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Digital strategies to reduce salt consumption

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Digital strategies to reduce salt consumption

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Editorial: Digital strategies to reduce salt consumption

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Editorial on the Research Topic
Digital strategies to reduce salt consumption

Salt consumption has become a pressing public health concern worldwide, with most individuals consuming double the daily recommended amount set by the World Health Organization (WHO) (1). This increase can be attributed to the proliferation of ultra-processed foods and lifestyle changes that prioritize convenience over health (2). The consequences of high salt consumption are dire, leading to preventable non-communicable diseases such as high blood pressure, cardiovascular disease, and stroke (3).

Addressing the challenge of reducing salt consumption requires concerted efforts at both the individual and population levels (4). While individuals must take responsibility for their dietary choices, it is crucial to incentivize and facilitate salt reduction strategies on a broader scale (5). These strategies can range from policy changes to social marketing campaigns and behavior change interventions. In this context, the advent of digital health presents a wealth of opportunities for cost-effective public health interventions to reduce salt consumption at the population level (6).

The aim of the Research Topic "Digital strategies to reduce salt consumption" is to shed light on the latest research surrounding digital interventions aimed at reducing salt consumption. Specifically, the articles published in this Research Topic collectively provide valuable insights into the use of digital technology to address salt intake reduction and related health concerns across diverse regions.

For digital platforms to be effective and scalable in reducing salt consumption, the following themes warrant special consideration:

1. **Digital engagement**: Smartphone applications and social media tools have emerged as effective channels for educating communities, with a particular focus on school children and families. In Sun et al. and Jarrar et al., researchers explore the potential, and effectiveness, of digital platforms to engage populations in reducing salt intake.
2. **Health behavior associations**: Emphasizing holistic public health approaches that consider the complex interplay of factors such as stress, unhealthy dietary habits, and lifestyle choices is essential for overall wellbeing. Yang et al. and Mahmoud et al. investigate these intricate connections among populations.

3. **Cultural variations and vulnerable populations**: Adapting interventions to suit specific cultural and regional contexts is crucial when designing digital strategies to reduce salt consumption. The study by Al-Qahtani sheds light on unique cultural influences on dietary choices among male university students in Saudi Arabia.
4. **Education and awareness**: Effective mass media campaigns should actively involve the target audience and use tailored communication materials to engage and educate vulnerable subgroups. Capitão et al. focuses on the development of such campaigns to promote healthy eating.
5. **Preventive strategies**: Prioritizing preventive measures in the development and implementation of digital strategies for reducing salt consumption is key. Negesse et al. examine broader health concerns, including dental caries, obesity, and diarrhea prevention, in specific Diarrhea hot-spot regions of Ethiopia, stressing the importance of considering various factors such as residence, educational level, health insurance, and media exposure in designing prevention and control strategies.
6. **Policy recommendations**: The implementation of policies such as food reformulation, warning labels, and communication campaigns can effectively promote healthier eating habits and reduce sodium consumption. Campos-Nonato et al. provide policy recommendations, particularly in the context of Mexico, to reduce table salt intake and monitor salt consumption.

Increasing evidence suggest the potential of digital health interventions, comprising smartphone applications, digital platforms, and legislative interventions, to address the pervasive issue of excessive salt consumption and its associated health risks (7). These digital strategies should be complemented with tailored communication, education, and behavior change initiatives for wider uptake and effectiveness.

In conclusion, digital strategies offer promising avenues to tackle the global burden of high salt consumption (Jarrar et al.). By leveraging technology and implementing evidence-based interventions, we can create scalable and sustainable solutions to reduce population-level salt intake (8). However, further research and collaboration are needed to optimize these strategies and ensure their effectiveness in diverse contexts. By embracing digital health innovations, we can pave the way for a healthier future, reducing the burden of non-communicable diseases and promoting wellbeing for all (9).

Author contributions

SB conceptualized and wrote the manuscript and approved the submitted version.

Conflict of interest

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

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References

1. WHO. *New WHO Benchmarks Help Countries Reduce Salt Intake and Save Lives*. (2021). Available from: https://www.who.int/news/item/05-05-2021-new-who-benchmarks-help-countries-reduce-salt-intake-and-save-lives (accessed June 22, 2023).

2. Elizabeth L, Machado P, Zinöcker M, Baker P, Lawrence M. Ultra-processed foods and health outcomes: a narrative review. *Nutrients*. (2020) 12:1955. doi: 10.3390/nu12071955

3. Strazzullo P, D'Elia L, Kandala NB, Cappuccio FP. Salt intake, stroke, and cardiovascular disease: meta-analysis of prospective studies. *Bmj*. (2009) 339:b4567. doi: 10.1136/bmj.b4567

4. Trieu K, Neal B, Hawkes C, Dunford E, Campbell N, Rodriguez-Fernandez R, et al. Salt reduction initiatives around the world - a systematic review of progress towards the global target. *PLoS ONE*. (2015) 10:e0130247. doi: 10.1371/journal.pone.0130247

5. Cobb LK, Appel LJ, Anderson CA. Strategies to reduce dietary sodium intake. *Curr Treat Options Cardiovasc Med*. (2012) 14:425–34. doi: 10.1007/s11936-012-0182-9

6. Bhaskar S, Rastogi A, Chattu VK, Adisesh A, Thomas P, Alvarado N, et al. Key strategies for clinical management and improvement of healthcare services for cardiovascular disease and diabetes patients in the coronavirus (COVID-19) settings: recommendations from the REPROGRAM consortium. *Front Cardiovasc Med*. (2020) 7:112. doi: 10.3389/fcvm.2020.00112

7. Hartin PJ, Nugent CD, McClean SI, Cleland I, Tschanz JT, Clark CJ, et al. The empowering role of mobile apps in behavior change interventions: the gray matters randomized controlled trial. *JMIR Mhealth Uhealth*. (2016) 4:e93. doi: 10.2196/mhealth.4878

8. Vargas-Meza J, Gonzalez-Rocha A, Campos-Nonato I, Nilson EAF, Basto-Abreu A, Barquera S, et al. Effective and scalable interventions to reduce sodium intake: a systematic review and meta-analysis. *Curr Nutr Rep*. (2023) 12:486–494. doi: 10.1007/s13668-023-00477-w

9. Monaco A, Palmer K, Holm Ravn Faber N, Kohler I, Silva M, Vatland A, et al. Digital health tools for managing noncommunicable diseases during and after the COVID-19 pandemic: perspectives of patients and caregivers. *J Med Int Res*. (2021) 23:e25652. doi: 10.2196/25652

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REVIEW
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Digital Formats for Community Participation in Health Promotion and Prevention Activities: A Scoping Review

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Objectives: Digital technologies in public health are primarily used in medical settings and mostly on an individual and passive way of use. There are research gaps on digital media facilitating participation, empowerment, community engagement, and participatory research in community settings. This scoping review aims to map existing literature on digital formats that enable participation in the field of health promotion and prevention in community settings.

Design: The databases Medline, EMBASE, and PsycINFO were used to identify studies published from 2010 up to date (date of literature search) onward that used digital formats in all or in the main sequences of the process to enable high levels of participation in health promotion and prevention activities in community settings.

Results: This review identified nine out of 11 included studies relevant to the research question. We found five studies that applied qualitative participatory research, two studies on peer support and one study each on empowerment and crowdsourcing. The digital technologies used varied widely and included social media platforms, bulletin boards, online forum webpages, and customized web providers and programs. Most studies mentioned anonymity, flexibility, and convenience as benefits of digital interventions. Some papers reported limitations such as difficulties by interpreting written-only data or the possibility of selection bias due to the digital divide.

Conclusion: This scoping review identified only few studies relevant to our objective, indicating an existing gap in research on this topic. Digital formats were found to be particularly suitable for purposes where anonymity and flexibility are beneficial, such as for online peer exchange and peer support programs.

Keywords: health promotion, digitalization, public health, participation, community, empowerment

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INTRODUCTION

The Ottawa Charta and the Alma Ata Declaration defined community participation as a basic element and key principle for health-promoting activities and programs (1, 2). The Ottawa Charta for Health Promotion was published at the conclusion of the first International Conference on Health Promotion by the World Health Organization (WHO) in Ottawa on November 21, 1986.

It is considered one of the most important follow-up documents to the Declaration of Alma-Ata (1978), in which WHO declared basic health care and health promotion to be a fundamental human right. Since these declarations, community participation has become an increasing subject of interest in research and practice (3). Involving members of a community in health promotion may increase the effectiveness of public health interventions and reduce health inequalities for socially disadvantaged groups (4). Participation processes can strengthen social networks that reinforce healthy behaviors and reduce feelings of isolation (5). On an individual level, participation in decision-making processes increase the experience of self-efficacy. Furthermore, participation may initiate a process of empowerment, which enables communities to shape their environment, health, and lives according to their own interests (6). Community-based participatory strategies are based on the assumption that community members are experts of their own lives and thus know best how to improve the health of their community (6).

Communities can be defined as geographic entities ranging from neighborhoods to towns or cities, as well as larger geographic areas (7). Irrespective of geographic boundaries, a community can also be defined by common identity "based on race, gender, religious belief, sexual orientation, or a community-based organization united for a particular cause" (8). Participation was first categorized in Arnstein's ladder of citizen participation. It consists of eight rungs describing a range from non-participation to tokenism to the degree of citizen power (9). This idea has been further developed and adapted in the stage model of participation by Wright et al. (10). They define true participation as involving community members in the decision-making process, including the level in which community members are encouraged to make decisions, have partial decision-making authority, or have decision-making power (11). Below these stages, there are preliminary stages of participation, such as consultation like surveys, or stages that are not considered as participation, such as instruction. Beyond the level of participation goes empowerment by teaching participants necessary skills to initiate and carry out measures in a self-organized manner (12).

Advancing digitalization offers opportunities to exploit new possibilities in the implementation of health promotion and prevention programs (13). Many digital technologies, specifically devices such as computers, mobile phones, and tablets, are already accessible to a wide range of people of all ages and continue to evolve. A review by Clar et al. (14) on existing systematic reviews about the use of digital methods in public health found a wide variety of examples for digital approaches in the public health sector such as eHealth services, social marketing campaigns, apps, video games, telephone interventions, online photovoice, online discussion forums, virtual communities, or online collaborative writing applications. The review found that digital technologies were primarily used in medical settings and mostly in an individual and passive manner. Identified research gaps were digital media facilitating participation, empowerment, community engagement, and participatory research in community settings.

To our best knowledge, there is no review identifying existing studies on digital formats for community participation, irrespective of a specific group or a specific type of community participation. For this reason, we conducted a scoping review to systematically map the research in this area on a broader level and identify core concepts.

This scoping review aims to map existing literature on digital formats that enable participation in the field of health promotion and prevention in community settings to provide a better and more comprehensive understanding of the research area. This review will focus only on interventions with a true level of participation according stage model of participation by Wright et al., meaning that participants had at least to be involved in the decision-making process, and interventions that follow a digital approach at all stages of the participative elements. Specific aims are to describe (1) the participatory elements that were used in the interventions, (2) how the digital formats were used to conduct health promotion and prevention activities ensuring participatory approaches, and (3) benefits and limitations mentioned in relation to the digital format.

METHODS

We conducted a scoping review to identify existing literature on digital formats that enable participation in the field of health promotion and prevention in community settings. The aim of a scoping review is to map existing literature on a specific topic and to identify characteristics and concepts behind it (15). In contrast to a systematic review, the focus is not on the synthesis of results on a specific question, e.g., the effect of an intervention, but on providing an overview and a description of the field of research. As another goal is to identify the range of evidence on the topic, different study designs may be included and a formal assessment of the methodological quality of the included studies is usually not performed (16).

This scoping review was based on the framework of Arksey and O'Malley (17) and incorporated suggestions for improvement from Levac et al. (18), Daudt et al. (19) and the Joanna Briggs Institute (20). Additionally, the preferred reporting items of the PRISMA checklist for scoping reviews (PRISMA-ScR) (21) were taken into account.

The following steps were conducted:

Step 1: Identifying the research question
Step 2: Identifying relevant studies
Step 3: Study selection
Step 4: Charting data
Step 5: Collating, summarizing and reporting results

Abbreviations: COVID-19, Coronavirus disease 19; FB, Facebook; GBMSM, Gay, bisexual, and other men who have sex with men; GBQ, Gay, bisexual, and queer; HIV, Human immunodeficiency virus; LGBTQ, Lesbian, gay, bisexual, transgender, queer; MSM, Men who have sex with men; WMD, Wheeled mobility devices.

TABLE 1 | Inclusion and exclusion criteria.

Category	Inclusion criteria	Exclusion criteria
Population	Members of a community, including geographically defined communities, communities connected through common interests or lifestyles or virtual communities	Institutional settings (e.g., health care settings, school settings, or occupational settings), clinical populations
Concept	Interventions or research methods that use digital formats in all, or in the main sequences of the participatory process Participation is defined as level 6–9 of the stage model of participation by Wright (10)	Interventions or research methods that - use analogous formats in all, or in the main sequences of the participatory process - only allow participation under level 6 of the stage model of participation by Wright, Unger and Block (10)
Context	All actions and programs relating to health promotion or health prevention	Actions and programs not related to health promotion or health prevention
Study design	Any empirical study design	- Non-empirical studies (e.g., commentaries, letters, editorials, recommendations, guidelines or overviews) - Reviews or meta-analyses

Arksey and O'Malley suggest an optional Step 6 where practitioners and consumers can be consulted (17). This step was not performed in this review.

A protocol was developed a priori by the author team, following the same guidelines as described in this scoping review. The final protocol was registered with the Open Science Framework on February 21, 2021 (https://osf.io/v9jfc/).

Step 1: Identifying the Research Question

This scoping review was guided by the question: What kind of literature does already exist on digital formats that enable participation in the field of health promotion and prevention in community settings? Specific questions were: (1) Which participatory elements were used in the intervention? (2) How were digital formats used to conduct health promotion and prevention activities ensuring a participatory approach? (3) What benefits and limitations were mentioned related to the digital format?

We focused on the participation levels six to nine, according to the stage model of participation by Wright et al. (10). It defines true participation as participants being involved in the decision-making process or reaching a level of self-management. Furthermore, we were looking for an end-to-end digital approach that would be maintained throughout all or most sequences of the participation process, so that it would be feasible even in times of contact restrictions, as with the coronavirus pandemic.

Step 2: Identifying Relevant Studies

Literature searches were conducted in the databases Medline, EMBASE, and PsycINFO. The search strategy for the database search included database-controlled vocabulary and additional keywords, using truncations to search by title and abstract. The search strategy was identical for all three databases, adapted to the respective subheadings of the database and contained the following terms: communit* OR municipal* OR citi* OR city OR local OR neighborhood OR rural OR urban AND community participation OR participatory research OR participat* OR empower* OR involve* OR engage* OR partnership AND internet OR mobile applications OR social media OR smartphone OR mobile OR online OR digital OR photo* OR video* AND health promotion OR public health OR prevention OR health education.

Given the rapidly changing technological developments over the last decade, the search was limited to publications from 2010 to current studies (up to date when search was performed: 11/13/2020). Only studies in English were included.

Hand searches were additionally performed from the reference list of relevant reviews identified during the title and abstract screening to search for literature that may not have been captured by the databases used. After the search, duplicates were removed in the *EndNote* citation management software.

Step 3: Study Selection

The third stage of Arksey and O'Malley's framework aims to identify the studies to be included in the scoping review. To maintain clear congruence between title, objectives, and research question, we based the inclusion and exclusion criteria on a PCC framework, consisting of the categories: population, concept, and context. "Study design" was added as an additional category (20).

We searched for members of a community, including geographically defined communities, communities connected through common interests or lifestyles or virtual communities. We focused on intervention or research concepts that used digital formats in all, or in the main sequences of the process for enabling participation or empowerment in the context of health promotion or prevention. Any empirical study designs except reviews or meta-analysis were included. The inclusion and exclusion criteria are shown in **Table 1**.

An iterative team approach was used for the screening process, which was conducted in two phases: first a title and abstract screening and second a full text screening with all included studies from the first phase. Prior to the initial title and abstract screening, an iterative process was used to screen the first 100 citations and discussed by the research team (MC, CJS, CS, SV) until inclusion and exclusion criteria were sufficiently specified. For the screening of records, one author (CS) screened 100% of the citations. The other authors divided 50% of the citations among each other, resulting in half of the records being double-screened independently. For the screening process, the web-based literature management program *Rayyan* was used.

Conflicting reviewer decisions whether a study met the inclusion criteria were discussed and resolved in the team.

In the following full-text screening, a similar approach was used, resulting in 100% of the records being double-screened independently. Again, all conflicting classifications were discussed and resolved within the team. To ensure that no articles were missing, reference lists of relevant reviews were screened by the first author by title and abstract, and in full-text where appropriate.

The selection process is illustrated by a PRISMA flow chart displaying the results of the screening steps.

Step 4: Charting Data

In the fourth stage of the scoping review framework, data was extracted from the included studies using an *Excel* spreadsheet. Following the recommendations from Levac et al. (18), the data extraction framework was developed collaboratively by the research team and iteratively updated. Four of the included studies were extracted independently by two authors and then discussed to test the coherence of the framework.

The extraction items where categorized into general information and specific information. The extracted data of the general information section were author, title, journal, year, country, health topic, study type, objectives, population (age, sex, characteristics, total number, setting), type and description of intervention, recruitment methods, data collection, sample size, analysis method, and findings.

The data extracted for the specific information section were type of digital elements and further detailed description of these elements, type of participatory activities and further description (such as level of participation) and benefits, limitations and conclusions related to the use of the digital formats.

Step 5: Collating, Summarizing, and Reporting Results

The results were collated and summarized based on relevance to the research questions and reported in three tables. The first and second table focus on general information about each study, with the first table providing preliminary information and the second table presenting details about the methodology and results. The third table focuses on answering the three specific research questions. It contains information about the interventions related to the participatory aspect, the digital format, and the experiences made with it. The presented tabular results are accompanied by a narrative summary.

RESULTS

A total of 5,384 articles were found through database searching. After duplicates were removed in *Endnote*, 3,735 articles remained for title and abstract screening. The reference lists of eight relevant reviews (22–29) identified in the title and abstract screening were additionally screened, but no priorly unknown relevant study was found. From this initial screening phase, 85 articles were included in the full-text screening. Eleven studies were finally identified that met our inclusion criteria. The most common reasons for exclusion in the full-text screening were "no access to full text" ($n = 28$), mostly because only abstracts were available, and "wrong concept in relation to the digital format" ($n = 29$). Of the included 11 studies, three reported on the same intervention (30–32). The process of study selection is shown in the PRISMA flow chart (**Figure 1**) (33).

Characteristics of Included Studies

Table 2 provides general information on the 11 included studies on publication year, country, study type, health topic addressed, and the study objectives.

The included studies were published between 2010 and 2018. Seven studies were from the USA (30–32, 34, 37, 39, 41), noting that three studies were from the same research group, two were from Canada (38, 40), one from Australia (35), and one from Switzerland (36). Most studies ($n = 6$) followed a qualitative study design (34–38, 41), two were feasibility studies (39, 40), and the three studies from Young et al. were randomized controlled trials (30–32). Various public health topics were covered in the studies, such as breastfeeding (35), wheeled mobility devices (38), violence prevention (40), and health promotion in informal communities (39). The most common topic was HIV prevention, which was addressed in five of nine unique studies (30, 34, 36, 37, 41). The study objectives of the qualitative studies were all related to exploring the perspectives of the participants and therefore gaining a deeper understanding of the topic under research. The feasibility studies described the envisaged aims of their project and the RCT studies intended to measure the effectiveness of the intervention compared to a control group.

Table 3 presents general information of the 11 included studies regarding the target population and community setting, the data collection sources, the analysis methods, information on the participants of the sample and the main results.

The target population were adolescents or young adults in three studies (34, 36, 41), adults aged 18 years or older in six studies (30–32, 37–39) and adolescents and adults in one study (40). One study did not specify its target population (35). All studies focused on community settings defined by common identity. Four of the nine unique studies additionally searched for a geographic community setting by looking for residents of a specific city (30, 38–40). The remaining studies had no specific geographic setting or only a widely defined one. One study targeted virtual communities (35).

Of the six qualitative studies, four collected data using online focus groups (35, 37, 38, 41) and two *via* written discussions from online forums (34, 36). One study conducted in-depth interviews in addition to focus groups (35). Three of these studies performed content analyses (34, 37, 38) and three conducted thematic analyses (35, 36, 41). Snider et al. (40) used a concept mapping software for collecting the data and performed a cluster analysis. Rothpletz-Puglia et al. (39) used various sources for data collection, such as self-reported activity logs and participant questionnaires, and applied a mixed methods approach. Young's studies also used multiple data sources, with baseline and follow-up surveys in each study, and conducted a mix of quantitative analysis methods (30–32).

The number of participants in the focus group studies varied between eight and 79 participants. The crowdsourcing project

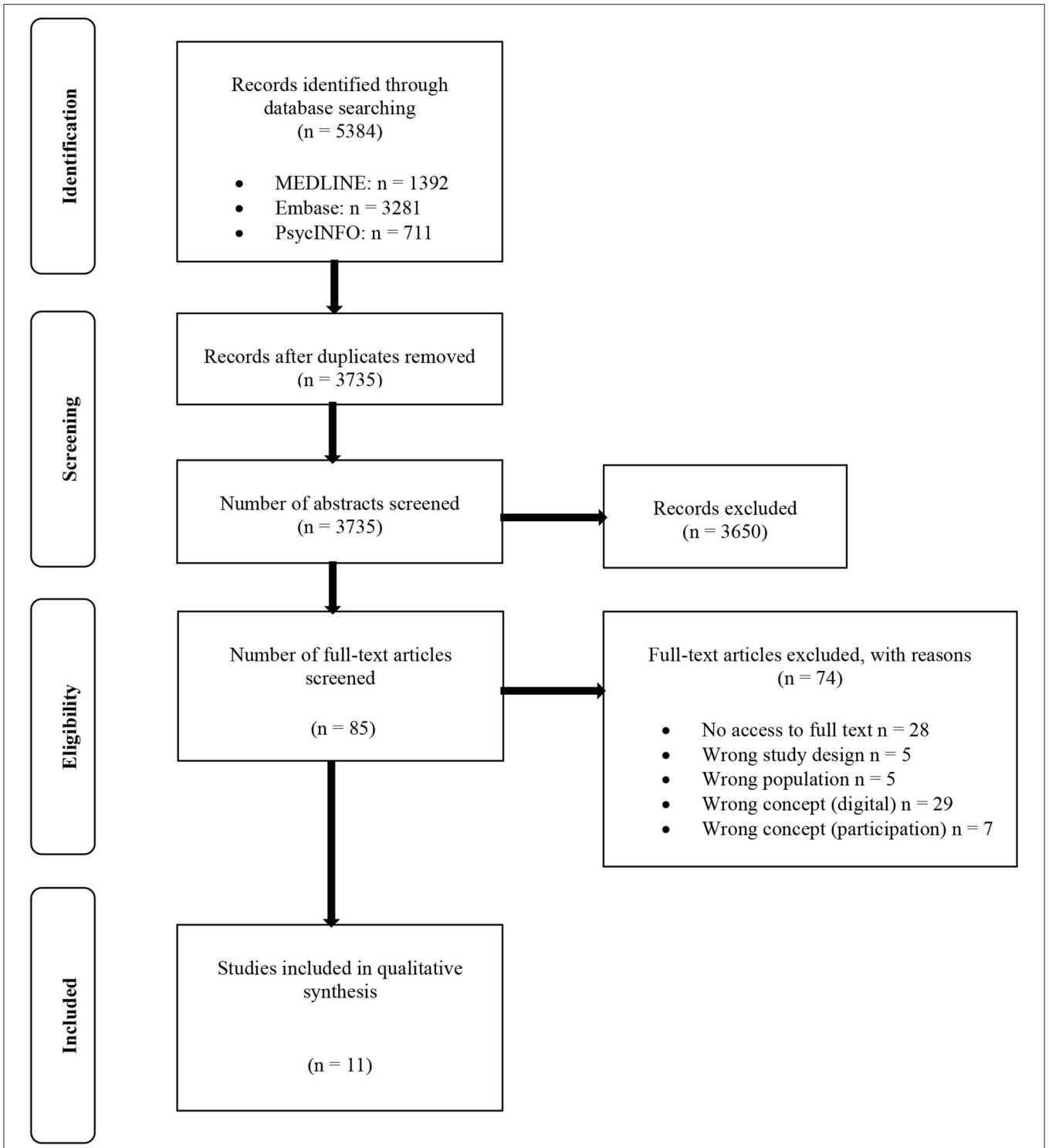

FIGURE 1 | PRISMA flow chart according to Page et al. (33).

involved a total of 5,102 participants (36) and Snider's (40) concept mapping project a total of 278. Two studies by Young et al. reported the same sample (31, 32). These had a total number of 105 participants. The other study sample had a total number of 498 participants (30). All studies that conducted content or thematic analysis reported a deeper understanding regarding their study objectives. The two studies testing feasibility were able to confirm and reported a successful implementation and

TABLE 2 | General information about included studies.

First author	Year	Country	Study type	Health topic	Objectives
Barry et al. (34)	2018	USA	Qualitative study, based on RCT	HIV prevention	To understand how resilience processes are shared among young Black GBMSM.
Bridges (35)	2016	Australia	Qualitative study	Breastfeeding support	To advance understanding of the experiences of mothers using closed Facebook groups for breastfeeding support.
Hildebrand et al. (36)	2013	Switzerland	Qualitative study	HIV prevention	To present a focused thematic analysis of a sub-section of the views expressed in the online and offline forums.
Iantaffi et al. (37)	2015	USA	Qualitative study	HIV prevention	To examine the acceptable level of sexual explicitness in HIV prevention advertisements.
Ripat and Colatruglio (38)	2016	Canada	Qualitative study	Wheeled mobility devices	To gain understanding of what people who use wheeled mobility devices identify as environmental barriers to community participation in cold weather climates.
Rothpletz-Puglia et al. (39)	2013	USA	Feasibility study	Health promotion	To offer opportunity and support for women at risk for or living with HIV to identify, create, and provide health promotion messaging within their informal personal networks.
Snider et al. (40)	2010	Canada	Feasibility study	Violence prevention	To engage youths, parents, and community workers in conceptualizing a hospital-based violence prevention intervention and to identify outcomes relevant to the community.
Ybarra et al. (41)	2014	USA	Qualitative study	HIV prevention	To examine self-reported behavioral and attitudinal changes among GBQ adolescent males who took part in online focus groups.
Young et al. (30)	2015	USA	Cluster randomized controlled trial	HIV prevention	To examine the efficacy of using the HOPE social media intervention to increase HIV testing among MSM in Peru.
Young et al. (31)	2014	USA	Randomized controlled trial	HIV prevention	To assess whether changes in network growth are associated with increased HIV prevention and testing behaviors.
Young et al. (32)	2013	USA	Cluster randomized controlled trial	HIV prevention	To determine whether social networking communities can increase HIV testing among African American and Latino MSM.

acceptability of their intervention (39, 40). The studies by Young et al. that tested a peer-mentoring intervention were able to confirm its effectiveness compared to a control group.

Types of Participation

Table 4 maps specific information of the interventions including a brief description of the intervention (if applicable), a more detailed description of the participatory elements, information about the type of digital format and how it was used, and a collection of strengths and weaknesses mentioned in relation to the digital format. The three studies by Young et al. (30–32) are combined in this table as they report the same intervention.

We found five studies that conducted qualitative participatory research. As reported above, four of them used online focus groups as research method (35, 37, 38, 41). One study additionally conducted in-depth interviews (35). In the focus groups and interviews, the researchers sought a nuanced understanding of the participants' views and perspectives on a particular issue affecting their lives. Participants were asked about their experiences, opinions, ideas, thoughts and recommendations. One study used concept mapping as a community-based participatory research method (40). Through this process, community members were enabled to gather their opinions and ideas about how hospitals could help youth avoid violence in the future. After that participants could sort and rate these ideas through an online process. In a face-to-face meeting, these results were developed into an intervention concept.

One intervention enabled peer support using online forums where participants could connect and support each other by starting conversation threads or responding to staff-generated threads (34). Another intervention that also used a peer support approach, trained peers of a community to become peer mentors who provided HIV prevention by communicating with the participants through *Facebook* groups (30–32).

We found one study that implemented an empowerment project providing opportunity and support for women at risk or living with HIV to identify, create and deliver health-promoting messages in their informal personal networks (39). To facilitate this project, a partnership was established between an academic and community agency.

One study used a crowdsourcing method to allow young people to participate in policy decision-making by both formulating the problems and generating solutions for the AIDS response (36). Similar to the concept mapping process, participants were able to share ideas and vote on what should be included in a strategy paper for the UNAIDS Secretariat, which was created through a public co-authoring process.

Utilization of Digital Formats

Online focus groups were mostly conducted in an asynchronous manner, meaning that participants did not have to respond immediately. Bridges (35) used the social network platform *Facebook* for both focus groups and interviews. Focus group questions were posted on a wall using the "event" function,

TABLE 3 | Methods and results of included studies.

Author, year	Target population and setting	Data collection	Analysis method	Sample participants	Findings
Barry et al. (34)	Age: 18–30 Sex: males Setting: Black, gay, bisexual MSM, recruited in southeastern US	Posts on the intervention website	Qualitative content analysis	Total number: 48 (RCT: 474) Average age: 24.3 years	Findings illustrate the width of roles that peer-level support played in fostering resilience. Self-acceptance and sex-positive norms were identified as new subthemes.
Bridges (35)	Age: all ages Sex: females Setting: breastfeeding mothers, members of closed Facebook groups attached to Australian Breastfeeding Association	3 online interviews, 3 online focus groups	Thematic analysis	Total number: 23 Administrators: 3 Group members: 20 Average age: not collected	Online breastfeeding support groups provide primarily support from a trusted community. Social networking sites are further described as immediate, complementary to existing support services, and a source of information for users.
Hildebrand et al. (36)	Age: 15–29 Sex: all genders Setting: young people of 79 countries, connected to the UNAIDS network	Data from a secondary analysis of the themes and texts that emerged during the UNAIDS discussions	Focused thematic analysis	Total number: 5,102 Online forums: 3,497 Offline forums: 1,605 Average age: not collected	Youth identified the need to change the way sex and relationships are dealt with through comprehensive sexuality education, overcoming social and cultural taboos, and changing how sex is talked about.
Iantaffi et al. (37)	Age: 18 or older Sex: males Setting: MSM regularly viewing sexually explicit media, living in the US	13 online focus groups	Content analysis	Total number: 79 Average age: 18–44 years (most participants were white, HIV-negative men)	The acceptable level of sexual explicitness in HIV prevention campaigns depends on factors of audience, location, and community representation.
Ripat and Colatruglio (38)	Age: adults Sex: all genders Setting: users of wheeled mobility devices (WMD), residents of Manitoba, Canada	1 online asynchronous focus group	Content analysis	Total number: 8 (7 wheelchair users, 1 scooter & walker user)	"Study confirms that elements of the environment, including the natural environment, supports, services, policies, and WMDs can alternatively serve as a barrier or facilitator to community participation." (p. 102)
Rothpletz-Puglia et al. (39)	Age: adults Sex: females Setting: women at risk for or living with HIV, living in New Jersey	Self-reported activity logs, participant questionnaires, and community-recipient evaluations	Mixed methods approach	Total number: 57 in-person group: 38 online group: 19	Women in both groups successfully provided health promotion to 5,861 people in their social networks. This demonstrates the feasibility of building social networks for disseminating health information and reducing health disparities in communities.
Snider et al. (40)	Age: youth and adults Sex: all genders Setting: youths, parents, and community youth workers, recruited in Toronto	Data was collected through 'The Concept System' software	Cluster analysis	Total number: 278 Brainstorming: 48 Sorting: 103 Rating: 102 Interpretation: 25 Average age (if youth): 12–24	It is feasible to use information generated by youth to develop successful and meaningful interventions to prevent youth violence.

