-friendly ingredients can assuage vegan guilt (10, 35, 50, 51).

Curiosity

People curious about veganism tend to try vegan restaurants for the experience. Curiosity, which is associated with exploration, investigation, and learning (52, 53), is strongly linked to human growth and the desire to acquire knowledge and skills (53, 54). Owing to the increasing interest in vegan diets, there had been a growth in restaurants that only serve plant-based food, which in turn has sparked further curiosity. In addition, According to Dedehayir et al. (55), it is necessary to make dishes that increase curiosity to appeal to more adventurous individuals in major non-vegan markets, and their curiosity induces initial purchases. A study on plant-based food motives among college students in the Midwestern United States found that Fifty-five percent had tried a plant-based alternative to meat. The top reasons were enjoying new foods and curiosity about the products (56). Therefore, curiosity is an important part of choosing a vegan diet.

Environmental Concerns

With growing interest in the impact of eating habits on global health, there is a growing worldwide interest in the environmental sustainability of dietary patterns (5, 57). A 2010 United Nations report claimed that animal agriculture requires more resources and generates higher greenhouse gas emissions than plant-based agriculture (58), which has raised public awareness about the impacts of food production on the environment (36, 37, 59). In this context, plant-based diets, such as vegetarian or vegan diets, have emerged as solutions for healthier eating and reducing environmental impact. Willet et al. (60) claimed that adopting a plant-based or vegan diet may have significant environmental benefits, such as reduced greenhouse gas emissions, land use, and water use compared to animal agriculture. Consequently, environmental concerns are a major reason people choose to follow a vegan diet and dine in vegan restaurants (37, 58, 61). Therefore, it can be said people often choose to follow a vegan lifestyle for environmental concerns.

Multiple Attributes Ascribed to Vegan Restaurants and Customer Engagement

Customer engagement, is the level of a consumer's cognitive, physical, and emotional connections with products or services (18, 62–65), is the highest priority for the service and marketing sectors (66, 67). So et al. (68) took a cognitive, emotional, and behavioral perspective and categorized customer engagement into five dimensions: enthusiasm, attention, identification, absorption, and interaction and suggested that they had covary; that is, changes in one led to proportionally associated changes in the others (69). In this regard, a study of hotel guests (restaurant, lobby, and room) by Rather and Sharma (66) found that positive attributes of a hotel form a significant causal relationship with sub-factors of customer engagement leading to customer loyalty. In addition, such sub-factor leading to customer engagement was found to interact with each other.

Enthusiasm comprises vigor and activation (64), both of which imply a high degree of energy; attention is the focused engagement on a product, service, or company (68); identification is a perception of oneness or belonging (66); absorption is the action of being entirely focused, happy, and deeply immersed in certain goods and services (64, 66, 70); and interaction is a behavioral expression of customer engagement (68). For instance, a highly engaged customer may devote more attention on posts, advertising, or product in-formation (66). These five fundamental customer engagement components are closely associated with a consumer's psychology, emotions, and behavior.

As restaurant food choices influence satisfaction with life and physical and mental health (71), they extend beyond just nutrition and health to mood, sensory experience, beauty, and personal ethics (71, 72). In particular, sensory restaurant experiences can stimulate psychological and behavioral responses (73). Coveney and Bunton (74) reported that because many people feel that the consumption of plant-based (vegan) foods has physical and psychological benefits, the act of doing so can elicit feelings of wellbeing; therefore, the multiple attributes that people ascribe to vegan restaurants have a significant causal relationship with psychological consumer satisfaction, which can significantly affect customer engagement. Therefore, based on prior studies, the following hypotheses are proposed:

Hypothesis 1: The multiple attributes ascribed to vegan restaurants have a positive impact on identification.
Hypothesis 2: The multiple attributes ascribed to vegan restaurants have a positive impact on enthusiasm.
Hypothesis 3: The multiple attributes ascribed to vegan restaurants have a positive impact on attention.
Hypothesis 4: The multiple attributes ascribed to vegan restaurants have a positive impact on absorption.
Hypothesis 5: The multiple attributes ascribed to vegan restaurants have a positive impact on interaction.

Multiple Attributes Ascribed to Vegan Restaurants and Psychological Resilience

From a psychological perspective, food is a good factor in such tactics as people use to become well-differentiated and independent entities (14, 75). At the individual level, the demand for particular types of food is driven primarily by social psychological factors, such as beliefs, attitudes, norms, and values (13, 76–79). In particular, the vegan eating pattern can be said to be a self-defining lifestyle composed of psychological aspects such as an individual's ethical, moral, and value beliefs beyond

simple dietary preferences (11–13, 80). A study by Von Essen and Mårtensson (14) found that food-related positive internalized memories can be used to build resilience by helping young people adapt to and better manage developmental stress.

People may choose to follow a vegan diet for different psychological reasons, such as beauty, health, animal rights (ethics), sensory disgust, environmental concerns, and the influence of others (32, 33, 81). Simons et al. (82) claimed that a vegan diet responded to bodily signals that could contribute to regulating states and emotions and provided opportunities for creative activities and psychological resilience. Therefore, the patronage of vegetarian restaurants may have significant causal relationships with psychological factors, such as guilt, curiosity, and other concerns. Cagnina et al. (36) found that positive experiences, such as the need to have psychological resilience at a vegan restaurant, in-creased the intention to approach. Consequently, choosing to eat at vegan restaurants may be significantly associated with psychological resilience, which increases the intention to approach a vegan restaurant. Therefore, based on prior studies, the following hypotheses are proposed:

Hypothesis 6: The multiple attributes ascribed to vegan restaurants have a positive impact on psychological resilience.
Hypothesis 7: The psychological resilience gained from dining at vegan restaurants has a positive impact on approach intention.

Customer Engagement and Approach Intentions

Positive thoughts and impressions can raise the intention to approach; therefore, cognitive and emotional constructs, such as identification, attention, absorption, enthusiasm, and interaction, are essential aspects of intention (68, 83, 84). An engaged individual has a strong psychological bond with a company or brand, which increases the possibility of a loyal response (85). So et al.'s (68) survey of hotel and airline customers found that customer engagement significantly impacted visit intention and positive psychological behavior in both hotel and airline customers, and Kim et al. (71) found that vegan restaurants often offered free samples of their latest snacks and creations to customers to solicit feedback on menu development, which allowed the restaurants to form emotional and psychological bonds with the customers, thereby enhancing customer engagement and approach. These interactions highlight the importance of engaging with customers to build loyalty (e.g., approach and recommendation intentions) beyond the transactions in an emerging vegan restaurant environment (36). Therefore, based on prior studies, the following hypotheses are proposed:

Hypothesis 8: Identification has a positive impact on vegan restaurant approach intentions.
Hypothesis 9: Enthusiasm has a positive impact on vegan restaurant approach intentions.
Hypothesis 10: Attention has a positive impact on vegan restaurant approach intentions.
Hypothesis 11: Absorption has a positive impact on vegan restaurant approach intentions.
Hypothesis 12: Interaction has a positive impact on vegan restaurant approach intentions.

Research Model

The conceptual framework of this study comprises eight theoretical structures describing the attributes of a vegan restaurant, including customer engagement, which consists of identification, enthusiasm, interaction, attention, absorption, and interaction; psychological resilience; and approach intention. In this study, attributes of a vegan restaurant are categorized into health and beauty, guilt, curiosity, and environmental concern, and a total of 12 hypotheses are included within the proposed theoretical framework. The research model presented in this study is shown in **Figure 1**.

METHODOLOGY

Qualitative Approach

This study aims to identify attributes of a vegan restaurant to develop marketing activation measures and strategies given today's consistent increase in customers' interest in and patronization of vegan restaurants. To identify the characteristics and fundamental elements of attributes of vegan restaurants, a literature review was conducted, followed by focus group interviews with experts. The expert group interviews were conducted with vegan restaurant staff who had a clear understanding of the purpose of this study, customers with vegan restaurant experiences, and professors specializing in restaurant management. Through these interviews, the opinions, thoughts, and ideas of experts on vegan restaurants were collected, and the conclusions proposed by each expert were shared with other members. Opinions and ideas obtained through expert group interviews were summarized and divided into overlapping and conflicting parts. The latter were then revised and enhanced through two group discussions. Through this process, it was possible to improve the processing quality of developing the attributes of vegan restaurants. A total of 18 properties were obtained through expert group interviews and discussions, and three properties that were considered to be inconsistent with the subject and purpose of this study were excluded. Accordingly, in this study, a total of 15 properties was established. The 15 properties were categorized into four attributes by referring to the qualitative approach proposed by Spiggle (86). Thus, four attributes of vegan restaurants were developed in this study: health and beauty, guilt, curiosity, and environmental concern.

Measurement Tools for Other Constructs

In this study, validity- and reliability-confirmed measurement items from existing studies were used to measure customer engagement (e.g., identification, enthusiasm, at-attention, absorption, and interaction), psychological resilience, and approach intention; the properties of vegan restaurants were excluded. Specifically, 19 questions of customer engagement were used based on the study of So et al. (68), and three questions of psychological resilience were used based on the study of

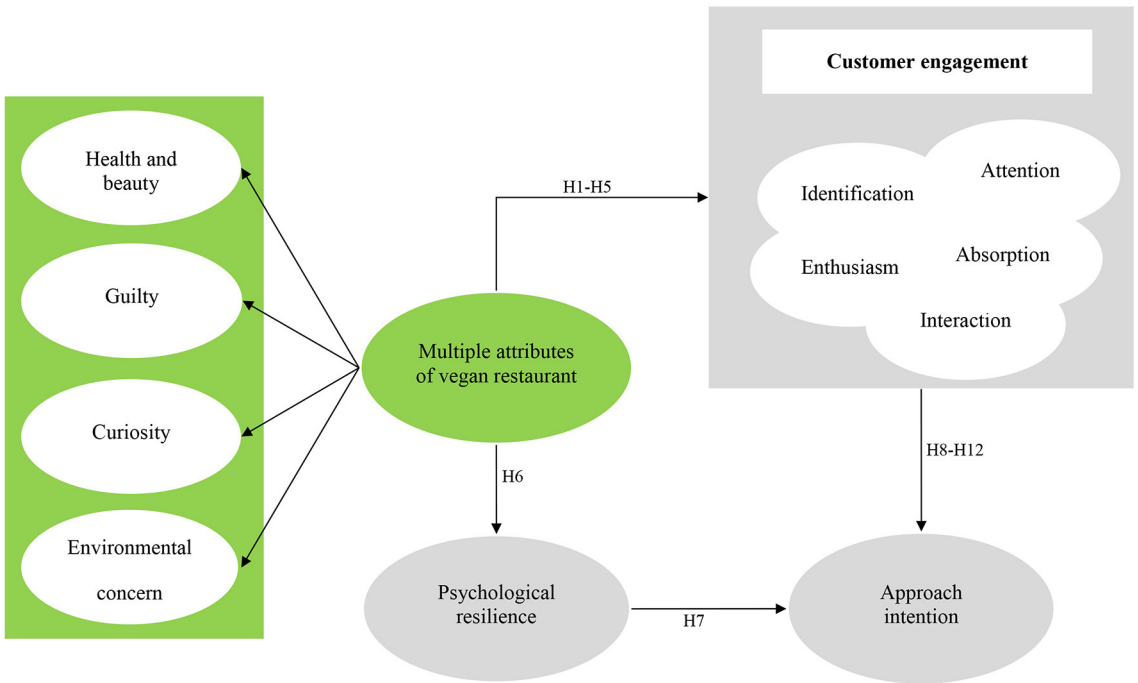


FIGURE 1 | The proposed conceptual framework.

Gascon et al. (87). In addition, four questions were used based on a study by Wu et al. (88). Interviewees were limited to those who had visited vegan restaurants more than once over the past year, and their responses were rated on a 7-point Likert scale ranging from 1 to 7 points (strongly disagree to strongly agree, respectively). Subsequently, a pre-test was conducted to improve and develop the contents of the interview. The pre-test was conducted on a group composed of vegan restaurant employees, graduate students majoring in restaurant management, and professors specializing in restaurant management.

Data Collection and Sample Characteristics

The data used for this study were collected through a web-based system of an Internet research agency specialized in data collection. The respondents were randomly selected through e-mail for Korean vegan customers and the contents of the interview were designed so that respondents could clearly understand the purpose of this study. Through this method, 305 individuals were recruited in total, and 302 individuals were included in the empirical analysis; three individuals were excluded owing to insincere responses. To determine the sample's demographic characteristics, frequency analysis was conducted using SPSS 22.0. The demographic characteristics of the respondents who participated in the survey are as follows: in terms of gender, 39.7% (120) were male, and 60.3% (182) female; regarding age, 22.8% (69) were in their 20s, 51.7% (156) were in their 30s, 16.6% (50) were in their 40s, and 8.9% (27) were in their 50s; regarding annual income, 4.6% (14) earned below US$30,000, 58.9% (178) earned between US$30,000 and US$50,000, 26.6% (80) earned between US$50,000 and US$70,000, and 9.9% (30) earned above US$70,000; regarding academic background, 1.3% (4) were high school graduates, 70.9% (214) had a bachelor's degree and 27.8% (84) had a master's degree or above; regarding marriage, 32.1% (97) were unmarried and 67.9% (205) were married.

RESULTS

Measurement Model Results

Exploratory Factor Analytic Approach

In this study, exploratory factor analysis (EFA) was conducted using SPSS 22.0 to understand the properties of vegan restaurants. In addition, principal factor analysis was used to extract the key figures of vegan restaurants, and the varimax orthogonal rotation method was used to prevent problems of independence and multi collinearity of the extracted factors (89). Furthermore, the suitability of variables was confirmed through Kaiser-Meyer-Olkin and Bartlett values; as a result, the value of Kaiser-Meyer-Olkin was 0.954, and the value of Bartlett was at the $p < 0.01$ level, showing statistical relevance. The results of EFA conducted to identify the properties of vegan restaurants were as follows. First, it was found that four factors had an intrinsic value of one or more, and the total variance was 89.083. In other words, four properties of vegan restaurants were shown. The first was "health and beauty", which consisted of four questions, where the variance was 30.523%. The second factor was "guilt", which consisted of four questions, with a variance of 26.042%. The third

TABLE 1 | Summary of exploratory factor analysis results.

Factors	% of variance	Factor loadings	Cronbach's alpha
Factor 1: Healthy and beauty	30.523		0.921
I feel I am getting healthier when I eat food from vegan restaurants		0.907	
I feel that my skin improves when I eat food from vegan restaurants		0.900	
I feel that my body becomes beautifully shaped when I eat food from vegan restaurants		0.894	
I feel like I am getting cured when I eat food from vegan restaurants		0.892	
Factor 2: Guilty	26.042		0.916
I feel guilty when I think of visiting meat- and seafood-based restaurants instead of vegan restaurants		0.869	
I feel like I am abusing animals when I think of visiting meat- and seafood-based restaurants instead of vegan restaurants		0.836	
I feel like I am harming my body when I think of visiting meat- and seafood-based restaurants instead of vegan restaurants		0.887	
I think that it is ethically wrong to visit meat- and seafood-based restaurants instead of vegan restaurants		0.820	
Factor 3: Curiosity	24.496		0.902
I am constantly curious about vegan restaurants		0.824	
I am curious about food provided in vegan restaurants		0.829	
I am curious about characteristics of those who visit vegan restaurants		0.855	
I am deeply interested in ingredients (e.g., beans, wheat, and alternative meat) used in vegan restaurants		0.904	
Factor 4: Environmental concern	8.022		0.950
Environments are destroyed when people visit meat- and seafood-based restaurants instead of vegan restaurants.		0.862	
The amount of greenhouse gas emissions increases when people visit meat- and seafood-based restaurants instead of vegan restaurants.		0.858	
Ingredients used in vegan restaurants lead to a decrease in the amount of carbon emissions.		0.880	

Total variance explained: 89.083, KMO measure of sampling adequacy: 0.954, Bartlett's test of sphericity ($p < 0.01$).

factor was "curiosity", which consisted of four questions, and a variance of 24.496%. Lastly, the fourth factor was "environmental concern", which consisted of three questions, and a variance of 8.022%. Next, reliability analysis was conducted to confirm the internal consistency of the measured properties presented in this study. The results were as follows: health and beauty (β: 0.962), guilt (β: 0.908), curiosity (β: 0.931), and environmental concern (β: 0.942). In other words, all of the Cronbach's alpha values of the presented measured properties were 0.7 or higher, proving its compatibility with internal consistency. The results of EFA conducted to understand the properties of vegan restaurants are shown in detail in **Table 1**.

Presented Measurement Model Results

In this study, confirmatory factor analysis (CFA) was conducted using AMOS 22.0 to verify the validity and reliability of the presented measurement model. CFA can be said to be the most pragmatic analytic method to verify the single dimensionality of the scale, its reliability, and the validity of the measurement model (90). The CFA results are as follows. The eligibility of the measurement model presented in this study was statistically appropriate, with $\chi^2 = 1{,}876.997$, df $= 539$, $p < 0.01$, $\chi^2/\text{df} = 3.482$, RMSEA $= 0.074$, CFI $= 0.901$, TLI $= 0.903$. Next, standardized regression weight was measured to verify the reliability of the measured properties: the results were between 0.745 and 0.946. Therefore, reliability was certified with the standardized regression weight of all measured properties being 0.5. The values of average variance extracted (AVE) and composite reliability (CR) were analyzed to verify the internal consistency and concentrated validity of proposed measured variables. As a result, the AVE value was from 0.622 to 0.784, and the CR value ranged from 0.830 to 0.936. Thus, it can be said that the internal consistency and concentrated validity of the measured properties are statistically appropriate. Finally, discriminant validity was analyzed to verify the differentiation between the presented constituent concepts; discriminant validity can be said to be irreproachable when the AVE value is greater than the square of the correlation coefficient (91). Upon examination of the analyses results, discriminant validity was confirmed because the AVE value was larger than the square value of the correlation coefficient. The detailed results of the CFA of this study are shown in **Table 2**.

Structural Equation Modeling

In this study, structural equations were used to verify the proposed conceptual features and hypotheses. The results of the

TABLE 2 | Measurement model assessment and correlations.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Health and beauty (1)	1.000										
Guilty (2)	0.567[a] (0.321)[b]	1.000									
Curiosity (3)	0.650 (0.422)	0.605 (0.366)	1.000								
Environmental concern (4)	0.649 (0.421)	0.580 (0.336)	0.578 (0.334)	1.000							
Identification (5)	0.596 (0.355)	0.511 (0.261)	0.624 (0.389)	0.471 (0.221)	1.000						
Enthusiasm (6)	0.462 (0.213)	0.586 (0.343)	0.534 (0.285)	0.537 (0.288)	0.450 (0.202)	1.000					
Attention (7)	0.427 (0.182)	0.546 (0.298)	0.438 (0.191)	0.532 (0.283)	0.449 (0.201)	0.554 (0.306)	1.000				
Absorption (8)	0.550 (0.302)	0.575 (0.330)	0.552 (0.304)	0.546 (0.298)	0.458 (0.209)	0.617 (0.380)	0.628 (0.394)	1.000			
Interaction (9)	0.569 (0.323)	0.544 (0.295)	0.430 (0.184)	0.537 (0.288)	0.472 (0.222)	0.583 (0.339)	0.533 (0.284)	0.559 (0.312)	1.000		
Psychological resilience (10)	0.574 (0.329)	0.592 (0.350)	0.587 (0.344)	0.585 (0.342)	0.529 (0.279)	0.593 (0.351)	0.431 (0.185)	0.543 (0.294)	0.445 (0.198)	1.000	
Approach intention (11)	0.499 (0.249)	0.514 (0.264)	0.496 (0.246)	0.490 (0.240)	0.421 (0.177)	0.506 (0.256)	0.439 (0.192)	0.449 (0.201)	0.457 (0.208)	0.465 (0.216)	1.000
Mean	5.615	5.585	5.538	5.661	5.500	5.588	5.598	5.664	5.931	6.098	5.972
SD	1.268	1.231	1.346	1.370	1.471	1.229	1.263	1.205	1.053	0.909	1.025
CR	0.936	0.879	0.904	0.885	0.920	0.864	0.844	0.830	0.868	0.897	0.877
AVE	0.784	0.645	0.637	0.721	0.793	0.682	0.643	0.622	0.686	0.744	0.705

Goodness-of-fit statistics for the measurement model: $\chi^2 = 1{,}876.997$, $df = 539$, $p < 0.001$, $\chi^2/df = 3.482$, $RMSEA = 0.074$, $CFI = 0.901$, $IFI = 0.903$.