(Continued)

TABLE 3 | Continued

Author, year	Target population and setting	Data collection	Analysis method	Sample participants	Findings
Ybarra et al. (41)	Age: 14–18 Sex: males Setting: gay, bisexual, and queer males, recruited nationally (USA)	4 questions subsequent to online focus groups	Thematic analysis	Total number: 75 Group with no sexual experience: 36 Group with sexual experience: 39	The majority reported that their participation positively changed their views and behavioral intentions about their sexuality. Sexually inexperienced youth most commonly reported positive effects of feeling less isolated.
Young et al. (30)	Age: 18 or older Sex: males Setting: Participants and peer leaders are MSM with a Facebook account, living in Lima (Peru). Participants should be HIV negative or serostatus unknown.	Baseline survey before the intervention	Multivariate adjusted logistic regression	Total number: 498 Intervention group: 252 Control group: 246 Peer leaders: 34 Average age: 28.9 years	Participants in the HIV intervention groups were more likely to request an HIV test than were those in the control groups. Peer-mentored social media communities seemed to be an effective method to increase HIV testing among high-risk populations in Peru
Young et al. (31)	Age: 18 or older Sex: males Setting: Participants and peer leaders are MSM with a Facebook account, living in Los Angeles. Peer leaders should be African American or Latino.	Baseline and follow-up survey, participants' FB friend lists	Network visualizations, regression analyses	Total number: 105 Peer leaders: 16 Average age: 31.5 years (90% were Latino or African American)	Among the intervention group, a positive trending relationship between increased network ties and likelihood of HIV testing, follow-up for test results, and participation in online community discussions was found.
Young et al. (32)	Age: 18 or older Sex: males Setting: Participants and peer leaders are MSM with a Facebook account, living in Los Angeles. Peer leaders should be African American or Latino.	Baseline and follow-up survey	Chi-square tests, *t*-tests, rates of home-based HIV testing	Total number: 105 Peer leaders: 16 Average age: 31.5 years (90% were Latino or African American)	"Social networking communities are acceptable and effective tools to increase home-based HIV testing among at-risk populations." (p. 2)

TABLE 4 | Characteristics of interventions.

Author, year	Description of intervention	Type of community participation	Description of participatory activities	Type of digital element	Description of digital elements	Benefits related to the digital format	Limitations related to the digital format
Barry et al. (34)	HealthMpowerment is an online intervention that aimed to reduce condomless anal intercourse and foster community among young Black GBMSM. In online forums the intervention group could react to pre-populated or staff-generated conversations (control group got an information-only website).	Peer support *via* online forums	Online forums created spaces for participants to connect and support each other, which fostered resilience processes. Topics for the pre-populated or staff-generated conversations were identified through formative research with young Black GBMSM.	Website (mobile phone optimized), which provided two online forums (*The Forum* and *Getting Real*) for participant interaction	"*The Forum* was a space where participants could read and contribute to existing conversation threads or start new threads. *Getting Real* was designed to be a creative space where participants could post and respond to topics with videos, poems, reflections, audio, and pictures." (p. 4)	- Anonymity (facilitated more candid questions and discussions than might have been provided in-person) - Flexibility to choose how and what to contribute - Close to real life interactions because interpersonal interactions increasingly take place online, particularly among stigmatized groups	"It can be difficult to interpret the tone and intention of online data." (p. 14)
Bridges (35)	/	Participatory research *via* online in-depth interviews and online focus groups	In the interviews and focus groups, participants were asked about their experiences administering or participating in closed Facebook groups for breastfeeding support.	Social media platform *Facebook* used for qualitative interviews and focus groups	Interviews were conducted *via* the "Messenger" function. Questions were typed in and answered asynchronously or synchronously by the participants. The focus groups were conducted *via* the "Event" function. All questions were created as wall posts and answered asynchronously by participants *via* the "comment" function.	- Asynchronous conduction: participants could answer any time they wanted in the interviews and focus groups - Easy accessibility *via* Facebook: participation possible from any location (both points helpful as participants were mothers of young children)	/
Hildebrand et al. (36)	CrowdOutAIDS is a participatory online policy project using a crowdsourcing process. It consists of 4 steps to enable young people to both formulate the problems as well as generate solutions in the AIDS response, resulting in a strategy document for the UNAIDS Secretariat.	Crowdsourcing process to enable policy participation	1) A community of interested young people were connected 2) Young people could share their experiences, ideas, and information 3) Participants were enabled to find solutions *via* voting 4) Final strategy document was co-authored in public online sessions, and a drafting committee of young people worked with the UNAIDS Secretariat to implement the strategy	1) Social media and online platform 2) Social networking platforms: *Facebook, RenRen* and *Vkontakte* 3) Customized osqa.net application 4) Customized GoogleDocs application	1) Initial buzz *via* social media and implementation *via* the online platform CrowdOutAIDS.org 2) 9 regional online forums, conducted *via Facebook, RenRen*, and *Vkontakte* 3) Customized osqa.net application for voting 4) Customized GoogleDocs application (no further description provided)	- The digital crowdsourcing processes facilitates the integration of grassroots perspectives from across the globe, engagement, and participation. - Enabled participation beyond youth networks and organizations to involve "ordinary" young people - "Despite the digital divide, online tools can effectively be used to mobilize for offline action." (p. 67)	- Digital divide (counteracted in the 2nd step through offline forums) - Selection bias: Online participants had a higher socioeconomic background

(Continued)

TABLE 4 | Continued

Author, year	Description of intervention	Type of community participation	Description of participatory activities	Type of digital element	Description of digital elements	Benefits related to the digital format	Limitations related to the digital format
Iantaffi et al. (37)	/	Participatory research *via* online focus groups	Participants were asked to give their opinions on HIV-prevention poster advertisements and one video advertisement	Adobe Connect used for online synchronous focus groups, bulletin board for asynchronous follow-up questions	The synchronous focus groups were conducted *via* the "chat" function, without the use of audio or video. After conclusion, participants were invited to respond asynchronously to follow-up questions and comments posted on a message board.	Higher confidentiality, by not using audio or video functions.	Data is limited to written text and does not give access to audio or visual participants' reactions.
Ripat and Colatruglio (38)	/	Participatory research *via* online focus group	"The researchers were seeking a nuanced understanding of WMD users' experiences regarding community participation and winter barriers, the strategies they employ to overcome those barriers, and the recommendations they had for improving winter community participation." (p. 97)	WordPress.com for hosting asynchronous online focus group	Participants had 1 week to respond asynchronously to daily questions posed by a moderator.	"Time for more in-depth and reflective responses from participants, greater participant anonymity, increased convenience in terms of participating from any location at any time, and automatic capture of discussion data" (p. 97)	/
Rothpletz-Puglia et al. (39)	Shout-out Health is a community-driven health promotion approach aiming to empower high-risk community members to develop and provide health promotion messaging delivered in their informal social networks.	Empowerment intervention for providing health promotion in informal social networks	Within in-person or online groups participants identified health problems and developed ways to promote health information in their informal social networks over a 5–6 week period. Therefor a 5-step intervention process was conducted.	Asynchronous online group (no information about the program)	Over a 3-month period, women in the online group worked asynchronously except for 2 conference calls. For the participants' convenience, they could choose the meeting format but could not move back and forth between the 2 approaches. (no further description provided)	- Convenience for participants to choose between online and in-person group - No significant differences in the productivity by group meeting format (p. 3)	/

(Continued)

TABLE 4 | Continued

Author, year	Description of intervention	Type of community participation	Description of participatory activities	Type of digital element	Description of digital elements	Benefits related to the digital format	Limitations related to the digital format
Snider et al. (40)	/	Community-based participatory research using concept mapping	Opinions and ideas from community members about how hospitals could help youth avoiding violence in the future were collected, sorted, and rated online. In a face-to-face meeting, participants discussed the assessment results and drafted an intervention concept.	"The Concept System" software for conducting the online concept mapping processes	1) Brainstorming: participants were asked to enter statements in response to a prompt (8 weeks) 2) Sorting: online participant sorted the brainstormed statements into piles (6 weeks) 3) Rating: participants rated each statement in terms of importance (6 weeks)	- Anonymity (given the sensitivity of the subject) - Flexibility: "Participants could partake in any or all steps of the concept mapping process." (p. 878)	- Due to anonymity, determination of how many participants took part in all four steps not possible - "A limitation of the software used in this study is a restriction on the number of demographic questions that can be asked." (p. 883)
Ybarra et al. (41)	/	Participatory research *via* online focus groups	Participants took part in two rounds of asynchronous focus groups in which they discussed their ideas, thoughts, and concerns about an HIV prevention program. Afterward, they were asked 4 questions how their participation in the focus groups influenced or changed their views or behaviors.	Bulletin board used for asynchronous focus groups and the following questions	"Each day, questions were posted on the bulletin board in the morning and then again, in the afternoon. Participants were instructed to visit the board at least twice a day to respond to questions, reply to moderator probes, and interact in discussions with other group members." (p. 3)	- Safe and anonymous environment, in which participants could talk more freely about their sexuality - Online focus groups represent a low-cost, scalable intervention	/
Young et al. (30–32)	The HOPE Social Media Intervention tested whether MSM in Facebook groups with peer-mentored HIV prevention and behavior change information would be more likely to test for HIV than those in groups without a peer-leader.	Peer-mentoring and peer support	MSM who were described as well-respected among the MSM community were trained as peer-leaders. They were advised to communicate with their assigned participants on Facebook in addition to general "friendly" conversation about HIV prevention and testing.	Social media platform *Facebook* used for conducting online intervention	Private Facebook groups consisted of 30 participants and 4–6 peer leaders who communicated by sending messages, chats, and wall posts. Participants had no obligations to respond or to stay in the Facebook group.	- Low costs HIV solution - Broader reach than traditional public health interventions - Reduce travel and time costs - Easy implementation - Growing international popularity of social media - Easier data collection than in field settings	- Duplicate respondents found during recruiting (non-unique usernames)

interview questions were typed in *via* the "messenger" function. Iantaffi et al. (37) used *Adobe Connect* for conducting synchronous focus groups *via* the "chat" function, without the audio or video function, and an asynchronous bulletin board for follow-up questions. The online focus group of Ripat and Colatruglio (38) was also conducted in an asynchronous manner by commenting on questions from a moderator hosted on *WordPress.com*. Ybarra et al. (41) used a bulletin board to conduct the focus groups and the subsequent behavior change questions. Participants were able to respond to questions, reply to moderator probes and interact in discussions with other group members.

Barry (34) used a website that was later optimized by a mobile phone application, which offered two online forums. In both forums, participants had the opportunity to read and contribute to existing conversation threads or start new threads and to post and respond to topics with videos, poems, reflections, audio, and pictures.

The HOPE Social Media Intervention was conducted *via* the social networking platform *Facebook* by creating closed groups in which the peer mentors could communicate with the participants by sending messages, chats, and wall posts (30–32).

Snider et al. (40) used a special program called *The Concept System* for the concept mapping process, in which participants could brainstorm ideas online, sort them, and rate them over a period of several weeks.

The CrowdOutAIDS program used various online applications for its four-step crowdsourcing process. Participants were recruited *via* social media and directed to the CrowdOutAIDS.org website. Online forums were then conducted through the social networks *Facebook, RenRen* and *Vkontakte*, and additional community forums were organized through online participant volunteers. Statements abstracted from the forums were voted for *via* a customized *osqa.net* application. In subsequent public online sessions, the final strategy document was created in a co-authoring process *via* a customized *GoogleDocs* application. A more detailed description of the applications was not provided.

The Empowerment project by Rothpletz-Puglia et al. (39) offered a choice between online and in-person groups. The online group worked asynchronously except for two conference calls. More information about the digital format and its usage was not provided.

Benefits and Limitations Associated With Digital Approach

One of the strengths of online forums is that they offered anonymity, which facilitated discussion of more candid questions (40). It was also noted by Barry et al. (34) that communication *via* online platforms came close to their real-life interactions and was therefore familiar. In addition, the flexibility for participants to decide how and what to contribute was mentioned as a strength. As a limitation, the difficulty of interpreting the tone and intention of online data was noted.

Similar points were mentioned in the study from Iantaffi et al. (37). The anonymity of online focus groups offered higher confidentiality by not using audio or video functions, but the lack of access to audio or visual participants' reactions made the interpretation of the data more difficult.

Snider et al. (40) concluded that anonymity is a strength of the online concept mapping process, which was particularly valuable with regard to the topic of experienced violence. Also, the flexibility of allowing participants to decide for themselves whether they wanted to participate in any or all steps was cited as a strength. The disadvantage of this procedure, however, was that it was not possible to evaluate how many participants took part in all steps of the process.

Ybarra et al. (41) also mentioned that the online format created a safe and anonymous environment that allowed participants to talk more freely about their sexuality. Moreover, it is added that online focus groups can represent a scalable low-cost intervention.

The social media intervention The HOPE was also identified as a low-cost solution for HIV prevention that enabled a broader reach than traditional public health interventions, was easy to implement, reduced travel and time costs and facilitated data collection (30–32). A disadvantage of social media interventions was cited as finding duplicate respondents during recruitment through non-unique usernames.

Hildebrand et al. (36) highlighted the broader reach of digital methods as a strength, enabling the integration of grassroots perspectives from across the globe and the involvement of young people who would not have normally been involved through traditional participatory processes. As a limitation of digital formats, Hildebrand mentioned the digital divide and the associated selection bias, as it was assumed that online participants have a higher socioeconomic background.

Conducting the asynchronous focus groups and interviews *via Facebook* was beneficial for easy accessibility and flexibility for participants to decide for themselves the time and place they want to respond (35). Especially for young mothers this format was considered suitable.

Ripat and Colatruglio (38) mentioned the increased convenience in terms of participating from any location at any time given by online focus groups, in addition to anonymity, the automatic data collection, and the fact that participants have time to give more reflective responses.

Rothpletz-Puglia et al. (39) compared the productivity between online groups and in-person groups and found no significant differences. They described the possibility to choose between both formats as a convenience for participants.

DISCUSSION

With this scoping review we mapped the existing literature on digital formats that enable participation in the field of health promotion and prevention in community settings. Furthermore, we gained a more comprehensive understanding of core concepts in this research area in terms of the enabled types of participation, the ways of utilizing the digital formats and the benefits and limitations linked to it. We identified nine unique out of 11 included studies relevant to the research question. Although these

are a relatively small number of studies, they seem to reflect to some extent the diversity of methods and topics as well as certain trends in the literature.

Characteristics of Included Studies

The majority of included studies dealt with vulnerable populations, mostly targeting communities at risk for or living with HIV. The huge amount of studies focusing on community-based HIV prevention programs and activities was also noticeable in the title and abstract screening. This may indicate that digital interventions are often used to reach stigmatized or vulnerable groups who commonly face challenges in seeking support. The easier accessibility and anonymity are particularly beneficial for reaching those populations (42).

Only youths and younger adults between 12 and 44 years were targeted or included in the interventions of our selected studies. This may reflect the fact that this age group can be reached better and more easily using digital media than older adults. As interpersonal interactions of younger adults increasingly take place online, digital interventions more closely resemble their real-life interactions than they do for older people, who generally have less exposure to digital media and lower levels of e-health literacy (34, 43).

Types of Participation

We found three studies that used community participation methods, like crowdsourcing and concept mapping, to enable large groups of people to actively define relevant issues for their community themselves and help shape solutions. We also found participatory research studies that mostly used a focus group approach. Through this method, participants were able to express their views and perspectives on a specific issue affecting their lives. The deeper insights into participants' experiences, opinions, thoughts, and recommendations not only benefited the researchers in generating more detailed data. Through participation in focus groups, community members reported benefits including new insights and a broader perspective on issues shared within the group, in addition to a sense of inclusion and community building (44). This was most evident in the study by Ybarra et al. (41), which found that online focus groups discussions should be further explored as low-cost prevention programs.

Utilization of Digital Formats

The digital technologies used varied widely, from social media platforms to customized web providers and programs. Digital technologies were used in most cases to establish direct communication between researchers and participants or to establish communication between participants. In the crowdsourcing, and concept mapping interventions, digital formats were used for mass community engagement that enabled democratic processes such as voting, brainstorming, sorting and rating. These findings demonstrate that digital technologies can, on the one hand, facilitate communication between community members and thus foster social networks. On the other hand, they can be used to create open environments to involve large groups of individuals for community participation processes (45). Crowdsourcing, in particular, is a method of mass collaboration that increases in the field of public health (27).

Benefits and Limitations Associated With Digital Approach

Three studies found that the interaction with like-minded people in online spaces increased feelings of support and self-acceptance among participants and reduced feelings of isolation (34, 35, 41). It was stated that the anonymity facilitated by the digital formats was beneficial to these interactions, as well as the easy and immediate access to support and flexibility to decide how much and when to participate. This is congruent with the reasons why digital peer support formats are increasingly offered in the field of mental health identified by a systematic review (46). Most of our identified qualitative participatory research studies used online asynchronous focus groups. For this method it is essential to create a "safe space" where participants have a feeling of confidentiality to express their opinions and experiences freely. The frequent choice for asynchronous formats could be an indication that this necessary environment can be created particularly well by this approach, by allowing a higher degree of anonymity and flexibility for participants to determine when and where to respond.

None of the included studies mentioned ethical aspects and data protection issues as a limitation or barrier of digital formats. This may be due to the fact that the majority of studies were from Anglo-American countries. This should be taken into account when transferring the study concepts to countries with high data protection requirements, such as Germany. Only five studies reported limitations related to the digital format, including difficult interpretation of written data. Previous research has already indicated that sufficient written literacy must be a criterion when conducting interventions limited to written discussions (47). This carries the risk of excluding certain groups of people, which is why suitability for the target population needs to be considered. In the title and abstract screening, we also found many studies on photovoice that were often not included because the subsequent focus group discussions were mostly conducted in a non-digital format. Since photovoice is less about examining participants' views on something and more about creating an impact, face-to-face formats may be better suited for this purpose (48).

Existing studies on digital interventions in various community settings mention several benefits compared to traditional formats. A review by Gilbey et al. (42) outlined in regard of the LGBTQ (lesbian, gay, bisexual, transgender, queer) community the anonymity aspect of digital interventions which facilitates access to support by minimizing stigma. Wadham et al. (49) found that specific communities like adolescents and young adults can be easier reached with new digital media interventions, because they use digital ways for information sharing on a regular basis. A review by Fortuna et al. (46) mentioned that digital peer support is increasingly delivered through social media networks, smartphone apps, and technologies that enable synchronous and asynchronous communication. This allows for a wider reach of peer support services. Digital interventions

also become increasingly popular due to easy implementation, cost-effectiveness, and remote accessibility (50). On the other side, higher drop-out rates and a lack of evidence on the effectiveness of digital interventions have been reported (42, 51). Additionally, according to Hall et al. (52), aspects of "poor technology skills, interfaces that are not user-friendly, concerns around data security, and a lack of support from healthcare professionals" should be considered when implementing digital interventions.

The COVID-19 pandemic resulted in the implementation of certain non-pharmaceutical measures, such as cancelling public events, restricting social gatherings to a minimum and closing schools and workplaces (53). Social distancing demonstrated the need and potential for using digital solutions with a consistent digital approach to engage people in health promotion and prevention activities.

However, there are some open questions with regard to the implementation of digital formats in community-based health promotion interventions which should be focused on in future research activities. It should be considered carefully whether digital formats could replace traditional formats for health promotion and prevention activities especially in vulnerable populations. From our perspective, one of the most urgent unanswered questions is whether the implementation of digital health promotion interventions leads to a further increase of a selection bias or whether such interventions counteract this bias and are used and accepted by vulnerable groups and settings in which traditional formats fail.

Strengths and Limitations

This review contains some methodological limitations. First, we may have missed some relevant studies related to the research questions for a few reasons. Our search was restricted to three databases without including grey literature. We searched for publications in English only and therefore might have missed studies published in other languages from geographic areas where digital public health technologies are known to be widely used (e.g., Korea, Japan). There were also a high number of studies that had to be excluded because the full texts were not available. In addition, we conducted the database search in November 2020, which may have been too early to find relevant studies related to the COVID-19 pandemic. Second, we did not perform a quality assessment of the included studies and did not focus on ethical and data protection aspects of using digital formats. However, this was not considered relevant to the objective of this study, which was to collect existing literature on this topic and examine it for key concepts. Considering the relatively low number of included studies compared to the number of papers found by the literature search, this might be explained by the clearly defined and specific inclusion criteria, as we were looking for interventions with a high level of participation for communities and a high proportion of digital implementation in the intervention. This focus was also reflected in the search strategy, where we searched specifically for community, participation and their synonymous terms. These criteria were needed for narrowing the amount of publications found at the initial search. However, this may have led to the omission of publications that might have been of interest for our work. Despite these limitations, we do consider this clear focus to be a strength and a quality criterion of this paper.

Other strengths of this review were the sound methodology based on recommended frameworks of Arksey and O'Malley and the PRISMA checklist for preferred reporting items.

CONCLUSION

This scoping review only found a few studies following a consequent digital format to enable a high level of community participation in health promotion and prevention, indicating an existing gap in research on this topic. Digital formats were found to be suitable for purposes where anonymity is helpful. In the included studies, this was apparent in qualitative participatory research studies, particularly in online focus groups that required participants to talk about sensitive subjects. Furthermore, the aspects of anonymity and easy accessibility appeared to be beneficial in supporting vulnerable and stigmatized communities, such as through peer exchanges and peer support programs. Further research should be conducted on the purposes for which digital formats can be more effective than traditional formats in enabling participation, in order to make more targeted use of the potential of digital technologies and social media. Disadvantages of digital formats, such as possible selection bias due to the digital divide and difficulties in interpreting written-only data, have to be weighed against the benefits. The consequences of social distancing due to the COVID-19 pandemic and the unpredictability of similar exceptional circumstances in the future stress the need to further develop and implement digital formats in health promotion and prevention activities in community settings.

AUTHOR CONTRIBUTIONS

CS conducted the database search. During the screening process, CS screened all records in the title/abstract and in the full-text screening stage. MC, SV, and CJ-S divided half of the records among each other during the title/abstract screening. In the full-text screening phase, MC and SV screened half of the records each. CS, SV, and MC were involved in the data extraction process. CS drafted the first version of this manuscript and developed it further based on feedback from SV and MC. CS, SV, CJ-S, and MC all read, reviewed, and approved of the final version of the manuscript. All authors contributed to the conception of the study and the development of the search strategy.

REFERENCES

1. World Health Organization. *Ottawa Charter for Health Promotion: First International Conference on Health Promotion Ottawa*. (1986). Available online at: https://www.euro.who.int/__data/assets/pdf_file/0004/129532/Ottawa_Charter.pdf (accessed February 6, 2021).
2. World Health Organization. Declaration of Alma-Ata International Conference on Primary Health Care, Alma-Ata, USSR, 6–12 September 1978. *Development*. (2004) 47:159–61. doi: 10.1057/palgrave.development.1100047
3. George AS, Mehra V, Scott K, Sriram V. Community participation in health systems research: a systematic review assessing the state of research, the nature of interventions involved and the features of engagement with communities. *PLoS ONE*. (2015) 10:e0141091. doi: 10.1371/journal.pone.0141091
4. O'Mara-Eves A, Brunton G, Oliver S, Kavanagh J, Jamal F, Thomas J. The effectiveness of community engagement in public health interventions for disadvantaged groups: a meta-analysis. *BMC Public Health*. (2015) 15:129. doi: 10.1186/s12889-015-1352-y
5. Abbott S. Social capital and health: the role of participation. *Soc Theory Health*. (2010) 8:51–65. doi: 10.1057/sth.2009.19
6. Navarro AM, Voetsch KP, Liburd LC, Giles HW, Collins JL. Charting the future of community health promotion: recommendations from the National Expert Panel on Community Health Promotion. *Prev Chronic Dis*. (2007) 4:A68.
7. Jeffres LW. Community. In: Michalos AC, editor. *Encyclopedia of Quality of Life and Well-Being Research*. Dordrecht: Springer. (2014). p. 1034–6.
8. Springer MV, Skolarus LE. Community-based participatory research. *Stroke*. (2019) 50:e48–50. doi: 10.1161/STROKEAHA.118.024241
9. Arnstein SR. A ladder of citizen participation. *J Am Inst Plann*. (1969) 35:216–24. doi: 10.1080/01944366908977225
10. Wright, MT, Block M, von Unger H, editor. *Partizipative Qualitätsentwicklung in der Gesundheitsförderung und Prävention. 1. Aufl. s.l.*: Verlag Hans Huber (2010). Available online at: http://elibrary.hogrefe.de/9783456948676/A (accessed October 22, 2021).
11. Duarte AMB, Brendel N, Degbelo A, Kray C. Participatory design and participatory research. *ACM Trans Comput Hum Interact*. (2018) 25:1–39. doi: 10.1145/3145472
12. Bethmann A, Hilgenböcker E, Wright M. Partizipative Qualitätsentwicklung in der Prävention und Gesundheitsförderung. In: Tiemann M, Mohokum M, editors. *Prävention und Gesundheitsförderung*. Berlin, Heidelberg: Springer Berlin Heidelberg (2020). p. 1–13.
13. Zeeb H, Pigeot I, Schüz B. Digital Public Health – Rasanter technischer Fortschritt, aber viele offene Public-Health-Fragen. *Bundesgesundheitsblatt Gesundheitsforschung Gesundheitsschutz*. (2020) 63:135–6. doi: 10.1007/s00103-020-03092-0
14. Clar C, Dyakova M, Curtis K, Dawson C, Donnelly P, Knifton L, et al. Just telling and selling: current limitations in the use of digital media in public health: a scoping review. *Public Health*. (2014) 128:1066–75. doi: 10.1016/j.puhe.2014.09.009
15. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Med Res Methodol*. (2018) 18:143. doi: 10.1186/s12874-018-0611-x
16. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. *Int J Evid Based Healthc*. (2015) 13:141–6. doi: 10.1097/XEB.0000000000000050
17. Arksey H, O'Malley L. Scoping studies: towards a methodological framework. *Int J Soc Res Methodol*. (2005) 8:19–32. doi: 10.1080/1364557032000119616
18. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. *Implement Sci*. (2010) 5:69. doi: 10.1186/1748-5908-5-69
19. Daudt HML, van Mossel C, Scott SJ. Enhancing the scoping study methodology: a large, inter-professional team's experience with Arksey and O'Malley's framework. *BMC Med Res Methodol*. (2013) 13:48. doi: 10.1186/1471-2288-13-48
20. Peters MDJ, Godfrey CM, McInerney P, Soares CB, Khalil H, Parker D. *The Joanna Briggs Institute Reviewers' Manual 2015: Methodology for JBI Scoping Reviews*. Joanna Briggs Institute, The University of Adelaide, Adelaide, SA, Australia (2015).
21. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): checklist and explanation. *Ann Intern Med*. (2018) 169:467–73. doi: 10.7326/M18-0850
22. Campbell IH, Rudan I. Effective approaches to public engagement with global health topics. *J Glob Health*. (2020) 10:1040901. doi: 10.7189/jogh.10.010901
23. Dogba MJ, Dossa AR, Breton E, Gandonou-Migan R. Using information and communication technologies to involve patients and the public in health education in rural and remote areas: a scoping review. *BMC Health Serv Res*. (2019) 9:128. doi: 10.1186/s12913-019-3906-7
24. Kruse C, Betancourt J, Ortiz S, Valdes Luna SM, Bamrah IK, Segovia N. Barriers to the use of mobile health in improving health outcomes in developing countries: systematic review. *J Med Internet Res*. (2019) 21:e13263. doi: 10.2196/13263
25. Ronen K, Grant E, Copley C, Batista T, Guthrie BL. Peer group focused eHealth strategies to promote HIV prevention, testing, and care engagement. *Curr HIV/AIDS Rep*. (2020) 17:557–76. doi: 10.1007/s11904-020-00527-w
26. Sharma AE, Frederiksen BN, Malcolm NM, Rollison JM, Carter MW. Community education and engagement in family planning: updated systematic review. *Am J Prev Med*. (2018) 55:747–58. doi: 10.1016/j.amepre.2018.06.022
27. Wu D, Ong JJ, Tang W, Ritchwood TD, Walker JS, Iwelunmor J, et al. Crowdsourcing methods to enhance HIV and sexual health services: a scoping review and qualitative synthesis. *J Acquir Immune Defic Synd*. (2019) 82(Suppl. 3):S271–8. doi: 10.1097/QAI.0000000000002193
28. Catalani C, Minkler M. Photovoice: a review of the literature in health and public health. *Health Educ Behav*. (2010) 37:424–51. doi: 10.1177/1090198109342084
29. Agdal R, Midtgård IH, Meidell V. Can asset-based community development with children and youth enhance the level of participation in health promotion projects? A qualitative meta-synthesis. *Int J Environ Res Public Health*. (2019) 16:3778. doi: 10.3390/ijerph16193778
30. Young SD, Cumberland WG, Nianogo R, Menacho LA, Galea JT, Coates T. The HOPE social media intervention for global HIV prevention in Peru: a cluster randomised controlled trial. *The Lancet HIV*. (2015) 2:e27–32. doi: 10.1016/S2352-3018(14)00006-X
31. Young SD, Holloway I, Jaganath D, Rice E, Westmoreland D, Coates T. Project HOPE: online social network changes in an HIV prevention randomized controlled trial for African American and Latino men who have sex with men. *Am J Public Health*. (2014) 104:1707–12. doi: 10.2105/AJPH.2014.301992
32. Young SD, Cumberland WG, Lee SJ, Jaganath D, Szekeres G, Coates T. Social networking technologies as an emerging tool for HIV prevention: a cluster randomized trial. *Ann Intern Med*. (2013) 159:318–24. doi: 10.7326/0003-4819-159-5-201309030-00005
33. 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
34. Barry MC, Threats M, Blackburn NA, LeGrand S, Dong W, Pulley DV, et al. "Stay strong! keep ya head up! move on! it gets better!!!!": resilience processes in the healthMpowerment online intervention of young black gay, bisexual and other men who have sex with men. *AIDS Care*. (2018) 30(suppl. 5):S27–38. doi: 10.1080/09540121.2018.1510106
35. Bridges N. The faces of breastfeeding support: experiences of mothers seeking breastfeeding support online. *Breastfeed Rev*. (2016) 24:11–20.
36. Hildebrand M, Ahumada C, Watson S. CrowdOutAIDS: crowdsourcing youth perspectives for action. *Reprod Health Matters*. (2013) 21:57–68. doi: 10.1016/S0968-8080(13)41687-7
37. Iantaffi A, Wilkerson JM, Grey JA, Rosser BRS. Acceptability of sexually explicit images in HIV prevention messages targeting men who have sex with men. *J Homosex*. (2015) 62:1345–58. doi: 10.1080/00918369.2015.1060066
38. Ripat J, Colatruglio A. Exploring winter community participation among wheelchair users: an online focus group. *Occup Ther Health Care*. (2016) 30:95–106. doi: 10.3109/07380577.2015.1057669
39. Rothpletz-Puglia P, Jones VM, Storm DS, Parrott JS, O'Brien KA. Building social networks for health promotion: shout-out health, New Jersey, 2011. *Prev Chronic Dis*. (2013) 10:E147. doi: 10.5888/pcd10.130018
40. Snider CE, Kirst M, Abubakar S, Ahmad F, Nathens AB. Community-based participatory research: development of an emergency department-based

youth violence intervention using concept mapping. *Acad Emerg Med.* (2010) 17:877–85. doi: 10.1111/j.1553-2712.2010.00810.x
41. Ybarra ML, DuBois LZ, Parsons JT, Prescott TL, Mustanski B. Online focus groups as an HIV prevention program for gay, bisexual, and queer adolescent males. *AIDS Educ Prev.* (2014) 26:554–64. doi: 10.1521/aeap.2014.26.6.554
42. Gilbey D, Morgan H, Lin A, Perry Y. Effectiveness, acceptability, and feasibility of digital health interventions for LGBTIQ+ young people: systematic review. *J Med Internet Res.* (2020) 22:e20158. doi: 10.2196/20158
43. Schaeffer D, Vogt D, Berens EM, Hurrelmann K. *Gesundheitskompetenz der Bevölkerung in Deutschland*. Bielefeld: Ergebnisbericht (2016).
44. Nared J, Bole D. *Participatory Research and Planning in Practice*. Cham: Springer International Publishing (2020).
45. Tucker JD, Day S, Tang W, Bayus B. Crowdsourcing in medical research: concepts and applications. *PeerJ.* (2019) 7:e6762. doi: 10.7717/peerj.6762
46. Fortuna KL, Naslund JA, LaCroix JM, Bianco CL, Brooks JM, Zisman-Ilani Y, et al. Digital peer support mental health interventions for people with a lived experience of a serious mental illness: systematic review. *JMIR Ment Health.* (2020) 7:e16460. doi: 10.2196/16460
47. Hansen K. Using An Asynchronous Discussion Board For Online Focus Groups: A Protocol And Lessons Learned. In: *College Teaching & Learning Conference*. Orlando, FL (2006).
48. Hartung S, Wihofszky P, Wright MT. *Partizipative Forschung*. Wiesbaden: Springer Fachmedien Wiesbaden (2020).
49. Wadham E, Green C, Debattista J, Somerset S, Sav A. New digital media interventions for sexual health promotion among young people: a systematic review. *Sex Health.* (2019) 16:101–23. doi: 10.1071/SH18127
50. Howarth A, Quesada J, Silva J, Judycki S, Mills PR. The impact of digital health interventions on health-related outcomes in the workplace: a systematic review. *Digit Health.* (2018) 4:2055207618770861. doi: 10.1177/2055207618770861
51. Marcolino MS, Oliveira JAQ, D'Agostino M, Ribeiro AL, Alkmim MBM, Novillo-Ortiz D. The impact of mHealth interventions: systematic review of systematic reviews. *JMIR Mhealth Uhealth.* (2018) 6:e23. doi: 10.2196/mhealth.8873
52. Hall CL, Sanderson C, Brown BJ, Andrén P, Bennett S, Chamberlain LR, et al. Opportunities and challenges of delivering digital clinical trials: lessons learned from a randomised controlled trial of an online behavioural intervention for children and young people. *Trials.* (2020) 21:1011. doi: 10.1186/s13063-020-04902-1
53. Askitas N, Tatsiramos K, Verheyden B. Estimating worldwide effects of non-pharmaceutical interventions on COVID-19 incidence and population mobility patterns using a multiple-event study. *Sci Rep.* (2021) 11:1972. doi: 10.1038/s41598-021-81442-x