[a] *Correlations between the variables are below the diagonal.*

[b] *The squared correlations between the variables are within the parentheses.*

analysis are as follows. First, the result of the model suitability was $\chi^2 = 1{,}957.962$, df = 578, $p < 0.01$, $\chi^2/df = 3.387$, RMSEA = 0.077, CFI = 0.902, TLI = 0.902; thus, statistically satisfactory. Second, the results of the second-order factor structure of vegan restaurants' properties demonstrated that standardized coefficients of the four proposed first-order factors were health and beauty (β = 0.937), guilt (β = 0.968), curiosity (β = 0.914), and environmental concern (β = 0.915); thus, statistically meaningful at $p < 0.1$. The results of 12 hypothesis verifications were as follows. To verify hypotheses 1–6, the influencing relationship of multiple attributes of vegan restaurants on customer engagement and psychological resilience composed of five factors were analyzed. As a result, multiple attributes of vegan restaurants had a positive effect on identification (β = 0.850, $p < 0.01$), enthusiasm (β = 0.657, $p < 0.01$), attention (β = 0.628, $p < 0.01$), absorption (β = 0.658, $p < 0.01$), interaction (β = 0.635, $p < 0.01$), and psychological resilience (β = 0.593, $p < 0.01$). To verify hypotheses 7–12, the influencing relationship of customer engagement and psychological resilience consisting of five sub-factors on approach intentions was examined. As a result, identification (β = 0.091, $p > 0.01$) was found to be statistically non-significant, while enthusiasm (β = 0.147, $p < 0.01$), attention (β = 0.124, $p < 0.01$), absorption (β = 0.164, $p < 0.01$), interaction (β = 0.288, $p < 0.01$), and psychological resilience (β = 0.397, $p < 0.01$) were found to be statistically significant. Therefore, out of 12 hypotheses presented in this study, hypothesis 8 was not confirmed, and the remaining hypotheses 1–7 and 9–12 were verified. Details of the hypotheses verification results are shown in **Figure 2** and **Table 3**.

DISCUSSION AND IMPLICATIONS

Even Despite its psychological importance, it was unclear how the multiple attributes ascribed to vegan restaurants were associated with individual psychological resilience and customer engagement, and the information was scarce about the psychological beliefs that drive people to choose to dine in vegan restaurants. Therefore, to better understand vegan restaurant adoption, it is essential to identify the attributes of vegans who experienced such changes. Hence, this study tried to examine the multiple attributes that have been ascribed to vegan restaurants, verify the effects, and assess the impacts of psychological resilience and customer engagement on vegan restaurant patronage.

The most important finding of this study was that the variables suggested as the factors for choosing a vegan diet were the multiple attributes that consumers ascribed to vegan restaurants. The proposed attributes were found to have a significant relationship, with health and beauty being the most crucial factor. This result supports previous studies by Oh et al. (31) and Larsson et al. (79) on the choice attributes of vegan restaurants. In addition, it was found that the multiple

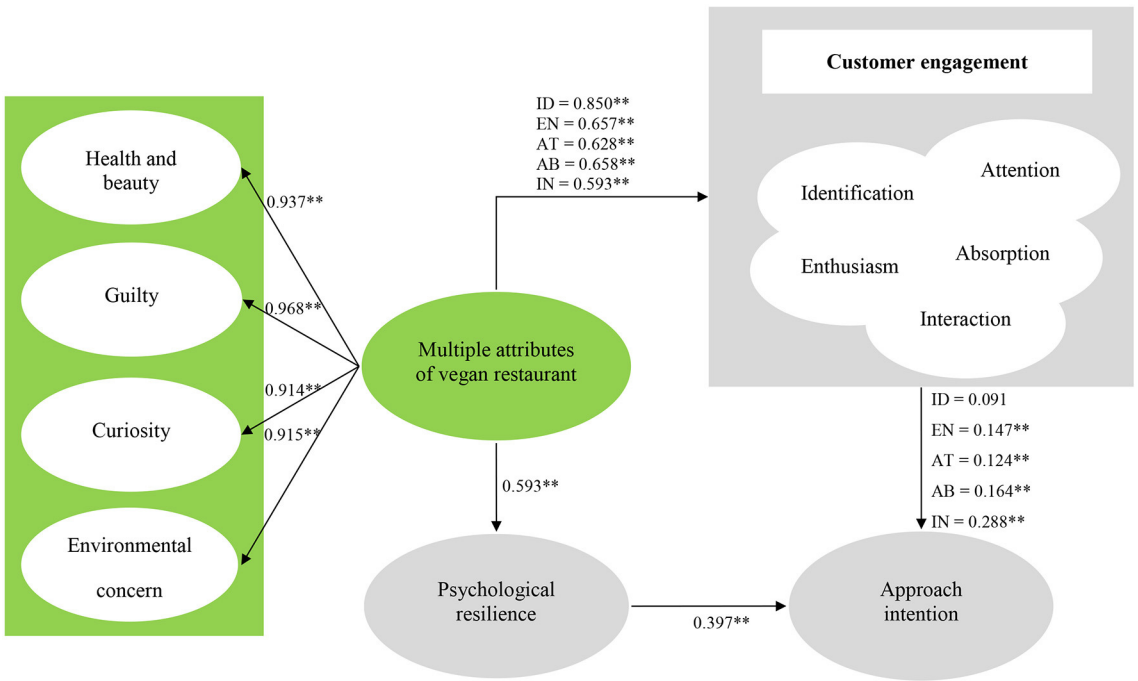


FIGURE 2 | Results of structural model. *$p < 0.05$, **$p < 0.01$.

attributes ascribed to vegan restaurants improved customer engagement, with identification being the most important factor. In other words, key personal-psychological drivers, such as health and beauty, guilt, curiosity, and environmental concerns, were significant factors for customer engagement and catalysts that increased the approach intention toward vegan restaurants. Therefore, it is necessary to emphasize this so that more people can visit vegan restaurants by identifying the main drivers (Health and beauty) of those who choose a vegan diet. In addition, identification is the recognition of oneness with the organization or a sense of belonging (66), and it is necessary to emphasize this aspect in order to increase customer engagement and intention to approach vegan restaurants. Consequently, the result of this study is the driving force of approach intention to vegan restaurants leads to the vitalization through positive customer engagement, especially from a long-term perspective.

These results confirmed that the personal beliefs or values about vegan restaurants and the importance of the ascribed multiple attributes of vegan restaurants played essential roles in customer engagement and consumer psychological resilience. These results corresponded to previous studies that emphasized the psychological roles associated with veganism and the building of psychological resilience to personal health problems, guilt, and environmental concerns that arise from not following veganism done by Kalof et al. (13), Von Essen and Mårtensson (14), and Larsson et al. (79). Furthermore, these results suggested that psychological resilience was a key factor in increasing vegan diet choices and vegan restaurant approach intentions. Therefore, to improve vegan restaurant approach intentions, it is crucial to strengthen unique vegan restaurant characteristics and consumer psychological resilience. This study suggests important academic implications for the importance and necessity of strengthening psychological resilience in veganism and vegan restaurant visits. In addition, emphasizing the psychological resilience of vegan restaurants has practical implications that can help entice more people to choose vegan and approach the restaurants.

All factors barring identification significantly affected the relationship between the composition factors leading to vegan restaurant customer engagement and approach intentions. Therefore, Hypothesis 8 was rejected, but all other hypotheses were supported, which partially corresponded to previous studies done by Ashley et al. (62). In addition, the study of Rather and Sharma (66) on the importance of customer engagement for strengthening customer loyalty in the hospitality sector also corresponds partially with the result.

These results provided meaningful insights. First, it suggests that enthusiasm, attention, absorption, and interaction significantly contribute to increasing the approach intention in building customer relationships. Hence, vegan restaurant managers should also consider personalized services to increase customer engagement and intention to approach where necessary. In addition, as interaction has the greatest influence among factors that increase customer engagement, it is essential to devise various ways to strengthen interaction with customers for the successful operation of vegan restaurants. Second, research shows that vegan restaurants can actively incorporate various strategies to enhance customer engagement,

TABLE 3 | The structural model estimation.

Hypothesized paths			Coefficients	*t*-values
H1: MAVR	→	ID	0.850	16.241**
H2: MAVR	→	EN	0.657	9.873**
H3: MAVR	→	AT	0.628	10.115**
H4: MAVR	→	AB	0.658	11.156**
H5: MAVR	→	IN	0.635	10.555**
H6: MAVR	→	PR	0.593	9.226**
H7: PR	→	AI	0.397	7.953**
H8: ID	→	AI	0.091	1.700
H9: EN	→	AI	0.147	3.236**
H10: AT	→	AI	0.124	2.794**
H11: AB	→	AI	0.164	3.568**
H12: IN	→	AI	0.288	6.205**

Indirect effect:

$\beta_{MAVR \rightarrow ID/EN/AT/AB/IN/PR \rightarrow AI} = 778^{**}$

Explained variance:

R^2 (H) = 0.878 R^2 (ID) = 0.722 R^2 (IN) = 0.403

R^2 (G) = 0.937 R^2 (EN) = 0.432 R^2 (PR) = 0.352

R^2 (C) = 0.836 R^2 (AT) = 0.394 R^2 (AI) = 0.797

R^2 (E) = 0.837 R^2 (AB) = 0.433

$^{**}p < 0.01$.

MAVR, multiple attributes of vegan restaurant; H, heathy and beauty; G, guilty; C, curiosity; E, environmental concern; ID, identification; EN, enthusiasm; AT, attention; AB, absorption; IN, interaction; PR, psychological resilience; AI, Approach intention.

Goodness-of-fit statistics for the structural model: $\chi^2 = 1{,}957.962$, $df = 578$, $p < 0.001$, $\chi^2/df = 3.387$, RMSEA = 0.077, CFI = 0.902, IFI = 0.902.

which in turn develops sustainable customer relationships by increasing customer engagement. In particular, identification is the most crucial factor leading to customer engagement in vegan restaurants. Identification is the recognition of oneness with the organization or a sense of belonging (66), and it is necessary to emphasize this aspect in order to increase customer engagement and intention to approach vegan restaurants. Consequently, this study is a very meaningful result that proves that all customer engagement factors suggested through indirect effect verification are essential to increase customer approach intention to vegan restaurants, and in particular, interaction with customers is an important factor.

Identification is a person's perceived oneness with or belongingness to an organization and is positively related to customer attitudinal engagement (66, 92, 93). However, the relationship found between the identification of customer participation and approach intentions differed from the conclusions in previous studies (62, 68). Therefore, it can consider that identification does not fully explain the psychological/emotional aspect of the approach intentions. These results further implied that individual values and beliefs were important when choosing to dine in vegan restaurants; however, the aspect that increased access through the identification process was weak compared with the other factors.

This study focused on the psychological factors associated with choosing to be a vegan and the main attributes ascribed to vegan restaurant visits and verified that individual norms, beliefs, and environmental values were the main attributes for choosing to patronize vegan restaurants. Health and beauty were found to be the important factors that provide some guidance for vegan restaurant operators. In particular, the proposed attributes were found to have a significant causal relationship with the factors that increased customer engagement and suggested that this main vegan restaurant attribute enhanced approach intentions by enhancing the customer's psychological resilience. Therefore, this study successfully addressed the insufficiencies in previous vegan-related studies. It is suggested that emphasizing the interactions between the customer engagement factors and psychological resilience could improve vegan restaurant operations.

CONCLUSION

The number of vegan restaurants continues to grow as demand for vegan products increases. As people choose to follow vegan diets for various reasons, this study focused on the attributes ascribed to vegan restaurants, customer engagement factors, and role of consumer psychological resilience. The reasons for visiting vegan restaurants were theoretically and empirically investigated, and the various attributes that influenced vegan restaurant patronage were examined by comparing them with existing research results. All presented attributes were found to have a significant relationship, with the most significant being health and beauty. In addition, it was found that personal psychological factors, such as guilt, curiosity, and environmental concerns, were attributes ascribed to vegan restaurants. A significant relationship was found between the five customer engagement factors (i.e., identification, enthusiasm, attention, absorption, and interaction) and the multiple attributes ascribed to vegan restaurants. In particular, identification was found to be the key factor for vegan restaurant customer engagement. However, all multiple attributes ascribed to vegan restaurants contributed to customer psychological resilience, which had a significant influence on vegan restaurant approach intentions. All the four customer engagement factors, except identification, significantly affected vegan restaurant approach intentions.

LIMITATION

Despite the meaningful results, this study had several limitations. First, as this study targeted Koreans, a culture in which there is relatively little vegan awareness and adherence, there is a limit to generalizing the study results. Second, the results cannot be applied to other vegan industries as it only targeted vegan restaurant customers. Third, it was not possible to verify the attribution and psychological factors associated with choosing to eat in a vegan restaurant for general customers as only vegan customers were focused on. Therefore, future studies should expand the study to examine all potential users of the various vegan-related industries that have not been discussed in previous studies.

DATA AVAILABILITY STATEMENT

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

AUTHOR CONTRIBUTIONS

All authors contributed to conceptualization, formal analysis, investigation, methodology, writing, and editing the original draft.

REFERENCES

1. Chinea C, Suárez E, Hernández B. Meaning of food in eating patterns. *Br Food J.* (2020) 122:3331–41. doi: 10.1108/BFJ-02-2020-0144
2. Martinelli E, De Canio F. Non-vegan consumers buying vegan food: the moderating role of conformity. *Br Food J.* (2021) 124:14–30. doi: 10.1108/BFJ-01-2021-0023
3. Expert Market Research. *Global Vegan Food Market*. (2020). Available online at: https://www.expertmarketresearch.com/reports/vegan-food-market/ (accessed December 24, 2021).
4. Choi HY, Joung HW. Exploring restaurant selection attributes of vegetarian customers. *Culin Sci Hosp Res.* (2018) 24:83–8. doi: 10.20878/cshr.2018.24.7.009
5. Janssen M, Busch C, Rödiger M, Hamm U. Motives of consumers following a vegan diet and their attitudes towards animal agriculture. *Appetite.* (2016) 105:643–51. doi: 10.1016/j.appet.2016.06.039
6. Radnitz C, Beezhold B, DiMatteo J. Investigation of lifestyle choices of individuals following a vegan diet for health and ethical reasons. *Appetite*. (2015) 90:31–6. doi: 10.1016/j.appet.2015.02.026
7. Cheng CH, Lin SY, Tsai CC. Investigating consumer preferences in choosing vegetarian restaurants using conjoint analysis. *Curr Urban Stud.* (2014) 2:279. doi: 10.4236/cus.2014.23026
8. McCormick B. *Why People Go Vegan: 2019 Global Survey Results*. (2019). Available online at: https://vomadlife.com/blogs/news/why-people-go-vegan-2019-global-survey-results/ (accessed December 14, 2021).
9. Le LT, Sabaté J. Beyond meatless, the health effects of vegan diets: findings from the Adventist cohorts. *Nutrients.* (2014) 6:2131–47. doi: 10.3390/nu6062131
10. McDonald B. "Once you know something, you can't not know it" an empirical look at becoming vegan. *Soc Anim.* (2000) 8:1–23. doi: 10.1163/156853000510961
11. Cliceri D, Spinelli S, Dinnella C, Prescott J, Monteleone E. The influence of psychological traits, beliefs and taste responsiveness on implicit attitudes toward plant-and animal-based dishes among vegetarians, flexitarians and omnivores. *Food Qual Prefer.* (2018) 68:276–91. doi: 10.1016/j.foodqual.2018.03.020
12. Dietz T, Stern PC. Toward a theory of choice: socially embedded preference construction. *J Socio Econ*. (1995) 24:261–79. doi: 10.1016/1053-5357(95)90022-5
13. Kalof L, Dietz T, Stern PC, Guagnano GA. Social psychological and structural influences on vegetarian beliefs. *Rural Sociol.* (1999) 64:500–11. doi: 10.1111/j.1549-0831.1999.tb00364.x
14. Von Essen E, Mårtensson F. Young adults' use of emotional food memories to build resilience. *Appetite.* (2017) 112:210–8. doi: 10.1016/j.appet.2017.01.036
15. Norwood R, Cruwys T, Chachay VS, Sheffield J. The psychological characteristics of people consuming vegetarian, vegan, paleo, gluten free and weight loss dietary patterns. *Obesity Sci Pract.* (2019) 5:148–58. doi: 10.1002/osp4.325
16. Meng B, Choi K. An investigation on customer revisit intention to theme restaurants: the role of servicescape and authentic perception. *Int J Contemp Hosp Manag.* (2018) 30:1646–62. doi: 10.1108/IJCHM-11-2016-0630
17. Sashi CM, Brynildsen G, Bilgihan A. Social media, customer engagement and advocacy: an empirical investigation using Twitter data for quick service restaurants. *Int J Contemp Hosp Manag.* (2019) 31:1247–72. doi: 10.1108/IJCHM-02-2018-0108
18. Vivek SD, Beatty SE, Morgan RM. Customer engagement: exploring customer relationships beyond purchase. *J Mark Theor Pract.* (2012) 20:122–46. doi: 10.2753/MTP1069-6679200201
19. Miguel I, Coelho A, Bairrada CM. Modelling attitude towards consumption of vegan products. *Sustainability.* (2020) 13:9. doi: 10.3390/su13010009
20. Kandampully J, Zhang TC, Bilgihan A. Customer loyalty: a review and future directions with a special focus on the hospitality industry. *Int J Contemp Hospit Manag.* (2015) 27:379–414. doi: 10.1108/IJCHM-03-2014-0151
21. Losasso C, Eckert EM, Mastrorilli E, Villiger J, Mancin M, Patuzzi IG, et al. Assessing the influence of vegan, vegetarian and omnivore oriented westernized dietary styles on human gut microbiota: a cross sectional study. *Front Microbiol.* (2018) 9:317. doi: 10.3389/fmicb.2018.00317
22. Lynch H, Johnston C, Wharton C. Plant-based diets: considerations for environmental impact, protein quality, and exercise performance. *Nutrients.* (2018) 10:1841. doi: 10.3390/nu10121841
23. Medawar E, Huhn S, Villringer A, Veronica Witte A. The effects of plant-based diets on the body and the brain: a systematic review. *Transl Psychiatry.* (2019) 9:1–17. doi: 10.1038/s41398-019-0552-0
24. Tomova A, Bukovsky I, Rembert E, Yonas W, Alwarith J, Barnard ND, et al. The effects of vegetarian and vegan diets on gut microbiota. *Front Nutr.* (2019) 6:47. doi: 10.3389/fnut.2019.00047
25. Davis MH. *Empathy: A Social Psychological Approach*. New York, NY: Routledge (2018).
26. Forgrieve J. *The Growing Acceptance of Veganism*. Forbes (2018). Available online at: https://www.forbes.com/sites/janetforgrieve/2018/11/02/picturing-a-kindler-gentler-world-vegan-month/#1d5ede8d2f2b (accessed December 27, 2021).
27. Beveg. *Vegan Business and Restaurant Certification*. (2024). Available online at: https://www.beveg.com/vegan-business-and-restaurant-certification/ (accessed December 29, 2021).
28. Bresnahan M, Zhuang J, Zhu X. Why is the vegan line in the dining hall always the shortest? Understanding vegan stigma. *Stigma Health.* (2016) 1:3. doi: 10.1037/sah0000011
29. Hirschler CA. "What pushed me over the edge was a deer hunter": being vegan in North America. *Soci Anim.* (2011) 19:156–74. doi: 10.1163/156853011X562999
30. Lindquist A. Beyond hippies and rabbit food: the social effects of vegetarianism and veganism. *Soc Anthropol Theses*. (2013) 3:1–21.
31. Oh M, Badu Baiden F, Kim S, Lema J. Identification of delighters and frustrators in vegan-friendly restaurant experiences *via* semantic network analysis: evidence from online reviews. *Int J Hosp Tour Admin.* (2021) 1–28. doi: 10.1080/15256480.2021.1981186
32. Craig WJ. Health effects of vegan diets. *Am J Clin Nutr.* (2009) 89:1627–33. doi: 10.3945/ajcn.2009.26736N
33. Dyett PA, Sabaté J, Haddad E, Rajaram S, Shavlik D. Vegan lifestyle behaviors. An exploration of congruence with health-related beliefs and assessed health indices. *Appetite.* (2013) 67:119–24. doi: 10.1016/j.appet.2013.03.015
34. Lundahl O. Dynamics of positive deviance in destigmatisation: celebrities and the media in the rise of veganism. *Consump Mark Cult.* (2020) 23:241–71. doi: 10.1080/10253866.2018.1512492
35. Twine R. Vegan killjoys at the table—Contesting happiness and negotiating relationships with food practices. *Societies.* (2014) 4:623–39. doi: 10.3390/soc4040623
36. Cagnina MR, Cicero L, Osti L. Dining motivations, experiences and loyalty at vegan/vegeterian restaurants. In: *XIV SIM Conference Il Marketing di Successo; 2017 Oct 26-27; Bergamo, Lombardia*. Italia: Società Italiana Marketing (2017). p. 1–7.
37. Greenebaum J. Veganism, identity and the quest for authenticity. *Food Cult Soc.* (2012) 15:129–44. doi: 10.2752/175174412X13190510222101
38. Dewell A, Weidner G, Sumner MD, Chi CS, Ornish D. A very-low-fat vegan diet increases intake of protective dietary factors and decreases