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Field Epidemiology and Public Health Research Priorities in the Eastern Mediterranean Region: Delphi Technique

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Research is essential for evidence-based decision making. This study aimed to identify research priorities in the areas of field epidemiology and public health in the Eastern Mediterranean Region (EMR) from the perspectives of public health professionals. A Delphi technique, using online survey, was employed to reach 168 public health professionals who have experience in the EMR countries. The study took place between November 2019 and January 2020. Consensus on the research priorities was reached after two-round online questionnaires. A list of top 10 field epidemiology and public health research priorities in the EMR was developed. Of those priorities, four fell under health in emergency, war and armed conflict, two under communicable diseases, two under immunization, one under digital health, and one under sexual, reproductive, and adolescent health. Availability, adequacy, and quality of health services in crisis settings were scored as a top priority (mean = 4.4, rank 1), followed by use of technology to improve the collection, documentation, and analysis of health data (mean = 4.28, rank 2), and capacity of countries in the region to respond to emergencies (mean = 4.25, rank 3). This study was conducted prior to COVID-19 pandemic and, thus, it did not capture COVID-19 research as a priority area. Nevertheless, identified priorities under communicable diseases including outbreak investigation of infectious diseases, epidemics and challenges related to communicable diseases in the EMR were still notable. In conclusion, the field epidemiology and public health research priorities identified in this study through a systematic inclusive process could be useful to make informed decisions and gear the research efforts to improve the health of people in the EMR.

Keywords: field epidemiology, public health, research priorities, Eastern Mediterranean Region, conflict countries

INTRODUCTION

Strengthening the field epidemiology and public health services in the Eastern Mediterranean Region (EMR) is a top priority nowadays due to several health challenges that resulted from political conflicts, environmental threats and natural disasters (1). The recent COVID-19 pandemic clearly revealed the fragility of health systems in many EMR countries, especially conflict-affected countries (2, 3).

Research is a vital tool that enables the improvement of health and health equity in low- and middle-income countries (LMICs), taking into consideration the critical needs and importance of sustainable development outcomes in these countries (4, 5). The 2013 World Health Report released by the World Health Organization (WHO) identifies four essential ways in which health systems can support health research: setting research priorities, building research capacity, defining norms and standards for research and translating evidence into practice (5). In LMICs, research should be prioritized to respond directly to community health needs. Otherwise, there is a risk that research conducted in LMICs will be according to funders' agendas, distort national priorities, undermine the role of national research in LMIC or fail to respond to explicit health needs (4, 6). If research priorities are not set, researchers and research sponsors cannot align their activities with national health and development goals (4).

Knowledge of the stage of health transition of a country and identifying diseases burden are necessary for effective setting of research priorities. Several studies have been conducted in LMICs to identify research priorities, including priorities in the fields of multisectoral collaboration for health (7), human resources for health (8), and adolescent health (9). A study conducted in 2019 that aimed to address primary care research priorities in 50 LMICs found four emerging priority areas: effective transition of primary and secondary services, horizontal integration within a multidisciplinary team and intersectoral referral, integration of private and public sectors, and ways to support successfully functioning PHC professionals (10).

There are several methods that are used for health research priority setting, including the 3-Dimensional Combined Approach Matrix (3D CAM) (11), the Child Health and Nutrition Research Initiative (CHNRI) method (12), the Council on Health Research and Development (COHRED) method (13), and the Delphi method (14). The Delphi method is based on a structured process for collecting and distilling knowledge from a group of public health professionals by means of a series of questionnaires interspersed with controlled opinion feedback. The aim of this process is to determine the future development of a particular topic by the public health professionals and help decision making on a profound basis. The features of the Delphi method include anonymity, iteration of arguments, communicativeness, well-founded feedback, wide range of expertise, rapidity of achieving consensus, and learning with dialogue (14). This technique has been extensively applied in research priority development and healthcare program planning (15).

This study aimed to identify research priorities in the areas of field epidemiology and public health in the EMR from the perspectives of public health professionals. The findings of this study are expected to help in decision making and planning of research resources, research funding, and implementation in the region to solve priority public health problems.

METHODS

Delphi technique was used in this study to reach an unanimity among public health professionals on field epidemiology and public health research priorities in the EMR Region. We employed this technique to instigate informational cascade from 168 public health professionals to reach a structured consensus. An experienced facilitator used a validated questionnaire followed by a prioritization tool employing a Likert scale (1–5) while conforming with the Delphi technique key features to reach consensus including: anonymity to avoid domination, private ranking in the group iteration that occurred in "rounds" and allowing the participants to change their minds. The consensus was reached after two rounds with controlled feedback.

We included a total of 168 public health professionals from all countries of the region representing different institutions, including ministries of health and academia, who were involved in Field Epidemiology Training Programs (FETPs), local and/or national level public health programs, and/or research entities in the EMR countries. These public health professionals were identified and selected from current Eastern Mediterranean Public Health Network (EMPHNET) databases, including its Regional Roster of Public health professionals and the EMPHNET Resources Engine (ERE). The public health professionals came from a wide range of background expertise and research interests in various public health areas. They all had leading/technical positions in their relevant institutions which contributed to the identification of the priority research areas during the Delphi process. They served as individuals with expert opinion about the subject matter and key informants to the prioritization process.

This research project comprised of a two-round online questionnaire. A facilitator familiar with the Delphi technique facilitated the process of identifying the focal points for FETPs recruiting public health professionals and following up with them in both rounds. The main language used throughout the process (both rounds) was English. However, some initial inputs for the first round were also provided in Arabic and were translated to English. Both rounds took place between November 2019 and January 2020.

The first-round questionnaire was developed using the KoBo Toolbox platform and sent to public health professionals by email. It collected general demographic details including years of experience. Each expert was then requested to identify up to five specific priority research questions in the area of field Epidemiology and/or public health in their respective countries or in the EMR region. They were also asked if they were willing to receive the second-round questionnaire to prioritize

research areas. The median duration spent on filling out the first-round questionnaire was 17 min, with at least one third of the participants filling out the questionnaires in 6 to 15 min.

The research questions raised by the public health professionals in round one were then synthesized, clustered, and grouped into 11 major areas: (1) Mental health, (2) Sexual, reproductive health and adolescent health, (3) Communicable diseases, (4) Non-communicable diseases, (5) Health in Emergency, War and Armed Conflict, (6) Immunization/vaccination, (7) Disease surveillance, (8) Field Epidemiology Training Program (FETP), (9) Health care and health system, (10). Health technology, and (11) Zoonotic diseases, with research topics under each area.

The results obtained from this questionnaire (i.e., the research topics/questions under each) were analyzed to develop the second-round questionnaire. The second online survey that included a battery of research topics (for countries and for the region) was then sent using the same platform and only to those who agreed to be contacted again. At this stage, participating public health professionals were asked to score/rank the research topics using five-point Likert scale; 1—Not a priority, 2—Low priority, 3—Medium priority, 4—High priority, and 5—Essential. Respondents were requested to rate each research topic. The responses from the second questionnaire were analyzed using the average scores from the above ranking. In addition to calculation of mean priority score, the percentages of public health professionals who rated the research topic as essential were calculated. To conclude, the analysis was shared with the public health professionals to standardize their responses. The overall process is summarized in **Figure 1**.

RESULTS

Participants' Characteristics

A total of 168 public health professionals (112 males and 56 females) from all EMR countries responded to first round questionnaire. Their average years of experience after graduation from the highest degree they earned was 9.7 years. Of the total health professionals, 67 (39.9%) were from ministries of health, 54 (32.1%) from academia, 25 (14.9%) from FETPs, 12 (7.1%) from local and/or national level public health programs, and 10 (6.0%) from research entities in the EMR countries.

Round 1

A total of 1,187 research questions were raised by the public health professionals. After removing duplicates and repetitive questions, the remaining questions (425 questions) were synthesized by merging similar questions and coming with broader research topics. Finally, a total of 54 research topics were clustered and grouped into 11 major areas. The 54 research topics were then presented and used in the second-round questionnaire to be ranked.

Round 2

Table 1 shows the priority scoring of 54 research topics categorized according to research area. Of the top 10 priority areas identified according to the mean priority score: four priority areas fell under Health in Emergency, War and Armed Conflict, two under communicable diseases, two under immunization, one under digital health, and one under sexual, reproductive, and adolescent health. **Table 2** shows the top 10 priority research areas. Availability, adequacy, and quality of health services in crisis settings were scored as a top priority (mean = 4.4, rank 1), followed by the use of technology to improve the collection, documentation and analysis of health data (mean = 4.28, rank 2), and capacity of countries in the region to respond to emergencies (mean = 4.25, rank 3). The other research topics identified as among top 10 priority topics were outbreak investigation of infectious, causes of maternal and infant mortality, state of preparedness in the region to address a disease outbreak, epidemics and challenges related to communicable diseases in the EMR Region, situation of health during crisis/emergencies in the EMR region, risk assessment of emergencies and threats in the EMR Region, and immunization gaps in the region identified through disease surveillance and regional response guidelines.

Using the percentage of respondents who identified the research area as essential, two areas belonging to immunization and surveillance were identified as of less priority. Instead, the impact of Field Epidemiology Training Programs on the timeliness of disease surveillance, detection, and response (percentage = 41.7%, rank = 5) and impact of vaccination on human health/reduction of diseases (percentage = 40.0%, rank = 6) were identified among the top 10 research priorities.

DISCUSSION

Of the 10 priorities, four fell under health in emergency, war and armed conflict. This finding may be explained by the fact that, in the past years, the Region has been affected most by emergencies, war, and armed conflict. Most of the field epidemiology staff in these countries are dealing with issues caused by these crises, including the issues related to the availability, adequacy, and quality of health services, workforce capacity and preparedness to respond to crises and disease outbreaks, and any assessments needed during crises/emergencies. However, this study still represents a wide view of public health professionals regarding the field epidemiology and public health in the EMR Region. In terms of practicality of the approach, the median duration for filling out first round questionnaires was 17 min, which provides insights into planning for questionnaires of a similar length for distribution to a large list-serve/roster of public health professionals and getting back valuable inputs in a reasonably short period of time. This study was conducted before the COVID-19 pandemic. Thus, the questionnaires did not specifically ask for and capture any prioritization of COVID-19 research. However, although not mentioned directly in the collected questions, public health professionals provided six questions about MERS-CoV and one on SARS in the collected data, indicating the importance of this family of viruses even before the COVID-19 pandemic. These questions focused on the prevalence of SARS and MERS-CoV in the EMR region, risk of travel associated cases of MERS CoV, exploring the difference of MERS CoV strain of viruses from one country

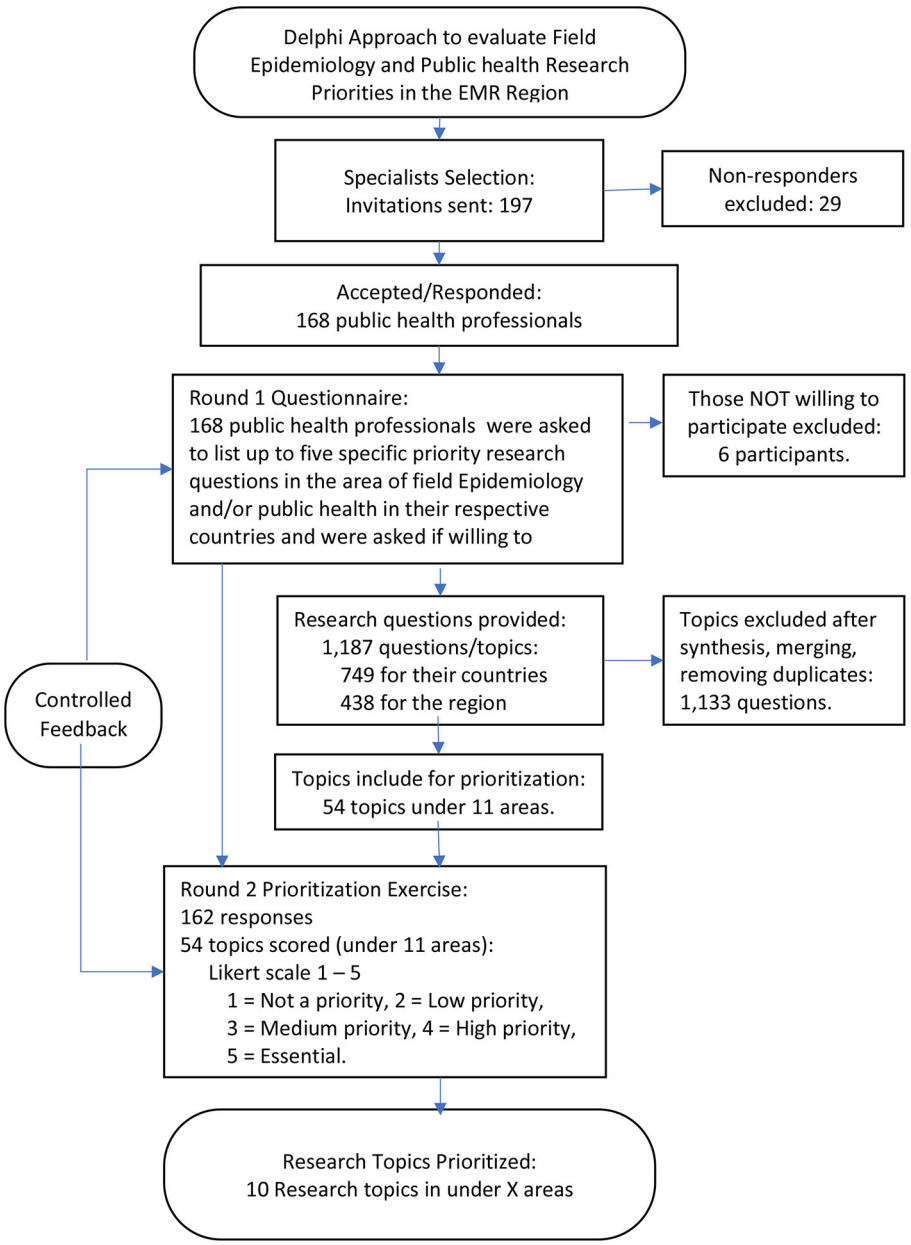

FIGURE 1 | The Delphi process to evaluate research priorities in the EMR.

to another, and the role of cultural and religious leaders in controlling MERS-CoV.

The top research priority was focused on the availability, adequacy, and quality of health services in crisis settings (emergency, war and armed conflict). The EMR is afflicted with several foci of humanitarian crises and civil unrest, including the Syrian, Yemeni, Libyan, Iraqi, Palestinian and Sudanese crises. Following the Syrian crisis in 2011, approximately 6.6 million Syrians were internally displaced, and around 5.6 million sought refuge in surrounding countries (16). As for the Yemeni crisis in 2011, more than 2 million people were displaced, and 14 million are now facing pre-famine conditions (17). The region is facing many health problems, including the re-emergence of communicable diseases such as polio and malaria, in addition to non-communicable diseases such as malnutrition, and post-traumatic stress disorder (PTSD).

In areas of conflict, research is not prioritized, as resources are directed toward security, conflict resolution, acute humanitarian response, and refugee/ migration management. A study conducted in Lebanon, a country with a long history of political conflicts and a home to many refugees, showed that there is a lack of nationwide research culture, health

TABLE 1 | The priority scoring of 54 research topics categorized according to research area.

Research Areas and Research Topics	Priority average score		Scored as "essential"	
	Mean	SD	n	%
Mental health				
Mental health of refugees, particularly children and adolescents	3.83	1.08	19	31.7
Promotion and protection of the rights of people with mental disorders	3.56	0.82	6	10.0
Mental health promotion and advocacy	3.58	0.81	6	10.0
Evaluation of mental health programs	3.48	0.91	8	13.3
Sexual, reproductive, and adolescent health				
Causes of maternal and infant mortality	4.22	0.98	30	50.0
Importance of enforcing and implementing public health legislation to reduce morbidity and mortality in the EMR	4.08	0.89	22	36.7
Sexual transmitted diseases	3.82	0.87	15	25.0
Integrating Minimum Initial Service Package (MISP) into primary healthcare	3.78	1.03	17	28.3
Sexual Based Violence (SBV) and Gender Based Violence (GBV)	3.67	0.88	10	16.7
Pattern of domestic violence	3.32	0.85	4	6.7
Burden, leading causes and treatment of infertility	3.18	0.98	6	10.0
Zoonotic diseases				
Opportunities and challenges of zoonotic disease surveillance and one health approach	4.03	0.82	18	30.0
Managing, treating and preventing common zoonotic diseases in the EMR (i.e., brucellosis, rabies, hemorrhagic fever)	3.93	0.92	19	31.7
Climate change and the emergence of vector-borne diseases	3.82	0.97	17	28.3
Impact of war on the emergence of zoonotic disease	3.68	1.09	12	20.0
Communicable disease				
Outbreak investigation of infectious diseases (H1N1, Cholera, measles, polio, brucellosis)	4.23	0.70	22	36.7
Epidemics and challenges related to communicable diseases in the EMR region	4.20	0.71	22	36.7
Real burden of Anti-Microbial Resistance (AMR), microorganisms of concern, and interventions to manage/prevent AMR	4.07	0.78	19	31.7
Burden, management and treatment of MERS-CoV in the EMR region	4.02	0.87	21	35.0
Effect of armed conflicts in the region on the map of infectious diseases	3.92	1.06	20	33.3
Hospital acquired infections	3.92	0.77	13	21.7
Mathematical modeling to control emerging infectious diseases	3.75	0.84	10	16.7
The pattern of diseases encountered among pilgrims	3.68	0.89	11	18.3
Research topics related to Non-Communicable Diseases (NCDs)				
Burden, challenges, prevention, control of Non-Communicable Diseases in the region (Cardiovascular diseases, obesity, diabetes)	4.08	0.81	20	33.3
Effect of smoking cigarettes/ e-cigarettes on health	3.65	1.09	17	28.3
The determinants of uncontrolled obesity and how to overcome it	3.58	0.98	11	18.3
Health in Emergency, War and Armed Conflict				
Availability, adequacy and quality of health services in crisis settings	4.40	0.69	30	50.0
Capacity of countries to respond to emergencies	4.25	0.75	25	41.7
State of preparedness to address a disease outbreak	4.22	0.72	22	36.7
Situation of health during crisis/emergencies in the EMR region	4.20	0.75	22	36.7
Development of interventions to improve the health of vulnerable populations	4.03	0.66	13	21.7
Assessment of health systems and health-related interventions in War and Armed Conflict areas	4.02	1.03	21	35.0
Health of refugees/conflict related victims and the quality of services delivered to this population	3.88	0.87	13	21.7
Association between conflicts/wars and emergence of diseases	3.77	0.93	10	16.7
Supporting sustainable development and community-based assets in fragile settings	3.76	0.86	11	18.3
Research topics related to Immunization/vaccination				
Immunization gaps in the region identified through disease surveillance and regional response guidelines	4.10	0.84	21	35.0
Re-emergence of diseases (i.e., measles) despite vaccination efforts	4.05	0.83	18	30.0
Impact of vaccination on human health / reduction of diseases	3.95	1.07	24	40.0

(Continued)

TABLE 1 | Continued

Research Areas and Research Topics	Priority average score		Scored as "essential"	
	Mean	SD	n	%
Impact of Expanded Program on Immunization (EPI) coverage	3.95	0.91	19	31.7
Disease Surveillance				
Risk assessment of emergencies and threats	4.15	0.68	18	30.0
Initiatives to strengthen priority disease surveillance	4.08	0.65	15	25.0
Utilization of innovative tools/ research for evolving Public Health Surveillance	4.00	0.76	15	25.0
Level of networking and collaboration between stakeholders during outbreaks in the EMR region	3.98	0.75	15	25.0
Research topics related to Field Epidemiology Training Program (FETP)				
Impact of Field Epidemiology Training Programs on the timeliness of disease surveillance, detection and response	4.08	1.01	25	41.7
Field screening to determine disease outbreak in the region (i.e., vector-borne outbreaks)	3.98	0.83	17	28.3
Health care and health system				
Challenges in ensuring data quality of health information system and utilization of data for policy action	4.07	0.67	15	25.0
Strategies to improve the health system in the region.	4.07	0.69	14	23.3
Challenges of achieving Universal Health Coverage (UHC) in the region	4.05	0.77	18	30.0
Allocating and utilizing resources to improve the health of the community	4.05	0.62	13	21.7
Rebuilding Health Systems in Fragile and Conflict Affected States	3.95	0.84	13	21.7
The effect of social/cultural factors on shaping the health seeking behavior	3.73	0.81	7	11.7
Human right	3.67	1.08	15	25.0
Digital health				
Use of technology to improve the collection, documentation and analysis of health data	4.28	0.72	25	41.7
Developing national electronic health records	4.02	0.83	18	30.0

TABLE 2 | The top 10 priority research topics in public health and field epidemiology.

Research areas	Priority research topics	Mean priority score	Rank	Percentage scored essential	Rank
Health in Emergency, War and Armed Conflict	Availability, adequacy, and quality of health services in crisis settings	4.4	1	50	1
Digital health	Use of technology to improve the collection, documentation and analysis of health data	4.28	2	41.7	3
Health in Emergency, War and Armed Conflict	Capacity of countries in the region to respond to emergencies	4.25	3	41.7	4
Communicable disease	Outbreak investigation of infectious diseases (H1N1, Cholera, measles, polio, brucellosis)	4.23	4	36.7	7
Sexual, reproductive, and adolescent health	Causes of maternal and infant mortality	4.22	5	50	2
Health in Emergency, War and Armed Conflict	State of preparedness in the region to address a disease outbreak	4.22	6	36.7	8
Communicable disease	Epidemics and challenges related to communicable diseases in the EMR	4.2	7	36.7	9
Health in Emergency, War and Armed Conflict	Situation of health during crisis/emergencies in the EMR	4.2	8	36.7	10
Disease surveillance	Risk assessment of emergencies and threats in the EMR	4.15	9	30	21
Immunization/vaccination	Immunization gaps in the region identified through disease surveillance and regional response guidelines	4.1	10	35	12

researchers facing insufficient funding and limited access to data, insufficient training of medical students to conduct research and poor impact of research on policy (18). However, research capacity strengthening in conflict settings aids in collecting highest standard evidence, assessing health needs of affected population, bridging the gap between research and practice, and

eventually, informing advocacy and policy change. Furthermore, strengthening research capacity may help address major endemic diseases, evaluate and improve relief work, and support social changes to improve the quality of assistance provided.

Use of technology to improve the collection, documentation and analysis of health data was ranked the second top research priority. In many countries in the EMR, health informatics governance is very weak due to a lack of national strategies and policies, or non-adherence to them, leading to a fragmented health information development and implementation. The public are not involved in policy development, monitoring and accountability for health information technology, causing lack of confidentiality and uncertainty regarding data ownership. Furthermore, integrated health informatics education programs are scarce in the region (19).

Ranked third and fourth top priority research topics were capacity of countries in the region to respond to emergencies and outbreak investigation of infectious diseases. Countries in the EMR are a hotspot for emerging and reemerging infectious diseases. In the past decade, Sudan has experienced 3 outbreaks of Yellow fever, and Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Tunisia, the United Arab Emirates and Yemen faced the Middle East Respiratory Syndrome, among several other widespread outbreaks in the EMR, such as Chikungunya, Cholera, and influenza A (H1N1, H5N1, and H9N2) (20). Furthermore, internally displaced people, refugees and host communities are at a high risk of potential outbreaks due to fragile public health systems and weak surveillance and detection.

Low levels of awareness concerning infection symptoms at the early stages of the disease, especially at the primary care level and in hospital departments for NCDs, leads to clinical diagnostic mistakes, and poor management of infection control measures. The regional preparedness, response and control efforts toward communicable diseases face major challenges such as poor surveillance, lack of integrated vector management approaches, week multidisciplinary and intersectoral collaboration, and the absence of comprehensive readiness and response plans (21). Moreover, there is a need for consensus for establishing a standard case definition for infections to prevent major gaps in definition and reporting of mortality rates between endemic countries.

The fifth top research priority was causes of maternal and infant mortality. Maternal mortality ratio (MMR) is one of the main criteria of health outcomes and an indicator of socioeconomic development. In the EMR Region, except in Djibouti, Palestine and Afghanistan, maternal mortality from 1990 to 2015 has declined, but the burden remains higher than the global average (22). A study that aimed to prioritize research on sexual and reproductive health in the African and EMR found that one of the priorities is addressing adolescent violence and preventing early pregnancy, as early marriage and pregnancy leads to higher maternal and infant mortality rates (23). Morocco and Jordan have implemented interventions that have drastically reduced maternal mortality by >75% from the year 1990 to 2015, while low-income countries have seen minimal to no improvement (22). Some challenges to improving maternal health include manmade disasters and conflicts, political instability, domestic crises, and economic sanctions (22, 24).

Epidemics and challenges related to communicable diseases, health during crisis/emergencies, risk assessment of emergencies and threats and immunization gaps were ranked among the top 10 priority research topics. The EMR has seen a great improvement in routine vaccination coverage, but political unrest, complex emergencies, humanitarian crises and socioeconomic hardship affecting the region have caused disruption of immunization systems in several countries. For example, the coverage of the Diphtheria, Tetanus and Pertussis vaccine and third dose of the oral polio vaccine in the region has dropped form 86% in 2010 to 80% in 2015, with wide inter-and intra-country differences (25).

There are many disparities in influenza vaccination rates between different countries in the EMR, as well as low vaccination coverage. A study that investigated seasonal influenza vaccination policies in the EMR showed that of the 20 countries involved in the study, only 14 had seasonal influenza vaccination policies at the time of the survey, and of these 14, only five included the vaccine in their national immunization program (26). Furthermore, of the 20 countries, three countries did not have an active influenza surveillance system.

One of the strengths of this research approach is the convenience and the rapid consensus that was achieved in two rounds. The whole process was virtual without having the participants in the same room to get the group dynamics and reach agreement. We were able to gather wide range of public health professionals from all countries of EMR at a relatively low cost of administration and analysis. The respondents were free to express their opinion against the group thinking. The Delphi technique was useful to gain valuable insightful data about a topic where knowledge was lacking.

Limitations

Like every other study, this one has its limitations because the Delphi technique does not cope well with widely differing opinions or paradigm shifts. Also, there may be chances of selection bias involved because participation was voluntary and those who responded to the two rounds of questionnaires might be different from those who did not respond. However, an explanation of the four priorities linked with public health emergencies can be found at the beginning of the Discussion section. Also, the existence of any selection bias could not be detected through the implemented technique and, given the qualitative nature of the collected information, any mechanism to look for such bias would have little effect on the type of questions that were generated by subject matter experts in the first round and ranked in the second round.

CONCLUSIONS

The results of our study highlight the importance of training future researchers in a contextualized approach toward field epidemiology and public health in conflict settings. Furthermore, there is a need to improve and expand health informatics

training to increase the number of health information technology professionals. Policymakers should be involved in designing research agendas, and this can be achieved by multiple stakeholder involvement and collaboration. Strategic frameworks should be developed for prevention and control of emerging diseases, and for integrating early warning systems for diseases outbreaks in countries affected by humanitarian crises. Moreover, there is a need for establishing standard case definitions for infections, and developing an algorithm for clinical, epidemiological, occupational, and other demographic characteristics.

DATA AVAILABILITY STATEMENT

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

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Institutional Review Board of Jordan University of Science and Technology. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

MAN, TC, and YK contributed to conception, design of the study, manuscript revision, and wrote the first draft of the manuscript. YK performed the statistical analysis. HT wrote sections of the manuscript and contributed to manuscript revision. All authors contributed to the article and approved the submitted version.

REFERENCES

1. Mataria A, Hajjeh R, Al-Mandhari A. Surviving or thriving in the Eastern Mediterranean Region: the quest for universal health coverage during conflict. *Lancet.* (2020) 395:13–5. doi: 10.1016/S0140-6736(19)33061-2
2. Da'ar OB, Haji M, Jradi H. Coronavirus disease 2019 (COVID-19) : potential implications for weak health systems and conflict zones in the Middle East and North Africa region. *Int J Health Plan Manag.* (2020) 35:1240–5. doi: 10.1002/hpm.2982
3. AlKhaldi M, Kaloti R, Shella D, Al Basuoni A, Meghari H. Health system's response to the COVID-19 pandemic in conflict settings: policy reflections from Palestine. *Glob Public Health.* (2020) 15:1244–56. doi: 10.1080/17441692.2020.1781914
4. McGregor S, Henderson KJ, Kaldor JM. How are health research priorities set in low and middle income countries? A systematic review of published reports. *PLoS ONE.* (2014) 9:e108787. doi: 10.1371/journal.pone.0108787
5. World Health Organization. *World Health Report 2013: Research for Universal Health Coverage*. Wahington, DC: WHO Regional Office for Africa (2013).
6. Sridhar D. Who Sets the Global Health Research Agenda? The Challenge of Multi-Bi Financing *PLoS Med.* (2012) 9:e1001312. doi: 10.1371/journal.pmed.1001312
7. Glandon D, Meghani A, Jessani N, Qiu M, Bennett S. Identifying health policy and systems research priorities on multisectoral collaboration for health in low-income and middle-income countries. *BMJ Glob Heal*th. (2018) 3(Suppl. 4):970. doi: 10.1136/bmjgh-2018-000970
8. WHO. *Identification of Priority Research Questions in Three Thematic Areas: Human Resources for Health, Health Financing and the Role of the Non-State Sector*. WHO. 2007; Available online at: https://www.who.int/alliance-hpsr/projects/makerere_iprqthematicareas/en/ (accessed May 5, 2020).
9. Nagata JM, Ferguson BJ, Ross DA, Ch B. Research priorities for eight areas of adolescent health in low- and middle-income countries. *J Adolesc Health.* (2016) 59:50–60. doi: 10.1016/j.aogh.2016.04.468
10. Goodyear-Smith F, Bazemore A, Coffman M, Fortier R, Howe A, Kidd M, et al. Primary care research priorities in low-and middle-income countries. *Ann Fam Med.* (2019) 17:31–5. doi: 10.1370/afm.2329
11. Ghaffar A, Collins T, Matlin S, Olifson S. *The 3D Combined Approach Matrix: An Improved Tool for Setting Priorities in Research for Health*. Geneva: Global Forum for Health Research (2009).
12. Chongtrakul P, Datta M, Figueroa P, Ann Lansang Chair M, Neufeld V, Ontario H, et al. *A Manual for Research Priority Setting using the ENHR Strategy*. Geneva: COHRED (2000).
13. Montorzi G, De S, Carel H, Contributions I, Kennedy A, Becerra F, et al. *Priority Setting for Research for Health A management process for countries Council on Health Research for Development (COHRED)*. Geneva: COHRED (2010).
14. Okoli C, Pawlowski SD. The Delphi method as a research tool: an example, design considerations and applications. *Inf Manag.* (2004) 42:15–29. doi: 10.1016/j.im.2003.11.002
15. de Villiers MR, de Villiers PJT, Kent AP. The Delphi technique in health sciences education research. *Med Teach.* (2005) 27:639–43. doi: 10.1080/13611260500069947
16. UNHCR. *Situation Syria Regional Refugee Response* [Internet]. 2020 [cited 2020 May 5]. Available online at: https://data2.unhcr.org/en/situations/syria/location/36 (accessed May 5, 2020).
17. United Nations. *Half the Population of Yemen At Risk of Famine: UN Emergency Relief Chief*. 2018. Available online at: https://news.un.org/en/story/2018/10/1023962
18. El Achi N, Honein-Abouhaidar G, Rizk A, Kobeissi E, Papamichail A, Meagher K, et al. Assessing the capacity for conflict and health research in Lebanon: a qualitative study. *Confl Health.* (2020) 14:59. doi: 10.1186/s13031-020-00304-x
19. Househ M, Taweel A, Othmani MB. Middle East and North African Health Informatics Association (MENAHIA): building sustainable collaboration. *Yearb Med Inform.* (2018) 27:286–91. doi: 10.1055/s-0038-1641207
20. Buliva E, Elhakim M, Tran Minh NN, Elkholy A, Mala P, Abubakar A, et al. Emerging and reemerging diseases in the World Health Organization (WHO) Eastern Mediterranean Region—progress, challenges, And WHO initiatives. *Front Public Health.* (2017) 5:276. doi: 10.3389/fpubh.2017.00276
21. Araj R, Alqasrawi S, Samy S, Alwahdanee G, Wadi J, Mofleh J, et al. Preventing emerging and re-emerging infections in the Eastern Mediterranean Region: gaps, challenges, and priorities. *JMIR Public Health Surveill.* (2019) 5:e14348. doi: 10.2196/14348
22. Khalil I, Collison M, El Bcheraoui C, Charara R, Moradi-Lakeh M, Afshin A, et al. Maternal mortality and morbidity burden in the Eastern Mediterranean Region: findings from the Global Burden of Disease 2015 study. *Int J Public Health.* (2018) 63:47–61. doi: 10.1007/s00038-017-1004-3
23. Ali M, Farron M, Ouedraogo L, Mahaini RK, Miller K, Kabra R. Research gaps and emerging priorities in sexual and reproductive health in Africa and the Eastern Mediterranean Regions. *Reprod Health.* (2018) 15:39. doi: 10.1186/s12978-018-0484-9
24. Mokdad AH, Forouzanfar MH, Daoud F, El Bcheraoui C, Moradi-Lakeh M, Khalil I, et al. Health in times of uncertainty in the Eastern Mediterranean Region, 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013. *Lancet Glob Heal.* (2016) 4:e704–13. doi: 10.1016/S2214-109X(16)30168-1
25. Al Gunaid M, Lami F, Jarour N, A. Collaborative initiative to strengthen sustainable public health capacity for polio eradication and routine immunization activities in the Eastern Mediterranean Region. *JMIR Public Heal Surveill.* (2019) 5:e14664. doi: 10.2196/14664
26. Abubakar A, Melhem N, Malik M, Dbaibo G, Khan WM, Zaraket H. Seasonal influenza vaccination policies in the Eastern Mediterranean

Region: current status and the way forward. *Vaccine.* (2019) 37:1601–7. doi: 10.1016/j.vaccine.2019.02.001

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Process Evaluation of an Application-Based Salt Reduction Intervention in School Children and Their Families (AppSalt) in China: A Mixed-Methods Study

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Background: Salt reduction is a cost-effective, and rather challenging public health strategy for controlling chronic diseases. The AppSalt program is a school-based multi-component mobile health (mhealth) salt reduction program designed to tackle the high salt intake in China. This mixed-methods process evaluation was conducted to investigate the implementation of this program across sites, identify factors associated with the implementation, and collect evidence to optimize the intervention design for future scale-up.

Methods: Mixed methods were used sequentially to collect data regarding five process evaluation dimensions: fidelity, dose delivered, dose received, reach, and context. Quantitative data were collected during the intervention process. Participation rate of intervention activities was calculated and compared across cities. The quantitative data was used for the selection of representative intervention participants for the qualitative interviews. Qualitative data were collected in face-to-face semi-structured interviews with purposively selected students ($n = 33$), adult family members ($n = 33$), teachers ($n = 9$), heads of schools ($n = 9$), key informants from local health, and education departments ($n = 8$). Thematic analysis technique was applied to analyze the interview transcripts using NVivo. The qualitative data were triangulated with the quantitative data during the interpretation phase.

Results: The total number of families recruited for the intervention was 1,124. The overall retention rate of the AppSalt program was 97%. The intervention was implemented to a high level of fidelity against the protocol. About 80% of intervention participants completed all the app-based salt reduction courses, with a significant difference across the three cities (Shijiazhuang: 95%; Luzhou: 73%; Yueyang: 64%). The smartphone app in this program was perceived as a feasible and engaging health education tool by most intervention participants and key stakeholders. Through the interviews with participants and key stakeholders, we identified some barriers to implementing this program at

primary schools, including the left-behind children who usually live with their grandparents and have limited access of smartphones; perceived adverse effects of smartphones on children (e.g., eyesight damage); and overlooked health education curriculum at Chinese primary schools.

Conclusion: This process evaluation demonstrated the feasibility and acceptability of using smartphone applications delivered through the education system to engage families in China to reduce excessive salt intake.

Clinical Trial Registration: The AppSalt study was registered at www.chictr.org.cn, identifier: ChiCTR1800017553. The date of registration is August 3, 2018.

Keywords: process evaluation, salt reduction, mHealth (mobile Health), primary school, mixed method approach

INTRODUCTION

Salt reduction is one of the best-buy strategies for controlling the burden of non-communicable diseases (NCDs) (1). Many high-income countries have implemented their national salt reduction strategies (2) and achieved a significant reduction of average population salt intake, such as Finland and the United Kingdom (3, 4). However, their experience might not be suitable for the Chinese context because of the significant differences in dietary habits. For instance, most of the salt in the Chinese diet is discretionarily added by the consumers to dishes or soups during cooking, such as salt, soy sauces, and other sauces (5).

Unhealthy dietary habits typically emerge from early childhood and result in long-term health damage in adulthood (6, 7). Therefore, cultivating healthy lifestyles to prevent related diseases is essential during childhood and early adolescence (8). A randomized controlled trial conducted in Northern China demonstrated that a school-based education program (School-EduSalt) could effectively reduce the salt intake of primary school students and their family members (9). This program exemplifies a potential cost-effective salt reduction intervention model through the education system for the Chinese context (10). However, the generalizability of this intervention model is limited because of its reliance on teachers for intervention delivery and the extra workload to schools. Built on the School-EduSalt program, a further study, named AppSalt, was designed to incorporate a smartphone application to deliver salt awareness education in order to alleviate the workload of health education on school teachers (11).

To test the effectiveness of the AppSalt program, the researchers conducted a cluster randomized controlled trial (cRCT) at 3 cities (Shijiazhuang, Luzhou, Yueyang) and recruited 54 primary schools to participate in the trial (11). These 3 cities were located in the north, southwest, and central China, which were selected for their geographical locations and relevant dietary habits differences. Half of the recruited schools at each site were randomized to the intervention group and participated in the AppSalt intervention activities for 1 year. The control group continued with their usual health education curriculum. The usual health education courses for third graded students include the following topics: infectious diseases prevention, healthy lifestyles, sight protection, smoking cessation, etc. The knowledge on salt is not covered in the usual curriculum. The primary outcome for assessing the effectiveness of the trial is measured by the difference between the intervention and control groups in the change of salt intake measured by 24-h urinary sodium from baseline to the end of the trial (11). The effectiveness evaluation found that the salt intake in intervened adults decreased by 0.82 g/day (12).

Process evaluation is recommended as an integral part of complex interventions by the UK Medical Research Council (13). With the development of modern technology, mobile phones and apps have become a popular platform for public health interventions (14). However, there is a paucity of studies investigating the implementation process of these mobile health(mHealth) interventions, participants' satisfaction with these apps, or factors affecting the implementation. Additionally, most of these mhealth programs at schools were conducted among middle/high school students (15). Fewer programs have used apps for health education among primary school students, who require parents' assistance of using phones. Therefore, the intervention mechanism of the AppSalt program is different from other mHealth interventions.

We designed and conducted a mixed-methods process evaluation alongside the cRCT to investigate the intervention process of the AppSalt program in a real-world setting. Besides, key stakeholders' opinions on scaling up the program were collected through semi-structured interviews.

METHODS

Intervention Design and Implementation

AppSalt program is a multi-component salt reduction platform used to deliver salt reduction knowledge and skills to primary school students and their families (11). The intervention strategies were developed following the principles of Health Belief model and Socioecological model (16, 17). In this program, a smartphone app named "AppSalt" was designed for delivering standardized health education courses and tasks to third-grade students (8–9 years old) and their parents. These courses and tasks are the core intervention strategies at the individual level. Besides, offline intervention strategies were developed to enable interpersonal and community impacts

TABLE 1 | AppSalt program intervention components.

Intervention components	Description	Objectives	Ideal frequency	Implementer	Participants involved
App-based intervention					
Online health education courses	9 courses on salt reduction, each with a 10-min video, a quiz, and a practical task Module 1: The basics of salt Module 2: High-salt food in our life Module 3: Low sodium salt Module 4: Misunderstandings of reducing salt intake in life Module 5: First re-cap Module 6: How to reduce salt used in cooking? Module 7: Salt and pre-packaged food Module 8: How to reduce salt when eating out? Module 9: Second re-cap	• To provide the key messages of salt reduction to students and their families	Monthly	Central program officer	Students with (grand)parent's assistance
7-day salt intake monitoring	Use the function module embedded in the App to calculate the average salt intake amount by keeping a 7-day diet diary	• To improve participant's awareness of their salt intake amount and the gap between their current intake amount and the recommended amount to regularly monitor the change of salt intake	Quarterly	Central program officer	(Grand)parents
Offline intervention					
Parent group meetings	Teachers organize parent group meeting at the beginning and the end of each term with CDC staff's support	• To facilitate peer communication between the participants • To collect participants' feedback	Twice every term	Teachers with CDC staff's support	(Grand)parents and students
Competitions and awards	Teachers organize some competitions regarding salt reduction. Top 30 students at each site will be awarded with certificates and prizes	• To motivate students and parents for active participation	Four times in total	Teachers with support from central program office	Students with (grand)parents' support
Supportive environment	Headteachers regularly post posters on campus	• To cultivate supportive environment for salt reduction on campus	Once every month	School principals	Publicly available to all students, teachers, and parents in the intervention schools

for salt reduction, including parent group meetings, class competitions, and school environment cultivation. All students in the selected intervention school, who have access to smartphones with their (grand)parents' assistance and are willing to take part, are considered eligible to participate in the AppSalt program. The details of the AppSalt program intervention components are provided in **Table 1**. These intervention activities should be completed in two terms (∼10 months). A more detailed description of the AppSalt program and its logic model are reported in previous publications (11, 18).

The implementation of the AppSalt program in the trial was facilitated by a joint partnership of multiple stakeholders, including the intervention schools, the local CDC office, local education authority, and the central program office. In this AppSalt program, the parents and students were instructed by teachers to install the App and use it for salt reduction courses and salt intake monitoring. During the implementation, the staff of the intervention schools, especially the teachers, were responsible for checking children's homework, communicating with students and parents, organizing offline activities, and making school-level motivation schemes for

students. Local CDC office and education departments were responsible for providing professional support to schools and facilitating the implementation of offline intervention activities. The central program office provided technical assistance and support to partners, managed the delivery of online health education sessions, and monitored the implementation progress.

When the intervention group received AppSalt program, the control group continued their usual health education curriculum. The usual health education courses for third graded students include the following topics: infectious diseases prevention, healthy lifestyles, sight protection, smoking cessation, etc. The knowledge on salt was not covered in the usual curriculum.

Study Design and Participants

This study was informed by the process evaluation framework proposed by Steckler et al. (19). A mixed-methods approach was used to systematically evaluate the implementation process of the AppSalt program, including fidelity, reach, dose delivered, dose received, and context. We only evaluated the intervention group in the trial. The control group was not evaluated as they continued with their usual health education and did not receive any extra intervention activities or materials from the program. The detailed demograhic characteristics of the participants in the AppSalt program could be found in our previous publication (12).

Data Collection

Quantitative Data Collection

The quantitative data, including app logs, activity logs, and routine monitoring data, were collected alongside the intervention process. App usage log was generated when the users logged onto the App and used it for health education and other functions. Activity logs were kept by the teachers, which recorded the details of offline intervention activities, including the date, number of participants, and description of the activities. Routine monitoring data was collected by a program coordinator every week in the intervention process to evaluate the implementation of all intervention strategies. Preliminary analysis of routine monitoring data was conducted to identify implementation deviations and optimize the intervention process.

Qualitative Data Collection

The qualitative data was collected using one-on-one semi-structured interviews from October 2019 to December 2019, i.e., within 1 month after completing the 1-year intervention of the AppSalt program. In total, 32 students, 32 family members, 9 teachers, 9 heads of schools, and 8 representatives from local health and education departments were interviewed by trained researchers.

Maximum variation sampling was applied for selecting participants for the interviews (20). At each study site, we purposively selected three intervention schools to represent different implementation performance levels. From each selected school, the trained interviewers conveniently selected 3 or 4 students and their adult family members to participate in the interviews regarding their experience of participating in the AppSalt program. In addition, the interviewers also invited the teachers, and school head-teachers for the interviews to ask their experience of organizing and implementing this program. At each study site, we also invited representatives from local health and education authorities for interviews. More details are published in the protocol of this study (21).

The interviews with selected students, family members, teachers, and school principals were performed one-on-one in the classroom or office at intervention schools; interviews with local health and education authorities were performed at their office. Each interviewee was offered a gift as a token of appreciation for participating in the interviews.

Data Analysis and Interpretation

Quantitative Data Analysis

The participation rate of online health education courses and offline activities were analyzed to represent participants' adherence to the intervention program. The participation rate was compared across sites. Descriptive statistics (comparisons of means, medians, or percentage as appropriate) was used to assess the implementation rates of the five intervention components of the AppSalt program.

Qualitative Data Analysis

Deductive analysis of semi-structured interviews was performed using thematic analysis and managed using QSR Nvivo 12 (22). The lead author (YS), a public health researcher responsible for routine monitoring of the AppSalt program, developed the preliminary coding scheme based on the semi-structured interview guides and the process evaluation framework adopted in this study. Another public health researcher (JS) independently used the preliminary coding scheme and coded 5 interview transcripts to examine the feasibility and accuracy of this coding scheme. Discrepancies emerged during this phase were discussed. We refined the coding scheme through consensus-building. Once the coding scheme was agreed by both authors, YS continued coding all the interview transcripts. The coding scheme could be found in **Additional File 1**. After completing the coding, researchers summarized the patterns of the codes and identified recurrent themes from these interviews. The transcripts are in Chinese, and the selected quotations were translated into English for use in this manuscript.

Integration

The qualitative data is triangulated with the quantitative data during the interpretation phase to explain the 5 process evaluation dimensions. The quantitative data evaluate how the implementation of the AppSalt program is achieved in different settings. The qualitative data provide complementary information to the 5 evaluation components, which allow researchers to investigate the in-depth reasons behind the varied implementation performance (23). As the fidelity and dose delivered are closely related, we combined these two components when interpretating and presenting the results of this study (24).

RESULTS

Reach

The total number of families recruited for the intervention was 1,124 (Shijiazhuang: 467; Luzhou: 324; Yueyang: 333). The number of students recruited from each intervention class varied from 11 to 57, with a median of 46. This program's reach was highest in Shijiazhuang, where 96% of eligible students participated in this program. The other two sites both recruited about 72% of eligible students for participation.

In the interviews with participants, we found different initial motivations for joining this program. 19 out of 32 parents said they volunteered to participate in the program as they wanted to learn some knowledge on salt and its health impacts. About 40% of the parents said they were selected by the teachers and agreed to participate in helping the teachers complete their tasks.

Although some participants were probably not self-motivated when first joining the program, most of them completed their 1-year participation in the AppSalt program, which helped achieve a high retention rate. In total, 34 students dropped out of the program during the intervention (Shijiazhuang 7; Luzhou 13; Yueyang 14), resulting in a retention rate of 97%. These dropping-outs were mostly due to inevitable reasons, including transferring to another school or inaccessibility of smartphones happened during the intervention process.

Fidelity and Dose Delivered

Salt reduction knowledge and skills were delivered to the participants through multiple channels in the AppSalt program, including online health education courses and tasks, 7-day salt intake monitoring, offline salt reduction activities, communication leaflets, and brochures.

App-Based Intervention Strategies

During the 1-year intervention period, online salt reduction courses and tasks were posted on the App following the intervention schedule. Nine online salt reduction courses, six online practical sessions, and four 7-day salt intake monitoring tasks were delivered through the App as scheduled. Each online session was open for the users for 2 weeks, from the day it was posted.

Adaptation Made During the Intervention

The central program office performed weekly supervision of app usage and implementation status to ensure timely monitoring of program implementation status and identifying potential implementation deviation. After about 4-months of implementation, the researchers noticed that many users answered the after-class quizzes without watching the health education videos. This issue would reduce the amount of knowledge received by the participants. To improve the dose of intervention received, the researchers adapted the App, which made watching 80% of online videos a mandate pre-requisite for answering the quizzes.

Offline Intervention Strategies

The fidelity of implementing offline intervention activities varied across schools in the three study sites, especially for the parent group meetings. Four class-level activities were designed in the protocol and implemented in all intervention schools by teachers during the intervention. The fidelity of implementing offline activities was higher in Shijiazhuang than that at Luzhou and Yueyang.

Four parent group meetings were required in the protocol and should be delivered at the beginning and the end of both terms. Of the 27 intervention schools, 12 schools completed four or more group meetings, eight schools did three group meetings, and the rest seven schools did only two group meetings (**Figure 1**). All intervention schools in Yueyang did not manage to deliver the required number of parent group meetings.

Factors Affecting the Implementation of Offline Intervention Activities

Teachers and school staff were the focal implementers of this program and should implement the offline activities with support from local CDC staff. Their experiences and perceptions of the salt reduction intervention would cause a remarkable difference in the intervention dose delivered to the participants, especially for those offline intervention activities. Almost all teachers recognized the importance of reducing salt intake and said they learned some salt reduction knowledge from this program.

One teacher said

> *"In the beginning, I considered this program as a task from the city education department. Then I gradually realized the importance and benefits of salt reduction. Now, I would not eat any high-salt food, and even do not want to look at these foods." (Teacher A, School A, Luzhou)*

However, many teachers said that this program created extra time demands on their already-tight schedule, which made them feel burned out. Therefore, they could not fully implement this program as required, especially the parent group meetings. Some teachers mentioned that the biggest challenge for implementing this program was communicating with students' parents and asking them to complete the tasks on time, because most parents thought this program was extra work on their schedule.

> *" I have to use my spare time to work for this project, including communicating with students' parents and making plans for motivating students, which was challenging for me." (Teacher B, School B, Luzhou)*
>
> *" When parents approached me with a question on this program, I had to ask the CDC staff because I was not trained in that field. Luckily, the CDC staff provided much support. Then I added him to our class WeChat group so that the parents could ask him questions directly." (Teacher A, School A, Yueyang)*
>
> *"Communicating with students' parents was the greatest difficulty for me when delivering the program. First, this is a long-term program. Second, this program does not have much to do with my teaching. I am more used to teaching students rather than pushing parents." (Teacher C, School C, Luzhou)*

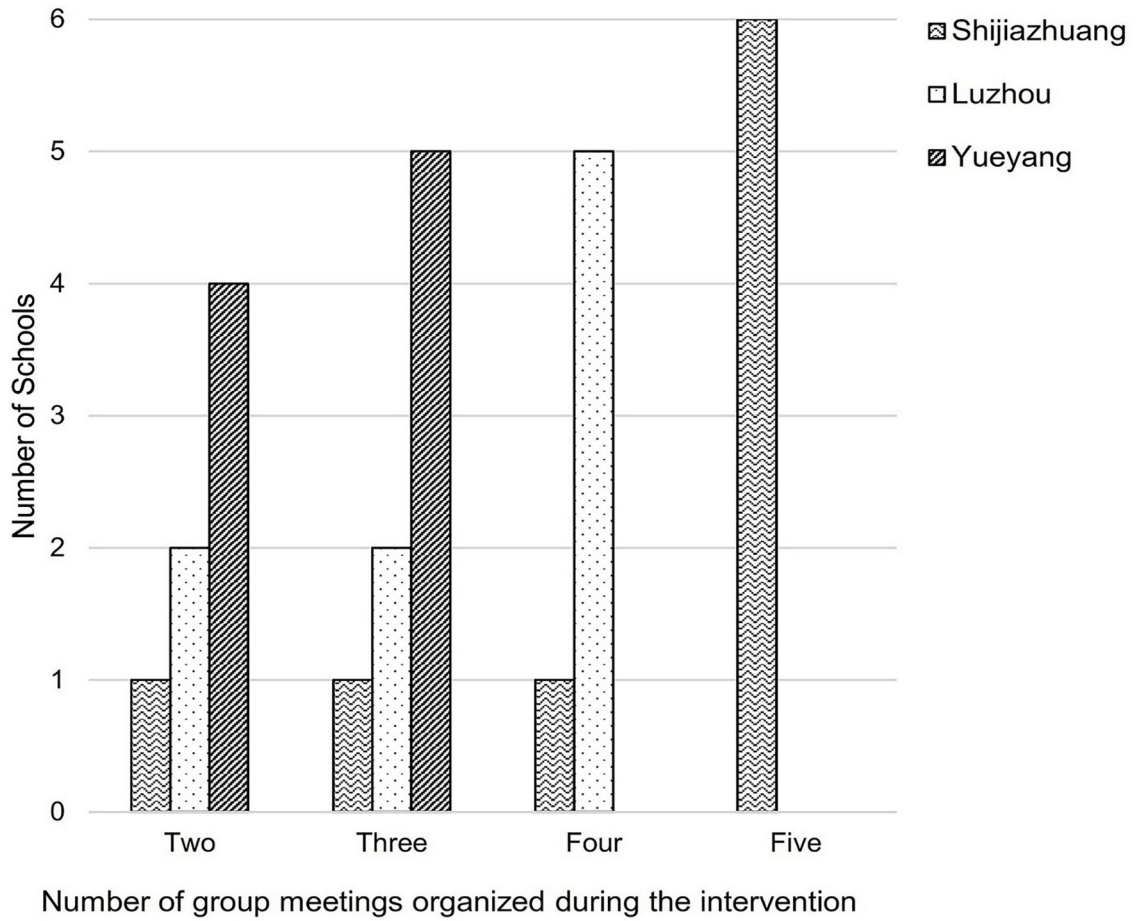

FIGURE 1 | Number of parent group meetings held at intervention schools.

Dose Received

The Dose Received of Online Intervention Activities

Participation in online intervention strategies was high at three study sites. About 80% of participants completed all nine sessions of online salt reduction courses; about 75% of participants completed four or more times of 7-day salt reduction monitoring during the intervention process. As shown in **Table 2**, the online intervention strategies achieved a significantly higher participation rate in Shijiazhuang than in Luzhou or Yueyang.

The Dose Received of Offline Intervention Activities

The participation rate of offline activities varied across three sites and was highest in Shijiazhuang. The knowledge competitions were the most popular activities, while the art competition was the least popular among the participants (**Table 2**).

Satisfying Experiences of Using the App Among Participants

The participant's experience of using the App was generally satisfying, especially for those younger parents. Most parents said that the App was easy and convenient to use. In the interviews, several parents mentioned the difficulties encountered in using the App. For example, the volume of videos was low for the first several sessions; the App's installation was not easy compared with installing other apps. Most of these problems were resolved quickly by the information technology (IT) team.

Suggestions for Improving the Contents and Design of Intervention Materials

The videos, posters, leaflets, brochures are the main intervention materials used in the AppSalt program. Suggestions for improving the course videos consistently emerged in the interviews. Three students and 3 teachers said that the videos were a bit dull for watching and could be improved and made more interestingby bringing in cartoon characters.

Regarding the article-based intervention materials (leaflets and brochures), 22% (7/32) of the interviewed adult participants said they did not read these things because they did not have time. In addition, 50% (16/32) of the interviewed adults thought these materials were not helpful for reducing salt intake. As for the posters, 4 out of 9 interviewed teachers said that the posters could not attract much attention from the students and should be designed according to schools' context and needs.

TABLE 2 | Participation in intervention activities at three study sites.

Intervention strategies	Shijiazhuang (*N* = 467)	Luzhou (*N* = 324)	Yueyang (*N* = 333)	Total (*N* = 1,124)
Online courses				
Completed <6 sessions	0.21%	5.56%	5.99%	3.46%
Completed 6–8 sessions	5.13%	21.06%	29.94%	17.23%
Completed all 9 sessions	94.66%	72.84%	64.07%	79.31%
Practical tasks				
Completed <4 tasks	1.50%	14.81%	16.77%	9.86%
Completed 4 or 5 tasks	12.39%	26.23%	38.32%	24.07%
Completed all 6 tasks	86.11%	58.95%	44.91%	66.07%
7-day salt intake monitoring				
0–2 times	1.7%	11.7%	14.7%	8.44%
3 times	6.0%	29.9%	17.1%	16.18%
4 times	38.2%	25.9%	35.7%	33.96%
More than 5 times	54.1%	32.4%	32.4%	41.42%
Offline competitions				
1st knowledge competition	98.9%	95.7%	94.6%	96.7%
2nd knowledge competitions	99.4%	91.0%	83.5%	92.2%
Art competition	83.4%	55.0%	74.2%	72.5%
Composition competitions	95.9	85.5%	75.5%	86.9%

Polarized Feedbacks on the Effectiveness of 7-Day Salt Intake Monitoring

Participants' feedback on 7-day salt intake monitoring was polarized. Most adult participants thought it was a useful tool to monitor the family's salt reduction progress and make them aware of the gap between their current salt intake level and the recommended amount of salt intake.

> *"This (7-day salt intake monitoring) is a handy tool, which could give you a subjective amount of your salt intake. When I saw the result of the first 7-day salt intake monitoring, I realized that my family members and I ate too much salt, and we have to reduce it." (Parent A, School A, Shijiazhuang)*

Some participants said that 7-day monitoring took too much time and effort to complete. And some participants were concerned about the accuracy of the monitoring results.

> *"This task cost too much time and energy. First, we needed to weigh the take-out food and record its weight whenever we eat it. Second, it took seven days to complete. Sometimes, I might forget to fill it out and need to restart it from the beginning." (Parent A, School B, Luzhou)*
>
> *"I doubt the accuracy of its results. Because in the process, I was not sure if I put the right information in the right place. If the information was not accurate, I could not be sure of the accuracy of its results." (Parent C, School C, Yueyang)*

Knowledge Sharing Within the Intervention Families

Knowledge sharing on salt reduction within the intervention families was bidirectional, either from children to parents/grandparents or from parents to children. Most parents said that they would encourage the students to share the salt reduction knowledge with their grandparents. Some parents said that they would personally watch the online courses first and then tell their children about salt knowledge in the online courses.