intake of pathogenic dietary factors. *J Am Diet Assoc.* (2008) 108:347–56. doi: 10.1016/j.jada.2007.10.044
39. Larsson CL, Johansson GK. Dietary intake and nutritional status of young vegans and omnivores in Sweden. *Am J Clin Nutr.* (2002) 76:100–6. doi: 10.1093/ajcn/76.1.100
40. Larsson CL, Johansson GK. Young Swedish vegans have different sources of nutrients than young omnivores. *J Am Diet Assoc.* (2005) 105:1438–41. doi: 10.1016/j.jada.2005.06.026
41. Marrone G, Guerriero C, Palazzetti D, Lido P, Marolla A, Di Daniele F, et al. Vegan diet health benefits in metabolic syndrome. *Nutrients.* (2021) 13:817–39. doi: 10.3390/nu13030817
42. Marmot M, Atinmo T, Byers T, Chen J, Hirohata T, Jackson A, et al. Food, nutrition, physical activity, and the prevention of cancer: a global perspective. *World Cancer Res Fund Am Instit Cancer Res.* (2007) 517.
43. Cruwys T, Norwood R, Chachay VS, Ntontis E, Sheffield J. "An important part of who I am": the predictors of dietary adherence among weight-loss, vegetarian, vegan, paleo, and gluten-free dietary groups. *Nutrients.* (2020) 12:970. doi: 10.3390/nu12040970
44. Ryan YM. Meat avoidance and body weight concerns: nutritional implications for teenage girls. *Proc. Nutr. Soc.* (1997) 56:519–24. doi: 10.1079/PNS19970052
45. Costa I, Gill PR, Morda R, Ali L. "More than a diet": a qualitative investigation of young vegan Women's relationship to food. *Appetite.* (2019) 143:104418. doi: 10.1016/j.appet.2019.104418
46. Gilbody SM, Kirk SF, Hill AJ. Vegetarianism in young women: another means of weight control? *Int J Eating Disord.* (1999) 26:87–90. doi: 10.1002/(sici)1098-108x(199907)26:1<87::aid-eat11>3.0.co;2-m
47. Lim KA, Ham S, Moon HY, Jang YJ, Kim CS. How does food choice motives relate to subjective well-being and loyalty? A cross-cultural comparison of vegan restaurant customers in South Korea and Singapore. *J Foodserv Bus Res.* (2022) 25:168–208. doi: 10.1080/15378020.2021.1935188
48. Tangney JP, Dearing RL. *Shame and Guilt*. New York, NY: Guilford Press (2003).
49. Goffman E. *Relations in Public*. New Brunswick; London: Transaction Publishers (2009).
50. Ghaffari M, Rodrigo PGK, Ekinci Y, Pino G. Consumers' motivations for adopting a vegan diet: a mixed-methods approach. *Int J Consum Stud.* (2021) 1–16. doi: 10.1111/ijcs.12752
51. Berndsen M, van der Pligt J, Doosje B, Manstead A. Guilt and regret: the determining role of interpersonal and intrapersonal harm. *Cogn Emot.* (2004) 18:55–70. doi: 10.1080/02699930244000435
52. Berlyne DE. A theory of human curiosity. *British journal of psychology.* (1954) 45:180–91. doi: 10.1111/j.2044-8295.1954.tb01243.x
53. Fellner G, Pitts W, Zuss M. Beyond the sensible world: a discussion of Mark Zuss' the practice of theoretical curiosity. *Cult Stud Sci Educ.* (2012) 7:745–60. doi: 10.1007/s11422-012-9438-7
54. Conner TS, Brookie KL, Richardson AC, Polak MA. On carrots and curiosity: eating fruit and vegetables is associated with greater flourishing in daily life. *Br J Health Psychol.* (2015) 20:413–27. doi: 10.1111/bjhp.12113
55. Dedehayir O, Riverola C, Velasquez S, Smidt M. Diffusion of vegan food innovations: a dual-market perspective. In: Leal Filho, W., Azul, AM, Brandli, L., Özuyar, PG, Wall, T., editors *Responsible Consumption and Production*. (2019). p. 1–9.
56. Davitt ED, Winham DM, Heer MM, Shelley MC, Knoblauch ST. Predictors of plant-based alternatives to meat consumption in midwest university students. *J Nutr Educ Behav.* (2021) 53:564–72. doi: 10.1016/j.jneb.2021.04.459
57. Figueroa C, Echeverría G, Villarreal G, Martínez X, Ferreccio C, Rigotti A. Introducing plant-based mediterranean diet as a lifestyle medicine approach in Latin America: opportunities within the Chilean context. *Front Nutr.* (2021) 8:680452. doi: 10.3389/fnut.2021.680452
58. Mylan J, Morris C, Beech E, Geels FW. Rage against the regime: Niche-regime interactions in the societal embedding of plant-based milk. *Environ Innovation Soc Trans.* (2019) 31:233–47. doi: 10.1016/j.eist.2018.11.001
59. Stehfest E. Food choices for health and planet. *Nature.* (2014) 515:501–2. doi: 10.1038/nature13943
60. 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
61. Rosi A, Mena P, Pellegrini N, Turroni S, Neviani E, Ferrocino I, et al. Environmental impact of omnivorous, ovo-lacto-vegetarian, and vegan diet. *Sci Rep.* (2017) 7:1–9. doi: 10.1038/s41598-017-06466-8
62. Ashley C, Noble SM, Donthu N, Lemon KN. Why customers won't relate: obstacles to relationship marketing engagement. *J Bus Res.* (2011) 64:749–56. doi: 10.1016/j.jbusres.2010.07.006
63. Brodie RJ, Ilic A, Juric B, Hollebeek L. Consumer engagement in a virtual brand community: an exploratory analysis. *J Bus Res.* (2013) 66:105–14. doi: 10.1016/j.jbusres.2011.07.029
64. Patterson P, Yu T, De Ruyter K. Understanding customer engagement in services. In: *Advancing Theory, Maintaining Relevance, Proceedings of ANZMAC 2006 Conference Brisbane*. (2006). p. 4–6.
65. Shawky S, Kubacki K, Dietrich T, Weaven S. A dynamic framework for managing customer engagement on social media. *J Bus Res.* (2020) 121:567–77. doi: 10.1016/j.jbusres.2020.03.030
66. Rather R, Sharma J. Customer engagement for evaluating customer relationships in hotel industry. *Eur J Tour Hosp Recreat.* (2017) 8:1–13. doi: 10.1515/ejthr-2017-0001
67. Verhoef PC, Reinartz WJ, Krafft M. Customer engagement as a new perspective in customer management. *J Serv Res.* (2010) 13:247–52. doi: 10.1177/1094670510375461
68. So KKF, King C, Sparks B. Customer engagement with tourism brands: scale development and validation. *J Hosp Tour Res.* (2014) 38:304–29. doi: 10.1177/1096348012451456
69. Hair JF, Black WC, Babin BJ, Anderson RE, Tatham RL. *Multivariate Data Analysis*. 7th ed. New Jersey, NJ: Prentice-Hall, Inc (2006).
70. Ostrom AL, Bitner MJ, Brown SW, Burkhard KA, Goul M, Smith-Daniels V, et al. Moving forward and making a difference: research priorities for the science of service. *J Serv Res.* (2010) 13:4–36. doi: 10.1177/1094670509357611
71. Kim SJ, Kwon OD, Lee EJ, Ock SM, Kim KS. Impact of a family history of cardiovascular disease on prevalence, awareness, treatment, control of dyslipidemia, and healthy behaviors: findings from the Korea National Health and Nutrition Examination Survey. *PLoS ONE.* (2021) 16:e0254907. doi: 10.1371/journal.pone.0254907
72. Milošević J, ŽeŽelj I, Gorton M, Barjolle D. Understanding the motives for food choice in Western Balkan Countries. *Appetite.* (2012) 58:205–14. doi: 10.1016/j.appet.2011.09.012
73. Huang CC, Chen SE. Establishing and deepening brand loyalty through brand experience and customer engagement: evidence from Taiwan's chain restaurants. *J Qual Assur Hosp Tour.* (2022) 23:217–39. doi: 10.1080/1528008X.2020.1864565
74. Coveney J, Bunton R. In pursuit of the study of pleasure: implications for health research and practice. *Health.* (2003) 7:161–79. doi: 10.1177/1363459303007002873
75. Kerr ME, Bowen M. *Family Evaluation: The Role of the Family as an Emotional Unit That Governs Individual Behavior and Development*. 1st ed. Markham, ON: Penguin Books (1988).
76. Breidenstein PA. *On the creation of organizational folk theories: An analysis of storytelling and language behavior* (dissertation/PhD thesis). West Lafayette, (IN): Purdue University (1988).
77. Chen PJ, Antonelli M. Conceptual models of food choice: influential factors related to foods, individual differences, and society. *Foods.* (2020) 9:1898–926. doi: 10.3390/foods9121898
78. Guseman PK, McIntosh WA, Sapp SG. Traditional and non-traditional explanations of food consumption: the case of beef. *J Rural Soc Sci.* (1986) 4:8.
79. Larsson CL, Rönnlund U, Johansson G, Dahlgren L. Veganism as status passage: the process of becoming a vegan among youths in Sweden. *Appetite.* (2003) 41:61–7. doi: 10.1016/S0195-6663(03)00045-X
80. Sapp SG, Harrod WJ. Social acceptability and intentions to eat beef: an expansion of the Fishbein-Ajzen model using reference group theory. *Rural Sociol.* (1989) 54:420.
81. Ruby MB. Vegetarianism. A blossoming field of study. *Appetite.* (2012) 58:141–50. doi: 10.1016/j.appet.2011.09.019
82. Simons J, Vierboom C, Klink-Lehmann J, Härlen I, Hartmann M. Vegetarianism/veganism: a way to feel good. *Sustainability.* (2021) 13:3618. doi: 10.3390/su13073618

83. Cheng Y, Wei W, Zhang L. Seeing destinations through vlogs: implications for leveraging customer engagement behavior to increase travel intention. *Int J Contemp Hosp Manag.* (2020) 32:3227–48. doi: 10.1108/IJCHM-04-2020-0319
84. Lee S, Scott D, Kim H. Celebrity fan involvement and destination perceptions. *Ann Tour Res.* (2008) 35:809–32. doi: 10.1016/j.annals.2008.06.003
85. Islam JU, Rahman Z. The impact of online brand community characteristics on customer engagement: an application of Stimulus-Organism-Response paradigm. *Telem Inform.* (2017) 34:96–109. doi: 10.1016/j.tele.2017.01.004
86. Spiggle S. Analysis and interpretation of qualitative data in consumer research. *J Cons Res.* (1994) 21:491–503. doi: 10.1086/209413
87. Gascon M, Zijlema W, Vert C, White MP, Nieuwenhuijsen MJ. Outdoor blue spaces, human health and well-being: a systematic review of quantitative studies. *Int J Hyg Environ Health.* (2017) 220:1207–21. doi: 10.1016/j.ijheh.2017.08.004
88. Wu HC, Cheng CC, Ai CH. A study of experiential quality, experiential value, trust, corporate reputation, experiential satisfaction and behavioral intentions for cruise tourists: the case of Hong Kong. *Tour Manag.* (2018) 66:200–20. doi: 10.1016/j.tourman.2017.12.011
89. Hair JF, Anderson RE, Tatham RL, Black WC. *Multivariate Data Analysis Prentice Hall*. Upper Saddle River, NJ, (1998).
90. Anderson JC, Gerbing DW. Structural equation modeling in practice: a review and recommended two-step approach. *Psychol Bull.* (1988) 103:411. doi: 10.1037/0033-2909.103.3.411
91. Fornell C, Larcker DF. Evaluating structural equation models with unobservable variables and measurement error. *J Mark Res.* (1981) 18:39–50. doi: 10.1177/002224378101800104
92. Bhattacharya CB, Rao H, Glynn MA. Understanding the bond of identification: an investigation of its correlates among art museum members. *J Mark.* (1995) 59:46–57. doi: 10.1177/002224299505900404
93. Prentice C, Han XY, Hua LL, Hu L. The influence of identity-driven customer engagement on purchase intention. *J Retail Cons Serv.* (2019) 47:339–47. doi: 10.1016/j.jretconser.2018.12.014

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

TYPE Original Research
PUBLISHED 23 August 2022
DOI 10.3389/fnut.2022.871238

OPEN ACCESS

EDITED BY
Veronica Ginani,
University of Brasilia, Brazil

REVIEWED BY
Jagmeet Madan,
SNDT Women's University, India
Panchali Moitra,
SNDT Women's University, India

*CORRESPONDENCE
José Francisco López-Gil
josefranciscolopezgil@gmail.com

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

RECEIVED 08 February 2022
ACCEPTED 15 July 2022
PUBLISHED 23 August 2022

CITATION
López-Gil JF, Smith L, López-Bueno R and Tárraga-López PJ (2022) Breakfast and psychosocial behavioural problems in young population: The role of status, place, and habits. *Front. Nutr.* 9:871238. doi: 10.3389/fnut.2022.871238

Breakfast and psychosocial behavioural problems in young population: The role of status, place, and habits

José Francisco López-Gil[1]*, Lee Smith[2], Rubén López-Bueno[3] and Pedro Juan Tárraga-López[4]

[1]Health and Social Research Center, Universidad de Castilla-La Mancha, Cuenca, Spain, [2]Centre for Health, Performance and Wellbeing, Anglia Ruskin University, Cambridge, United Kingdom, [3]Department of Physical Medicine and Nursing, University of Zaragoza, Zaragoza, Spain, [4]Departamento de Ciencias Médicas, Facultad de Medicina, Universidad de Castilla-La Mancha, Albacete, Spain

The aim of this study was to examine whether breakfast status, place and habits are associated with psychosocial behavioural problems in a nationally representative sample of young people aged 4–14 years residing in Spain. This study analysed secondary data from the Spanish National Health Survey (2017), including 3,772 Spanish children and adolescents. Breakfast status, place, and habits were assessed by *ad hoc* questions answered by parents/guardians. The Strengths and Difficulties Questionnaire (SDQ) parents' version form was applied to evaluate the psychosocial health of their children. Skipping breakfast and eating breakfast out of home were linked to greater odds of psychosocial behavioural problems (skipping breakfast: OR = 3.29; CI 95%, 1.47–7.35; breakfast out of home: OR = 2.06; CI 95%, 1.27–3.33) than eating breakfast at home. Similarly, not consuming coffee, milk, tea, chocolate, cocoa, yogurt, etc., for breakfast was related to greater odds of psychosocial behavioural problems (OR = 1.76; CI 95%, 1.21–2.55). This association was also found for those who did not eat bread, toast, cereals, pastries, etc., for breakfast (OR = 1.31; CI 95%, 1.01–1.73). Conversely, not consuming eggs, cheese, ham, etc., was associated with lower odds of psychosocial behavioural problems (OR = 0.56; CI 95%, 0.38–0.83). Our results show that eating breakfast (specifically at home) and breakfast habits related to the intake of certain food/beverages groups were associated with higher or lower odds of psychosocial behavioural problems.

KEYWORDS

healthy diet, nutrition, lifestyle, mental health, preschoolers, children, adolescents

Introduction

Psychosocial health is broadly defined to include psychological and social psychological outcomes interlinked with socioeconomic factors (1). There is no accepted definition in the field, although it usually includes characteristics such as self-esteem and mood, as well as affect, such as anxiety (2). Importantly, affective disorders (e.g., anxiety) are the leading causes of illness and disability (3), as well as years lost due to disability (4) among children and adolescents (young people). Most affective disorders begin in childhood (3) and have been shown to be considerably stable over time (5). Therefore, early identification and treatment of such complications is essential during this life period (3). Owing to this, the assessment of affective disorders in childhood has expanded over the last two decades (3, 6, 7).

One potentially important factor associated with an increased risk of psychosocial complications is lower adherence to a healthy diet. In a meta-analysis (8) including 14 studies and 399,550 participants, skipping breakfast was related to a higher risk of stress, depression, and psychological distress in all age groups, as well as anxiety in adolescents. Likewise, another systematic review found similar findings (9).

Consuming a healthy breakfast on a daily basis has been observed to have multiple beneficial effects on psychosocial and health behaviours, such as improved memory recall and cognitive function, as well as higher levels of physical activity, among others (10). Furthermore, O'Sullivan et al. (11) indicated that breakfast quality is a key factor in the interaction between lifestyle and psychosocial health during early adolescence. Concluding that in children, a high-quality breakfast should include cereals, low-fat milk or other dairy products, and fruit or fruit juice (12). However, the intake of whole fruit rather than fruit juices has been discussed because of the more conclusive evidence of the health benefits of whole fruit (13). Thus, the Spanish Society of Community Nutrition (14) indicates that an adequate breakfast should be composed of the triad: (1) dairy products (one glass of milk, one fresh yogurt or cheese); (2) cereals (bread, cookies, whole wheat bread, homemade pastries or breakfast cereals); and (3) fruit or natural juice. Furthermore, it could also be complemented on some occasions with other protein foods, such as eggs, ham, nuts, etc. Thus, it is not surprising that daily breakfast consumption along with adequate breakfast selections have been highlighted as an important public health message (15).

The association between eating breakfast and psychosocial health in young people has been previously studied (8, 11, 16, 17). However, to date, the association between breakfast place (i.e., at home, out-of-home) and breakfast habits in relation to psychosocial behavioural problems in young people remains unknown. Interestingly, a systematic review suggested that the social context (e.g., breakfast at home) plays a key role in breakfast consumption (18). Similarly, eating at home favours the accessibility and availability of different foods, in addition to the key sociocultural scenario that family meals represent, since they provide a setting in which parents/guardians often control children's behaviours, interact with them, and imposes rules and expectations on them (19). Supporting this notion, a systematic review by Lachat et al. (20) has pointed out that eating out of home is a risk factor for greater energy and fat consumption and lower consumption of micronutrients. More specifically, in children, the consumption out of home (e.g., coffee shops/restaurants) seems to favour a greater consumption of energy-dense foods and a lower consumption of nutrient-rich foods (21). This consumption of meals out of home could translate into a lower quality of individual meals (e.g., breakfast) and/or global diet, which could influence (as mentioned above) the psychosocial health complications of young people (22). Therefore, it could be suggested that eating breakfast away from the home or skipping breakfast *per se*, as well as consuming a breakfast that does not follow the Spanish recommendations, may be related to psychosocial behavioural problems in young people. Considering these premises, the aim of this study was to examine whether breakfast status, place and habits are associated with psychosocial behavioural problems in a nationally representative sample of young people aged 4–14 years residing in Spain.

Materials and methods

Population sample and study design

A cross-sectional study was carried out using nationwide data from the Spanish National Health Survey (2017) (23). This survey was conducted by the Ministry of Health, Consumer Affairs and Social Welfare *and the* National Statistics Institute (24). The sampling framework involved non-institutionalised Spanish individuals (i.e., people who live in group quarters other than institutions, such as college dormitories, rooming houses, religious group homes, communes, and halfway houses). A three-stage sampling design was applied. The census section was the first stage, the households were the second-stage units, and the individuals were the third-stage units. Within each household, an adult (aged 15 or older) was chosen to complete the Adult Questionnaire, and if there were minors (from 0 to 14 years of age), a minor was randomly chosen to complete the Minors Questionnaire. Data on the minors were reported by the parents/guardians. The participants were informed about the survey methodology through an informative letter from the Ministry of Health, Consumer Affairs and Social Welfare describing the aims of the survey, the anonymous and voluntary nature of participation, and the visit of a qualified and authorised interviewer.

For the purpose of this study, the sample was restricted to individuals aged 0–14 years old (Minors Questionnaire).

The sample originally consisted of 6,106 participants. As psychosocial behavioural problems were only evaluated in children and adolescents from 4 to 14 years, we excluded 1,502 participants under the age of 4 years. Moreover, 832 participants were removed due to missing data in relation to diet, weight or height or any covariate. Thus, the final sample included 3,772 (49.4% females) Spanish children and adolescents. Differences between the included and excluded samples can be found in **Supplementary Table 1**.

Anonymised data were obtained from the Ministry of Health, Consumer Affairs and Social Welfare (23). Following the Spanish regulations, no Ethics Committee approval was needed for this study due to the use of secondary data.

Procedures

Breakfast status and breakfast place

Using the original question from the Spanish National Health Survey (2017), we determined breakfast status (eating breakfast/skipping breakfast) and breakfast place (eating breakfast at home/eating breakfast out of home): "Where does your child usually eat breakfast?." The options varied from (a) "at home"; (b) "out of home"; and (c) "no breakfast."

Breakfast habits

Breakfast habits were determined by the following question: What does your child usually eat for breakfast? This question was applied for five different food/beverage groups: (a) "coffee, milk, tea, chocolate, cocoa, yogurt, etc."; (b) "bread, toast, cookies, pastries, etc."; (c) "fruit and/or juice"; (d) "eggs, cheese, ham, etc."; (e) "other foods." These categories correspond to those originally designed for the Spanish National Health Surveys and were designed to report what has been defined in Spain as a complete breakfast: hot drink (e.g., milk, cacao), accompanied by a solid food (e.g., bread, toasts), and fruit/fruit juice (25).

Strengths and difficulties questionnaire

The Strengths and Difficulties Questionnaire (SDQ) (26) parents' version form was applied for the evaluation of different behavioural, emotional, and social problems related to the psychosocial health of children and adolescents.[1] In this study, the Spanish version of the SDQ, which has been previously validated in other studies (7, 27), was applied. The SDQ contains a total of 25 items with five different subscales: (a) "emotional problems", (b) "conduct problems", (c) "hyperactivity", (d) "peer problems"; and (e) "prosocial behaviour." A Likert-scale with three possible options (0: "not true"; 1: "somewhat true"; 2: "certainly true") was applied. Furthermore, the score on each subscale varies from 0 to 10 points. The first four subscales (hyperactivity, emotional problems, conduct problems, and peer problems) were used to establish a total score of psychosocial behavioural problems. The original 3-band categorisation of SDQ included normal (0–13 points), borderline (14–17 points), or "abnormal" (17–40 points). For additional analyses, the SDQ score was dichotomised into (a) no psychosocial behavioural problems (normal and borderline) and (b) psychosocial behavioural problems (abnormal).

Covariates

Age, sex, region, and immigrant status were declared by the parents/guardians. Social class was categorised according to the reference person's occupation. Height and weight were also reported by parents/guardians. These values were used to determine the body mass index (BMI), which was transformed into BMI z score (zBMI) following the sex- and age-criteria from the International Obesity Task Force (IOTF) (28). According to the zBMI, participants were categorised as "no excess weight" ("underweight," and "normal weight") and "excess weight" ("overweight," and "obesity"). Physical activity was evaluated by a modified short version of the International Physical Activity Questionnaire (29), with only one specific question about engagement in physical activity during free time. The question has four possible options: (a) "no exercise" (free-time mainly engaged in sedentary behaviours such as watching television, reading, going to the cinema, etc.); (b) "occasional sport or physical activity"; (c) "physical activity several times a month", and (d) "sports or physical training several times a week" (23). Recreational screen time was assessed by asking respondents for weekdays and weekends independently: How much time does your child typically spend on a weekday/weekend in front of a screen, including a computer, tablet, television, video, video game or cell phone screen?." The possible options were (a) "nothing or almost nothing"; (b) "less than 1 h"; and (c) "1 h or more." The proportion of the young population meeting the recreational screen time recommendation was determined through the World Health Organization international guidelines for children under 5 years old (30) and the Canadian guidelines on screen time for the young population (31). Sleep duration was assessed by the following question: "Approximately how many hours does your child usually sleep per day? (Including nap times)." The meeting of the sleep recommendation was determined by the National Sleep Foundation's sleep duration guidelines (32). Global quality diet was assessed by the Spanish Health Eating Index (S-HEI) (33), which is an adapted version of the original Healthy Eating Index (HEI) (34). The S-HEI includes 10 food groups (vegetables, cereals, legumes, fruit, meat, dairy, sweets, soft drinks, cold meats, and variety of the diet) divided into five categories ("never or hardly ever," "one time per week," "from one to two times per week," "more than three times per week, but not daily," and "daily") according to the frequency of food intake indicated within the guidelines of the Spanish Society

1 www.sdqinfo.org

of Community Nutrition (35). The score on each food group ranged from 0 to 10 points. The total score for the S-HEI was calculated by summing the frequency of intake from the different food groups (**Supplementary Table 2**). A higher S-HEI score denotes a greater adherence to the guidelines of the Spanish Society of Community Nutrition (i.e., global quality diet). The choice of these covariates was based on prior literature (2, 22, 36–39).

Statistical analysis

Continuous information was depicted as the mean (standard deviation), while categorical information was displayed as a number (percentage). Normality assumption was tested by statistical procedures (Kolmogorov–Smirnov test), as well as graphical procedures (normal probability plot). The SDQ score did not meet the assumption of normality. Consequently, we opted for the bootstrapping technique as a reliable method to determine confidence intervals for measures of both central tendency and association, as well as robust assessments of standard errors. To assess the differences between the mean values of the SDQ score (dependent variable) across breakfast habits (independent variable), analyses of covariance (ANCOVAs) were applied. For the ANCOVAs performed, we used the following *a priori* parameters: effect size (f) = 0.10, alpha (α) error probability = 0.05, statistical power (1-β) = 0.95, number of dependent variables = 1, number of groups = 2, and number of covariates = 15. Thus, a sample size with 1,302 observations would be enough to reach high effect sizes. The effect sizes of different ANCOVAs performed were computed by omega squared (ω^2). Preliminary analyses did not indicate significant interactions between sex or age group and breakfast status, place and habits and mean differences in SDQ ($p > 0.05$ for all). Thus, all analyses were performed including both sex (girls and boys) age groups (preschoolers, children, and adolescents) together to obtain increased statistical power. Binary logistic regression analyses were performed to determine the association of psychosocial behavioural problems (dependent variable) according to breakfast status, place, and habits (independent variables). Age, sex, region, social class, immigrant status, physical activity level, recreational screen time, sleep duration, and S-HEI score were included as potential covariates. Additionally, since for most participants, breakfast consisted of a combination of habits, the analyses were adjusted for the remaining different possible habits. For instance, the consumption of "coffee, milk, tea, chocolate, cocoa, yogurt, etc." was further adjusted by the consumption of "bread, toast, cookies, pastries, etc.," "fruit and/or juice," "eggs, cheese, ham, etc.," and "other foods." Statistical analyses were conducted with SPSS 25.0 (IBM Corp, Armonk, New York, NY, United States). A p-value lower than 0.050 was applied to determine statistical significance.

Results

Table 1 depicts the characteristics of the study participants. The final sample included 3,772 Spanish young people. According to parents/guardians, 98.9% of the analysed sample ate breakfast, of whom 95.8% ate breakfast at home. The consumption of bread, toast, cereals, pastries, etc., was the most reported habit for breakfast (94.5%) by parents/guardians. The SDQ mean score was 7.4 ± 5.1. Furthermore, 12.9% of the sample presented borderline/abnormal values for the SDQ score.

The mean differences in SDQ scores in relation to breakfast status and breakfast place are shown in **Figure 1**. A higher SDQ mean score was found for those who skipped breakfast in comparison with those eating breakfast ($p < 0.001$), with a small effect size ($\omega^2 = 0.006$). Similarly, this greater SDQ mean score was found in those who ate breakfast out of home compared to those who breakfast at home ($p < 0.001$), with a small effect ($\omega^2 = 0.008$).

In relation to the mean differences between the SDQ score according to the different foods/beverages, **Figure 2** shows that those who do not consume coffee, milk, tea, chocolate, cocoa, yogurt, etc., or bread, toast, cereals, pastries, etc., for breakfast showed a greater SDQ mean score ($p < 0.05$ for both). The effect sizes for both associations were small (coffee, milk, tea, chocolate, cocoa, yogurt, etc.: $\omega^2 = 0.006$; bread, toast, cereals, pastries, etc.: $\omega^2 = 0.003$). In addition, those consuming eggs, cheese, ham, etc., for breakfast showed higher SDQ mean scores ($p = 0.006$), with a small effect ($\omega^2 = 0.003$).

On the other hand, **Figure 3** shows the association between breakfast status, place or habits and psychosocial behavioural problems. Skipping breakfast and eating breakfast out of home were linked to greater odds of psychosocial behavioural problems (skipping breakfast: OR = 3.29; CI 95%, 1.47–7.35; breakfast out of home: OR = 2.06; CI 95%, 1.27–3.33) than eating breakfast at home. Similarly, not consuming coffee, milk, tea, chocolate, cocoa, yogurt, etc., for breakfast was related to greater odds of psychosocial behavioural problems (OR = 1.76; CI 95%, 1.21–2.55), with a small effect size $\omega^2 = 0.006$). This association was also found for those who did not consume bread, toast, cereals, pastries, etc., for breakfast (OR = 1.31; CI 95%, 1.01–1.73). Conversely, not consuming eggs, cheese, ham, etc., was associated with lower odds of psychosocial behavioural problems (OR = 0.56; CI 95%, 0.38–0.83), with a small effect size ($\omega^2 = 0.003$).

Discussion

To the best of our knowledge, the present study is the first to assess the role of breakfast status, place and habits

10.3389/fnut.2022.871238

TABLE 1 Descriptive data of the study participants (N = 3,772).

Variables	M (SD)/*n* (%)	CI 95%
Age (years)	9.4 (3.2)	8.4–10.4
Sex		
Boys	1908 (50.6)	49.0–52.2
Girls	1864 (49.4)	47.8–51.0
Immigrant status		
Native	3591 (95.2)	94.5–95.9
Immigrant	181 (4.8)	4.1–5.5
Social class		
Class 1 (the highest)	507 (13.4)	12.4–14.5
Class 2	317 (8.4)	7.5–9.3
Class 3	756 (20.0)	18.8–21.3
Class 4	529 (14.0)	12.9–15.1
Class 5	1199 (31.8)	30.3–33.3
Class 6 (the lowest)	464 (12.3)	11.3–13.3
Anthropometric data		
Weight (kg)	37.5 (14.8)	37.0–38.0
Height (cm)	139.4 (20.6)	138.7–140.1
BMI (kg/m^2)	18.6 (3.7)	18.5–18.7
BMI (z-score)	0.57 (1.37)	0.53–0.61
Eating healthy		
S-HEI[a] (score)	70.0 (8.8)	69.7–70.3
Movement behaviours		
Physical activity (%, sports/physical training several times a week)	1276 (33.8)	32.3–35.3
Meeting screen time recommendation (%, yes)	1857 (49.2)	47.6–50.8
Meeting sleep duration recommendation (%, yes)	2921 (77.4)	76.1–78.8
Breakfast status		
Eating breakfast (%)	3731 (98.9)	98.6–99.2
Skipping breakfast (%)	41 (1.1)	0.8–1.4
Breakfast place		
At home (%)	3613 (96.8)	96.3–97.4
Out of home (%)	118 (3.2)	2.6–3.7
Breakfast habit		
Coffee, milk, tea, chocolate, cocoa, yogurt, etc. (%, yes)	3563 (94.5)	93.7–95.2
Bread, toast, cookies, cereals, pastries, etc. (%, yes)	3330 (88.3)	87.3–89.3
Fruit and/or juice (%, yes)	780 (20.7)	19.4–22.0
Eggs, cheese, ham, etc. (%, yes)	197 (5.2)	4.5–5.9
Other foods (%, yes)	53 (1.4)	1.0–1.8
Psychosocial behavioural problems		
SDQ (score)[b]	7.4 (5.1)	7.2–7.6
Normal (%)	3295 (87.0)	86.3–88.4
Borderline (%)	259 (6.8)	6.1–7.7
Abnormal (%)	232 (6.1)	5.4–6.9

BMI, body mass index; SDQ, strengths and difficulties questionnaire; S-HEI, Spanish healthy eating index.
[a]Spanish Healthy Eating Index ranges from 0 to 100 points (33).
[b]Strengths and Difficulties Questionnaire ranges from 0 to 40 points (26).

related to the intake of certain food/beverages groups and psychosocial behavioural problems in a young population. In the present study, we found that skipping breakfast, eating breakfast out of home, and eating some breakfast habits were associated with higher or lower odds of psychosocial behavioural problems in the young population after adjustment for several sociodemographic, anthropometric, and lifestyle factors.

One interesting finding is that skipping breakfast was associated with higher odds of psychosocial behavioural problems. Similarly, an association between an unhealthy diet and psychosocial behavioural problems has been suggested in the young population (8, 9), as well as in other age stages (8). Recently, a meta-analysis by Mullan and Singh (18) found that skipping breakfast was positively associated with odds of depression, stress and psychological distress in all age groups and anxiety in adolescence. Richards and Smith (40) showed that not eating breakfast daily was linked to psychosocial behavioural problems (e.g., anxiety, stress, depression). Despite this evidence, there are no well-defined mechanisms that explain why skipping breakfast might affect psychosocial health (8). Two possible explanations could partly justify this finding. First, a young population skipping breakfast might not be able to obtain the nutrients lost with the rest of the meals of the day (41). Second, children and adolescents who skip breakfast may compensate for their daily energy intake by consuming more energy-dense foods during the rest of the day or during lunch (42). These two factors could lead to an overall unhealthy/low-quality diet, which has been associated with depression or poorer psychosocial health in the young population (9, 22). Accordingly, breakfast consumption, as a part of healthy eating habits, may be promoted as a helpful approach to prevent psychosocial health problems (8).

Another interesting finding of this study is that young people who eat breakfast out of home showed higher odds of psychosocial behavioural problems than those who eat breakfast out of home. One reason explaining (at least partially) our results may be related to family meals. The social context (e.g., breakfast at home) may play a key role in breakfast intake, as it appears to be associated with higher quality breakfast intake (i.e., including dairy, cereal, and fruit groups) (18, 43). Children and adolescents who eat breakfast at home are more likely to do so in the presence of their family members. Thus, Kameyama et al. (44) showed that children (aged 7–12 years) who ate breakfast with their families less than once a week and those who ate breakfast alone on weekends showed a greater prevalence of borderline or abnormal psychosocial health status than those who ate breakfast seven times a week and those who ate breakfast on weekends with their families, respectively. Furthermore, one study by Videon and Manning (45) indicated that adolescents who regularly used to eat out of home/missed family meals show a greater prevalence of skipping breakfast, as well as a lower quality diet (e.g., low intake of dairy products). Similarly, Agathão et al. (46)

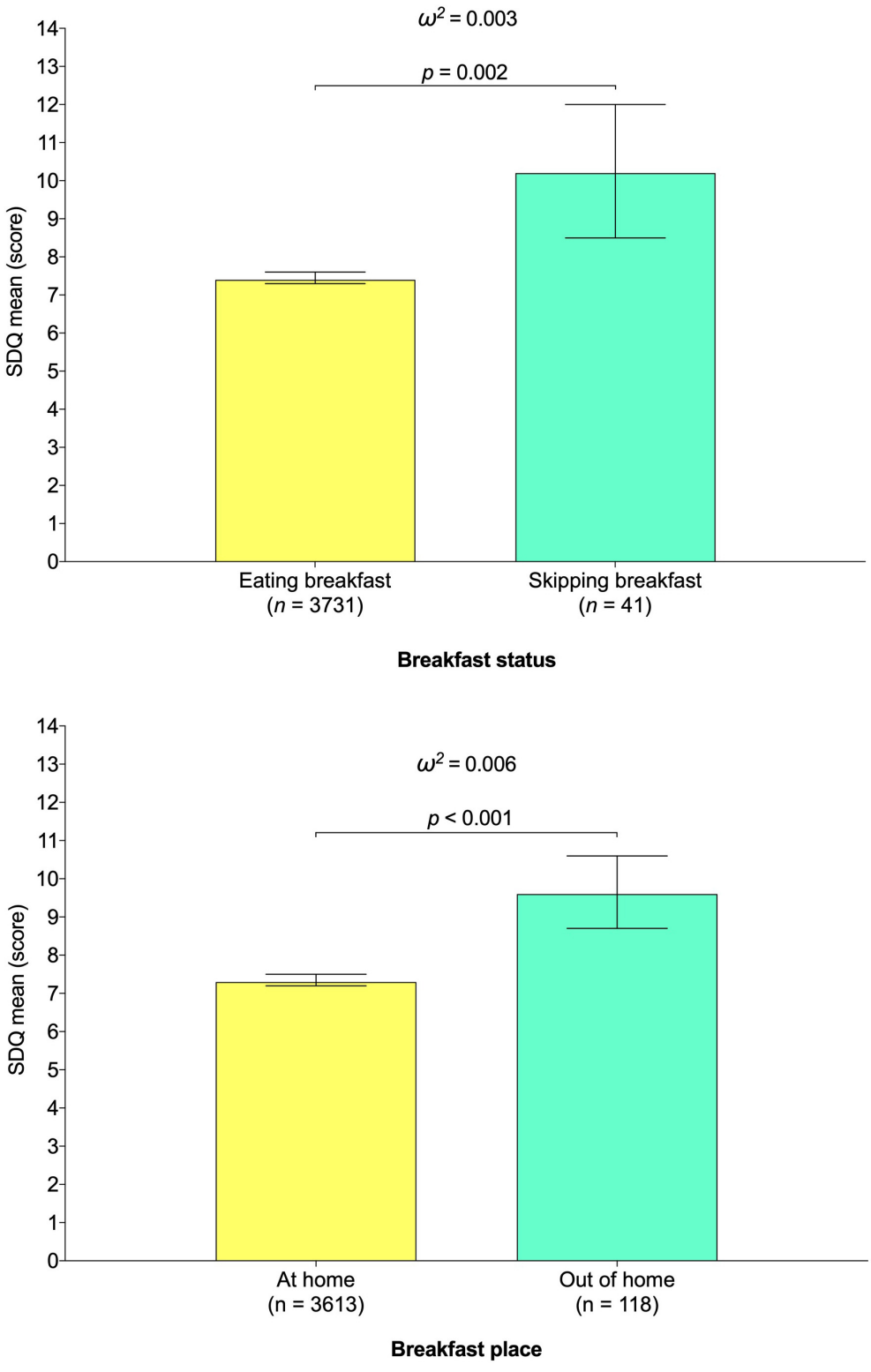


FIGURE 1
Association between breakfast status and breakfast place and Strengths and Difficulties Questionnaire mean score in young population. Estimated mean (bars) and 95% CIs (lines) represent values after adjustment for age, sex, region, social class, immigrant status, excess weight, physical activity level, recreational screen time, sleep duration, Spanish Healthy Eating Index score, and breakfast habits.