> *"My mother (student's grandmother) prepares meals for the whole family, and the meals were salty before we took part in this program. After we joined this program, I started to tell them the salt reduction knowledge. And we are gradually reducing salt intake this year." (Parent B, School B Luzhou)*

Context

For identifying enabling and barriers factors for implementing this program, we qualitatively interviewed selected participants and key informants. From these interviews, many key stakeholders mentioned that some public health programs relevant to salt reduction were being implemented regionally, which could raise public health awareness and therefore promote the implementation of the AppSalt program at schools.

Although the raised awareness of salt intake might be beneficial for implementing the AppSalt program in primary schools, we also identified some barriers for implementation and scale-up in the interviews with selected participants and key stakeholders. The most noted barriers are as follows.

Perceived Adverse Effects of Using Mobile Phones on Students

Many interviewees, including 4 parents, 5 teachers, 3 school principals, and 2 representatives from local authorities, mentioned their concerns about letting children use smartphones because of the potential damage to their eyesight. Moreover, several interviewed parents said that they would limit their child's screen time per day and would not give them smartphones if it is not necessary. In addition, some interviewees were concerned that using mobile phones would make the students exposed to the temptations of games and other things. One school principal said in the interview that:

> *"App has its advantages for adult users, such as convenience and flexibility. Every adult has his/her own phone and are willing to use it for self learning. However, the students usually do not have a phone for themselves. If you let them(students) to use the phone for education, they might use it for something else, such as games. Therefore, the teachers and parents can not relax at all." (School head, School B, Yueyang)*

Left-Behind Children

In the interviews with teachers and school headteachers in Luzhou and Yueyang, left-behind children were widely recognized as a barrier to implementing the AppSalt program in these two sites. The left-behind students usually live with their grandparents, as their parents left the hometown for job opportunities in big cities. The accessibility to smartphones might limit the availability of the intervention content among these left-behind children. A school headteacher of a primary school in Luzhou said in the interview:

> *"More than 10 students live with their grandparents. Some of these grandparents do not have a smartphone. Therefore, our participation rate is relatively low compared with other schools." (School head, School B, Luzhou)*

Current Health Education Curriculum at Primary Schools

From the interviews with teachers and school headteachers, we perceived the difficulties of health education at primary schools. Most school headteachers said that they did arrange health education courses once every 2 weeks according to education authorities" requirements. However, schools usually do not have trained teachers to deliver health education courses. Therefore, these health education classes were generally delivered by the Physical Exercise (PE) teachers or the school doctors. In addition, there is no standard textbooks and evaluation of the health education delivered at primary schools.

Stakeholders' Suggestions for Scaling up the Program

To scale up the AppSalt program in broader settings, we asked the interviewees their opinions for refining the program design for scaling up. The followings are the suggestions collected.

To Empower the Teachers for Delivering Health Education

In the interviews, some teachers expressed their worries for delivering health education courses to students and their parents as they lacked the expertise and professional training. During the implementation process, the teachers usually relied on the local CDC staff's support to teach the salt reduction knowledge and skills at parents group meetings. For scaling up the program, more professional training are required to empower teachers for delivering health education courses. A representative from the local education department raised her concerns for empowering teachers.

> *"Health education requires professional training. For example, although salt reduction is not a very difficult topic for our teachers, they still need to prepare for this course in advance. Where should they get the knowledge? Who should provide the textbook? Who should provide the training to teachers?" (Informant A, Education department, Shijiazhuang)*

To Design More Effective Motivation Schemes for Teachers and Students/Parents

In the interviews with parents and teachers, some interviewees said that this program caused many extra time demands on families and teachers. To better motivate the students and parents for participation, some teachers designed their student motivation scheme. However, as for teachers themselves, there was no effective motivation scheme to implement this program. In the interviews, the teachers were asked what kind of motivation would be effective for them to implement this program. Most teachers said that the recognition from the local education department, such as certificates or awards, would be more valuable for them compared with monetary motivations.

To Incorporate Salt Reduction Contents Into the Regular Health Education Curriculum

Most teachers and heads of schools agreed that it might be easier for them to deliver the salt reduction courses if the content of salt reduction could be incorporated into the health education curriculum of primary schools. Almost all teachers, school heads, and representatives from local education departments agreed on the feasibility and potential beneficial effects of delivering salt reduction knowledge through a regular health education curriculum.

DISCUSSION

Summary of Major Findings

Salt reduction is an urgent and challenging public health issue for China (25, 26). The AppSalt program proposed an app-based multi-component intervention program through the education system aiming to engage primary school students and their family members to reduce salt intake (11). This article systematically evaluated the implementation process of the AppSalt program in 27 primary schools to enlighten the "blackbox" between design and outcome (27). A summary of key quantitative and qualitative findings is provided in **Table 3**. The mixed data

TABLE 3 | Quantitative and qualitative findings for explaining the process evaluation dimensions.

Evaluation dimensions	Quantitative findings	Qualitative findings
Reach	Number of families recruited: • Total: 1,124; • Shijiazhuang: 467; Luzhou: 324; Yueyang: 333 Proportion of eligible participants reached: • Shijiazhuang: 96% • Luzhou:72% • Yueyang: 72% Retention rate: 97%	Motivation of participating in this program: • Wanted to receive more knowledge on salt and its health impacts • Selected by teachers and chose to cooperate Reasons for dropping out: • Transferring to other schools • In accessibility to smartphones happened during the intervention process
Fidelity and dose delivered	App-based courses and tasks: high fidelity achieved; all nine courses and tasks were delivered on schedule Class activity: moderate fidelity achieved at three sites Group meetings: varied fidelity across 3 sites; 44% of intervention schools organized enough meetings; higher fidelity achieved in Shijiazhuang Supportive environment cultivation: low fidelity Adaptation made during the intervention: watching videos was made a must for completing courses.	Teachers' experience of implementing this program: • Learned some health knowledge for themselves. • Demanding tasks of implementing this program • Had difficulties of communicating with parents regarding this program
Dose received	Average participation rate: • App-based interventions: ○ Courses: ○ Practical tasks: ○ 7-day salt intake monitoring: • Offline intervention activity	• General satisfying experience of using the app • Improving the contents and design of intervention materials, especially those article-based materials, e.g., posters. • Polarized feedbacks regarding 7-day salt intake monitoring • Bidirectional knowledge sharing happened in the intervention awareness
Context		Facilitators: • Relevant public health policies being implemented • Raised public awareness regarding salt reduction Barriers: • Perceived adverse effects of smartphones on children • Left-behind children; • Overlooked health education curriculum

indicates that all online intervention activities, including health education courses and salt intake monitoring, were delivered to high fidelity against the protocol and achieved high participation rate. This study demonstrated that the smartphone app is widely accessible among the participants and could be a scalable tool for implementing health education through primary schools. Although the variation of implementing offline intervention activities was observed across the intervention sites, the overall dose delivered and participation rate reached an acceptable level at most intervention schools.

Although the implementation of the AppSalt program was generally acceptable at all three sites, higher participation rate in intervention activities and better participants' experience are observed in Shijiazhuang than the other two sites. There might be several possible socio-economic explanations for this phenomenon.

First, the intervention families in Shijiazhuang is generally better off than those in the other two sites, given the 12-month household income collected in the baseline survey (**Additional File 2**). Public health awareness is closely related to participants' socio-economic background, especially for the low- and middle-income countries (28). Therefore, our participants in Shijiazhuang were possibly more aware of salt's adverse effects and thus more interested in public health programs. Second, people of higher income and higher education are usually more used to using smartphones (29, 30). Therefore, an mhealth program using a smartphone app as the primary intervention tool tends to be better implemented in higher-income regions. Finally, the issue of left-behind children is more prevalent in Luzhou and Yueyang than in Shijiazhuang. The topic of left-behind children often emerged in interviews with key stakeholders in these two regions. The left-behind children usually live with their grandparents and do not have access to smartphones (31). Although the schools in Luzhou and Yueyang achieved a relatively high participation rate in intervention activities, the researchers should not overlook the issue of left-behind children when scaling up the AppSalt program.

Comparison With Existing Studies

The rapid development of mobile technology brings tremendous opportunities for public health interventions, including smoking cessation, chronic disease self-management, weight control (32–35). mHealth apps are also considered promising tools for delivering health education among students in school settings. A systematic review finds that school-based mHealth interventions effectively reduce multiple risk factors, including unhealthy diet, physical inactivity, smoking, and alcohol use (18). Most of these programs are conducted among middle or high school students who have their own mobile phones. However, unlike other mhealth school-based interventions among adolescents, this

AppSalt program relies on parental participation for achieving the intended outcome, as the third-grade primary school students were too young to use smartphones by themselves. Therefore, the implementers, especially the teachers, need to effectively motivate not only the students, but also their parents to participate in this program.

The equity issue of using the smartphone app as a primary intervention tool is also a concern that might limit the generalizability of mHealth programs (36, 37). The left-behind children usually live with their grandparents and suffer from multiple neglects compared with their peers (38). This study also indicates that the left-behind children do not have adequate access and support for using smartphone apps for online health education. The national monitoring data of migrant workers indicated that 30.1% of migrant workers left their children at home (38). This issue of left-behind children should be taken into consideration when promoting this program on a broader scale.

Implications for Future Scaling up

This mixed-methods process evaluation systematically examined the implementation of the AppSalt program at the intervention schools, whose findings will be used to speed the translation of the AppSalt intervention to a broader scale-up (39).

Primary school health education is an inter-disciplinary task, which calls for close cooperation of schools, local health departments, and local education departments. In the AppSalt program, the rapport established between the AppSalt implementers, the teachers, and the participants is a crucial factor that facilitated the delivery of the program. For broader scaling-up, the local CDC office might not have the capacity and enough personnel to support every individual school for implementing this program. Therefore, more empowerment training should be provided for teachers and enable them to deliver health education knowledge to students and parents. Besides, standardized course materials, including textbooks, slides, and videos, should be developed and provided to schools to support the delivery of health education courses. What's more, we suggest national health education authorities to incorporate salt reduction knowledge into usual health education curriculum, which would benefit the scaling up of this program and reduce the extra burden on headteachers to deliver relevant knowledge.

Although almost all intervention schools in the AppSalt program managed to achieve an acceptable or higher participation rate, the implementation variation should be considered when promoting this program to other regions. This process evaluation indicates that the AppSalt program is generally better implemented in higher-income regions. This finding is consistent with a nutrition education program conducted at Chinese primary schools (40). For the future scale-up to other provinces in China, the researchers need to accommodate more flexibility in the intervention design for various socio-economic settings and address the barriers identified through this study. For example, a combination of online and offline salt reduction intervention packages should be designed, which would allow schools to choose suitable intervention activities according to their local context and therefore improve the scalability of this program.

Strengths and Limitations

This study is a comprehensive process evaluation that involves mixed methods and multiple stakeholders. Both quantitative and qualitative data were used to evaluate the implementation process, and multiple stakeholders were interviewed in this study.

The study also has some limitations. First, only the participants from the intervention group are interviewed. Without evaluating the control group, we might overlook the contamination of the controlled arm during the study. However, we presume that the contamination effect should be minimal as the access to the App is strictly managed by the project office, and only the students in the intervention group were granted the account to use the App. Second, the selection of the informants from local health and education departments was carried out by local research collaborators (local CDC), which could also result in some recruitment bias. To minimize such bias, the researchers communicated in advance with local collaborators to explain the recruitment criteria. Third, although the schools were selected based on the maximum variation sampling methods, the interviewees, including parents and students, were actually self-volunteered to participate in the interviews from each selected school. We should acknowledge the possibility of recruitment bias brought by this convenience recruitment method. Fourth, we did not perform any observations to subjectively evaluate the implementation of this program in real settings due to time and personnel constraints. All monitoring data were collected with the implementer's/teacher's assistance. Therefore, some implementation problems might be neglected or not reported.

CONCLUSIONS

School can and should become a primary setting for children to receive health education and build up healthy life habits (41, 42). However, the health education curriculum in Chinese primary schools is usually overlooked and not followed due to the burden of getting higher marks for "more important" lessons.

The AppSalt program demonstrated the feasibility of a new mHealth model for providing health knowledge by using smartphone apps. This multi-component app-based school-based salt reduction program indicated that smartphone applications are feasible tools to provide salt reduction knowledge and skills to primary school students and their family members. Further work is underway to scale up the program to larger populations in diverse settings.

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 Peking University Institutional Review Board (No. IRB00001052-19096) and the Queen Mary Ethics of Research Committee (QMERC2020/22). Written informed consent to

participate in this study was provided by the participants' legal guardian/next of kin.

AUTHOR CONTRIBUTIONS

YS and RL designed this process evaluation with substantial support from the program management team and partners, especially YL, PZ, FH, and HL. CG performed qualitative data collection for this study. YS performed the data analysis and interpretation with JS's support. YS drafted the first version of this manuscript. YL, FH, HL, and PZ reviewed and revised the manuscript critically. All authors read and approved the final manuscript for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.744881/full#supplementary-material

REFERENCES

1. World Health Organization. *Tackling NCDs: 'best buys' and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases*. Geneva: World Health Organization (2017).
2. Trieu K, Neal B, Hawkes C, Dunford E, Campbell N, Rodriguez-Fernandez R, et al. Salt reduction initiatives around the world – a systematic review of progress towards the global target. *PLoS ONE.* (2015) 10:e0130247. doi: 10.1371/journal.pone.0130247
3. Hyseni L, Elliot-Green A, Lloyd-Williams F, Kypridemos C, O'Flaherty M, McGill R, et al. Systematic review of dietary salt reduction policies: evidence for an effectiveness hierarchy? *PLoS ONE.* (2017) 12:e0177535. doi: 10.1371/journal.pone.0177535
4. Laatikainen T, Pietinen P, Valsta L, Sundvall J, Reinivuo H, Tuomilehto, et al. Sodium in the Finnish diet: 20-year trends in urinary sodium excretion among the adult population. *Europ J Clin Nutr.* (2006) 60:965–70. doi: 10.1038/sj.ejcn.1602406
5. Anderson CAM, Appel LJ, Okuda N, Brown IJ, Chan Q, Zhao L, et al. Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: the INTERMAP study. *J Am Diet Assoc.* (2010) 110:736–45. doi: 10.1016/j.jada.2010.02.007
6. Gonçalves C, Abreu S, Padrão P, Pinho O, Graça P, Breda J, et al. Sodium and potassium urinary excretion and dietary intake: a cross-sectional analysis in adolescents. *Food Nutr Res.* (2016) 60:29442. doi: 10.3402/fnr.v60.29442
7. Chen C, Denney L, Zheng Y, Vinyes-Pares G, Reidy K, Wang H, et al. Nutrient intakes of infants and toddlers from maternal and child care centres in urban areas of China, based on one 24-hour dietary recall. *BMC Nutr.* (2015) 1:23. doi: 10.1186/s40795-015-0019-5
8. Abrignani MG, Lucà F, Favilli S, Benvenuto M, Rao CM, Di Fusco SA, et al. Lifestyles and cardiovascular prevention in childhood and adolescence. *Pediatr Cardiol.* (2019) 40:1113–25. doi: 10.1007/s00246-019-02152-w
9. He FJ, Wu Y, Feng X.-X, Ma J, Ma Y, Wang H, et al. School based education programme to reduce salt intake in children and their families (School-EduSalt): cluster randomised controlled trial. *BMJ.* (2015) 350:h770–h. doi: 10.1136/bmj.h770
10. Li X, Jan S, Yan LL, Hayes A, Chu Y, Wang H, et al. Cost and cost-effectiveness of a school-based education program to reduce salt intake in children and their families in China. *PLoS ONE.* (2017) 12:e0183033. doi: 10.1371/journal.pone.0183033
11. He FJ, Zhang P, Luo R, Li Y, Chen F, Zhao Y, et al. An application-based programme to reinforce and maintain lower salt intake (AppSalt) in schoolchildren and their families in China. *BMJ Open.* (2019) 9:e027793. doi: 10.1136/bmjopen-2018-027793
12. He FJ, Zhang P, Luo R, Li Y, Sun Y, Chen F, et al. App based education programme to reduce salt intake (AppSalt) in schoolchildren and their families in China: parallel, cluster randomised controlled trial. *BMJ.* (2022) 376:e066982. doi: 10.1136/bmj-2021-066982
13. Moore GF, Audrey S, Barker M, Bond L, Bonell C, Hardeman W, et al. Process evaluation of complex interventions: Medical Research Council guidance. *BMJ.* (2015) 350:h1258. doi: 10.1136/bmj.h1258
14. Dugas M, Gao GG, Agarwal, R. Unpacking mHealth interventions: a systematic review of behavior change techniques used in randomized controlled trials assessing mHealth effectiveness. *Digit Health.* (2020) 6:2055207620905411. doi: 10.1177/2055207620905411
15. Champion KE, Parmenter B, McGowan C, Spring B, Wafford QE, Gardner LA, et al. Effectiveness of school-based eHealth interventions to prevent multiple lifestyle risk behaviours among adolescents: a systematic review and meta-analysis. *Lancet Digital Health.* (2019) 1:e206–21. doi: 10.1016/S2589-7500(19)30088-3
16. Becker MH. The health belief model and sick role behavior. *Health Educ Monographs.* (1974) 2:409–19. doi: 10.1177/109019817400200407
17. Bronfenbrenner U, Morris PA. The bioecological model of human development. In: *Handbook of Child Psychology*. p. 793–828. doi: 10.1002/9780470147658.chpsy0114
18. Sun Y, Luo R, Li Y, He FJ, Tan M, MacGregor GA, et al. App-based salt reduction intervention in school children and their families (AppSalt) in China: protocol for a mixed methods process evaluation. *JMIR Res Protoc.* (2021) 10:e19430. doi: 10.2196/19430
19. Steckler AB, Linnan L, Israel B. *Process Evaluation for Public Health Interventions and Research*. San Francisco, CA: Jossey-Bass (2002).
20. Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood, et al. Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Adm Policy Ment Health.* (2015) 42:533–44. doi: 10.1007/s10488-013-0528-y
21. Sun Y, Luo R, Li Y, He FJ, Tan M, MacGregor GA, et al. App-based salt reduction intervention in school children and their families (AppSalt) in China: protocol for a mixed methods process evaluation. *JMIR Res Protoc.* (2021) 10:e19430. doi: 10.2196/preprints.19430
22. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol.* (2006) 3:77–101. doi: 10.1191/1478088706qp063oa
23. O'Cathain A, Murphy E, Nicholl J. Three techniques for integrating data in mixed methods studies. *BMJ.* (2010) 341:c4587. doi: 10.1136/bmj.c4587
24. Wilson DK, Griffin S, Saunders RP, Kitzman-Ulrich H, Meyers DC, Mansard L, et al. Using process evaluation for program improvement in dose, fidelity and reach: the ACT trial experience. *Int J Behav Nutr Phys Act.* (2009) 6:79. doi: 10.1186/1479-5868-6-79

25. Xi B, Hao Y, Liu F. Salt reduction strategies in China. *Lancet.* (2014) 383:1128. doi: 10.1016/S0140-6736(14)60567-5
26. Wang M, Moran AE, Liu J, Coxson PG, Penko J, Goldman L, et al. Projected impact of salt restriction on prevention of cardiovascular disease in China: a modeling study. *PLoS ONE.* (2016) 11:e0146820. doi: 10.1371/journal.pone.0146820
27. Harachi TW, Abbott RD, Catalano RF, Haggerty KP, Fleming CB. Opening the black box: using process evaluation measures to assess implementation and theory building. *Am J Commun Psychol.* (1999) 27:711–31. doi: 10.1023/A:1022194005511
28. Palafox B, McKee M, Balabanova D, AlHabib KF, Avezum A Jr, Bahonar A, et al. Wealth and cardiovascular health: a cross-sectional study of wealth-related inequalities in the awareness, treatment and control of hypertension in high-, middle- and low-income countries. *Int J Equity Health.* (2016) 15:199. doi: 10.1186/s12939-016-0478-6
29. Jeong J, Huang P, Mithas S. *The Great Equalizer? Smartphone Use at Workplace and Income Gaps*. New York, NY (2018). doi: 10.5465/AMBPP.2018.18810abstract
30. Neter E, Brainin E. eHealth literacy: extending the digital divide to the realm of health information. *J Med Internet Res.* (2012) 14:e19. doi: 10.2196/jmir.1619
31. Wen M, Lin D. Child development in rural china: children left behind by their migrant parents and children of nonmigrant families. *Child Dev.* (2012) 83:120–36. doi: 10.1111/j.1467-8624.2011.01698.x
32. Grady A, Yoong S, Sutherland R, Lee H, Nathan N, Wolfenden L. Improving the public health impact of eHealth and mHealth interventions. *Aust N Z J Public Health.* (2018) 42:118–9. doi: 10.1111/1753-6405.12771
33. WHO. *Global Observatory for eHealth. mHealth: New Horizons for Health Through Mobile Technologies: Second Global Survey on eHealth*. Geneva: World Health Organization (2011).
34. Rowland SP, Fitzgerald JE, Holme T, Powell J, McGregor A. What is the clinical value of mHealth for patients? *npj Digital Med.* (2020) 3:4. doi: 10.1038/s41746-019-0206-x
35. Marcolino MS, Oliveira JAQ, D'Agostino M, Ribeiro AL, Alkmim MBM, Novillo-Ortiz D. The impact of mhealth interventions: systematic review of systematic reviews. *JMIR Mhealth Uhealth.* (2018) 6:e23. doi: 10.2196/mhealth.8873
36. Mahmood A, Kedia S, Wyant DK, Ahn S, Bhuyan SS. Use of mobile health applications for health-promoting behavior among individuals with chronic medical conditions. *Digit Health.* (2019) 5:2055207619882181. doi: 10.1177/2055207619882181
37. Yang X, Kovarik CL. A systematic review of mobile health interventions in China: Identifying gaps in care. *J Telemed Telecare.* (2019) 27:3–22. doi: 10.1177/1357633X19856746
38. Wen YJ, Hou WP, Zheng W, Zhao XX, Wang XQ, Bo QJ, et al. The neglect of left-behind children in China: a meta-analysis. *Trauma Violence Abuse.* (2020) 22:1326–38. doi: 10.1177/1524838020916837
39. Gallo JJ, Lee SY. *Mixed Methods in Behavioral Intervention Research*. New York, NY: Springer Publishing Company (2015). p. 195-212.
40. Qian L, Newman IM, Yuen LW, Du W, Shell DF. Effects of a comprehensive nutrition education programme to change grade 4 primary-school students' eating behaviours in China. *Public Health Nutr.* (2019) 22:903–11. doi: 10.1017/S1368980018003713
41. Young I, Leger L, Blanchard C. Health-promoting schools: working in partnership to address global needs, a collaboration leading to the production of practical tools for practitioners. *Glob Health Promot.* (2013) 20(4 Suppl):122–7. doi: 10.1177/1757975913501005
42. Wang D, Stewart D, Yuan Y, Chang C. Do health-promoting schools improve nutrition in China? *Health Promot Int.* (2013) 30:359–68. doi: 10.1093/heapro/dat047

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POLICY BRIEF
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Reducing Sodium Consumption in Mexico: A Strategy to Decrease the Morbidity and Mortality of Cardiovascular Diseases

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Hypertension (HTN) and cardiovascular diseases (CVD) are important public health problems in Mexico. High sodium intake is linked to high blood pressure and increased risk of developing CVD. International organizations suggest consuming <2 g of sodium/day; however, the Mexican population consumes amounts above what is recommended: 3.1 g/day. Although efforts have been made to mitigate this problem, interventions are needed to improve cardiovascular health. This policy brief offers a short review of the current sodium consumption situation in Mexico and the importance of why decision makers should consider actions to reduce consumption. Recommendations to reduce sodium/salt intake include: Reformulation of ultra-processed-foods, promote the use warning labels, communication campaign, reduce the use of table salt, and monitor sodium intake.

Keywords: sodium, sodium reduction, salt, policy action, public health, Mexico

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INTRODUCTION

In Mexico, the main cause of mortality is cardiovascular disease (CVD), with an estimated rate of 134 deaths per 100,000 people (1). High blood pressure, or hypertension (HTN), is the most important risk factor for the development of CVD (2), which two out of four adults experience. This number could be higher, as 55% of people with this disease are often undiagnosed and have no symptoms (3).

One in ten deaths and one in five premature deaths (in people under 70 years of age) are attributable to sodium, both due to cardiovascular causes (4). The World Health Organization (WHO) recommends that sodium consumption does not exceed 2 g per day or 5 g of salt (one teaspoon) (5). However, the Mexican population, including children, adolescents and adults, exceed what is recommended by this organization (6, 7).

Sodium is an essential nutrient to maintain balance in humans since it participates in the regulation of the transmission of nerve impulses, and the contraction or relaxation of skeletal muscle, among other cellular processes (8). However, excess sodium intake causes increased sodium excretion through urine, which induces an increase in vascular resistance and blood pressure or HTN (9). This increase in HTN is related to kidney damage. Likewise, high sodium intake is related to other diseases; for example, to Helicobacter pylori infection, one of the main factors for stomach cancer; increased calcium absorption which leads to the presence of stones; and the consumption

of sugary drinks or total energy consumption, which is related to overweight and obesity (4, 9, 10). Therefore, high sodium intake may contribute to poor health (9). In addition, high sodium intake is usually combined with low potassium intake, which is related to different metabolic disorders (11), and increased vascular volume (12).

Of the total deaths in Mexico during 2019 (n = 738,424), 23% were due to CVD, of which 5.4% were attributed to high sodium intake. In addition, of the total deaths attributed to high sodium intake, 9% were due to hypertensive disease, 7% to stomach cancer, 5.5% to ischemic heart disease, 5.1% to infarction, and 4.6 % to atrial fibrillation. Among the states with higher mortality from hypertensive disease due to high sodium intake are Oaxaca, Veracruz, Jalisco, State of Mexico, and Mexico City (**Figure 1**) (1).

Policies to reduce sodium intake are cost-effective to help lower blood pressure (13, 14). Different countries have chosen policies according to their context. The actions that have had the greatest impact are the mandatory reformulation of foods, food labeling, taxes, and communication campaigns, since they have shown greater reductions in the total consumption of sodium in the population (15). This policy brief offers a review of the current sodium consumption situation in Mexico and discusses the importance of considering actions to reduce consumption among the population. It also provides evidence-based actions for decision-makers to reduce sodium intake and improve population cardiovascular health.

CHALLENGES

Current Sodium Intake Situation

Sodium is an essential nutrient. Foods and beverages that are naturally high in sodium are milk, eggs, and meat. Sodium is also found in industrialized foods and beverages or in processed and ultra-processed foods, since it is added to enhance flavor and texture, fix colors, and extend shelf life, among other things (16). During the last decade, the purchase of processed and ultra-processed foods has increased among the Mexican population (17), becoming one of the main dietary sources and contributing between 39 and 50% of sodium consumed (6). Ultra-processed foods that contain high added sodium content include: breads, crackers, processed meats, seasonings, and instant soups (18).

However, sodium is not only found in these foods; it is also found in the salt we add in food preparation and in ready-made foods. Due to its use and its importance in the diet, table salt is the second source of sodium in the Mexican diet (6).

In Mexico, most of the population consumes sodium in excess, since school children (5–12 years) consume about 2.8 g of sodium/day (7.1 g salt), adolescents (12–18 years) consume 3.7 g of sodium per day (9.4 g salt), while adults (>18 years) consume 3.1 g of sodium per day (7.8 g salt) (6). In addition, the amount of salt consumed by a large part of the population is still unknown, as well as the adverse health effects of excessive salt intake (19).

Therefore, daily sodium intake is composed of sodium from natural foods, processed and ultra-processed foods and sodium from salt. However, in Mexico the consumption of this nutrient is above the limits recommended by the WHO (**Figure 2**). Therefore, the trend of sodium consumption is a public health problem, which, together with the high prevalence of HTN, will affect the presence of complications such as CVD, which could increase mortality rates nationally and should be a priority for the country.

Actions Carried Out in Latin America to Reduce Sodium Intake

The countries where actions have been implemented to reduce sodium consumption in Latin America. Among the strategies that stand out in the region are, from greater to lesser potential impact, the mandatory reformulation of processed and ultra-processed foods, front-of-pack food labeling systems, healthy eating habits campaigns and the reduction of the use of salt in the production of bread. This impact is similar to the evidence of strategies developed at the international level (15).

In Brazil, where reformulation of processed foods has been carried out, the food industry voluntarily reduced the sodium content of its products (20). Despite the fact that its sustainability could not be ensured due to the results being a voluntary policy, the average sodium content of the included foods decreased from 5 to 21% in these first 2 years of implementation (21).

Other countries, such as Argentina in 2010, have implemented strategies to reduce salt intake. The National Ministry of Health in Argentina launched the "Less Salt, More Life" Initiative to reduce sodium consumption among the general population through different lines of action: voluntary reduction of sodium content in processed foods and community education (22). At the end of 2013, they became the first country in the Americas and the second in the world to implement a mandatory reformulation of sodium content in packaged products (23). Four years after this law went into effect (2014), an evaluation found that over 90% of the products included in the national sodium reduction law met the goals outline in the Standard (24).

On the other hand, Costa Rica developed a Regional Plan for Social Marketing and Communication for the Reduction of Salt in Latin America (25). So far it is unknown what the effects of this intervention are; however, these strategies are recognized by the WHO, due to their potential to increase knowledge to create behavioral changes (26).

To date, eight of the Latin American countries have implemented a mandatory food labeling system to try to reduce the intake of salt / sodium in the population. Five of these countries (Chile, Uruguay, Peru, and Mexico) have used a warning labeling system (27–30), which has been shown to be more effective in promoting healthier habits among Latin American populations and reducing sodium consumption in the population (31). Due to the positive results, other countries such as Brazil and Colombia are in the process of implementing this warning label system (32, 33).