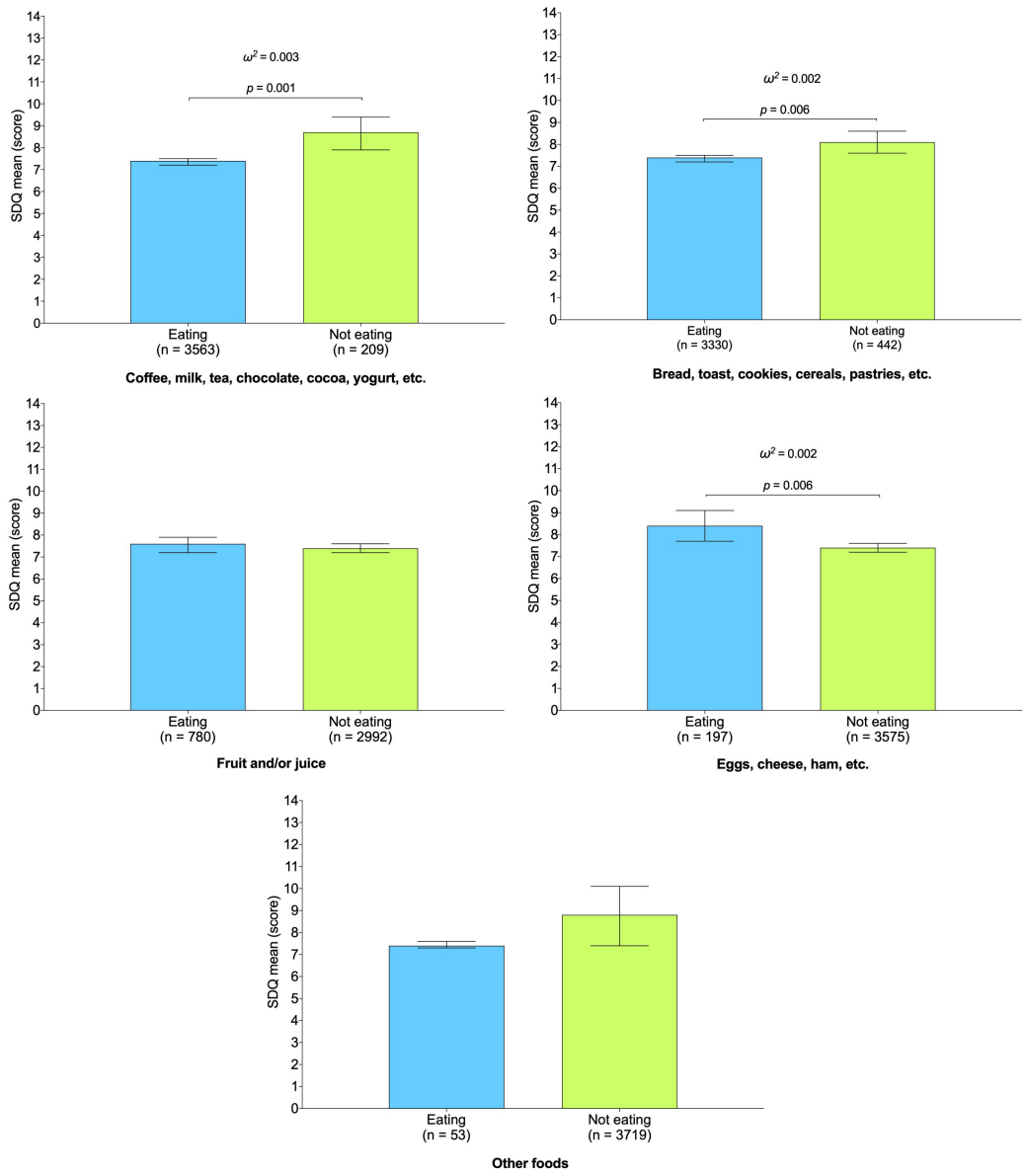


FIGURE 2
Association between different breakfast habits and Strengths and Difficulties Questionnaire mean score in young population. Estimated mean (bars) and 95% CIs (lines) represent values after adjustment for age, sex, region, social class, immigrant status, excess weight, physical activity level, recreational screen time, sleep duration, and Spanish Healthy Eating Index score. Analyses were also adjusted for the remaining possible habits (i.e., the consumption of "coffee, milk, tea, chocolate, cocoa, yoghurt, etc." was further adjusted for "bread, toast, biscuits, pastries, etc.," "fruit and/or juice," "eggs, cheese, ham, etc.", and "other foods."

pointed out the key protective role of regular family meals for psychosocial health. This is because family meals can facilitate parents to connect emotionally with children through feelings of closeness and belonging (47), as well as identify early changes in existing behavioural patterns (e.g., dress, friendships and academic performance) that may be associated with behavioural modification (48). In addition, family meals are a family time that provides an opportunity for families to connect despite the ongoing intense demands of modern life (49). Thus, current evidence indicates positive relations between diet quality and physical, emotional and mental strength in the young population, suggesting, as a promising strategy, the promotion of family-based meals, with a focus on breakfast. One possible reason justifying this relationship is that family meals (e.g., breakfast) could offer a formal/informal time in which parents/guardians could connect with their children's emotional well-being (50), control children's behaviours, or establish norms and restrictions (19). Another possible reason

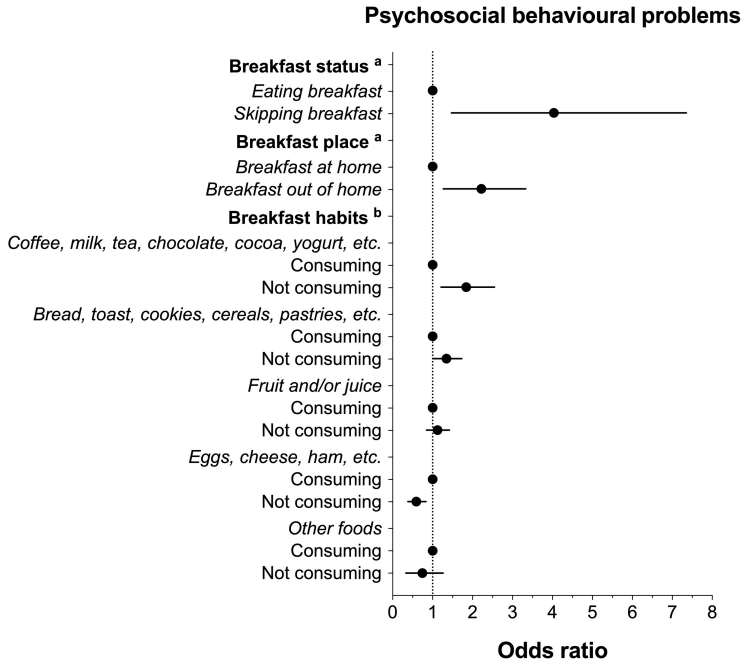


FIGURE 3
Odds of psychosocial behavioural problems according to breakfast status, place and habits. Data expressed as odds ratio (dots) and standard error (bars). No psychosocial behavioural problems group was considered as the reference category. Adjusted by age, sex, region, social class, immigrant status, excess weight, physical activity level, recreational screen time, sleep duration, and Spanish Healthy Eating Index score. [a]Analyses were further adjusted by breakfast habits. [b]Analyses were also adjusted for the remaining possible breakfast habits (i.e., the consumption of "coffee, milk, tea, chocolate, cocoa, yoghurt, etc." was further adjusted for "bread, toast, biscuits, pastries, etc.," "fruit and/or juice," "eggs, cheese, ham, etc.," and "other foods").

could lie in the relationship between breakfast out of home and a lower-quality breakfast/global diet. Eating out of home has been related to energy-dense and high-fat food consumption, as well as a lack of micronutrients (20). This association has also been shown in children (21). All of these aspects are associated with a lower quality breakfast/global diet, which has been associated with psychosocial behavioural problems among young people (22). Therefore, it seems reasonable to promote breakfast at home, preferably with the family and in a relaxed atmosphere, since family members have a great influence on the acquisition of habits among the young population (51).

On the other hand, we found that breakfast habits related to the intake of certain food/beverages groups were associated with lower (e.g., not consuming eggs, cheese, ham) or higher odds of psychosocial behavioural problems (e.g., not consuming coffee, milk, tea, chocolate, cocoa, yogurt, or not consuming bread, toast, cereals, pastries). With the questions provided by the Spanish National Health Survey, we are not able to know what and how many foods are consumed within a food group. For instance, it is possible that young people including in the group "coffee, milk, tea, chocolate, cocoa, yogurt, etc." consume milk or dairy products and not necessarily coffee. In fact, coffee consumption is not recommended for Spanish young people (14), and its intake is low among this population (52). Supporting this idea, the latest breakfast recommendations in Spain separate coffee from the group "milk or dairy products" and include it in the group "other foods" (51). Given the impossibility of separating foods from the established groups, future editions of the national health survey should provide more specific questions regarding the breakfast composition of the young population. Nevertheless, breakfast habits can potentially impact psychosocial behavioural problems through several pathways. In this sense, there are dietary benefits of consuming breakfast, specifically if it includes cereals, grains, lower fat milk, and fruit/fruit juices, in comparison to the potential negative impact of skipping breakfast (53). This is mainly because they are suitable nutrient sources that may influence brain function, including carbohydrates, calcium, B-complex vitamins (including folate), dietary fibre, and iron (11). Supporting this notion, there is emerging evidence of the relationship between breakfast cereal intake and higher feelings of well-being (54) (although further research is necessary). Likewise, whole grains are rich in several macronutrients, including magnesium that may have beneficial effects on psychosocial health (55). In addition, Ferrer-Cascales et al. (56) revealed that a high-quality breakfast, characterised by the intake of cereal and dairy products, is related to a higher health-related quality of life and lower levels of perceived

stress and depressive symptoms in adolescents. Similarly, adolescents eating a high-quality breakfast (e.g., cereals, milk) had an improved overall dietary pattern compared with their counterparts eating a low-quality breakfast (57). Similarly, children who ate breakfast had greater daily protein and energy consumption than children who skipped breakfast (58). Concerning psychosocial behavioural problems, it has been shown that the type of breakfast or lunch was associated with significant differences in well-being scores (59) and high levels of quality of life compared with those who eat a low-quality breakfast (in children) (60). Furthermore, O'Sullivan et al. (11) found in adolescents that for every additional food group eaten at breakfast, the associated total mental health score decreased after adjustment for potential confounding factors. The beneficial influence of an adequate quality breakfast (as a healthy lifestyle indicator) is especially important during childhood and adolescence, when dietary and other lifestyle habits begin to be acquired, resulting in long-term health and nutritional advantages in adulthood (60). Thus, the prevention of psychosocial behavioural problems in young populations supports the prevention of the onset in adulthood, suggesting that promoting a healthy breakfast (at home if possible) as a modifiable factor could be effective in preventing such problems (8).

Although the mechanisms through which breakfast habits contribute to decreased psychosocial behavioural problems remain unclear, certain mechanisms have been suggested. Thus, after eating breakfast, carbohydrates from foods (e.g., cereals, milk) are transformed into glucose, generating alterations in the levels of insulin, glutamate, acetylcholine, serotonin, and cortisol (11, 61). Carbohydrate intake is especially helpful for the brain after night fasting since it diminishes the production of cortisol levels, thereby reducing the "stress" signal (62). Furthermore, the transformation of carbohydrates into glucose is crucial for tryptophan formation, a precursor protein involved in the synthesis of serotonin, which regulates depressive symptoms, cognitive functioning, and irritable mood (63). Similarly, the consumption of tryptophan-rich foods has been noted as important to maintain a high quality of sleep and morning-type diurnal rhythm and indirectly improved psychosocial health, probably by the metabolism of tryptophan to serotonin in the daytime and melatonin at night in children (64). In contrast, the potentially beneficial effect of other vitamins (e.g., vitamin D) on psychosocial health in children has been pointed out in a recent systematic review (65). Additionally, it has been suggested that lower vitamin D levels may be linked to depression among children and adolescents (66). Thus, the consumption of milk and/or dairy products may provide greater amounts of vitamin D and, consequently, help to reduce the odds of psychosocial behavioural problems. In addition, B-complex vitamin deficiency (e.g., folate, B6, and B12) might also affect psychosocial behavioural problems, and it has been associated with mood and cognitive performance (67). Similarly, dietary patterns have been related to depression *via* alterations in folate and vitamin B12 serum levels (68). Moreover, Esnafoglu and Ozturan (66) has indicated that vitamin B12 and increased homocysteine may support the etiopathogenesis of depression. In addition, dietary fibre intake could also help in psychosocial behavioural problems. A meta-analysis of observational studies by Fatahi et al. (69) showed that a greater intake of total dietary fibre was linked to lower odds of depression, suggesting some possible mechanisms that could explain this association, such as the variations in the intestinal microbiome composition and the decrease in oxidative stress. Supporting this notion, one possible hypothesis is that a higher consumption in fibre-rich healthy foods (e.g., bread, cereals) may (to some degree) explain the association found. Another finding is the association found between the non-consumption of high-protein foods (e.g., eggs, cheese, ham) and lower odds of psychosocial behavioural problems. One possible explanation of this finding may be related to the ratio of carbohydrates/protein in the dietary intake. A higher intake of high-protein foods (e.g., eggs, cheese, ham) might displace carbohydrate-rich foods and modify the ratio of protein to carbohydrate, which has been related to consistent and reciprocal changes in important regulatory factors (e.g., cortisol). Despite this fact, it must be considered that the intake of some protein-rich foods (e.g., eggs) contains high amounts of choline that is essential for producing neurotransmitters that can positively affect psychosocial health (70). Based on the above, recommending what is considered a healthy breakfast in Spain [i.e., hot drink (e.g., milk, cacao), accompanied by a solid food (e.g., bread, toasts), and fruit/fruit juice (25)], could be useful for the prevention of psychosocial problems in young people.

This current study includes some limitations that should be noted. First, due to the cross-sectional design of this study, we cannot establish whether the observed relationships imply cause and effect associations. Longitudinal studies are necessary to determine how breakfast status, place and habits related to the intake of certain food/beverages groups could exert an essential role on psychosocial behavioural problems. Notwithstanding, this cross-sectional analysis could serve as a helpful first step in detecting relations between breakfast patterns and psychosocial behavioural problems in youth. Second, this study did not consider the influence of both daily energy intake and parental feeding practices, since there was no information available on both variables for analyses. Future studies using 24-h dietary recall or dietary history are needed to obtain more accurate information. However, it is complex to use more specific methodologies in relation to dietary intake or parental feeding practices in national epidemiological studies. Third, we were not able to establish individual associations between the consumption of a specific food and psychosocial behavioural problems, since frequencies and serving sizes of consumption of different breakfast items were not assessed. However, the

Spanish National Health Survey (2017), as well as previous waves, were designed to report information related to a typical Spanish complete breakfast (25). Fourth, we used parent-reported questionnaires. For this reason, both measurement and recall bias are still plausible. Nonetheless, information was reported by parents/guardians and not by young people, which may be closer to the reality of their children's breakfasts. Likewise, the SDQ and HEI are validated and useful instruments that have been widely used in the scientific literature for both psychosocial behavioural problems and diet quality. Fifth, BMI and excess weight were determined through height and weight reported by the parents/guardians for children and adolescents, which could introduce measurement error. Conversely, the main strength of this study is that, to date, it is the first study to examine the relationship between breakfast status, place and habits related to the intake of certain food/beverages groups and the association of psychosocial behavioural problems among a young population. Another strength is the nationwide, large sample of children and adolescents analysed. It is noteworthy that the relationship between breakfast (as an isolated meal) and the odds of psychosocial behavioural problems has been assessed. Therefore, it should be considered that a child or adolescent may not consume some of the foods listed for breakfast (e.g., fruits) and consume them later in the day at other meals. To try to minimise this concern, we adjusted the analyses performed by global quality diet (through the S-HEI score). Despite this fact, caution is required to interpret our results.

Conclusion

Our results show that skipping breakfast or eating breakfast out of home is associated with higher odds of psychosocial behavioural problems in a nationwide, large sample of Spanish children and adolescents. Similarly, some habits related to the consumption of certain foods/beverages are related to higher or lower odds of psychosocial behavioural problems. This finding is clinically meaningful, as psychosocial behavioural problems are one of the most important worldwide worries in the young population. It might be possible to underscore the significance of focussing not only on breakfast intake but also on habits related to the consumption of certain foods/beverages to try to reduce the deleterious effects of psychosocial behavioural problems in young populations. Nevertheless, further studies with different designs are needed to verify cause-effect associations.

Data availability statement

Publicly available datasets were analysed in this study. This data can be found here: https://www.sanidad.gob.es/estadisticas/microdatos.do.

Ethics statement

Ethical approval was not provided for this study on human participants because following the Spanish regulations, no ethics committee approval was needed for this study, due to the use of secondary data. Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin.

Author contributions

JL-G: conceptualisation, software, validation, formal analysis, and data curation. JL-G and LS: writing—original draft preparation. LS, RL-B, and PT-L: writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Acknowledgments

JL-G is a Margarita Salas Fellow (Universidad de Castilla-La Mancha – 2021-MS-20563).

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.2022.871238/full#supplementary-material

References

1. Smith L, Hamer M. Sedentary behaviour and psychosocial health across the life course. In: Leitzmann MF, Jochem C, Schmid D editors. *Sedentary behaviour epidemiology. Springer series on epidemiology and public health*. Cham: Springer International Publishing (2018). p. 311–8. doi: 10.1016/j.ypmed.2015.12.012

2. World Health Organization [WHO]. *Social determinants of mental health*. Geneva: World Health Organization (2014). p. 52.

3. World Health Organization [WHO]. *Adolescent mental health*. Geneva: World Health Organization (2020).

4. Guthold R, White Johansson E, Mathers CD, Ross DA. Global and regional levels and trends of child and adolescent morbidity from 2000 to 2016: An analysis of years lost due to disability (YLDs). *BMJ Glob Health.* (2021) 6:e004996. doi: 10.1136/bmjgh-2021-004996

5. Otto C, Reiss F, Voss C, Wüstner A, Meyrose A-K, Hölling H, et al. Mental health and well-being from childhood to adulthood: Design, methods and results of the 11-year follow-up of the BELLA study. *Eur Child Adolesc Psychiatry.* (2020) 30:1559–77. doi: 10.1007/s00787-020-01630-4

6. World Health Organization [WHO]. *The WHO special initiative for mental health (2019-2023): Universal health coverage for mental health*. Geneva: World Health Organization (2019).

7. Ortuño-Sierra J, Fonseca-Pedrero E, Paíno M, Aritio-Solana R. Prevalencia de síntomas emocionales y comportamentales en adolescentes españoles. *Rev Psiquiatr Salud Ment.* (2014) 7:121–30. doi: 10.1016/j.rpsm.2013.12.003

8. Zahedi H, Djalalinia S, Sadeghi O, Zare Garizi F, Asayesh H, Payab M, et al. Breakfast consumption and mental health: A systematic review and meta-analysis of observational studies. *Nutr Neurosci.* (2022) 25:1250–64. doi: 10.1080/1028415X.2020.1853411

9. Khalid S, Williams CM, Reynolds SA. Is there an association between diet and depression in children and adolescents? A systematic review. *Br J Nutr.* (2016) 116:2097–108. doi: 10.1017/S0007114516004359

10. Rani R, Dharaiya CN, Singh B. Importance of not skipping breakfast: A review. *Int J Food Sci Technol.* (2021) 56:28–38. doi: 10.1111/ijfs.14742

11. O'Sullivan TA, Robinson M, Kendall GE, Miller M, Jacoby P, Silburn SR, et al. A good-quality breakfast is associated with better mental health in adolescence. *Public Health Nutr.* (2009) 12:249–58. doi: 10.1017/S1368980008003935

12. Giovannini M, Verduci E, Scaglioni S, Salvatici E, Bonza M, Riva E, et al. Breakfast: A good habit, not a repetitive custom. *J Int Med Res.* (2008) 36:613–24. doi: 10.1177/147323000803600401

13. Scheffers FR, Boer JMA, Verschuren WMM, Verheus M, van der Schouw YT, Sluijs I, et al. Pure fruit juice and fruit consumption and the risk of CVD: The European Prospective Investigation into Cancer and Nutrition–Netherlands (EPIC-NL) study. *Br J Nutr.* (2019) 121:351–9. doi: 10.1017/S0007114518003380

14. Aranceta-Bartrina J, Partearroyo T, López-Sobaler AM, Ortega RM, Varela-Moreiras G, Serra-Majem L, et al. Updating the food-based dietary guidelines for the Spanish population: The Spanish society of community nutrition (SENC) proposal. *Nutrients.* (2019) 11:2675. doi: 10.3390/nu11112675

15. Papoutsou S, Briassoulis G, Hadjigeorgiou C, Savva SC, Solea T, Hebestreit A, et al. The combination of daily breakfast consumption and optimal breakfast choices in childhood is an important public health message. *Int J Food Sci Nutr.* (2014) 65:273–9. doi: 10.3109/09637486.2013.854750

16. Sawa S, Hashizume K, Abe T, Kusaka Y, Fukazawa Y, Hiraku Y, et al. Pathway linking physical activity, sleep duration, and breakfast consumption with the physical/psychosocial health of schoolchildren. *J Child Health Care.* (2021) 25:5–17. doi: 10.1177/1367493519891019

17. Ahadi Z, Kelishadi R, Qorbani M, Zahedi H, Aram M, Motlagh ME, et al. Association of breakfast intake with psychiatric distress and violent behaviors in iranian children and adolescents: The CASPIAN- IV study. *Indian J Pediatr.* (2016) 83:922–9. doi: 10.1007/s12098-016-2049-7

18. Mullan BA, Singh M. A systematic review of the quality, content, and context of breakfast consumption. *Nutr Food Sci.* (2010) 40:81–114. doi: 10.1108/00346651011015953

19. Scaglioni S, De Cosmi V, Ciappolino V, Parazzini F, Brambilla P, Agostoni C. Factors influencing children's eating behaviours. *Nutrients.* (2018) 10:706. doi: 10.3390/nu10060706

20. Lachat C, Nago E, Verstraeten R, Roberfroid D, Van Camp J, Kolsteren P. Eating out of home and its association with dietary intake: A systematic review of the evidence: Eating out and diet. *Obes Rev.* (2012) 13:329–46. doi: 10.1111/j.1467-789X.2011.00953.x

21. Moreira T, Severo M, Oliveira A, Ramos E, Rodrigues S, Lopes C. Eating out of home and dietary adequacy in preschool children. *Br J Nutr.* (2015) 114:297–305. doi: 10.1017/S0007114515001713

22. O'Neil A, Quirk SE, Housden S, Brennan SL, Williams LJ, Pasco JA, et al. Relationship between diet and mental health in children and adolescents: A systematic review. *Am J Public Health.* (2014) 104:e31–42. doi: 10.2105/AJPH.2014.302110

23. Ministry of Health, Consumer Affairs and Social Welfare. *Spanish National Health Survey*. Madrid: Ministry of Health, Consumer Affairs and Social Welfare (2018).

24. National Statistics Institute. *National health survey. Results. Madrid, España*. (2018). Available online at: https://www.ine.es/dyngs/INEbase/es/operacion.htm?c=Estadistica_C&cid=1254736176783&menu=resultados&idp=1254735573175#!tabs-1254736195650 (accessed November 1, 2021).

25. Aranceta Bartrina J, Pérez Rodrigo C, Serra Majem L, Delgado Rubio A. Hábitos alimentarios de los alumnos usuarios de comedores escolares en España. Estudio «Dime Cómo Comes». *Aten Primaria.* (2004) 33:131–9.

26. Goodman R. The strengths and difficulties questionnaire: A research note. *J Child Psychol Psychiatry.* (1997) 38:581–6. doi: 10.1111/j.1469-7610.1997.tb01545.x

27. Ezpeleta L, Granero R, de la Osa N, Penelo E, Domènech JM. Psychometric properties of the strengths and difficulties Questionnaire3–4 in 3-year-old preschoolers. *Compr Psychiatry.* (2013) 54:282–91. doi: 10.1016/j.comppsych.2012.07.009

28. Cole TJ, Lobstein T. Extended international (IOTF) body mass index cut-offs for thinness, overweight and obesity: Extended international BMI cut-offs. *Pediatr Obes.* (2012) 7:284–94. doi: 10.1111/j.2047-6310.2012.00064.x

29. Roman-Viñas B, Serra-Majem L, Hagströmer M, Ribas-Barba L, Sjöström M, Segura-Cardona R. International physical activity questionnaire: Reliability and validity in a Spanish population. *Eur J Sport Sci.* (2010) 10:297–304. doi: 10.1080/17461390903426667

30. World Health Organization [WHO]. *Guidelines on physical activity, sedentary behaviour, and sleep for children under 5 years of age*. (2019). Available online at: http://www.ncbi.nlm.nih.gov/books/NBK541170/ (accessed December 4, 2020).

31. Tremblay MS, Carson V, Chaput J-PP, Connor Gorber S, Dinh T, Duggan M, et al. Canadian 24-hour movement guidelines for children and youth: An integration of physical activity, sedentary behaviour, and sleep. *Appl Physiol Nutr Metab.* (2016) 41:S311–27. doi: 10.1139/apnm-2016-0203

32. Hirshkowitz M, Whiton K, Albert SM, Alessi C, Bruni O, DonCarlos L, et al. National Sleep Foundation's updated sleep duration recommendations: Final report. *Sleep Health.* (2015) 1:233–43. doi: 10.1016/j.sleh.2015.10.004

33. Norte Navarro AI, Ortiz Moncada R. [Spanish diet quality according to the healthy eating index]. *Nutr Hosp.* (2011) 26:330–6. doi: 10.1590/S0212-16112011000200014

34. Kennedy ET, Ohls J, Carlson S, Fleming K. The healthy eating index. *J Am Diet Assoc.* (1995) 95:1103–8. doi: 10.1016/S0002-8223(95)00300-2

35. Spanish Society of Community Nutrition (SSCN). *Healthy dietary guidelines*. (2014). Available online at: http://www.nutricioncomunitaria.org/es/otras-publicaciones (accessed November 1, 2021).

36. Zhang J, Paksarian D, Lamers F, Hickie IB, He J, Merikangas KR. Sleep patterns and mental health correlates in US adolescents. *J Pediatr.* (2017) 182:137–43. doi: 10.1016/j.jpeds.2016.11.007

37. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics.* (2016) 138:e20161642. doi: 10.1542/peds.2016-1642

38. Stiglic N, Viner RM. Effects of screentime on the health and well-being of children and adolescents: A systematic review of reviews. *BMJ Open.* (2019) 9:e023191. doi: 10.1136/bmjopen-2018-023191

39. Sutaria S, Devakumar D, Yasuda SS, Das S, Saxena S. Is obesity associated with depression in children? Systematic review and meta-analysis. *Arch Dis Child.* (2019) 104:64–74. doi: 10.1136/archdischild-2017-314608

40. Richards G, Smith AP. Breakfast and energy drink consumption in secondary school children: Breakfast omission, in isolation or in combination with frequent energy drink use, is associated with stress, anxiety, and depression cross-sectionally, but not at 6-month follow-up. *Front Psychol.* (2016) 7:106. doi: 10.3389/fpsyg.2016.00106

41. Ramsay SA, Bloch TD, Marriage B, Shriver LH, Spees CK, Taylor CA. Skipping breakfast is associated with lower diet quality in young US children. *Eur J Clin Nutr.* (2018) 72:548–56. doi: 10.1038/s41430-018-0084-3

42. Barrett N, Riordan F, Michels N, Frost Andersen L, vant Veer P, Moreno LA, et al. Breakfast Skipping and overweight/obesity among European adolescents, a cross-sectional analysis of the HELENA dataset: A DEDIPAC study. *HRB Open Res.* (2018) 1:19. doi: 10.12688/hrbopenres.12847.1

43. Aranceta J, Serra-Majem L, Ribas L, Pérez-Rodrigo C. Breakfast consumption in Spanish children and young people. *Public Health Nutr.* (2001) 4:1439–44. doi: 10.1079/PHN2001235

44. Kameyama N, Morimoto Y, Hashimoto A, Inoue H, Nagaya I, Nakamura K, et al. The relationship between family meals and mental health problems in Japanese elementary school children: A cross-sectional study. *Int J Environ Res Public Health.* (2021) 18:9281. doi: 10.3390/ijerph18179281

45. Videon TM, Manning CK. Influences on adolescent eating patterns: The importance of family meals. *J Adolesc Health.* (2003) 32:365–73. doi: 10.1016/S1054-139X(02)00711-5

46. Agathão BT, Cunha DB, Sichieri R, Lopes CS. The role of family meal frequency in common mental disorders in children and adolescents over eight months of follow-up. *PLoS One.* (2021) 16:e0243793. doi: 10.1371/journal.pone.0243793

47. Jones BL. Making time for family meals: Parental influences, home eating environments, barriers and protective factors. *Physiol Behav.* (2018) 193:248–51. doi: 10.1016/j.physbeh.2018.03.035

48. Skeer MR, Ballard EL. Are family meals as good for youth as we think they are? A review of the literature on family meals as they pertain to adolescent risk prevention. *J Youth Adolesc.* (2013) 42:943–63. doi: 10.1007/s10964-013-9963-z

49. Smith SL, Ramey E, Sisson SB, Richardson S, DeGrace BW. The family meal model: Influences on family mealtime participation. *OTJR Occup Particip Health.* (2020) 40:138–46. doi: 10.1177/1539449219876878

50. Eisenberg ME, Olson RE, Neumark-Sztainer D, Story M, Bearinger LH. Correlations between family meals and psychosocial well-being among adolescents. *Arch Pediatr Adolesc Med.* (2004) 158:792. doi: 10.1001/archpedi.158.8.792

51. Spanish Foundation for Nutrition [SFN]. *Breakfast situation in Spain*. Madrid: Spanish Foundation for Nutrition (2018).

52. Fernández-Alvira JM, Iglesia I, Ferreira-Pêgo C, Babio N, Salas-Salvadó J, Moreno LA. Fluid intake in Spanish children and adolescents; a cross-sectional study. *Nutr Hosp.* (2014) 29:1163–70. doi: 10.3305/nh.2014.29.5.7420

53. O'Neil CE, Nicklas TA, Fulgoni VL III. Nutrient intake, diet quality, and weight measures in breakfast patterns consumed by children compared with breakfast skippers: NHANES 2001-2008. *AIMS Public Health.* (2015) 2:441–68. doi: 10.3934/publichealth.2015.3.441

54. Williams PG. The benefits of breakfast cereal consumption: A systematic review of the evidence base. *Adv Nutr.* (2014) 5:636S–73S. doi: 10.3945/an.114.006247

55. Anjom-Shoae J, Sadeghi O, Hassanzadeh Keshteli A, Afshar H, Esmaillzadeh A, Adibi P. The association between dietary intake of magnesium and psychiatric disorders among Iranian adults: A cross-sectional study. *Br J Nutr.* (2018) 120:693–702. doi: 10.1017/S0007114518001782

56. Ferrer-Cascales R, Sánchez-SanSegundo M, Ruiz-Robledillo N, Albaladejo-Blázquez N, Laguna-Pérez A, Zaragoza-Martí A. Eat or skip breakfast? The important role of breakfast quality for health-related quality of life, stress and depression in Spanish adolescents. *Int J Environ Res Public Health.* (2018) 15:1781. doi: 10.3390/ijerph15081781

57. Matthys C, De Henauw S, Bellemans M, De Maeyer M, De Backer G. Breakfast habits affect overall nutrient profiles in adolescents. *Public Health Nutr.* (2007) 10:413–21. doi: 10.1017/S1368980007248049

58. Chitra U, Reddy CR. The role of breakfast in nutrient intake of urban schoolchildren. *Public Health Nutr.* (2007) 10:55–8. doi: 10.1017/S1368980007219640

59. Hayhoe R, Rechel B, Clark AB, Gummerson C, Smith SJL, Welch AA. Cross-sectional associations of schoolchildren's fruit and vegetable consumption, and meal choices, with their mental well-being: A cross-sectional study. *BMJ Nutr Prev Health.* (2021) 4:447. doi: 10.1136/bmjnph-2020-000205

60. Chen X, Sekine M, Hamanishi S, Wang H, Gaina A, Yamagami T, et al. Lifestyles and health-related quality of life in Japanese school children: A cross-sectional study. *Prev Med.* (2005) 40:668–78. doi: 10.1016/j.ypmed.2004.09.034

61. Hoyland A, Dye L, Lawton CL. A systematic review of the effect of breakfast on the cognitive performance of children and adolescents. *Nutr Res Rev.* (2009) 22:220–43. doi: 10.1017/S0954422409990175

62. Lee SA, Park EC, Ju YJ, Lee TH, Han E, Kim TH. Breakfast consumption and depressive mood: A focus on socioeconomic status. *Appetite.* (2017) 114:313–9. doi: 10.1016/j.appet.2017.04.007

63. Miller AH, Maletic V, Raison CL. Inflammation and its discontents: The role of cytokines in the pathophysiology of major depression. *Biol Psychiatry.* (2009) 65:732–41. doi: 10.1016/j.biopsych.2008.11.029

64. Harada T, Hirotani M, Maeda M, Nomura H, Takeuchi H. Correlation between breakfast tryptophan content and morningness–eveningness in japanese infants and students aged 0–15 yrs. *J Physiol Anthropol.* (2007) 26:201–7. doi: 10.2114/jpa2.26.201

65. Głąbska D, Kołota A, Lachowicz K, Skolmowska D, Stachoń M, Guzek D. The influence of vitamin D intake and status on mental health in children: A systematic review. *Nutrients.* (2021) 13:952. doi: 10.3390/nu13030952

66. Esnafoglu E, Ozturan DD. The relationship of severity of depression with homocysteine, folate, vitamin B12, and vitamin D levels in children and adolescents. *Child Adolesc Ment Health.* (2020) 25:249–55. doi: 10.1111/camh.12387

67. Lang UE, Beglinger C, Schweinfurth N, Walter M, Borgwardt S. Nutritional aspects of depression. *Cell Physiol Biochem.* (2015) 37:1029–43. doi: 10.1159/000430229

68. Khosravi M, Sotoudeh G, Amini M, Raisi F, Mansoori A, Hosseinzadeh M. The relationship between dietary patterns and depression mediated by serum levels of Folate and vitamin B12. *BMC Psychiatry.* (2020) 20:63. doi: 10.1186/s12888-020-2455-2

69. Fatahi S, Matin SS, Sohouli MH, Gãman M-A, Raee P, Olang B, et al. Association of dietary fiber and depression symptom: A systematic review and meta-analysis of observational studies. *Complement Ther Med.* (2021) 56:102621. doi: 10.1016/j.ctim.2020.102621

70. van Lee L, Quah PL, Saw SM, Yap FKP, Godfrey KM, Chong YS, et al. Maternal choline status during pregnancy, but not that of betaine, is related to antenatal mental well-being: The growing up in Singapore toward healthy outcomes cohort. *Depress Anxiety.* (2017) 34:877–87. doi: 10.1002/da.22637

frontiers | Frontiers in Public Health

TYPE Original Research
PUBLISHED 28 September 2022
DOI 10.3389/fpubh.2022.949170

OPEN ACCESS

EDITED BY
Yutang Wang,
Federation University Australia, Australia

REVIEWED BY
Rui Pu,
Zhejiang University, China
Mengqi Su,
University of Hongkong-Shenzhen Hospital, China

*CORRESPONDENCE
Wenbo Jiang
102593@hrbmu.edu.cn
Wei Wei
weiweibubble1994@163.com
Changhao Sun
changhaosun2002@163.com

†These authors have contributed equally to this work

SPECIALTY SECTION
This article was submitted to Public Health and Nutrition, a section of the journal Frontiers in Public Health

RECEIVED 20 May 2022
ACCEPTED 25 August 2022
PUBLISHED 28 September 2022

CITATION
Wu H, Wang J, Jiang H, Liu X, Sun X, Chen Y, Hu C, Wang Z, Han T, Sun C, Wei W and Jiang W (2022) The association of dietary spermidine with all-cause mortality and CVD mortality: The U.S. National Health and Nutrition Examination Survey, 2003 to 2014. *Front. Public Health* 10:949170. doi: 10.3389/fpubh.2022.949170

The association of dietary spermidine with all-cause mortality and CVD mortality: The U.S. National Health and Nutrition Examination Survey, 2003 to 2014

Huanyu Wu[1†], Jianing Wang[2†], Hongyan Jiang[1†], Xin Liu[1], Xinyi Sun[1], Yunyan Chen[1], Cong Hu[1], Zheng Wang[1], Tianshu Han[1], Changhao Sun[1*], Wei Wei[1*] and Wenbo Jiang[1*]

[1]National Key Discipline, Department of Nutrition and Food Hygiene, School of Public Health, Harbin Medical University, Harbin, China, [2]Department of Cerebrovascular Disease, The Fifth Afliated Hospital, Sun Yat-sen University, Zhuhai, China

Background: Current studies on the protective effects of dietary spermidine (SPD) on cardiovascular disease (CVD) are mainly limited to animal studies, and the relationship between dietary SPD and CVD mortality remains inconclusive.

Objective: This study aims to evaluate the association between dietary SPD intake and CVD and all-cause mortality.

Methods: A total of 23,894 people enrolled in the National Health and Nutrition Examination Survey (NHANES) from 2003 to 2014 were recruited for this study. The dietary intake of SPD from 11 specific food origins and total SPD was categorized into tertiles or quartiles. Cox proportional hazard regression models were developed to evaluate the association of SPD intake with CVD and all-cause mortalities.

Results: Among the 23,894 participants, 2,365 deaths, including 736 deaths due to CVD, were documented. After adjustment for potential confounders, compared with participants in the lowest quartile, participants in the highest quartile of total SPD had a significantly lower risk of CVD mortality (HR = 0.68, 95% CI: 0.51–0.91) and all-cause mortality (HR = 0.70, 95% CI: 0.60–0.82); participants in the highest tertiles or quartiles of vegetable-derived SPD, cereal-derived SPD, legume-derived SPD, nut-derived SPD, and cheese-derived SPD had a lower risk of CVD mortality ($HR_{vegetable-derivedSPD}$ = 0.68, 95% CI: 0.54–0.86; $HR_{cereal-derivedSPD}$ = 0.75, 95% CI: 0.57–0.97; $HR_{legume-derivedSPD}$ = 0.68, 95% CI: 0.52–0.88; $HR_{nut-derivedSPD}$ = 0.66, 95% CI: 0.53–0.80; $HR_{cheese-derivedSPD}$ = 0.68, 95% CI: 0.52–0.88) and all-cause mortality ($HR_{vegetable-derivedSPD}$ = 0.73, 95% CI: 0.64–0.84; $HR_{cereal-derivedSPD}$ = 0.80, 95% CI: 0.69–0.93; $HR_{legume-derivedSPD}$ = 0.70, 95% CI: 0.60–0.80;$HR_{nut-derivedSPD}$ = 0.72, 95% CI: 0.64–0.81; $HR_{cheese-derivedSPD}$ = 0.70, 95% CI: 0.61–0.81) than those in the lowest tertiles or quartiles. Moreover, subgroup analysis showed consistent associations among the people with hypertension and hyperlipidemia.

Conclusion: Higher intake of dietary SPD is associated with decreased risk of CVD and all-cause mortality, and among specific food origin SPD, SPD derived from vegetables, cereals, legumes, nuts, and cheese was associated with reduced CVD and all-cause mortality.

KEYWORDS

SPD, CVD mortality, all-cause mortality, NHANES, autophagy

Introduction

The rising prevalence of cardiovascular disease (CVD) has become the leading cause of morbidity and mortality worldwide that reduces human life expectancy and causes a heavy burden on the healthcare system (1). Increasing evidence establishes that nutritional factors are strongly associated with the development, treatment, and prevention of CVD (2, 3). Spermidine (SPD), as a naturally occurring endogenous polyamine, is widely available in foods of both animal and plant origins and plays a crucial role in the growth and development of eukaryotic cells (4). Increasing epidemiologic research has demonstrated that SPD has a wide range of beneficial effects, such as cardiovascular protection, immune system regulation, and neuroprotective effects (5–7).