Recently (2021), the WHO (Global and Regional) published updated sodium benchmarks for different food categories, which helps promote the reformulation of food products and make progress in sodium reduction (34, 35). Therefore, it is

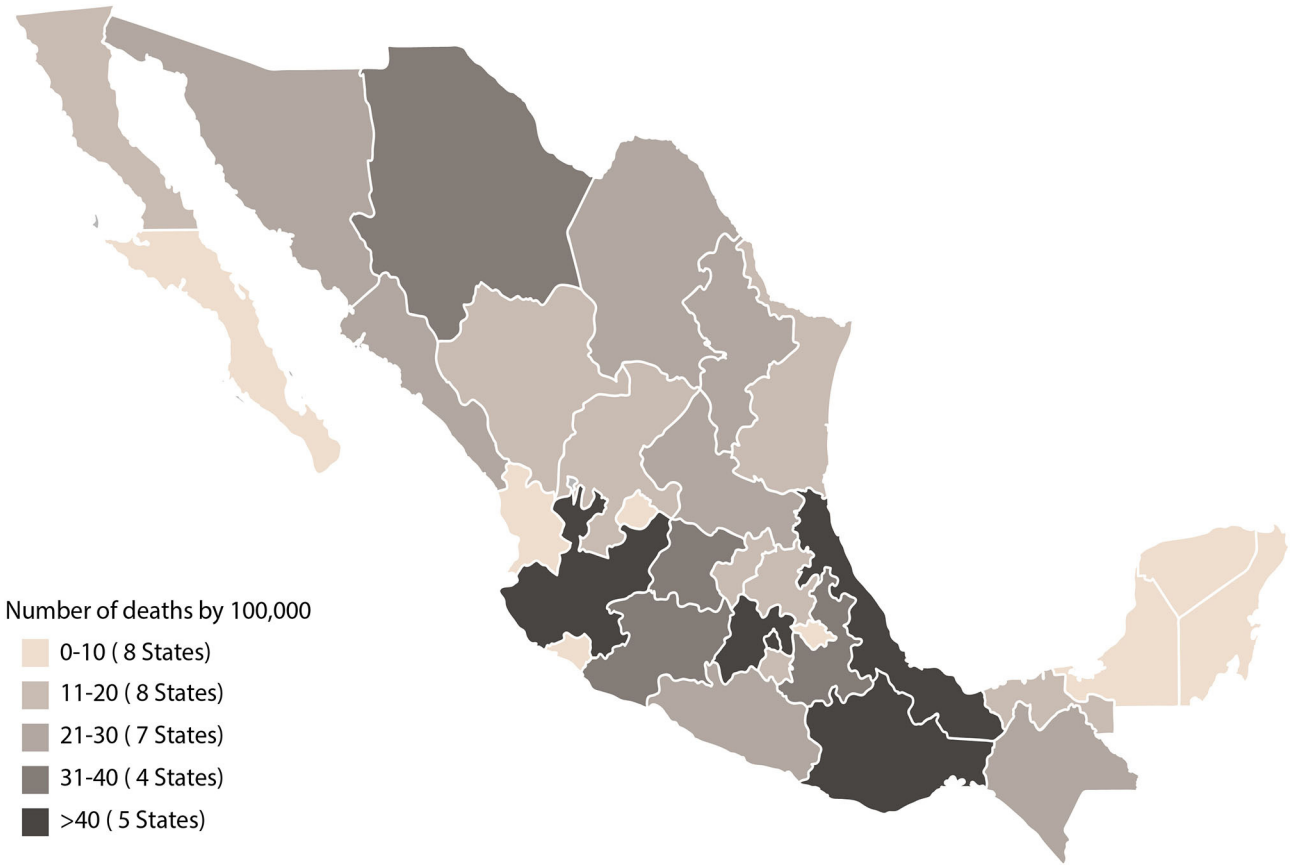

FIGURE 1 | Mortality due to hypertensive causes associated with high sodium intake in Mexico 2019. Source: Global Burden Disease (1).

important to consider these efforts by international agencies, as they are useful for countries in establishing national policies and strategies.

Strategies Carried Out in Mexico to Reduce Sodium Intake

Despite the fact that non-communicable chronic diseases emerged a little more than two decades ago in Mexico, and that during 2016, two of these diseases were identified as epidemiological emergencies (36), few efforts have been made to treat cardiovascular problems such as HTN and its complications.

One of the most relevant strategies was employed in 2010 during the launch of the National Agreement for Food Health as a strategy against overweight and non-communicable chronic diseases. Some of the objectives of this agreement were to decrease daily sodium consumption; reduce the amount of sodium added to foods; and increase the availability and accessibility of low-sodium or sodium-free products, fostering the participation of different sectors such as the government, civil society, and the food and restaurant industry (37). To meet this objective, the Federal Commission for the Protection against Sanitary Risks implemented the Healthy Mexico Program, targeting restaurants and industrial canteens. This program raised awareness through providing training on healthy eating for the food industry and restaurants. In addition, they encouraged the restaurant community to voluntarily remove salt shakers from the tables and only provide it upon request from the customer (38).

During 2013, the Ministry of Health implemented the Less Salt More Health campaign, which consisted of a communication strategy to increase knowledge and educate the population about the consumption of salt and its benefits (39). However, no publications were identified regarding the results of this strategy.

In March 2020, the modification to the Official Mexican Standard 051 (NOM for its Spanish acronym) was published, which made front of pack warning labels mandatory. This system consists of five octagonal warning labels with the word "EXCESO" ("Excess") followed by sodium, saturated fat, trans fat, sugar, and calories. It also includes two warning legends for products containing sweeteners and caffeine (30). Given the recent implementation of NOM-051, results from this policy are not yet available. However, Chile, which was the first country to implement a warning labeling system, has documented a reduction in the number of products offered in the market after the implementation of the

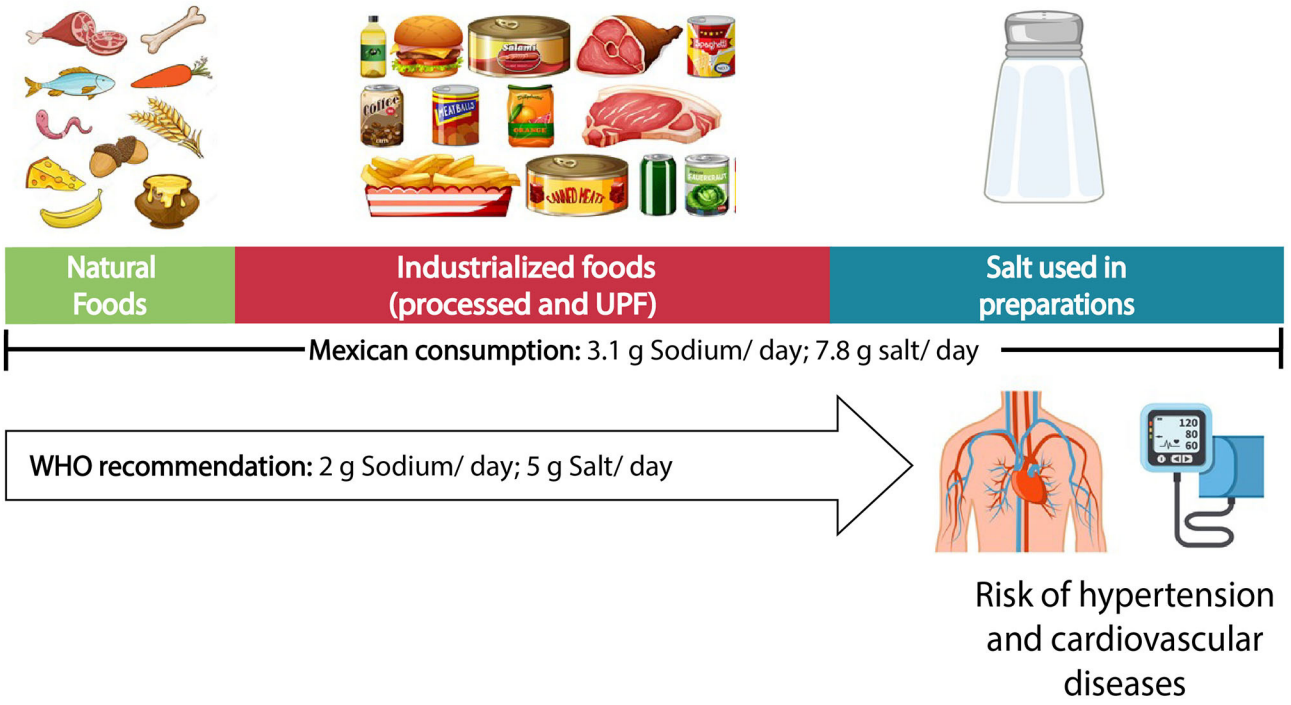

FIGURE 2 | Sources and consumption of sodium in the Mexican population. Source: Own elaboration.

warning labels, compared to the products that were offered before (31).

BENEFITS OF REDUCING SODIUM INTAKE

The main reason to consider reducing sodium consumption is that it is closely related to blood pressure; as sodium intake increases, blood pressure also increases (40). Therefore, reducing sodium consumption at the population level is one of the most economical and profitable strategies to reduce blood pressure (13), as well as mortality and the risk of developing CVD (41, 42).

On the other hand, studies that simulate the effect on health when sodium consumption is reduced have shown that consuming what is recommended by the WHO (<2 g sodium) reduces systolic/diastolic pressure by 7/4 mmHg in people with HTN and 4/2 mmHg in normotensive people (43). In addition, a study from Brazil has estimated that 47,000 deaths from CVD could be prevented by reducing sodium intake as recommended by the WHO (44). Costa Rica also estimated that 13% of all deaths from cardiovascular causes (n = 5,649) could be prevented if current sodium consumption is reduced by 46% (4 g/day), mainly in coronary heart disease and heart disease (45).

Furthermore, a higher threshold (<3 g sodium) has also shown positive effects since it could reduce morbidity from coronary heart disease, stroke and myocardial infarction by 50%, as well as reduce mortality from any cause by 48% (46). Likewise, Brazil has estimated that the health system could save approximately $220 million dollars for the treatment of coronary heart disease and stroke, as well as ∼$71 million dollars in indirect costs if the government established voluntary maximum limits for the sodium content on a 20 year plan (2013 to 2032) (47).

RECOMMENDATIONS

In order to gather the best strategies for reducing sodium consumption in the population, the Pan American Health Organization (PAHO) recently published the guide SHAKE (48). Below are some of the interventions proposed in this publication, highlighting their importance within the Mexican context.

- According to the WHO and the American Heart Association, it is important to reduce sodium intake in adults to <2 g/day (5 g/day of salt) to prevent HTN and the risk of CVD, stroke and coronary heart disease (5, 26, 49).
- The Mexican dietary guidelines should continue to include a recommendation to reduce salt/sodium intake in the first years of life. This will help children learn to enjoy natural flavors and may help them avoid excessive consumption of salt/sodium in the future (50). In addition, the guidelines will support the design of other policies or programs in the country.
- It is important to promote the reduction of table salt used when preparing and consuming food from early life stages, as well avoidance of foods that contain large amounts of sodium, through communication campaigns that encourage behavior change and increase knowledge about health problems associated with high sodium/salt intake. This action is important since part of the Mexican population does not know what their daily sodium /salt consumption should be

and is not aware of the health repercussions posed by the high consumption of this nutrient (19).

- Recently, Mexico implemented a mandatory warning labeling system for all available industrialized products (30). It is important to promote the use of this labeling system to reduce the selection and consumption of products that contain excessive amounts of sodium ("Exceso de Sodio"). This action is one of the greatest emphases to be made, since processed and ultra-processed foods are the source that contributes the most sodium to the Mexican diet.
- In addition to the above, it is important to promote reformulation strategies for processed and ultra-processed foods that contain large amounts of sodium. Decreasing the sodium content in these products would reduce the total sodium intake in the population's diet. Although it may be challenging for the food industry to reduce the amount of sodium in their products, some industrialized food producers have been able to do so successfully to avoid "excess sodium" labels on their products (51, 52). However, this reformulation must be in accordance with the WHO regional sodium benchmarks in order to comply with the standards imposed by international agencies (35). Latin American countries have managed to implement this action, including Argentina, Chile, Colombia and Brazil (53–56).
- It is important to encourage the use of salt alternatives added to food to reduce the amount of sodium consumed by the population. Mexico has a great diversity of herbs, spices, and different dried chilis.
- WHO suggests continuous monitoring of sodium intake and sources. They also recommend monitoring and evaluating the programs and actions that have been implemented to reduce sodium. This allows programs to be redesigned, providing evidence for future interventions and scalability.

CONCLUSIONS

Sodium consumption is usually a health problem that is "not visible" and poorly positioned in the public agenda as one of the main risk factors for chronic diseases. However, excessive sodium intake is a public health problem, which is directly related with HTN and CVD.

The actions described above provide the federal government, as well as stakeholders, with public policy tools that help consumers make healthier and more informed decisions to reduce sodium/salt intake. Some successful strategies to reduce sodium consumption in the population have been implemented in: (1) Brazil (voluntary) and Argentina (mandatory), which reduced the sodium content of foods and beverages that contributed to high sodium consumption in the population through reformulation; (2) Chile, Costa Rica, Argentina and Colombia, which all carried out communication campaigns through the "Less Salt more health" strategy; and (3) Argentina, Costa Rica and Chile, which reduced added salt in bread (57). Most of the countries have a comprehensive strategy and have previously carried out more than two actions. However, multiple strategies exist around the world to mitigate this problem; for example, the reduction of the sodium content in food prepared or consumed outside the home; taxes on foods with a high sodium content; regulation of foods in specific settings (schools and hospitals) (15); as well as specific warning messages on salt containers (Argentina is in the process of implementing the latter) (23).

By implementing a set of these interventions with a comprehensive strategy, sodium consumption at the population level could be close to that recommended by the WHO (58). Because the country's current cardiovascular health is compromised, actions and strategies to reduce sodium consumption among the population are urgently needed to improve morbidity and mortality in Mexico.

AUTHOR CONTRIBUTIONS

IC-N and JV developed the draft of the article. CN and AA carried out a miniature review on the challenges of the main problem. IC-N, JV, and SB wrote the study's recommendations and conclusions. All authors contributed to the article and approved the submitted version.

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REFERENCES

1. Insitute for Health Metrics and Evaluation (IHME). *Global Burden Disease Compare Data Visualization*. Seattle, WA: IHME (2019).
2. Welsh CE, Welsh P, Jhund P, Delles C, Celis-Morales C, Lewsey JD, et al. Urinary sodium excretion, blood pressure, and risk of future cardiovascular disease and mortality in subjects without prior cardiovascular disease. *Hypertension.* (2019) 73:1202–9. doi: 10.1161/HYPERTENSIONAHA.119.12726
3. Campos-nonato I, Hernández-Barrera L, Oviedo-solís C, Ramírez-villalobos D, Hernández B, Barquera S. Epidemiología de la hipertensión arterial en adultos mexicanos: diagnóstico, control y tendencias. ensanut 2020. *Salud Publica Mex.* (2021) 63:692–704. doi: 10.21149/12851
4. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, et al. Global sodium consumption and death from cardiovascular Causes. *N Engl J Med.* (2014) 371:624–34. doi: 10.1056/NEJMoa1304127
5. OMS. *Organización Mundial de la Salud. Ingesta de sodio en adultos y niños*. Geneva (2013). Available online at: http://apps.who.int/iris/bitstream/10665/85224/1/WHO_NMH_NHD_13.2_spa.pdf.
6. Vargas-Meza J, Cervantes-Armenta MA, Campos-Nonato I, Nieto C, Marron-Ponce JA, Barquera S, et al. Dietary sodium and potassium intake: data from

the Mexican national health and nutrition survey 2016. *Nutrients.* (2021) 14:81. doi: 10.20944/preprints202107.0391.v1
7. Campos-Nonato I, Flores-Aldana M, Mendoza K, Vargas-Meza J, Correa-Rotter R, Barquera S. Sodium and potassium estimated from urine sample according to ENSANUT MC 2016. *BMC Public Health.* (2021).
8. Pirahanchi Y, Aeddula NR. *Physiology, Sodium Potassium Pump (Na+ K+ Pump).* (2019). Available online at: https://www.ncbi.nlm.nih.gov/books/NBK537088/ (accessed April 2, 2020).
9. He FJ, Tan M, Ma Y, MacGregor GA. Salt reduction to prevent hypertension and cardiovascular disease: JACC state-of-the-art review. *J Am Coll Cardiol.* (2020) 75:632–47. doi: 10.1016/j.jacc.2019.11.055
10. Clemmer JS, Pruett WA, Coleman TG, Hall JE, Hester RL. Mechanisms of blood pressure salt sensitivity: new insights from mathematical modeling. *Am J Physiol - Regul Integr Comp Physiol.* (2017) 312:R451–66. doi: 10.1152/ajpregu.00353.2016
11. Morris RC Jr, Schmidlin O, Frassetto LA, Sebastian A, Morris RC, Schmidlin O, et al. Relationship and interaction between sodium and potassium. *J Am Coll Nutr.* (2013) 25:37–41. doi: 10.1080/07315724.2006.1071957
12. Adrogué HJ, Madias NE. The impact of sodium and potassium on hypertension risk. *Semin Nephrol.* (2014) 34:257–72. doi: 10.1016/j.semnephrol.2014.04.003
13. Hope SF, Webster J, Trieu K, Pillay A, Ieremia M, Bell C, et al. systematic review of economic evaluations of population-based sodium reduction interventions. *PLoS ONE.* (2017) 12:e0173600. doi: 10.1371/journal.pone.0173600
14. He FJ, MacGregor GA. Salt and sugar: their effects on blood pressure. *Pflugers Arch.* (2015) 467:577–86. doi: 10.1007/s00424-014-1677-x
15. Hyseni L, Elliot-Green A, Lloyd-Williams F, Kypridemos C, O'Flaherty M, McGill R, et al. Systematic review of dietary salt reduction policies: evidence for an effectiveness hierarchy? *PLoS ONE.* (2017) 12:e0177535. doi: 10.1371/journal.pone.0177535
16. Codex alimentarius: international food standards. *General Standard For Food Additives Codex.* (2019). Available online at: https://www.fao.org/fao-who-codexalimentarius/codex-texts/dbs/gsfa/en/ (accessed November 17, 2021).
17. Marrón-Ponce JA, Tolentino-Mayo L, Hernández-F M, Batis C. Trends in ultra-processed food purchases from 1984 to 2016 in Mexican households. *Nutrients.* (2019) 11:1–15. doi: 10.3390/nu11010045
18. Nieto C, Tolentino-Mayo L, Medina C, Monterrubio-Flores E, Denova-Gutiérrez E, Barquera S. Sodium content of processed foods available in the Mexican market. *Nutrients.* (2018) 10:2008. doi: 10.3390/nu10122008
19. Vargas-Meza J, Pedroza-Tobías A, Campos-Nonato I, Fernandes-Nilson E, Jauregui A, Barquera S. Retos del etiquetado frontal de alimentos para lograr la reducción del consumo de sodio (sal). *Salud Publica Mex.* (2019) 61:1. doi: 10.21149/10593
20. Nilson EAF, Spaniol AM, Gonçalves VSS, Moura I, Silva SA, L'Abbé M, et al. Sodium reduction in processed foods in Brazil: Analysis of food categories and voluntary targets from 2011 to 2017. *Nutrients.* (2017) 9:742. doi: 10.3390/nu9070742
21. Nilson EAF, Spaniol AM, Gonçalves VSS, Oliveira ML, Campbell N, L'Abbé M, et al. The impact of voluntary targets on the sodium content of processed foods in Brazil, 2011–2013. *J Clin Hypertens.* (2017) 19:939–45. doi: 10.1111/jch.13044
22. Ministerio de Salud. *Menos Sal + Vida.* Argentina. Available online at: http://www.msal.gob.ar/ent/index.php/informacion-para-ciudadanos/menos-sal--vida (accessed August 2, 2016).
23. Gobierno de Argentina. *Ley 26.905.* (2013). Available online at: https://www.boletinoficial.gob.ar/detalleAviso/primera/99389/20131216?busqueda=1 (accessed January 22, 2022).
24. Allemandi L, Tiscornia MV, Guarnieri L, Castronuovo L, Martins E. Monitoring sodium content in processed foods in Argentina 2017-2018: compliance with national legislation and regional targets. *Nutrients.* (2019) 11:1474. doi: 10.3390/nu11071474
25. Madriz K, Ramos E, Blanco-Metzler A, Saavedra L, Nilson E, Tiscornia V, et al. *Policy brief: El desafío de reducir el consumo de sal/sodio en la dieta de la población latinoamericana.* Tres Ríos, Costa Rica (2020). Available online at: https://idl-bnc-idrc.dspacedirect.org/bitstream/handle/10625/58947/IDL-58947.pdf (accessed November 28, 2021).
26. World Health Organization (WHO). *The SHAKE Technical Package for Salt Reduction.* Geneva (2016). Available online at: https://www.who.int/dietphysicalactivity/publications/shake-salt-habit/en/ (accessed December 11, 2021).
27. DOF. *Reglamento sanitario de los alimentos. D Oficcial la República N° 4193.* (2015). Available online at: http://web.minsal.cl/sites/default/files/decreto_etiquetado_alimentos_2015.pdf (accessed January 30, 2016).
28. Ministerio de. *Industria y Mineria. Decreto No 272/018: Criterios para definir exceso de sodio, azúcares y grasas saturadas Montevideo, Uruguay.* (2020).
29. El Peruano. *Ley N 30021, Ley de promoción de la alimentación saludable para niños, niñas y adolescentes, y su Reglamento aprobado por Decreto Supremo N° 017-2017-SA.* Normas Leg (2018). p. 58–63. Available online at: https://busquedas.elperuano.pe/download/url/aprueban-manual-de-advertencias-publicitarias-en-el-marco-de-decreto-supremo-n-012-2018-sa-1660606-1 (accessed December 15, 2021).
30. Secretaría de Economía. *MODIFICACIÓN a la Norma Oficial Mexicana NOM-051-SCFI/SSA1-2010, Especificaciones generales de etiquetado para alimentos y bebidas no alcohólicas preenvasados-Información comercial y sanitaria, publicada el 5 de abril de 2010.* 27 Marzo (2020). Available online at: https://www.dof.gob.mx/2020/SEECO/NOM_051.pdf (accessed June 12, 2020).
31. Reyes M, Smith Taillie L, Popkin B, Kanter R, Vandevijvere S, Corvalán C. Changes in the amount of nutrient of packaged foods and beverages after the initial implementation of the chilean law of food labelling and advertising: a nonexperimental prospective study. *PLoS Med.* (2020) 17:e1003220. doi: 10.1371/journal.pmed.1003220
32. Agência Nacional de Vigilância Sanitária. *Anvisa aprova norma sobre rotulagem nutricional.* (2020). Available online at: https://www.gov.br/anvisa/pt-br/assuntos/noticias-anvisa/2020/aprovada-norma-sobre-rotulagem-nutricional (accessed February 10, 2021).
33. Ministerio de Salud. *Colombia ya cuenta con etiquetado nutricional. Boletín Prensa No 681.* (2021). Available online at: https://www.minsalud.gov.co/Paginas/Colombia-ya-cuenta-con-etiquetado-nutricional.aspx (accessed October 26, 2021).
34. World Health Organization (WHO). *WHO Global Sodium Food For Different Benchmarks Categories.* Geneva (2021).
35. Organizacion Panamericana de la Salud. *Metas regionales actualizadas de la OPS para la reducción del sodio.* (2021). Available online at: https://iris.paho.org/handle/10665.2/54971 (accessed February 17, 2022).
36. Secretaría de Salud. *Emergencia epidemiológica para la prevención y el control de sobrepeso y obesidad.* (2016). Available online at: http://www.cenaprece.salud.gob.mx/programas/interior/emergencias/descargas/pdf/DeclaratoriaEmergenciaEpidemiologicaEE-4-16.pdf (accessed January 24, 2021).
37. Barquera S, Rivera J, Campos I, Hernández L, Santos-Burgoa C, Durán E, et al. Acuerdo Nacional Para la Salud Alimentaria Estrategia contra el sobrepeso y la obesidad. *Vivir Mejor.* (2010) 27:28.
38. Secretaría de Salud. *Programa México Sano (PROMESA).* (2011). Available online at: https://coprisjal.jalisco.gob.mx/riesgos-a-la-salud/alimentacion-equilibrada (accessed June 1, 2021).
39. Secretaría de salud. *Campaña Menos Sal, Más Salud.* (2013). Available online at: http://www.amr.org.mx/docs/Boletin-Menos-Sal-Mas-Salud.pdf (accessed June 19, 2021).
40. Ellison DH, Welling P. Insights into salt handling and blood pressure. *N Engl J Med.* (2021) 385:1981–93. doi: 10.1056/NEJMra2030212
41. He FJ, Campbell NRC, MacGregor GA. Reducing salt intake to prevent hypertension and cardiovascular disease. *Rev Panam Salud Publica.* (2012) 32:293–300. doi: 10.1590/S1020-49892012001000008
42. Aburto NJ, Ziolkovska A, Hooper L, Elliott P, Cappuccio FP, Meerpohl JJ. Effect of lower sodium intake on health: systematic review and meta-analyses. *BMJ.* (2013) 346:f1326. doi: 10.1136/bmj.f1326
43. He FJ, MacGregor GA. Effect of modest salt reduction on blood pressure: A meta-analysis of randomized trials. implications for public health. *J Hum Hypertens.* (2002) 16:761–70. doi: 10.1038/sj.jhh.1001459
44. Nilson EAF, Metlzer AB, Labonté M-E, Jaime PC. Modelling the effect of compliance with WHO salt recommendations on cardiovascular disease mortality and costs in Brazil. *PLoS ONE.* (2020) 15:e0235514. doi: 10.1371/journal.pone.0235514

45. Vega-Solano J, Blanco-Metzler A, Madriz-Morales K, Fernandes-Nilson EA, Labonté ME. Impact of salt intake reduction on CVD mortality in Costa Rica: a scenario modelling study. *PLoS ONE.* (2021) 16:1–11. doi: 10.1371/journal.pone.0245388
46. Bibbins-Domingo K, Chertow GM, Coxson PG, Moran A, Lightwood JM, Pletcher MJ, et al. Projected effect of dietary salt reductions on future cardiovascular disease. *N Engl J Med.* (2010) 362:590–9. doi: 10.1056/NEJMoa0907355
47. Nilson EAF, Pearson-Stuttard J, Collins B, Guzman-Castillo M, Capewell S, O'Flaherty M, et al. Estimating the health and economic effects of the voluntary sodium reduction targets in Brazil: microsimulation analysis. *BMC Med.* (2021) 19:225. doi: 10.1186/s12916-021-02099-x
48. Organización Panamerica de. la Salud. *SHAKE menos sal, más salud Guía técnica para reducir el consumo de sal.* Washington, DC (2018).
49. Appel LJ, Frohlich ED, Hall JE, Pearson TA, Sacco RL, Seals DR, et al. The importance of population-wide sodium reduction as a means to prevent cardiovascular disease and stroke: a call to action from the American heart association. *Circulation.* (2011) 123:1138–43. doi: 10.1161/CIR.0b013e31820d0793
50. Pérez-Escamilla R, Segura-Pérez S, Lott M, The on behalf of, Healthy RHEP on BP for P, Nutrition, Feeding Patterns and WS for I and, Months T from B to 24. *Feeding guidelines for infants and young toddlers: a responsive parenting approach*. Durham, NC. (2017). Available online at: https://healthyeatingresearch.org/ doi: 10.1097/NT.0000000000000234
51. El CEO. *Empresas encuentran en reformulación la forma de librarse del nuevo etiquetado.* (2020). Available online at: https://elceo.com/negocios/empresas-encuentran-en-reformulacion-la-forma-de-librarse-del-nuevo-etiquetado/ (accessed June 20, 2021).
52. Forbes México. *Lala está lista para el nuevo etiquetado con reformulación en sus productos.* (2020). Available online at: https://www.forbes.com.mx/negocios-lala-esta-lista-para-el-nuevo-etiquetado-con-reformulacion-en-sus-productos/#:$\sim$:text=Lala%2C empresa mexicana que fábrica,de algunos de sus productos (accessed June 15, 2021).
53. Allemandi L, Tiscornia MV, Ponce M, Castronuovo L, Dunford E, Schoj V. Sodium content in processed foods in Argentina: compliance with the national law. *Cardiovasc Diagn Ther.* (2015) 5:197–206. doi: 10.3978/j.issn.2223-3652.2015.04.01
54. Escobar MC. *Estrategia Nacional para la reducción del consumo de sal en Chile* (2010).
55. Colombia M de S de. *Estrategia Nacional Para La Reduccion Delconsumo De Sal/Sodio En Colombia 2012 – 2021* (2015).
56. Nilson EAF, Jaime PC, Resende DO. Iniciativas desenvolvidas no Brasil para a redução do teor de sódio em alimentos processados. *Rev Panam Salud Publica*. (2012) 34:287–92. https://www.paho.org/journal/sites/default/files/07--ARTI--Nilson--287-292.pdf?ua=1
57. Pan American Health Organization. *Mapping Dietary Salt / Sodium Reduction Policies and Initiatives in the Region of the Americas*. Washington, DC (2021).
58. OMS. *Reducir la ingesta de sodio para reducir la tensión arterial y el riesgo de enfermedades cardiovasculares en adultos.* (2011). Available online at: http://www.who.1int/elena/titles/sodium_cvd_adults/es/ (accessed September 20, 2015).

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Association Between Perceived Levels of Stress and Self-Reported Food Preferences Among Males and Females: A Stated Preference Approach Based on the China Health and Nutrition Survey

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Objective: Stress is a major public health challenge and is associated with undesirable eating behavior. This cross-sectional study aimed to explore whether there is an association between perceived level of stress and food preference among Chinese adults.

Study Design: Perceived level of stress was measured using the Chinese version of the 14-item Perceived Stress Scale, whereas self-reported food preferences were investigated by means of five food classification questions, including questions regarding the consumption of fast food, salty snacks, fruit, vegetables, and soft/sugary drinks.

Methods: The data were collected from the 2015 China Health and Nutrition Survey. Information of 8,216 adults (≥18 years) on perceived level of stress, self-reported food preferences, and other important covariates was available and analyzed.

Results: Perceived level of stress was negatively associated with a preference for fruit ($\beta = -0.58$, 95% CI: −0.81 to −0.34, $p < 0.0001$) and vegetables ($\beta = -1.13$, 95% CI: −1.41 to −0.85, $p < 0.0001$), while it was positively associated with a preference for fast food ($\beta = 0.36$, 95% CI: 0.08–0.64, $p = 0.011$) and soft/sugary drinks ($\beta = 0.48$, 95% CI: 0.30–0.66, $p < 0.0001$) after adjusting for potential confounders. No association between a preference for salty snacks and perceived level of stress was found in either men or women.

Conclusions: The present population-based study reported strong associations between perceived level of stress and self-reported food preferences among Chinese adults. Sex differences related to this association were also worthy of attention.

Keywords: perceived stress, food preference, eating behavior, population-based study, dietary

INTRODUCTION

Stress is considered a major public health challenge in modern society; it increases the risk of obesity, metabolic syndrome, and various other chronic diseases (1, 2). Simultaneously, stress-related eating is a potential factor in the obesity pandemic (3, 4). Food preferences are influenced by a myriad of environmental and internal factors, which include the availability and rewarding properties of food (5, 6). Consuming highly tasty foods stimulates the food reward system, and the pleasurable experience increases the likelihood of repeat consumption, potentially leading to overweight and obesity (7).

Previous studies have indicated that exposure to stress disrupts eating patterns; individuals may attempt to relieve stress by engaging in unhealthy—although often pleasurable—behaviors, including undesirable eating behavior (8). The association between the emotions related to stress and undesirable eating behavior, such as emotional eating, restrained eating, and external eating, has been reported in several studies (9–11). Both men and women perceive stress as leading to unhealthy changes in eating patterns (12). Evidence from animal studies have shown an increased intake of palatable foods in rats with chronic stress, which may assist in ameliorating anxiety—the alteration of the function of the hypothalamic–pituitary–adrenal axis may be the mediating factor in this association (13). A randomized controlled trial examined the effects of stress on food preferences and obesogenic behavior; however, the findings from this study do not support the hypothesis that perceived stress increases the preference for highly palatable foods (14). Although there is accumulating evidence of a possible association between perceived stress and food preferences and selection, some studies have found that stress suppresses appetite, whereas other studies report that persistent stress promotes the motivation to eat, especially foods with a high energy, sugar, and fat content (15, 16). Therefore, the primary aim of the present study was to determine whether there is an association between perceived level of stress and food preference.