Numerous mechanism studies have indicated that SPD could exhibit remarkable cardiac and vascular protection in a variety of model organisms by stimulating autophagy as well as anti-inflammatory and anti-oxidative stress pathways. For example, feeding SPD reduced myocardial hypertrophy and improved cardiomyocyte elasticity in aged mice *via* enhancing arterial expression of autophagy markers (8); significantly decreased infarct size and alleviated myocardial hypertrophy in SD rats by increasing autophagic flux (9); alleviated atherosclerosis by reducing epithelial fat accumulation in APOE model mice (10); and downregulated endoplasmic reticulum stress signaling components in mice with kidney injury (11).

With increasing mechanism evidence of the beneficial effects of SPD, greater attention has been paid to its life span-extending effects, which have been well demonstrated across species including yeast, nematodes, flies, mice, and rats (12–14). However, we cannot conclude that its beneficial effects are applicable to the general population because research on the relationship between SPD and survival time has been mostly limited to animal models with no epidemiological validation. Therefore, we proposed a hypothesis that higher dietary SPD is associated with increased survival time in human beings. In this study, we examined the association between dietary SPD intake and all-cause and disease-specific mortality in the U.S. population recruited in the National Health and Nutrition Examination Survey (NHANES) from 2003 to 2014.

Abbreviations: SPD, spermidine; CVD, cardiovascular disease; NHANES, National Health and Nutrition Examination Survey; HR, hazard ratio; NDI, National Death Index; BMI, body mass index; AHEI, Alternative Healthy Eating Index; CPH, Cox proportional hazards; NO, nitric oxide.

Method

Study population

NHANES is a stratified, multistage study using a nationally representative sample of the non-institutionalized civilian population of the U.S. Detailed NHANES has been provided elsewhere (15). After excluding participants with missing information on dietary SPD, all-cause and CVD mortality, and other covariates, 23,894 adults (age $\geq$ 18 years) with the data of interviews and examinations who participated in NHANES from 2003 to 2014, including 10,942 men and 12,952 women, were selected for this study. The NHANES protocol was approved by the National Health Statistics Research Ethics Committee, and written informed consent was obtained before data collection.

Dietary assessment

A 24-h dietary recall survey was used to obtain food intake on 2 non-consecutive days. The first 24-h dietary recall was conducted in-person, and the second 24-h dietary recall was conducted by telephone 3 to 10 days later. Dietary energy and nutrient intakes were estimated using the USDA Dietary Study Food and Nutrient Database. Dietary intake components were integrated into 37 MyPyramid major groups and subgroups according to the USDA MyPyramid Equivalency Database 2.0 (MPED 2.0) User's Guide for Survey Foods. The mean values of nutrient intake on the first and the second day of the 24-h dietary recall were calculated in the analysis. Dietary supplement use was obtained through a dietary supplement questionnaire.

We calculated the amount of total dietary SPD and the amount of SPD in foods of animal origin including fresh meat, cooked meat, dairy products, eggs, cheese, and seafood, and in foods of plant origin including vegetables, fruits, cereals, legumes, and nuts. The average SPD content (nmol/g) in various foods was determined based on previous research (16). The daily intake of SPD (nmol/d) was based on the average

SPD content (nmol/g) and the daily intake of various food components (mg/d).

Main exposure and main outcomes

The main exposures in our study were the accounts of total dietary SPD intake and SPD intake from foods of plant origin including vegetables, fruits, cereals, legumes, and nuts, and foods of animal origin including fresh meat, cooked meat, dairy products, eggs, cheese, and seafood. The outcome was the status of mortality as determined by the National Death Index (NDI). The NDI is a considerably reliable and widely used death identification resource. The ICD-10 was used to determine disease-specific death. ICD-10 codes I00–I09, I11, I13, I20–I51, or I60–I69 were assigned to death due to CVD. In summary, a total of 736 deaths due to CVD and 2,365 deaths due to all-cause were documented.

Covariates

The covariates in our study included age (years), sex (male/female), race/ethnicity (non-Hispanic white/Mexican American/non-Hispanic black/other), Alternative Healthy Eating Index (AHEI), current smoker (yes or no, a current smoker was defined as someone who had smoked 100 cigarettes in his or her lifetime and reported currently smoking), current drinker (having at least 12 alcohol drinks per year or not), education level (less than high school education, high school, or above), annual household income (<$20 000, ≥$20 000 and <$45 000, ≥$45 000 and <$75 000, ≥$75 000 and <$100 000, or ≥$100 000), total energy intake from the 24-h dietary recall (kcal/d), body mass index (BMI, kg/m^2), regular exercise (having engaged in recreational moderate and vigorous physical activity (MVPA) in the past 30 days or no), and a history of hypertension, diabetes, or hyperlipidemia defined as a physician diagnosis of self-reported hypertension, diabetes, or hyperlipidemia.

Statistical analysis

Demographic, dietary nutrient intake, and anthropometric characteristics were presented using the mean and standard deviation for the continuous variables, and number and percentage for categorical variables. The baseline characteristics were analyzed using chi-square tests and generalized linear models adjusted for age, and gender. All statistical analyses were performed by R 4.1.2 software, and the two-sided P<0.05 was regarded as statistically significant.

Cox proportional hazard (CPH) models

CPH models were used to calculate hazard ratios (HRs) and 95% CI for all-cause and CVD mortality. The time scale in the Cox model used the follow-up time obtained by person-months from the date of the interview to their death, or the end of 2015. The dietary SPD was categorized into quartiles and tertiles, and the lowest quartile and tertile are regarded as the reference group. The confounders in the CPH model included age, sex, race, smoking status, drinking status, exercise, total energy intake, education level, energy intake, annual household income, BMI, AHEI, diabetes, hypertension, and hyperlipidemia. We performed a log transformation of all non-normal continuous variables. The gender interaction in the Cox proportional hazard (CPH) model was conducted.

Sensitivity analysis

A total of five sets of sensitivity analyses were performed in this study. In sets 1 to set 2, we analyzed the relationship between dietary SPD and all-cause and CVD mortality in the hypertension population and hyperlipidemia population, respectively, to identify the robustness of our results. In set 3 and set 4, we analyzed the relationship between dietary SPD and all-cause and CVD mortality in male and female populations separately. The participants who had a follow-up time <5 years were analyzed in set 5.

Result

Baseline characteristics

The demographic and nutritional characteristics of the participants are presented in Table 1. Compared with survivors, the participants with CVD and all-cause mortality were more likely to be male, older, and non-Hispanic whites; have a higher prevalence of hypertension, diabetes, and hyperlipidemia; have lower BMI, household income, education level, and total energy intake; and more prone to have a higher intake of dairy-derived SPD and a lower intake of total SPD, vegetable-derived SPD, legume-derived SPD, fresh meat-derived SPD, nut-derived SPD, and cheese-derived SPD (all $P < 0.05$).

Dietary SPD and mortality

The associations between dietary total SPD and specific food-derived SPD intake with all-cause and CVD mortality in the total population are presented in Figures 1, 2. As indicated by HR and 95% CI, the participants in the highest quartiles (quartile 4) of total SPD had a lower risk of CVD mortality (HR = 0.68,

TABLE 1 Baseline characteristics of variables in survived people, CVD mortality, and all-cause mortality status.

Variable	Survival–people ($N = 21,529$)	CVD mortality ($N = 736$)	*P*–value (Survival people vs. CVD mortality)	All–cause mortality ($N = 2,365$)	*P*–value (Survival people vs. all–cause mortality)
Age (years)	49.0[36.0–63.0]	76.0[66.0–80.0]	<0.001	75.0 [64.0–80.0]	<0.001
Male, *N* (%)	10,026.0 (46.6%)	434.0 (59.0%)	<0.001	1,350.0 (57.1%)	<0.001
Non–Hispanic white, *N* (%)	10,188.0 (47.3%)	467.0 (63.5%)	<0.001	1,484.0 (62.7%)	<0.001
College graduate or above, *N* (%)	5,437.0 (25.3%)	99.0 (13.5%)	<0.001	315.0 (13.3%)	<0.001
>$100,000 annual household income, *N* (%)	2,924.0 (13.6%)	16.0 (2.2%)	<0.001	64.0 (2.7%)	<0.001
BMI (kg/m^2)	28.2 [24.5–32.7]	27.9[24.5–31.7]	0.083	27.4 [24.1–31.7]	<0.001
Total energy intake (kcal/d)	1,912.5 [1,469.0–2,473.0]	1,577.8[1,235.6–1,990.2]	<0.001	1,633.0 [1,274.0–2,058.0]	<0.001
Regular exercise, *N* (%)	5,143.0 (23.9%)	153.0 (20.8%)	0.2	479.0 (20.3%)	<0.001
Current drinking, *N* (%)	14,506.0 (67.4%)	447.0 (60.7%)	0.004	1,437.0 (60.8%)	<0.001
Current smoking, *N* (%)	4,659.0 (21.6%)	126.0 (17.1%)	0.023	468.0 (19.8%)	0.06
Hypertension, *N* (%)	8,055.0 (37.4%)	510.0 (69.3%)	<0.001	1,511.0 (63.9%)	<0.001
Hyperlipidemia, *N* (%)	8,239.0 (38.3%)	393.0 (53.4%)	<0.001	1,198.0 (50.7%)	<0.001
Diabetes, *N* (%)	2,622.0 (12.2%)	216.0 (29.3%)	<0.001	626.0 (26.5%)	<0.001
Total SPD (μm/d)	378.6 [271.2–512,5]	304.6 [228.0.5–401.1]	<0.001	316.5 [235.2–419.7]	<0.001
Fruit SPD (μm/d)	4.2[0.7–8.7]	4.9[1.4–8.7]	0.056	4.6[1.4–8.8]	0.007
Vegetable SPD (μm/d)	20.1[12.0–31.1]	16.9 [9.5–26.0]	<0.001	17.8[9.9–27.6]	<0.001
Cereals SPD (μm/d)	309.2[212.2–427.5]	254.6[189.6–348.4]	<0.001	264.9[189.9–358.4]	<0.001
Legumes SPD (μm/d)	8.2[0,6–18.7]	2.9[0.0–10.2]	<0.001	3.3[0.0–11.0]	<0.001
Fresh meat SPD (μm/d)	3.2[1.6–5.5]	2.6[1.2–4.2]	<0.001	2.6[1.1–4.3]	<0.001
Cooked meat SPD (μm/d)	5.6[3.4–8.5]	4.5[2.7–6.8]	<0.001	4.5[2.7–7.1]	<0.001
Nuts SPD (μm/d)	0.0 [0.0–3.5]	0.0[0.0–1.9]	<0.001	0.0 [0.0–2.0]	<0.001
Egg SPD (μm/d)	0.07[0.01–0.3]	0.08[0.01–0.3]	0.9	0.07[0.01–0.3]	0.4
Seafood SPD (μm/d)	0.0[0.0–1.7]	0.0[0.0–0.5]	0.002	0.0[0.0–0.8]	<0.001
Milk&Yogurt SPD (μm/d)	0.2[0.1–0.5]	0.3[0.1–0.6]	<0.001	0.3[0.1–0.6]	<0.001
Cheese SPD (μm/d)	9.0[0.7–20.8]	3.3[0.0–11.4]	<0.001	3.6[0.0–12.2]	<0.001

Continuous variables are presented as medians (IQRs). Categorical variables are presented as a percentage.

95% CI: 0.51–0.91) and all-cause mortality (HR = 0.70, 95% CI: 0.60–0.82) than those in the lowest quartile (quartile 1). Also, the intake of SPD from four specific food sources (vegetables, cereals, legumes, nuts, and cheese) was significantly associated with mortality outcomes.

For different dietary sources of SPD, the participants in the highest quartiles or tertiles had a lower risk of CVD mortality (HR = 0.68, 95% CI: 0.54–0.86 for vegetable-derived SPD; HR = 0.75, 95% CI: 0.57–0.97 for cereal-derived SPD; HR = 0.68, 95% CI: 0.52–0.88 for legume-derived SPD; HR = 0.66, 95% CI: 0.53–0.80 for nut-derived SPD; HR = 0.68, 95% CI: 0.52–0.88 for cheese-derived SPD) and all-cause mortality (HR = 0.73, 95% CI: 0.64–0.84 for vegetable-derived SPD; HR = 0.80, 95% CI: 0.69–0.93 for cereal-derived SPD; HR = 0.70, 95% CI: 0.60–0.80 for legume-derived SPD; HR = 0.72, 95% CI: 0.64–0.81 for nut-derived SPD; HR = 0.70, 95% CI: 0.61–0.81 for cheese-derived SPD). Sex was not a significant effect modifier of the aforementioned association ($P_{\text{effect modification with sex}} > 0.05$).

Sensitivity analysis

Consistent with the results of the total sample, analysis of subgroups among people with hypertension (Supplemental Figures 1, 2) and hyperlipidemia (Supplemental Figures 3, 4), as

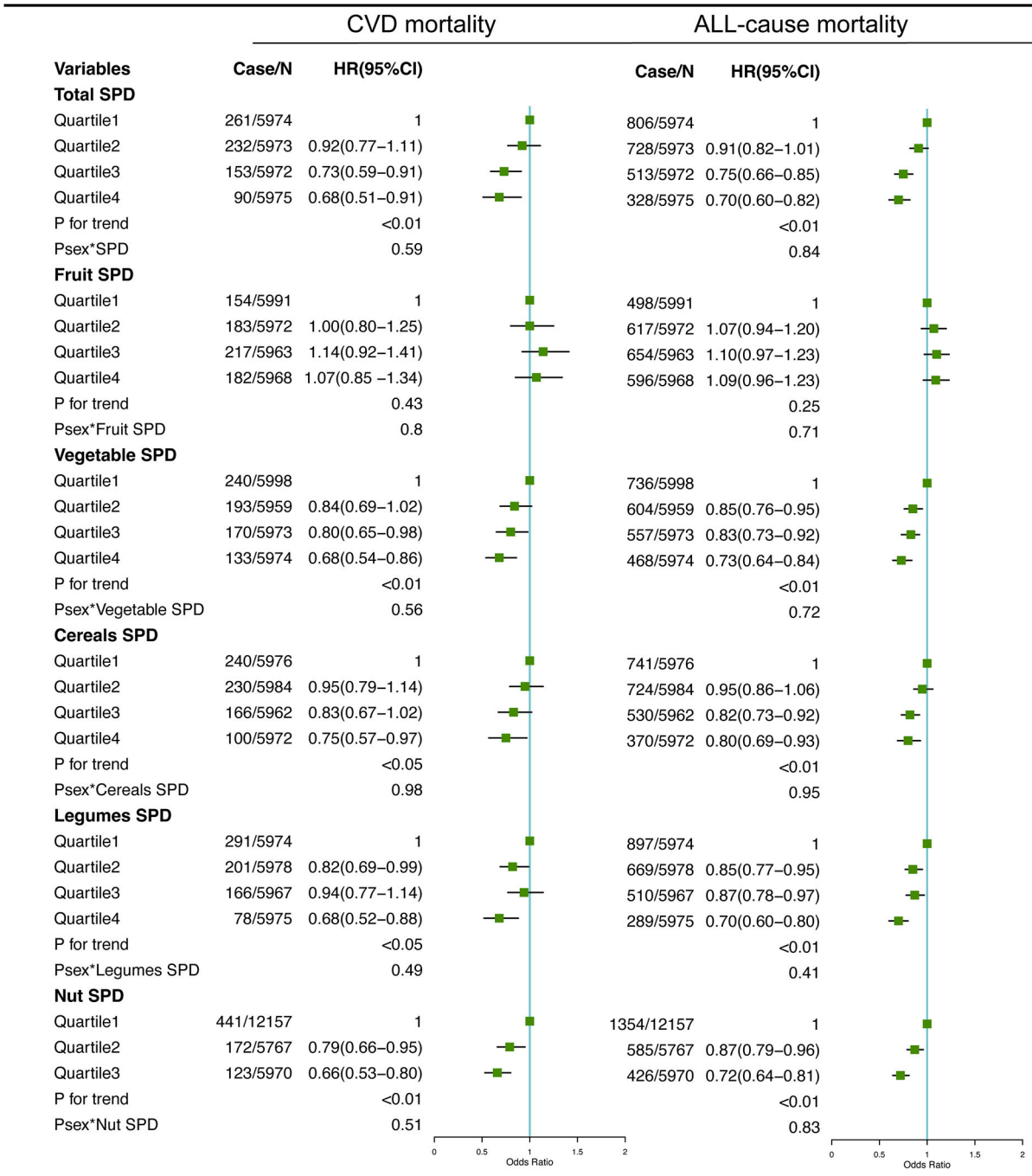


FIGURE 1
Multivariate adjusted hazard ratios (HRs) of the dietary total SPD, fruit-derived SPD, vegetable-derived SPD, cereal-derived SPD, legume-derived SPD, and nut-derived SPD with CVD and all-cause mortality. A logarithmic transformation was performed for non-normal continuous variables. Adjusting factors included age, gender, race, income, education level, regular exercise, smoking, alcohol consumption, BMI, body mass index; total energy intake, AHEI, Alternative Healthy Eating Index; diabetes, hypertension, and hyperlipidemia.

well as men (Supplemental Figures 5, 6), women (Supplemental Figures 7, 8), and those with less than 5 years of follow-up (Supplemental Figures 9, 10), also showed negative associations between the total and specific food source SPD intake and CVD and all-cause mortality, which indicated our results were relatively robust.

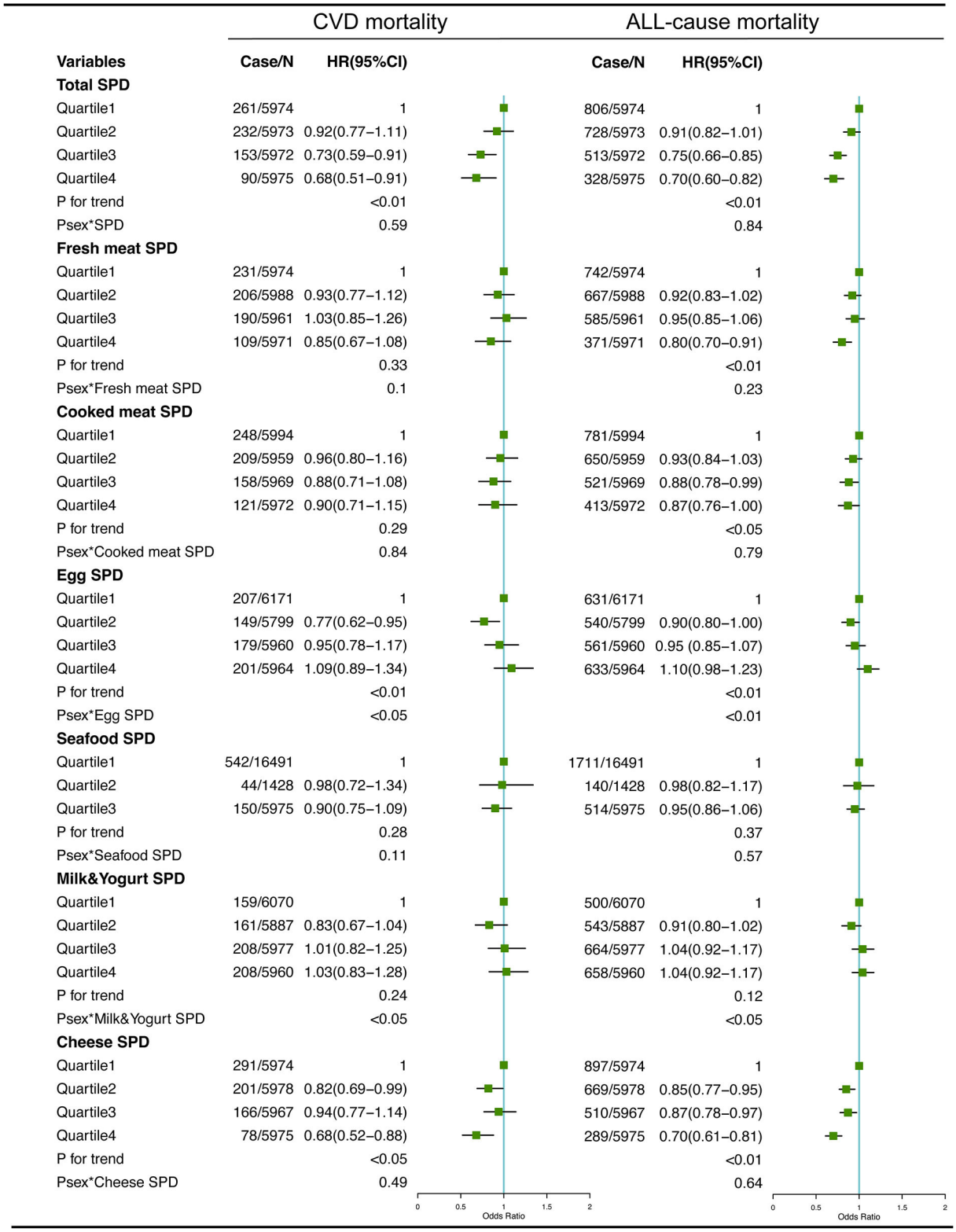


FIGURE 2
Multivariate adjusted hazard ratios (HRs) of the dietary total SPD, fresh meat-derived SPD, cooked meat-derived SPD, egg-derived SPD, seafood-derived SPD, milk & yogurt-derived SPD, and cheese-derived SPD with CVD and all-cause mortality. A logarithmic transformation was performed for non-normal continuous variables. Adjusting factors included age, gender, race, income, education level, regular exercise, smoking, alcohol consumption, BMI, body mass index; total energy intake, AHEI, Alternative Healthy Eating Index; diabetes, hypertension, and hyperlipidemia.