Furthermore, literature indicates that the influence of perceived stress on food choice varies based on sex (17, 18). An epidemiological study found that women with high levels of stress have an increased preference for sweet and high-fat foods compared to their counterparts with low levels of stress (19). However, another study found that men with no perceived stress consume more unhealthy foods than their counterparts with low levels of stress (20). The preference to adopt more indulgent eating behavior in response to stress is especially evident in women, while stress is not associated with indulgent eating behavior in men, regardless of the level of stress (21). Women, more often than men, employ indulgent eating as a stress management strategy, while men tend to follow a problem-focused approach to cope with stress (22). Accordingly, this study proposed to further explore sex differences in stress-induced dietary preferences.

To date, most research on the relationship between stress and food preferences has been conducted in Western countries; few studies focus on this association among China's large population. Chinese eating patterns and food preferences vastly differ from those of Western populations. Additionally, findings from previous studies are inconsistent. Herein, by using the database of the China Health and Nutrition Survey (CHNS), the main objective was to explore the underlying relationship between perceived level of stress and food preferences among males and females in Chinese adults, and to verify whether this association also exists after adjusting for potential confounders.

METHODS

Data Source and Study Participants

The CHNS comprises a series of population-based longitudinal household surveys conducted by the National Institute for Nutrition and Health of the Chinese Center for Disease Control and Prevention and the University of North Carolina at Chapel Hill in the United States (23). The household surveys cover nine provinces in China that vary substantially in geography, economic development, public resources, and health indicators, which was given to participants by paper questionnaires. The de-identified survey data are publicly available. The survey commenced in 1989 following a multistage, random cluster sampling method. To date, individual-level information on health, socioeconomic status, and social and family networks has been collected in 11 waves (i.e., in 1989, 1991, 1993, 1997, 2000, 2004, 2006, 2009, 2011, 2015, and 2018). The questionnaire was originally in Chinese, which included questions that related to individual activities, lifestyle, health status, marriage and birth history, body shape, and mass media exposure. Our study only selected the variables that we are interested in. The first survey to include the Perceived Stress Scale (PSS) was that conducted in 2015. The results of the 2018 wave were not yet available at the time of the present study; therefore, we used the data of the 2015 wave. In total, 12,863 individuals completed the 2015 CHNS interview. We excluded individuals with an age $<$18 years, missing PSS data ($n = 1{,}795$), missing age, height, weight, or education level data, and those with incorrect data concerning any of the abovementioned variables ($n = 2{,}852$). In total, 8,216 participants were included in the present analysis. **Figure 1** presents a detailed flowchart of participant selection. Further information regarding the CHNS project is available at the following URL: https://www.cpc.unc.edu/projects/china.

Data Collection

Data on all demographic variables, including age, sex, education level, weight (kg), height (m), daily sleep duration (hours), urban status, smoking status, and alcohol consumption status, were extracted from the original CHNS files. Weight and height measurements were obtained by means of detailed physical examinations, and the remaining variables by means of objective questionnaires.

The Chinese version of the 14-item PSS (PSS-14) was used to measure perceived level of stress, with the total score ranging from 0 to 56 (23). The original PSS consists of 14 items; it was translated from English to Chinese and subsequently back to English to ensure the accuracy of translation. Among the 8,216 included participants, we calculated the Cronbach's alpha of the

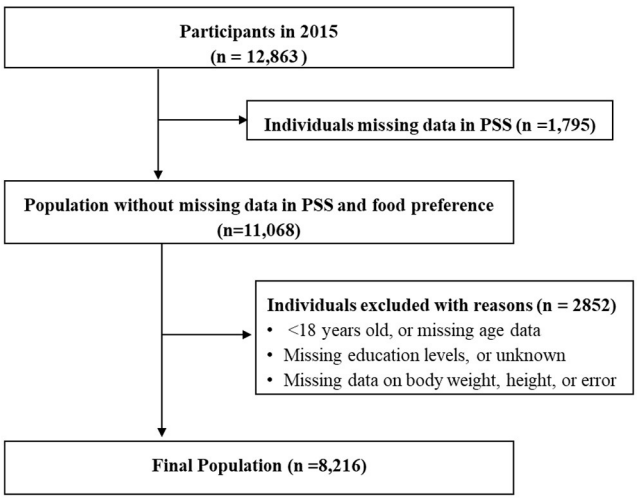

FIGURE 1 | Flow chart of the selection process of study participants from the China Health and Nutrition Survey.

PSS-14 as 0.829, which is similar to the scale reliability findings of Huang et al. calculated among 9,507 individuals from the same database (i.e., 0.830) (23). The scale is divided into two subscales: items 1, 2, 3, 8, 11, 12, and 14 constitute the negative subscale, focusing on the feeling of tension, whereas items 4, 5, 6, 7, 9, 10, and 13 constitute the positive subscale, focusing on the sense of feeling out of control. The negative subscale included questions regarding the frequency of negative incidents or feelings, such as 'In the last month, how often have you felt that you were unable to control important things in your life?' The positive subscale included positively stated items, e.g., "In the last month, how often have you felt confident about your ability to handle your personal problems?" A 5-point Likert scale was used to assess each item, ranging from 0 = "never" to 4 = "very often". To obtain meaningful odds ratios, perceived level of stress was rescaled based on the median total PSS-14 score (i.e., a low level and high level of perceived stress).

Self-reported food preferences were investigated by means of five food classification questions, including questions regarding the consumption of fast food (e.g., pizza and hamburgers), salty snacks (e.g., pretzels and potato chips), fruit, vegetables, and soft/sugary drinks (including fruit drinks and soft drinks) (24). For each question, the answer options were: "dislike very much", "dislike somewhat", "neutral", "like somewhat", or "like very much".

Statistical Analyses

According to the Chinese Working Group on Obesity (25), body mass index (BMI) was divided into the following groups: underweight, normal, overweight, and obese representing a BMI $<$18.5, 18.5–23.99, 24–27.99, and $\geq$28 kg/m^2, respectively. Data are presented as mean (standard deviation [SD]) or median (interquartile range) for continuous variables, and as percentages for categorical variables. For continuous variables, independent sample *t*-tests or one-way analysis of variance were used for comparisons between two or more independent groups. For categorical variables, the χ^2-test was used to assess the statistical significance of differences between various groups. The Bonferroni correction was used to reduce the chances of obtaining false-positive results (type I errors) when multiple pairwise tests were performed on a single set of data. Linear regression models were used to investigate the association between food preferences and PSS scores. Regression coefficients (β) and their 95% confidence intervals (CIs) were estimated. The association between the risk of high levels of perceived stress and food preferences was assessed using logistic regression models. The maximum likelihood method was used to estimate odds ratios and their 95% CIs (26). We adjusted for the confounders of basic characteristics (i.e., age, sex, education, and urban status) and physical conditions (i.e., BMI, smoking status, alcohol consumption status, and the presence of diabetes or hypertension) in the linear and logistic regression models; these were selected based on previous studies following a similar study design (27, 28). Most potential confounders are dichotomous or continuous variables. Only education is multicategorical variable, the first level (i.e., Grad from primary) is considered as reference. We used the variance inflation factor to detect potential multicollinearity in the regression models. A two-tailed $p < 0.05$ was considered statistically significant. All statistical tests were performed using Stata Statistical Software Release 15 (Stata Corp LLC, College Station, TX, USA).

RESULTS

Basic Participant Characteristics

Table 1 presents the basic characteristics of the sample population, stratified by sex. The 2015 CHNS wave included 8,216 adults ($\geq$18 years) with information on perceived level of stress, self-reported food preferences, and the remaining relevant covariates (**Figure 1**). In total, 4,197 (51.1%) participants were women and the mean age was 50.8 years (SD = 14.2). The education level of more than two-thirds of the participants was lower than high-school level education, and most (64.7%) were from urban areas. Approximately half of the participants were overweight (36.1%) or obese (14.4%), while the prevalence of diabetes and hypertension was 4.9 and 16.0%, respectively. Apart from the prevalence of diabetes, all variables differed significantly between men and women ($p < 0.05$).

Association Between Perceived Level of Stress and Basic Participant Characteristics

The associations between perceived level of stress and basic participant characteristics are presented in **Table 2**. Participants who differed in age group, education level, and weight category had different levels of perceived stress ($p < 0.05$). Additionally, those who resided in cities, towns, or county capital cities experienced higher levels of perceived stress than those who resided in suburban or rural villages (PSS-14 score: 22.9 vs. 22.3). Unexpectedly, participants who consumed alcohol and had hypertension experienced reported lower levels of perceived

TABLE 1 | The basic characteristics of selected participants.

Variables	Total (N = 8,216)	Male (n = 4,019)	Female (n = 4,197)	p-value*
Age (years, mean ± SD; n, %)	50.8 ± 14.2	52.2 ± 14.4	49.5 ± 14.0	<0.0001 [a]
Education (n, %)				
Grad from primary	1,601 (19.5)	705 (17.5)	896 (21.4)	<0.0001 [b]
Lower middle school degree	3,124 (38.0)	1,538 (38.3)	1,586 (37.8)	
Upper middle school degree	1,386 (16.9)	726 (18.1)	660 (15.7)	
Technical or vocational degree	794 (9.7)	378 (9.4)	416 (9.9)	
University or college degree and above	1,311 (16.0)	672(16.7)	639 (15.2)	
Urban Status (n, %)				
City, town, or county capital city	4,490 (64.7)	2,292 (57.0)	2,198 (52.4)	<0.0001 [b]
Suburban or rural village	3,726 (45.4)	1,727 (43.0)	1,999 (47.6)	
BMI (kg/m^2, mean ± SD; n, %)	24.3 ± 3.6	24.5 ± 3.6	24.1 ± 3.7	<0.0001 [a]
Underweight	362 (4.4)	150 (3.7)	212(5.1)	<0.0001 [b]
Normal	3,702 (45.1)	1,726 (42.9)	1,976 (47.1)	
Overweight	2,967 (36.1)	1,542 (38.4)	1,425 (33.9)	
Obese	1,185 (14.4)	601 (14.9)	584 (13.9)	
Smoking status (n, %)				
Yes	1,850 (22.8)	1,774 (45.1)	76 (1.8)	<0.0001 [b]
No	6,280 (77.2)	2,163 (54.9)	4,117 (98.2)	
Alcohol consumption (n, %)				
Yes	2,257 (28.7)	2,301 (52.6)	226 (5.7)	<0.0001 [b]
No	5,600 (71.3)	1,827 (47.4)	3,773 (94.3)	
Diabetes (n, %)				
Yes	382 (4.9)	202 (5.3)	180 (4.5)	0.127 [b]
No	7,461 (95.1)	3,647 (94.7)	3,814 (95.5)	
Hypertension (n, %)				
Yes	1,254 (16.0)	664 (17.2)	590 (14.8)	0.003 [b]
No	6,593 (84.0)	3,187 (82.8)	3,406 (85.2)	

p-value refers to the comparison between male and female. [a]P-values were calculated by two-tailed t-tests. [b]P-values were calculated by chi-square tests.

TABLE 2 | The comparison of perceived stress with different basic characteristics of participants.

Variables	n (%)	PSS-14 scores	p-value
Age (years)			
18–40	1,996 (24.3)	22.9 ± 5.9	0.011
41–59	3,790 (46.1)	22.7 ± 6.2	
≥60	2,430 (29.6)	22.4 ± 6.3	
Sex (n, %)			
Male	4,019 (48.9)	22.6 ± 6.1	0.279
Female	4,197 (51.1)	22.7 ± 6.2	
Education (n, %)			
Grad from primary	1,601 (19.5)	23.2 ± 6.1	<0.0001
Lower middle school degree	3,124 (38.0)	23.0 ± 6.0	
Upper middle school degree	1,386 (16.9)	22.4 ± 6.0	
Technical or vocational degree	794 (9.7)	22.0 ± 6.1	
University or college degree and above	1,311 (16.0)	21.8 ± 6.4	
Urban			
1-city, town or county capital city	4,490 (54.6)	22.9 ± 6.1	<0.0001
0-suburban or rural village	3,726 (45.4)	22.3 ± 6.1	
Weight category			
Underweight	362(4.4)	23.4 ± 6.1	0.007
Normal	3,702 (45.1)	22.7 ± 6.0	
Overweight	2,967(36.1)	22.6 ± 6.3	
Obese	1,185 (14.4)	22.2 ± 6.2	
Smoking status			
Yes	1,850 (22.8)	22.5 ± 6.1	0.318
No	6,280 (77.2)	22.6 ± 6.2	
Alcohol consumption			
Yes	2,257 (28.7)	22.3 ± 6.1	0.011
No	5,600 (71.3)	22.7 ± 6.2	
Diabetes			
Yes	382 (4.9)	22.0 ± 6.7	0.071
No	7,461 (95.1)	22.6 ± 6.2	
Hypertension			
Yes	1,254 (16.0)	22.1 ± 6.5	0.002
No	6,593 (84.0)	22.7 ± 6.1	

stress (both $p < 0.05$). We did not find differences in perceived stress levels between participants with or without diabetes ($p = 0.071$). The comparison of low and high levels of perceived stress based on the basic characteristics of the participants is presented in **Supplementary Table 1**. The details of original results are shown in **Supplemental Table 2**.

Association Between Perceived Level of Stress and Food Preferences

No potential multicollinearity was detected in the regression models. From the non-adjusted models, it was found that the PSS-14 score was negatively associated with a preference for fruit ($\beta = -0.61$, 95% CI: −0.83 to −0.38, $p < 0.0001$) and vegetables ($\beta = -1.18$, 95% CI: −1.45 to −0.91, $p < 0.0001$), while it was positively associated with a preference for soft/sugary drinks ($\beta = 0.52$, 95% CI: 0.35–0.69, $p < 0.0001$). The results remained similar for the abovementioned food preferences (fruit, vegetables, and soft/sugary drinks) after adjusting for confounders of basic characteristics (i.e., age, sex, education, and urban status) in Model 1, and those of basic characteristics and physical conditions (i.e., BMI, smoking status, alcohol consumption status, and presence of diabetes or hypertension) in Model 2. A preference for fast food was positively associated with the PSS-14 score in Model 1 ($\beta = 0.31$, 95% CI: 0.04–0.58, $p = 0.026$) and Model 2 ($\beta = 0.36$, 95% CI: 0.08–0.64, $p = 0.011$). The details are presented in **Table 3**. The logistic regression results,

TABLE 3 | The associations between PSS-14 scores and each variable of food preference.

Variables	Model*	β (95%CI)	t	p-value
Fast food	**Non-adjusted model**	0.27 (0.00, 0.54)	1.93	0.053
	Model 1	0.31 (0.04,0.58)	2.23	0.026
	Model 2	0.36 (0.08, 0.64)	2.55	0.011
Salty snack food	**Non-adjusted model**	0.08 (−0.18, 0.34)	0.62	0.537
	Model 1	0.08 (−0.18, 0.35)	0.63	0.529
	Model 2	0.07 (−0.20, 0.33)	0.48	0.631
Fruits	**Non-adjusted model**	−0.61 (−0.83, −0.38)	−5.20	<0.0001
	Model 1	−0.58 (−0.81, −0.35)	−4.90	<0.0001
	Model 2	−0.58 (−0.81, −0.34)	−4.73	<0.0001
Vegetables	**Non-adjusted model**	−1.18 (−1.45, −0.91)	−8.59	<0.0001
	Model 1	−1.17 (−1.44, −0.90)	−8.53	<0.0001
	Model 2	−1.13 (−1.41, −0.85)	−7.95	<0.0001
Soft/sugared drinks	**Non-adjusted model**	0.52 (0.35, 0.69)	6.03	<0.0001
	Model 1	0.51 (0.34,0.69)	5.84	<0.0001
	Model 2	0.48 (0.30, 0.66)	5.30	<0.0001

Model 1: adjusted for age, sex, urban status, education.
Model 2: model 1 + BMI+ smoking status + alcohol consumption + diabetes + hypertension.

reflecting the association between a high level of perceived stress and food preferences, are presented in **Supplementary Table 3**. We found that a high level of perceived stress was associated with a preference for fast food, salty snacks, and soft/sugary drinks after adjusting for the abovementioned confounders. Moreover, a low level of perceived stress was associated with a preference for fruit and vegetables in the adjusted model.

Sex Differences in the Association Between Perceived Level of Stress and Food Preferences

The results regarding the association between the PSS-14 score and food preferences in men compared with women are presented in **Table 4**. No association was found between a preference for salty snacks and perceived levels of stress in either men or women. A preference for fast food was positively associated with perceived level of stress in women after adjusting for potential confounders, including age, sex, education level, urban status, BMI, smoking status, alcohol consumption status, and presence of diabetes or hypertension ($\beta = 0.46$, 95% CI: 0.08–0.85, $p = 0.019$). The association between a preference for fruit and perceived level of stress was also significant in women ($\beta = -0.93$, 95% CI: −1.30 to −0.57, $p < 0.0001$), although it was not significant in men ($p > 0.05$), after adjusting for the abovementioned confounders. Moreover, perceived level of stress showed a significant negative association with a preference for vegetables, and a significant positive association with a preference for soft/sugary drinks, in both men and women before and after adjusting for potential confounders (all $p < 0.05$).

DISCUSSION

Using the large database of the 2015 CHNS, our study provides valuable evidence regarding the association between food preferences and perceived levels of stress among the Chinese population. Moreover, sex differences related to this association were also explored in this study. We found that perceived levels of stress were associated with unhealthy food preferences, including increased intake of fast food and soft/sugary drinks and decreased intake of fruit and vegetables. Perceived levels of stress were positively associated with a preference for fast food and negatively associated with a preference for fruit in women, but not men, in the adjusted models.

Our findings are similar to those from previous Western studies in that a higher perceived level of stress is associated with a preference for highly tasty foods (14). Various studies have reported that perceived levels of stress influence specific food preferences and alter food choices (29, 30). For example, some researchers suggest that stress induces people to eat in the absence of hunger and to choose higher energy foods, which may be related to the food reward system (29–31). Consistent with our findings, several original studies exploring the foods that individuals tend to consume under stress have confirmed that highly caloric fatty snacks, sweets, and foods are preferred (32–34). Accumulating evidence suggests that increased stress levels are associated with decreased consumption of fruit and vegetables (35–37). Similarly, we found that perceived levels of stress were negatively associated with a preference for a healthy dietary taste (i.e., fruit and vegetables). Overall, both our current findings and those of multiple previous studies demonstrated that chronic stress is positively associated with the frequency of emotional eating, snacking, and consuming tasty foods, and negatively associated with consuming fruit and vegetables (35–37). However, not all opinions support our findings. For example, a cross-sectional study among university students revealed that students who are not stressed consume more energy and fatty foods compared with those who are stressed when comparing the differences in nutritional intake (38).

Perceived stress has been related to unhealthy eating patterns in both men and women, with reports indicating that women have an increased preference for snacks, biscuits, and sweets,

TABLE 4 | Associations between PSS-14 scores and Each Variable of Food Preference in Male and Female.

Variable	Model*	Male			Female		
		β(95%CI)	*z*	*p*-values	*β*(95%CI)	*z*	*p*-values
Fast food	**Non-adjusted model**	0.22 (−0.17, 0.62)	1.12	0.264	0.30 (−0.07, 0.68)	1.60	0.111
	Adjusted model	0.25 (−0.16, 0.65)	1.20	0.231	0.46 (0.08, 0.85)	2.35	0.019
Salty snack food	**Non-adjusted model**	0.34 (−0.04, 0.72)	1.75	0.081	−0.16 (−0.51, 0.20)	−0.85	0.397
	Adjusted model	0.37 (−0.03, 0.76)	1.83	0.068	−0.18 (−0.55, 0.19)	−0.97	0.334
Fruits	**Non-adjusted model**	−0.38 (−0.68, −0.07)	−2.44	0.015	−0.97 (−1.32, −0.62)	−5.38	<0.0001
	Adjusted model	−0.31 (−0.62, 0.01)	−1.92	0.055	−0.93 (−1.30, −0.57)	−4.97	<0.0001
Vegetables	**Non-adjusted model**	−1.18 (−1.55, −0.81)	−6.27	<0.0001	−1.14 (−1.53, −0.74)	−5.65	<0.0001
	Adjusted model	−1.14 (−1.52, −0.75)	−5.83	<0.0001	−1.08 (−1.49, −0.67)	−5.17	<0.0001
Soft/sugared drinks	**Non-adjusted model**	0.39 (0.15, 0.63)	3.17	0.002	0.64 (0.40, 0.88)	5.25	<0.0001
	Adjusted model	0.35 (0.10, 0.61)	2.71	0.007	0.58 (0.33, 0.83)	4.58	<0.0001

**Adjusted model, adjusting for age, sex, education, urban status, BMI, smoking status, alcohol consumption, diabetes, and hypertension.*

while men have an increased preference for fast food and meat (12). Another original study found that women are more likely than men to increase their food intake when stressed, and experimentally demonstrated that stress causes food choices to shift from healthy low-fat foods to less healthy high-fat foods (39). In the present study, we also demonstrated sex differences related to food choices when under stress. Previous studies found that eating healthy foods such as vegetables and fresh fruit is negatively associated with perceived levels of stress in both men and women (40), which is slightly different from our findings. In our study, the association between a preference for fruit and perceived levels of stress was not significant after adjusting confounders in men, indicating the need for further exploration in different populations. Compared to men, women are more health-conscious and consume a larger variety of foods; therefore, they are more prone to lack of restraint when stress eating (41). Accordingly, when stress reduces the inhibitory effect induced by unhealthy high-energy foods, women are inclined to allow themselves to consume them (39). Women are more sensitive to emotion-centered coping methods, distracting themselves from feelings of stress through emotional eating, while men tend to cope with stress in a problem-centered way (22). Interestingly, the current analysis showed that alcohol use was associated with lower perceived levels of stress. A study illustrated that moderate alcohol consumption reduces stress-related neural activity; however, the chronic neurobiological effects of alcohol on stress are uncertain (42).

Overall, our study provides preliminary evidence of the association between perceived levels of stress and self-reported food preference. Further longitudinal studies are required to elucidate the effects of self-reported food preferences on changes in perceived levels of stress. In future research, individuals should be provided more information on the effects of stress on food intake and on foods that may alleviate stress to help them to adopt suitable eating behaviors to combat stress.

Strengths and Limitations

Our study has several strengths. First, the large sample size increases the generalizability of our findings. Second, all the data used in this study are based on highly reliable CHNS records. Moreover, we controlled for a variety of potential confounders during data analyses. However, the results of our study should be interpreted considering certain limitations. First, causality cannot be inferred owing to the cross-sectional design. Second, the large excluded sample also should be noted. Third, the PSS-14 is a self-report scale and the CHNS only assessed perceived stress levels once, which may have introduced measurement errors and cannot reflect long-term conditions. Moreover, differences may exist between eating preferences and eating behaviors. Finally, the dietary information of the included participants—gathered for the 2015 CHNS—was not publicly available, which limited the exploration of the relationship between perceived level of stress and dietary behavior.

CONCLUSION

The present population-based study reported strong associations between perceived level of stress and self-reported food preferences among Chinese adults. Further exploration of these associations using a longitudinal design in different populations is warranted. Dietary behavior should be considered in future studies. Moreover, the current findings provide valuable evidence inform that the future researches should consider the effects of stress on food intake and on foods, which may alleviate stress to help them to adopt suitable eating behaviors to combat stress.

DATA AVAILABILITY STATEMENT

The datasets presented in this study can be found in online repositories. The names of the repository/repositories and accession number(s) can be found below: https://www.cpc.unc.edu/projects/china.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by University of North Carolina at Chapel Hill and the Chinese Center for Disease Control and Prevention. The

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

AUTHOR CONTRIBUTIONS

BC and XG had full access to all the data in the study and take responsibility for the integrity of the data. BC, FY, and RL: study concept and design. RL and BC: acquisition or interpretation of data and drafting of the manuscript. All authors: critical revision of the manuscript for important intellectual content.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.850411/full#supplementary-material

REFERENCES

1. Slavich GM. Social safety theory: a biologically based evolutionary perspective on life stress, health, and behavior. *Annu Rev Clin Psychol.* (2020) 16:265–95. doi: 10.1146/annurev-clinpsy-032816-045159
2. Tavolacci MP, Ladner J, Grigioni S, Richard L, Villet H, Dechelotte P. Prevalence and association of perceived stress, substance use and behavioral addictions: a cross-sectional study among university students in France, 2009-2011. *BMC Public Health.* (2013) 13:724. doi: 10.1186/1471-2458-13-724
3. Jarvela-Reijonen E, Karhunen L, Sairanen E, Rantala S, Laitinen J, et al. High perceived stress is associated with unfavorable eating behavior in overweight and obese Finns of working age. *Appetite.* (2016) 103:249–58. doi: 10.1016/j.appet.2016.04.023
4. Laitinen J, Ek E, Sovio U. Stress-related eating and drinking behavior and body mass index and predictors of this behavior. *Prev Med.* (2002) 34:29–39. doi: 10.1006/pmed.2001.0948
5. Pallister T, Sharafi M, Lachance G, Pirastu N, Mohney RP, MacGregor A, et al. Food preference patterns in a UK Twin Cohort. *Twin Res Hum Genet.* (2015) 18:793–805. doi: 10.1017/thg.2015.69
6. Tarragon E, Moreno JJ. Role of endocannabinoids on sweet taste perception, food preference, and obesity-related disorders. *Chem Senses.* (2017) 43:3–16. doi: 10.1093/chemse/bjx062
7. Lutter M, Nestler EJ. Homeostatic and hedonic signals interact in the regulation of food intake. *J Nutr.* (2009) 139:629–32. doi: 10.3945/jn.108.097618
8. Krueger PM, Chang VW. Being poor and coping with stress: health behaviors and the risk of death. *Am J Public Health.* (2008) 98:889–96. doi: 10.2105/AJPH.2007.114454
9. Bennett J, Greene G, Schwartz-Barcott D. Perceptions of emotional eating behavior. A qualitative study of college students. *Appetite.* (2013) 60:187–92. doi: 10.1016/j.appet.2012.09.023
10. Ohara K, Mase T, Kouda K, Miyawaki C, Momoi K, Fujitani T, et al. Association of anthropometric status, perceived stress, and personality traits with eating behavior in university students. *Eat Weight Disord.* (2019) 24:521–31. doi: 10.1007/s40519-018-00637-w
11. Finch LE, Tomiyama AJ. Comfort eating, psychological stress, and depressive symptoms in young adult women. *Appetite.* (2015) 95:239–44. doi: 10.1016/j.appet.2015.07.017
12. Mohamed BA, Mahfouz MS, Badr MF. Food selection under stress among undergraduate students in Riyadh, Saudi Arabia. *Psychol Res Behav Manag.* (2020) 13:211–21. doi: 10.2147/PRBM.S236953
13. Machado TD, Dalle Molle R, Laureano DP, Portella AK, Werlang IC, Benetti Cda S, et al. Early life stress is associated with anxiety, increased stress responsivity and preference for "comfort foods" in adult female rats. *Stress.* (2013) 16:549–56. doi: 10.3109/10253890.2013.816841
14. Berg Schmidt J, Johanneson Bertolt C, Sjodin A, Ackermann F, Vibeke Schmedes A, Lynge Thomsen H, et al. Does stress affect food preferences?—a randomized controlled trial investigating the effect of examination stress on measures of food preferences and obesogenic behavior. *Stress.* (2018) 21:556–63. doi: 10.1080/10253890.2018.1494149
15. Rodgers RF, Lombardo C, Cerolini S, Franko DL, Omori M, Fuller-Tyszkiewicz M, et al. The impact of the COVID-19 pandemic on eating disorder risk and symptoms. *Int J Eat Disord.* (2020) 53:1166–70. doi: 10.1002/eat.23318
16. Ulrich-Lai YM, Fulton S, Wilson M, Petrovich G, Rinaman L. Stress exposure, food intake and emotional state. *Stress.* (2015) 18:381–99.
17. Matud MP. Gender differences in stress and coping styles. *Pers Individ Dif.* (2004) 37:1401–15. doi: 10.1016/j.paid.2004.01.010
18. Heiman A, Lowengart O. Calorie information effects on consumers' food choices: sources of observed gender heterogeneity. *J Bus Res.* (2014) 67:964–73. doi: 10.1016/j.jbusres.2013.08.002
19. Habhab S, Sheldon JP, Loeb RC. The relationship between stress, dietary restraint, and food preferences in women. *Appetite.* (2009) 52:437–44. doi: 10.1016/j.appet.2008.12.006
20. Zellner DA, Saito S, Gonzalez J. The effect of stress on men's food selection. *Appetite.* (2007) 49:696–9. doi: 10.1016/j.appet.2007.06.013
21. Kim D, Jang S. Stress and food choices: Examining gender differences and the time horizon framing effect. *Int J Hospital Manag.* (2017) 67:134–42. doi: 10.1016/j.ijhm.2017.08.012
22. Kandiah J, Yake M, Jones J, Meyer M. Stress influences appetite and comfort food preferences in college women. *Nutr Res.* (2006) 26:118–23. doi: 10.1016/j.nutres.2005.11.010
23. Huang F, Wang H, Wang Z, Zhang J, Du W, Su C, et al. Psychometric properties of the perceived stress scale in a community sample of Chinese. *BMC Psychiatry.* (2020) 20:130. doi: 10.1186/s12888-020-02520-4
24. Wu T, Hou X, Zhang F, Sharma M, Zhao Y, Shi Z. Association between self-reported food preferences and psychological well-being during perimenopausal period among Chinese women. *Front Psychol.* (2020) 11:1196. doi: 10.3389/fpsyg.2020.01196
25. Zhou BF. Effect of body mass index on all-cause mortality and incidence of cardiovascular diseases–report for meta-analysis of prospective studies open

optimal cut-off points of body mass index in Chinese adults. *Biomed Environ Sci.* (2002) 15:245–52.
26. Cao B, Wang DF, Yan LL, McIntyre RS, Rosenblat JD, Musial N, et al. Parental characteristics and the risk of schizophrenia in a Chinese population: a case-control study. *Nord J Psychiatry.* (2019) 73:90–5. doi: 10.1080/08039488.2018.1529196
27. He D, Qiao Y, Xiong S, Liu S, Ke C, Shen Y. Association between dietary quality and prediabetes based on the diet balance index. *Sci Rep*. (2020) 10:3190. doi: 10.1038/s41598-020-60153-9
28. Gauci S, Young LM, Arnoldy L, Lassemillante AC, Scholey A, Pipingas A. Dietary patterns in middle age: effects on concurrent neurocognition and risk of age-related cognitive decline. *Nutr Rev*. (2021) nuab047 doi: 10.1093/nutrit/nuab047
29. Born JM, Lemmens SG, Rutters F, Nieuwenhuizen AG, Formisano E, Goebel R, et al. Acute stress and food-related reward activation in the brain during food choice during eating in the absence of hunger. *Int J Obes (Lond).* (2010) 34:172–81. doi: 10.1038/ijo.2009.221
30. Tariq S, Tariq S, Tariq S. Association of perceived stress with healthy and unhealthy food consumption among teenagers. *J Pak Med Assoc.* (2019) 69:1817–21. doi: 10.5455/JPMA.302642278
31. Ha J, Kim J. Factors influencing perceived health status among elderly workers: occupational stress, frailty, sleep quality, and motives for food choices. *Clin Interv Aging.* (2019) 14:1493–501. doi: 10.2147/CIA.S210205
32. Oliver G, Wardle J. Perceived effects of stress on food choice. *Physiol Behav.* (1999) 66:511–5. doi: 10.1016/S0031-9384(98)00322-9
33. Cartwright M, Wardle J, Steggles N, Simon AE, Croker H, Jarvis MJ. Stress and dietary practices in adolescents. *Health Psychol.* (2003) 22:362–9. doi: 10.1037/0278-6133.22.4.362
34. Wardle J, Steptoe A, Oliver G, Lipsey Z. Stress, dietary restraint and food intake. *Psychosom Res.* (2000) 48:195–202. doi: 10.1016/S0022-3999(00)00076-3
35. Almajwal AM. Stress, shift duty, and eating behavior among nurses in Central Saudi Arabia. *Saudi Med J.* (2016) 37:191–8. doi: 10.15537/smj.2016.2.13060
36. Roberts CJ, Campbell IC, Troop N. Increases in weight during chronic stress are partially associated with a switch in food choice towards increased carbohydrate and saturated fat intake. *Eur Eat Disord Rev.* (2014) 22:77–82. doi: 10.1002/erv.2264
37. Tryon MS, Carter CS, Decant R, Laugero KD. Chronic stress exposure may affect the brain's response to high calorie food cues and predispose to obesogenic eating habits. *Physiol Behav.* (2013) 120:233–42. doi: 10.1016/j.physbeh.2013.08.010
38. Cheng SH, Kamil MKM. Stress and Food Intake among University Students - Is There a Relationship? *Sains Malays.* (2020) 49:121–8. doi: 10.17576/jsm-2020-4901-14
39. Zellner DA, Loaiza S, Gonzalez Z, Pita J, Morales J, Pecora D, et al. Food selection changes under stress. *Physiol Behav.* (2006) 87:789–93. doi: 10.1016/j.physbeh.2006.01.014
40. El Ansari W, Adetunji H, Oskrochi R. Food and mental health: relationship between food and perceived stress and depressive symptoms among university students in the United Kingdom. *Cent Eur J Public Health.* (2014) 22:90–7. doi: 10.21101/cejph.a3941
41. Davis C, Shapiro CM, Elliott S, Dionne M. Personality and other correlates of dietary restraint: An age by sex comparison. *Pers Individ Dif.* (1993) 14:297–305. doi: 10.1016/0191-8869(93)90127-O
42. Ronksley PE, Brien SE, Turner BJ, Mukamal KJ, Ghali WA. Association of alcohol consumption with selected cardiovascular disease outcomes: a systematic review and meta-analysis. *BMJ.* (2011) 342:13. doi: 10.1136/bmj.d671

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Using Digital Platform Approach to Reduce Salt Intake in a Sample of UAE Population: An Intervention Study

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Background: Non-communicable diseases (NCDs) are the leading causes of mortality globally, accounting for more deaths than all other causes combined. World Health Organization launched its initiative in 2013 to reduce the intake of salt, the number of countries that have national sodium reduction strategies reached to 89 countries in 2017. In 2020, a study conducted in UAE showed more than 65% of the population exceeded WHO recommendations for salt intake. This study aimed to measure effectiveness of using digital platform approach to deliver educational materials to facilitate salt reduction in a sample of UAE population.