Discussion

To the best of our knowledge, this study is the first epidemiologic study to assess the association between dietary SPD intake and all-cause and CVD mortality among the U.S. adult population. The results of this study showed that the consumption of total dietary SPD, vegetable-derived SPD, cereal-derived SPD, legume-derived SPD, nut-derived SPD, and cheese-derived SPD was associated with decreased risk of all-cause and CVD mortality. In addition, these associations were relatively robust, which could be consistently observed among different subgroups.

Currently, increasing experimental evidence has demonstrated the autophagy, anti-inflammatory, and anti-oxidative stress effects of SPD treatment. In addition, previous studies have indicated that SPD could prolong the life span of different species, from yeast to rodents, and promote the manifestation of age-related diseases *via* the induction of protective autophagy (12). However, very few epidemiological studies have found that dietary SPD may increase the survival time in the adult population, which is the most important finding of this study. Several studies have established an inverse association between dietary SPD and the risk of cancer-specific mortality, which could partially support our findings. In line with our epidemiological analysis finding, a prospective, population-based cohort study showed that dietary SPD intake was negatively linked to the prevalence of CVD. Moreover, animal studies also corroborated the cardiovascular protective effect of SPD. An aging mice model has revealed that SPD feeding could reduce myocardial hypertrophy and improve aging-related cardiomyocyte elasticity (17). Another animal study showed that SPD significantly reduced the infarct size of myocardial infarction in SD rats by increasing autophagic flux through the AMPK/mTOR signaling pathway and alleviated myocardial hypertrophy (9), and SPD-induced autophilia could prevent atherosclerosis by reducing epithelial fat accumulation in vascular smooth muscle cells (VSMCs) of the APOE model mice (10), alleviate vascular calcification in kidney injury (11), reverse aging-related vascular calcification, and improve aging-reduced aortic elasticity (8). These studies argued for autophagy as a pivotal mechanism underlying SPD-induced cardioprotection.

Autophagy is a complex degradation/recycling system in charge of non-apoptotic cell death and intracellular degradation of misfolded or aggregated proteins and dysfunctional organelles such as mitochondria, which is essential for maintaining cellular renovation and homeostasis (7, 18, 19). The role of SPD-induced autophagy has been widely demonstrated to be essential not only for cardiovascular system protection but also for alleviation of age-related cognitive impairment, and life span extension (7, 20, 21). Interestingly, autophagy and serum SPD in humans and multiple model organisms showed a significant age-related decrease (8). However, the prevalence of CVD dramatically increases with age (22). This has led to the conjecture that the autophagic capacity decreased with age, leading to a large accumulation of damaged cells and dysfunctional intracellular organelles in the cardiovascular system, thus causing CVD. However, intake of more dietary SPD and SPD-induced autophagy reversed this process, resulting in cardioprotective effects. This mechanism evidence may strongly support the negative association of dietary SPD with the reduced risk of CVD mortality.

In addition to the induction of autophagy, several potential mechanisms for the cardioprotective effects of SPD may exist as follows. As known, oxidative damage and inflammation are widely reported as the main factors leading to atherosclerosis, which is the most typical and major pathological change of CVD. The accumulation of oxidized LDL in the vascular endothelium is the most important factor during early plaque formation in atherosclerosis (23, 24), and the aggregation of pro-inflammatory factors may contribute to the acceleration of vascular calcification. As the most important member of the polyamine family, SPD is synthesized from putrescine and serves as a precursor of spermine (25). Numerous *in vitro* and *in vivo* experiments have shown that SPD and spermine may act as scavengers of ROS and then protect the cardiovascular system from oxidative damage (26). SPD has been linked to increased titin phosphorylation, which inhibits downstream inflammation and thus increases cardiomyocyte elasticity (17). In addition, due to its polycationic nature, SPD can readily bind negatively charged biological macromolecules, including DNA, RNA, proteins, and phospholipids, and can modulate the function of these macromolecules in many cases. It has been shown that SPD can enhance the stability and flexibility of DNA (26), which may be an underlying mechanism for the cardioprotective effect of SPD. Moreover, arginine, the raw material for SPD synthesis *in vivo*, is a substrate for the synthesis of nitric oxide (NO), which is a recognized cardiovascular dilator (27). NO also showed an age-related decrease (28, 29). It has been shown that SPD could improve the bioavailability of arginine for NO synthesis, implying that relatively sufficient SPD can lead to greater conversion of arginine to NO, thereby protecting the cardiovascular system (11, 12). This is another potential mechanism for the cardioprotective effect of SPD. In our study, these beneficial effects were found to be relatively robust, which was significant across many subgroups, including different genders and disease states, suggesting that a higher intake of dietary SPD contributes to a cardiovascular protective effect. Furthermore, significant sex-mediated effects were not found, except for the egg-derived SPD.

Another key finding of this study was the negative association between SPD from a specific food origin and CVD mortality. Our results suggest that vegetables, cereals, legumes,

nuts, and cheese would be better sources of SPD to protect the cardiovascular system. SPD is widely found in all foods containing nucleic acids and is abundant in coarse cereals, wheat germ, vegetables, and fermented foods containing bacteria and fungi such as stinky cheese and natto (16, 30). We found that dietary intake of SPD from vegetables, cereals, legumes, nuts, and cheese sources could significantly reduce the risk of CVD mortality. These dietary SPD sources with cardioprotective effects coincided with the Mediterranean dietary pattern, which is a recognized dietary pattern with proven cardiovascular protective effects (31). Although the negative relationships between the consumption of vegetables, cereals, legumes, nuts, and cheese and CVD mortality have been well established (32–35), the association between dietary intake of SPD from the aforementioned foods and CVD mortality was still significant after adjusting for AHEI, which indicates the protective role of dietary SPD was independent of other beneficial ingredients in food. Therefore, vegetables, cereals, legumes, nuts, and cheese should be consumed in greater quantities as an ideal food source of cardiovascular protective SPD. In addition, SPD is a highly absorbable polyamine that could be taken up in the small intestine and utilized by multiple systems without secondary degradation in the circulatory system, which allows dietary SPD to significantly contribute to elevated SPD concentrations in the cardiovascular system (36, 37). That is also an underlying biological basis for the cardioprotective effects of dietary SPD.

This study has several strengths. First, this is the first epidemiologic study to evaluate the relationship between dietary SPD and CVD mortality in a representative population sample of U.S. adults. Second, we identified specific dietary sources of SPD with cardio protective effects, which provide guidance for dietary supplementation of SPD. Third, the association reported in this study was relatively robust that it was significant in a multitude of subgroups so that we could provide dietary supplementation strategies for SPD in gender-specific populations, as well as in populations with multiple chronic diseases. We are also aware that this study has certain limitations. First, although 24-h dietary recall is the most valid and universal method of investigating dietary information in observational studies, measurement error arising from day-to-day variation in food intake still exists. Second, we were unable to control for variables that were not measured in the observational study. Third, this study lacked an internal exposure evaluation of dietary SPD, which needs to be refined for future research.

In conclusion, a higher intake of dietary SPD is associated with decreased risk of CVD and all-cause mortality, and among specific food origin SPD, vegetable-, cereal-, legume-, nut-, and cheese-derived SPD was associated with reduced CVD and all-cause mortality.

Data availability statement

Publicly available datasets were analyzed in this study. This data can be found here: https://www.cdc.gov/nchs/nhanes/index.htm.

Author contributions

CS, TH, and WJ conceived the idea. TH and WW drafted the manuscript. HW, WJ, and HJ conducted data interpretation. CH, JW, and ZW conducted the first analysis. YC, WJ, XL, and XS conducted the second analysis for verification. All authors critically assessed, reviewed and approved the manuscript.

Funding

This research was supported by funds from HMU Marshal Initiative Funding (HMUMIF-21011 to WJ; HMUMIF-21013 to WW).

Acknowledgments

We thank all participants in our study for their cooperation and participation.

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/fpubh.2022.949170/full#supplementary-material

References

1. Roth GA, Mensah GA, Johnson CO, Addolorato G, Ammirati E, Baddour LM, et al. Global burden of cardiovascular diseases and risk factors, 1990-2019: Update From the GBD 2019 Study. *J Am Coll Cardiol.* (2020) 76:2982–3021. doi: 10.1016/j.jacc.2020.11.010

2. Preventive Services Task US, Davidson KW, Mangione CM, Barry MJ, Cabana M, Caughey AB, et al. Behavioral counseling interventions to promote a healthy diet and physical activity for cardiovascular disease prevention in adults with cardiovascular risk factors: US preventive services task force recommendation statement. *JAMA.* (2020) 324:2069–75. doi: 10.1001/jama.2020.21749

3. Petermann-Rocha F, Parra-Soto S, Gray S, Anderson J, Welsh P, Gill J, et al. Vegetarians, fish, poultry, and meat-eaters: who has higher risk of cardiovascular disease incidence and mortality? A prospective study from UK Biobank. *Eur Heart J.* (2021) 42:1136–43. doi: 10.1093/eurheartj/ehaa939

4. Tong D, Hill JA. Spermidine promotes cardioprotective autophagy. *Circ Res.* (2017) 120:1229–31. doi: 10.1161/CIRCRESAHA.117.310603

5. Yang Q, Zheng C, Cao J, Cao G, Shou P, Lin L, et al. Spermidine alleviates experimental autoimmune encephalomyelitis through inducing inhibitory macrophages. *Cell Death Differ.* (2016) 23:1850–61. doi: 10.1038/cdd.2016.71

6. Gupta VK, Scheunemann L, Eisenberg T, Mertel S, Bhukel A, Koemans TS, et al. Restoring polyamines protects from age-induced memory impairment in an autophagy-dependent manner. *Nat Neurosci.* (2013) 16:1453–60. doi: 10.1038/nn.3512

7. Pietrocola F, Pol J, Vacchelli E, Rao S, Enot DP, Baracco EE, et al. Caloric Restriction Mimetics Enhance Anticancer Immunosurveillance. *Cancer Cell.* (2016) 30:147–60. doi: 10.1016/j.ccell.2016.05.016

8. LaRocca TJ, Gioscia-Ryan RA, Hearon CM, Seals DR. The autophagy enhancer spermidine reverses arterial aging. *Mech Ageing Dev.* (2013) 134:314–20. doi: 10.1016/j.mad.2013.04.004

9. Yan J, Yan J-Y, Wang Y-X, Ling Y-N, Song X-D, Wang S-Y, et al. Spermidine-enhanced autophagic flux improves cardiac dysfunction following myocardial infarction by targeting the AMPK/mTOR signalling pathway. *Br J Pharmacol.* (2019) 176:3126–42. doi: 10.1111/bph.14706

10. Michiels CF, Kurdi A, Timmermans J-P, De Meyer GRY, Martinet W. Spermidine reduces lipid accumulation and necrotic core formation in atherosclerotic plaques via induction of autophagy. *Atherosclerosis.* (2016) 251:319–27. doi: 10.1016/j.atherosclerosis.2016.07.899

11. Liu X, Chen A, Liang Q, Yang X, Dong Q, Fu M, et al. Spermidine inhibits vascular calcification in chronic kidney disease through modulation of SIRT1 signaling pathway. *Aging Cell.* (2021) 20:e13377. doi: 10.1111/acel.13377

12. Madeo F, Eisenberg T, Pietrocola F, Kroemer G. Spermidine in health and disease. *Science.* (2018) 359:eaan2788. doi: 10.1126/science.aan2788

13. Eisenberg T, Knauer H, Schauer A, Büttner S, Ruckenstuhl C, Carmona-Gutierrez D, et al. Induction of autophagy by spermidine promotes longevity. *Nat Cell Biol.* (2009) 11:1305–14. doi: 10.1038/ncb1975

14. Schroeder S, Hofer SJ, Zimmermann A, Pechlaner R, Dammbrueck C, Pendl T, et al. Dietary spermidine improves cognitive function. *Cell Rep.* (2021) 35:108985. doi: 10.1016/j.celrep.2021.108985

15. Shan Z, Rehm CD, Rogers G, Ruan M, Wang DD, Hu FB, et al. Trends in dietary carbohydrate, protein, and fat intake and diet quality among US adults, 1999-2016. *JAMA.* (2019) 322:1178–87. doi: 10.1001/jama.2019.13771

16. Muñoz-Esparza NC, Latorre-Moratalla ML, Comas-Basté O, Toro-Funes N, Veciana-Nogués MT, Vidal-Carou MC. Polyamines in Food. *Front Nutr.* (2019) 6:108. doi: 10.3389/fnut.2019.00108

17. Eisenberg T, Abdellatif M, Schroeder S, Primessnig U, Stekovic S, Pendl T, et al. Cardioprotection and lifespan extension by the natural polyamine spermidine. *Nat Med.* (2016) 22:1428–38. doi: 10.1038/nm.4222

18. Wang I-F, Guo B-S, Liu Y-C, Wu C-C, Yang C-H, Tsai K-J, et al. Autophagy activators rescue and alleviate pathogenesis of a mouse model with proteinopathies of the TAR DNA-binding protein 43. *Proc Natl Acad Sci U S A.* (2012) 109:15024–9. doi: 10.1073/pnas.1206362109

19. Mizushima N, Komatsu M. Autophagy: renovation of cells and tissues. *Cell.* (2011) 147:728–41. doi: 10.1016/j.cell.2011.10.026

20. Xu T-T, Li H, Dai Z, Lau GK Li B-Y, Zhu W-L, Liu X-Q, et al. Spermidine and spermine delay brain aging by inducing autophagy in SAMP8 mice. *Aging (Albany NY).* (2020) 12:6401–14. doi: 10.18632/aging.103035

21. Ghosh I, Sankhe R, Mudgal J, Arora D, Nampoothiri M. Spermidine, an autophagy inducer, as a therapeutic strategy in neurological disorders. *Neuropeptides.* (2020) 83:102083. doi: 10.1016/j.npep.2020.102083

22. Wang C, Yuan Y, Zheng M, Pan A, Wang M, Zhao M, et al. Association of age of onset of hypertension with cardiovascular diseases and mortality. *J Am Coll Cardiol.* (2020) 75:2921–30. doi: 10.1016/j.jacc.2020.04.038

23. Hansson GK, Hermansson A. The immune system in atherosclerosis. *Nat Immunol.* (2011) 12:204–212. doi: 10.1038/ni.2001

24. Falk E. Pathogenesis of atherosclerosis. *J Am Coll Cardiol.* (2006) 47:C7–12. doi: 10.1016/j.jacc.2005.09.068

25. Fan J, Feng Z, Chen N. Spermidine as a target for cancer therapy. *Pharmacol Res.* (2020) 159:104943. doi: 10.1016/j.phrs.2020.104943

26. Ha HC, Sirisoma NS, Kuppusamy P, Zweier JL, Woster PM, Casero RA. The natural polyamine spermine functions directly as a free radical scavenger. *Proc Natl Acad Sci U S A.* (1998) 95:11140–5. doi: 10.1073/pnas.95.19.11140

27. Patel KP, Schultz HD. Angiotensin peptides and nitric oxide in cardiovascular disease. *Antioxid Redox Signal.* (2013) 19:1121–32. doi: 10.1089/ars.2012.4614

28. Brandes RP, Fleming I, Busse R. Endothelial aging. *Cardiovasc Res.* (2005) 66:286–94. doi: 10.1016/j.cardiores.2004.12.027

29. Eisenberg T, Abdellatif M, Zimmermann A, Schroeder S, Pendl T, Harger A, et al. Dietary spermidine for lowering high blood pressure. *Autophagy.* (2017) 13:767–9. doi: 10.1080/15548627.2017.1280225

30. Kalač P. Health effects and occurrence of dietary polyamines: a review for the period 2005-mid 2013. *Food Chem.* (2014) 161:27–39. doi: 10.1016/j.foodchem.2014.03.102

31. Fernández-García JC, Martínez-Sánchez MA, Bernal-López MR, Muñoz-Garach A, Martínez-González MA, Fitó M, et al. Effect of a lifestyle intervention program with energy-restricted Mediterranean diet and exercise on the serum polyamine metabolome in individuals at high cardiovascular disease risk: a randomized clinical trial. *Am J Clin Nutr.* (2020) 111:975–82. doi: 10.1093/ajcn/nqaa064

32. Li H, Li J, Shen Y, Wang J, Zhou D. Legume Consumption and All-Cause and Cardiovascular Disease Mortality. *Biomed Res Int.* (2017) 2017:8450618. doi: 10.1155/2017/8450618

33. Martínez-González MA, Salas-Salvadó J, Estruch R, Corella D, Fitó M, Ros E, et al. Benefits of the mediterranean diet: insights from the PREDIMED study. *Prog Cardiovasc Dis.* (2015) 58:50–60. doi: 10.1016/j.pcad.2015.04.003

34. Chen G-C, Tong X, Xu J-Y, Han S-F, Wan Z-X, Qin J-B, et al. Whole-grain intake and total, cardiovascular, and cancer mortality: a systematic review and meta-analysis of prospective studies. *Am J Clin Nutr.* (2016) 104:164–72. doi: 10.3945/ajcn.115.122432

35. De Pergola G, D'Alessandro A. Influence of mediterranean diet on blood pressure. *Nutrients.* (2018) 10:E1700. doi: 10.3390/nu10111700

36. Porter CW, Bergeron RJ. Spermidine requirement for cell proliferation in eukaryotic cells: structural specificity and quantitation. *Science.* (1983) 219:1083–5. doi: 10.1126/science.6823570

37. Kaeberlein M. Spermidine surprise for a long life. *Nat Cell Biol.* (2009) 11:1277–8. doi: 10.1038/ncb1109-1277

Advantages of publishing in Frontiers

OPEN ACCESS
Articles are free to read for greatest visibility and readership

FAST PUBLICATION
Around 90 days from submission to decision

HIGH QUALITY PEER-REVIEW
Rigorous, collaborative, and constructive peer-review

TRANSPARENT PEER-REVIEW
Editors and reviewers acknowledged by name on published articles

Frontiers
Avenue du Tribunal-Fédéral 34
1005 Lausanne | Switzerland

Visit us: www.frontiersin.org
Contact us: frontiersin.org/about/contact

REPRODUCIBILITY OF RESEARCH
Support open data and methods to enhance research reproducibility

DIGITAL PUBLISHING
Articles designed for optimal readership across devices

FOLLOW US
@frontiersin

IMPACT METRICS
Advanced article metrics track visibility across digital media

EXTENSIVE PROMOTION
Marketing and promotion of impactful research

LOOP RESEARCH NETWORK
Our network increases your article's readership