Methods: A controlled parallel intervention study was conducted in 2020. A sample of 121 participants completed the study and fulfilled the inclusion criteria with female to male ratio of (0.95:1.05). Participants were distributed randomly into three groups Control group, WhatsApp group, and Electronic Brochures group. Educational materials were distributed among participants of WhatsApp and Electronic brochures groups for 6-weeks. 24-h urinary excretion for sodium, potassium and creatinine, were measured in addition to KAP questionnaire and physical activity on two occasions at baseline and endpoint after 10-weeks (6-weeks of educational intervention).

Results: Both intervention groups showed a reduction in sodium with 278 mg ($p < 0.001$) for WhatsApp group ($n = 41$) and 169 mg ($p < 0.018$) for Electronic brochures group ($n = 41$), while Control group didn't show any significant change. Moreover, the percentage of participants exceeding WHO recommendation of sodium intake was significantly reduced at the end of intervention, ($p = 0.004$). WhatsApp group was more efficient in the percentage of reduction of participants exceeding WHO recommendation compared with baseline, with $p = 0.023$. A significant reduction in the practice toward adding salt during cooking, use of table salt, adding salt before tasting the foods and use of chicken stocks for both intervention groups was noted with $p < 0.05$. Intervention

groups showed a significant improvement ($p < 0.001$) in Food and Health related knowledge after 6-weeks of intervention.

Conclusion: The digital platform approach such as WhatsApp and Electronic Brochure were effective in salt reduction. This study proves that UAE population is ready to reduce salt intake with appropriate education materials and easy delivery approach.

Keywords: social media, intervention, urinary sodium and potassium excretion, Knowledge, attitude and practice (KAP), digital platform

INTRODUCTION

Noncommunicable diseases (NCDs) are the leading causes of mortality globally, accounting for more deaths than all other causes combined. Nearly 80% of NCD-related deaths occur in the low- and middle-income countries (LMICs) (1). In the Eastern Mediterranean Region, it is estimated that NCDs account for over 50% of annual deaths (2.2 million deaths) and 60% of the disease burden (2, 3).

It is projected that deaths from NCDs will increase by 25% in the Region, recording the second highest projected increase among the 6 WHO regions (2). In fact, it is estimated that NCDs cause between 65 and 78% of deaths in the Gulf Cooperation Council (GCC) (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates (UAE) (4, 5), specifically, the prevalence of cardiovascular diseases (CVDs), which is rapidly growing, constitute the main underlying causes of morbidity and mortality in countries of the Eastern Mediterranean Region (2, 6).

High blood pressure is recognized as a major underlying risk factor for CVDs (7). According to WHO, it is estimated that 62% of all strokes and 49% of coronary heart disease events are secondary to high blood pressure (8, 9). Globally in 2017, high sodium intake led to ∼3 million deaths and loss of 70 million disability-adjusted life-years (7).

A key factor in the success of efforts to reduce sodium intake is that salt (sodium chloride), the primary source of sodium in the diet—has desirable characteristics from a culinary perspective.

Many Asian countries that have documented sodium sources consume most of their sodium from discretionary food sources, accounting for most dietary sodium intake. In the People's Republic of China, most (76%) dietary sodium was from salt added in home cooking, about 50% less in southern than northern areas of the country. In Japan, most (63%) dietary sodium came from soy sauce (20%), commercially processed fish/seafood (15%), salted soups (15%), and preserved vegetables (13%) (10).

In the United States, the United Kingdom and Australia most (95%) of dietary sodium came from processed foods, including breads/cereals/grains (6).

WHO has recommended different strategies approach to reduce salt intake at country levels, these includes; consumer education and awareness food reformulation, Front-of-pack labeling, and salt taxation (2, 7, 11). The number of countries that have national sodium reduction strategies doubled from 2010 to 2014 (7, 11). As of 2016–2017, 89 countries have national policies that support sodium reduction (5, 7). Although the specific strategies vary, almost all take a multi-component approach. Consumer education is the most common intervention, although an increasing number incorporate a regulatory approach as well (7, 11).

Strategies should be appropriate to the local context in terms of the sources of dietary sodium, existing regulatory mechanisms, and access to resources. No single strategy is enough to reach the WHO goal of a 30% reduction in sodium intake by 2025 (7).

Two cross sectional studies conducted in UAE one among adult population (4) and other one among University student (12). Both studies showed KAP toward salt intake was poor and most of the participants failed to recognized foods with high salt contents. Consumer awareness strategy recommended by WHO for salt reduction (2), promote Social Cognitive Learning Theory, which acknowledges the constant interaction that exists between the individual and his or her environment, both structural and social, to shape behavior (11, 13).

To date, there is no published intervention study conducted in the UAE that has used urinary sodium excretion and knowledge, attitude, and practice (KAP) to assess salt intake before and after an educational intervention. Therefore, this parallel study aimed to assess the efficiency and effectiveness of two different intervention approaches for 6-weeks (WhatsApp and electronic-brochures) to reduce sodium intake.

MATERIALS AND METHODS

This study obtained ethical approval from the University Research Ethics Committee at Oxford Brookes University (UREC), Number: 191337. In addition to, ethical approval from United Arab Emirates University (UAEU) Research Ethics Committee (ERS_2020_6107). This study was conducted according to the stated principles in the Declaration of Helsinki (14). All subjects gave written informed consent to participate in the study, and all the communication were online as a response to COVID-19.

Study Design and Participants

A controlled intervention parallel design study comparing the efficiency and effectiveness of two different educational intervention approaches (WhatsApp and electronic brochures) to reduce sodium intake, with a control group receiving no educational materials for the intervention period. The primary outcomes of the study were urinary sodium, potassium, knowledge attitude and practice (KAP), physical activity. All

these outcomes measured in two occasions at baseline and at endpoint after 10-weeks (6 weeks of educational intervention).

The sample size was determined based on the WHO Eastern Mediterranean Region Office (WHO-EMRO) protocol published in 2010 for 24-h urine collection and analysis (13). Participants were divided into two age groups, 20–29.9, and 30–40. To be able to detect a difference in 20 mmol/day of sodium (∼459 mg of sodium) with 25 mmol standard deviations, the sample size needed for each age stratum was 32 participants from both genders. Therefore, for the three intervention groups, 96 participants, (alpha = 0.05, power = 0.80), were recommended. To account for attrition—e.g., non-participation, incomplete collection, or implausible values—which may be as high as 20%, up to 115 participants from all age and gender strata should be recruited (13).

The parallel intervention study was conducted from October 2020–January 2021 in the United Arab Emirates. A random sample of 148 healthy individuals aged between 20 and 40 years were recruited to participate in the study from the three geographical areas of UAE (Western, Northern, and Eastern region). Participants were randomly distributed into the three groups (Control, WhatsApp, and Electronic Brochure) using Altman and Bland (15) procedure. RAND() function was generated according to gender-age group and the three intervention groups.

Several different methods were used for recruitment: email circulation to students and staff (Non-medical students and staff) from Applied Sciences and Humanities Colleges members of UAE University, and social media approach such as WhatsApp and Instagram for population out UAEU.

Inclusion criteria at screening were participants aged 20 to 40 years for both gender, non-pregnant, and non-lactating, no known chronic kidney disease, renal failure, hypertension with medications, and liver diseases, no medical condition(s) or medication(s) known to affect urination and ability to collect 24-h urine. While, the exclusion criteria at screening were those with chronic diseases (i.e., heart disease, hypertension on medications, renal failure, liver disease), pregnant and lactating women, those on diuretics, and women who had their menstrual cycle during the time of urine collection and those who had a positive COVID-19 test. Exclusion criteria after urine collection included those that were unable to collect adequate urine within the 24-h period (i.e., volume < 500 ml). In addition to that, creatinine level of the reference range 500 to 2,000 mg/day was used in the current study, which is equivalent to 9–26 mg/kg of body mass for female participants and 13–29 mg/kg of body mass for male participants (4, 16, 17).

Anthropometric Measurements

Body weight and height were measured for each participant and their body mass index (BMI) was calculated as weight (kg) divided by height (m) squared (kg/m^2). Height was recorded to the nearest 1 cm using a stadiometer (Seca Stadiometer, Seca Ltd., Birmingham, UK) and weight was recorded using a balance (Seca Stadiometer, Seca Ltd., Birmingham, UK) to the nearest 0.1 kg (18). All the precaution requirements implemented by UAEU and by Federal Government of UAE were performed on the participants, which included checking body temperature prior to entering nutrition clinics, physical distancing and space capacity. In addition, a valid negative test for COVID-19 for 30 days.

Knowledge, Attitude, and Practice (KAP) Questionnaire

Participants were asked to complete the self-reported questionnaire on two occasions, one at baseline and second time after 10-weeks (including 6-weeks of educational intervention). The questionnaire assessed knowledge related to salt and health outcomes, frequency of consumption and their perceived salt consumption. The Validated KAP questionnaire was obtained from WHO/PAHO protocol for the assessment of population sodium intake and behaviors (13). The development and performance of the specific questionnaire has been described elsewhere (4, 12). The KAP questionnaire was used to in two cross sectional studies in UAE population (4) and among University students (12).

Educational Materials

In the intervention stage, educational materials were shared with the two-intervention groups, aimed to improve the knowledge of the participants to reduce salt intake, highlight the health hazards of high salt intake, importance of checking food labels, and alternatives for salt.

Educational materials were developed using information from Weqaya program—Health Authority of Abu Dhabi—HAAD-UAE, https://weqaya.doh.gov.ae/, Central for Disease and Control Prevention (CDC—Salt https://www.cdc.gov/salt/index.htm. In addition, the information obtained from the outcome of the cross-sectional study conducted in UAE (4). For the WhatsApp group, every 7-days a new message was delivered for 6 weeks, with a new topic every week. Every 3-days the same message was repeated. While for the electronic brochure group, every 2 weeks a new electronic brochure with a new topic was sent to the participants by email.

24-h Urine Collections and Analysis

A single timed 24-h urine collection was obtained for the estimation of sodium excretion. Participants were given written and verbal instructions for the 24-h urine collection procedure. A 3-L coded plastic bottle was given to each participant for urine collection. Participants were asked to discard the first urine of the day and to collect all urine in the plastic bottle provided over the following 24-h. Participants were also asked to write on a separate sheet the time and date at the start and end of the urine collection, indicating occasions they missed urination. Urine analysis for sodium, potassium, and creatinine levels were conducted in the College of Agriculture & Veterinary Medicine (CAVM) laboratories at United Arab Emirates University (UAEU). For the measurement of sodium and potassium levels in the urine, 50 mL of the urine sample was mixed with 200 μL of 1% nitric acid. Analytical solutions were introduced to a Varian ICP-OES model 710-ES spectrometer for sodium and potassium measurements (19). 24-h urinary creatinine was measured using ab204537 Creatinine Assay Kit based on colorimetric Assay (20), with UV-Visible spectrophotometer (Multiscan Go, Thermo-Fisher

Scientific, MA, USA). The assay relies on Jaffe' reaction (20). The measurements were taken on two occasions at baseline and after 10 weeks (including 6-weeks of educational materials).

Statistical Analysis

Data were recorded and analyzed using the Statistical Package for Social Sciences (SPSS) software, version 25 (SPSS, Chicago, IL, USA). Normality of data across combination of independent variables was tested using Shapiro Wilks. Homogeneity of data was tested using Leven's test. Continuous variables were presented as mean ± standard deviation and categorical variables were expressed as numbers and percentages. Descriptive statistics were used to summarize the baseline characteristics of the study participants.

Mixed repeated measures ANOVA test was performed to assess the main effects of time (baseline vs. endpoint) and intervention groups (Control, WhatsApp, and Electronic Brochures) on 24-h urinary sodium and potassium, and creatinine excretions. For interaction analysis, One-way ANOVA, followed by Bonferroni *post-hoc* test, and dependent *t*-test were used to compare dependent variables according to time and intervention groups. One-sample *t*-test was used to compare the mean urinary sodium, salt, and potassium excretions with the recommended dietary allowance, and assessment was carried out based on gender using independent *t*-test. The effect size was calculated as Cohen *d* for *t*-test and partial eta-squared (η_p^2) for ANOVA. *P*-values < 0.05 were considered statistically significant.

RESULTS

Sample Characteristics

A total of 148 participants agreed to participate in the study, out of which 12 participants didn't answer the phones or messages, and 15 participants were excluded due to 24-h urinary creatinine levels below 9-mg/kg body weight for females and < 13 mg/kg body weight for males (4, 16, 17), as shown in **Figure 1**. At the end of the study, 121 participants completed the study and fulfilled the creatinine inclusion criteria−39 participants were in the control group with female to male ratio (0.95:1.05), while in WhatsApp group, 41 participants completed the study with a female to male ratio of 0.95:1.05 and for in the Electronic brochures group, 41 participants completed the study with a female to male ratio of 1.05:0.95 as shown in **Figure 1**.

Most of the study population were Emirati (67.8 %). Almost half of the study population were singles and around 75.0% of them were with university degree -educational status. Moreover, more than 50% of them were employed (**Table 1**).

Mean 24-h Urinary Sodium, Potassium, and Creatinine

The mean urinary sodium, salt, and potassium excretion per 24-h for the study population were 3,040.8 ± 665.3, 7,601.9 ± 1,635.7 and 1,984.4 ± 654.3 mg, respectively (**Table 1**). Moreover, mean urinary excretion for creatinine was 1,379.7 ± 339 mg/day, with significant differences between gender ($p = 0.001$, **Table 1**). In addition to that, 24-h urinary sodium excretion for total sample and according to gender ($p = 0.001$; **Table 1**), were significantly higher than WHO recommendation for sodium intake. Moreover, 24-h urinary potassium excretion for total sample and according to gender ($p = 0.001$; **Table 1**), were lower than WHO recommendation for potassium intake.

In the Control group, there were no significant differences between baseline and endpoint of 10-weeks (6-weeks of educational intervention) for urinary sodium and salt ($p = 0.055$; **Table 2**). While, participants in the WhatsApp group showed a significant reduction in 24-h urinary sodium and salt after 10-weeks (6 weeks of educational intervention) (3,019.5 ± 593.0 mg vs. 2,741.5 ± 636.0 mg, for sodium; 7,548.7 ± 1,482.5 mg vs. 6,853.6 ± 1,591.0 mg, for salt) ($p = 0.001$; **Table 2**). In addition to that, participants in the electronic brochures group showed also a significant difference in 24-h urinary sodium excretion and salt between baseline readings and endpoint ($p = 0.018$; **Table 2**). With respect to 24-h urinary excretion for potassium, WhatsApp group showed a significant improvement in potassium intake compared with baseline readings ($p = 0.033$; **Table 3**), while the control and Electronic Brochures groups did not show any differences.

Moreover, a 2 × 3 Mixed repeated measures ANOVA (time vs. group) revealed a significant main effect for time on 24-h urinary sodium excretion [$F_{(1,117)} = 11.812$; $p = 0.001$; $\eta_p^2 = 0.092$], and for interaction between time and group [$F_{(2,117)} = 10.093$; $p < 0.001$; $\eta_p^2 = 0.147$], No significant effect was detected for group [$F_{(2,117)} = 0.590$; $p = 0.556$; $\eta_p^2 = 0.010$].

There were no significant differences between baseline and endpoint after 6-weeks of education for 24-h urinary excretion for creatinine and creatinine as mg/kg body weight for the Control group and the two intervention groups (**Table 2**).

The percentage of participants exceeding WHO recommendation of Sodium intake for total population was 77.7% at baseline and became 71.1% at the end of the intervention period, with a significant reduction ($p = 0.004$, **Table 2**). In the WhatsApp group, the percentage of participants exceeding WHO recommendation of sodium intake was significantly lower after intervention ($p = 0.023$). While for the electronic brochure, there was no significant change ($p = 0.160$, **Table 2**).

Salt-Related Knowledge, Attitudes and Practices

Although 77.7% of the study population exceeded WHO recommendation of sodium intake according to 24-h urinary excretion, around 60.0% of the study population thought they just consumed the right amount at baseline (**Table 3**). After 6-weeks of intervention, 71.1% of the study population exceeded WHO recommendation of sodium intake according to 24-h urinary excretion, while around 65% believed that they just consumed the right amount of salt according to the KAP questionnaire response. This indicated that the study population is not able to give the right judgment of correct estimation of salt intake (**Table 3**). With respect to the attitude of the study population, the WhatsApp group was significantly more concerned ($p = 0.028$) about the amount of salt intake after

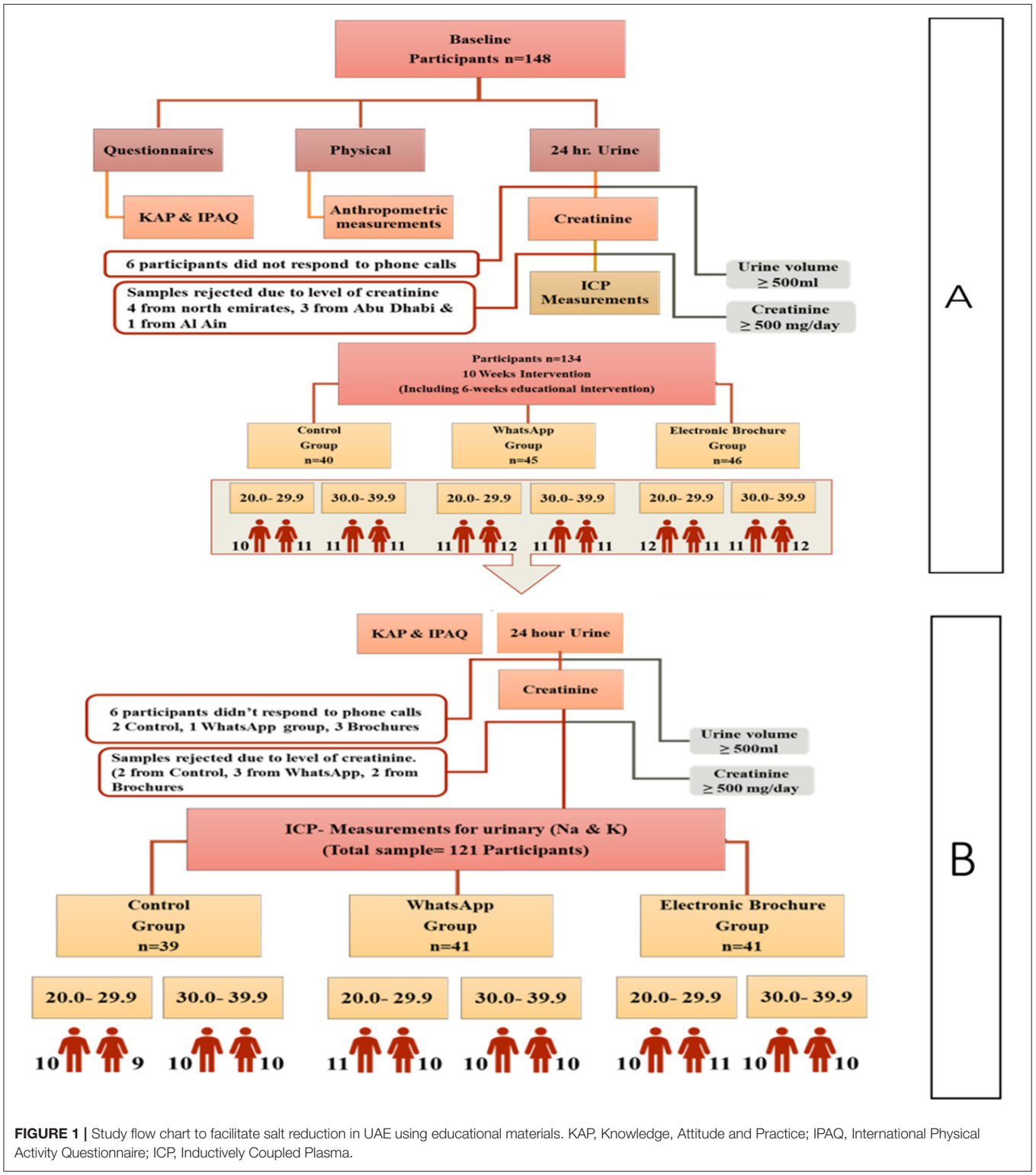

FIGURE 1 | Study flow chart to facilitate salt reduction in UAE using educational materials. KAP, Knowledge, Attitude and Practice; IPAQ, International Physical Activity Questionnaire; ICP, Inductively Coupled Plasma.

TABLE 1 | Demographic data and 24-h urinary sodium, potassium and creatinine excretions.

Characteristics	Total ($n = 121$) Mean ± SD[a]	Female ($n = 60$) Mean ± SD	Male ($n = 61$) Mean ± SD	
Age	28.5 ± 5.7	28.3 ± 5.9	28.7 ± 5.5	
BMI	26.0 ± 4.6	25.6 ± 4.2	26.4 ± 4.8	
BMI classification	*n* (%)	*n* (%)	*n* (%)	
Underweight (18.5) (*n*, %)	5 (4.1)	3 (5.0)	2 (3.3)	
Normal weight (18.5–24.9)	49 (40.5)	23 (38.3)	26 (42.6)	
Overweight (25–29.9)	49 (40.5)	25 (41.7)	24 (39.3)	
Obese	18 (14.9)	9 (15.0)	9 (14.8)	
Nationality	*n* (%)	*n* (%)	*n* (%)	
Emirati	82 (67.8)	42 (70.0)	40 (66.7)	
Arabs	39 (32.2)	18 (30.0)	21 (34.4)	
Marital status	*n* (%)	*n* (%)	*n* (%)	
Single	63 (52.1)	23 (38.3)	40 (55.7)	
Married	51 (42.5)	33 (55.0)	19 (31.6)	
Divorced	6.0 (5.0)	4 (6.7)	2 (3.3)	
Educational level	*n* (%)	*n* (%)	*n* (%)	
Undergraduate university level	73 (60.3)	39 (65)	34 (55.7)	
School level (Intermediate or lower)	31 (25.6)	14 (23.3)	17 (27.9)	
Postgraduate level	17 (14.0)	7 (11.7)	10 (16.4)	
Employment status	*n* (%)	*n* (%)	*n* (%)	
Student	29 (24.0)	21 (35.0)	8 (13.1)	
Unemployed	24 (19.8)	18 (30.0)	6 (9.8)	
Employed	68 (56.2)	21(35.0)	47(77.0)	
24-h urinary excretion	Mean ± SDα	Mean ± SD	Mean ± SD	*p*-value[c]
Sodium excretion (mg)	3,040.8 ± 665.3[b]	2,836.7 ± 497.3[b]	3,244.8 ± 721[b]	0.001
Salt (mg)	7,601.9 ± 1,635.7[b]	7,091.7 ± 1,243.3[b]	8,112.1 ± 1,822.4[b]	0.001
Potassium excretion (mg)	1,984.4 ± 654.3[d]	1,907.3 ± 608.5[d]	2,061.4 ± 701.5[d]	0.201
Creatinine (mg/day)	1,379.7 ± 339	1,150.2 ± 270.7	1,609.2 ± 226.7	0.001
Creatinine (mg/kg/day)	19.8 ± 4.0	18.1 ± 3.6	21.4 ± 3.8	0.001

[a]Data presented as Mean ± standard deviation. [b]Significantly higher than, the WHO recommendations for sodium and salt, (One- Sample t-test used to compare mean with RDA, Significance at α = 5%.). [c]Independent-Samples t-test used to assessed Significance at α = 5% for variable according to gender. [d]Significantly lower than, the WHO recommendations for potassium, (One- Sample t-test used to compare mean with RDA, Significance at α = 5%.).

10-weeks (6-weeks of educational intervention) compared with baseline (**Table 3**).

After educational intervention, both WhatsApp and Electronic Brochures groups showed a significant increase in awareness on the importance of reducing salt intake compared with baseline readings ($p = 0.001$), as shown in **Table 3**. Moreover, there was a significant increase in the attitude toward agreeing on the importance of reducing consumption of processed foods and reducing sodium intake after educational intervention for both WhatsApp and Electronic Brochures ($p < 0.05$).

Salt-Related Practices Among Study Population

After 10-weeks (6-weeks of educational intervention), the intervention groups (WhatsApp and Electronic Brochures) showed a significant increase ($p < 0.05$), in the percentage of participants checking food labels often (**Table 4**). In addition to that, there was a significant increase ($p < 0.05$) in checking labels specifically for salt/sodium content (often) and more participants reported that salt/sodium content on the label affects purchasing decisions (often) ($p < 0.05$; **Table 4**). However, the WhatsApp intervention group significantly improved the practice of buying "low salt" foods ($p = 0.002$) as shown in **Table 4**.

Practices toward adding salt during cooking, at the table, before tasting foods and using Stock Cubes during cooking were significantly reduced with ($p < 0.05$), in both intervention groups (WhatsApp and Electronic Brochures) after educational intervention (**Table 4**). Moreover, there was a significant increase in using spices, herbs and lemons as alternative of salt in both intervention groups (WhatsApp and Electronic Brochures) after 6-weeks of educational intervention (**Table 4**).

Food and Health Related Knowledge Among Study Population

Food related knowledge was significantly improved for both the WhatsApp and Electronic Brochure intervention groups after 10-weeks (6-weeks of educational intervention) with values of

TABLE 2 | 24-h urinary excretion for sodium, potassium, creatinine, and salt before and after the 6 weeks intervention.

Variables	Stage	Mean ± SD[1]			
		Control ($n = 39$)	WhatsApp ($n = 41$)	Brochures ($n = 41$)	Total ($n = 121$)
Urinary sodium excretion (mg)	Baseline	3,008.7 ± 664.0α	3,019.5 ± 593.0α	3,094.0 ± 605.0α	3,040.8 ± 654.3α
	End	3,112.5 ± 609.0α	2,741.5 ± 636.0α	2,925.2 ± 571.7α	2,926.4 ± 664.3α
	p-value[c]	0.055	0.001	0.018	0.189
Salt (mg/day)	Baseline	7,521.8 ± 1,510.0	7,548.7 ± 1,482.5	7,735.0 ± 1,513.6	7,601.9 ± 1,635.7
	End	7,781 ± 1,622.5	6,853.6 ± 1,591.0	7,313.1 ± 1,429.2	7,316.1 ± 1,626.3
	p-value[c]	0.055	0.001	0.018	0.189
Urinary potassium excretion (mg)	Baseline	2,037.0 ± 707[b]	1,868.7 ± 591.2[b]	2,047.0 ± 672.0[b]	1,984.8 ± 658.5[b]
	End	2,014.4 ± 663.0[b]	2,095 ± 630.0[b]	2,063.2 ± 522.4[b]	2,051.5 ± 602.0[b]
	p-value[c]	0.867	0.033	0.987	0.409
Sodium to potassium ratio	Baseline	1.5 ± 0.6	1.6 ± 0.8	1.5 ± 0.6	1.5 ± 0.7
	End	1.6 ± 0.7	1.3 ± 0.5	1.4 ± 0.5	1.4 ± 0.6
	p-value[c]	0.536	0.009	0.270	0.238
Exceeding WHO recommendation of Sodium intake [*n* (%)] [d]	Baseline	31 (79.5)	32 (78.0)	31 (75.6)	94 (77.7)
	End	30 (76.9)	27 (65.8)	29 (70.7)	86 (71.1)
	p-value[e]	0.323	0.023	0.160	0.004
Urinary creatinine excretion (mg)	Baseline	1,340.6 ± 327.0	1,424.9 ± 371.4	1,369.6 ± 319.0	1,378.4 ± 339
	End	1,324.0 ± 356.0	1,437.7 ± 365.3	1,387.6 ± 304.8	1,383.1 ± 344
	p-value[c]	0.369	0.768	0.711	0.902
Creatinine excretion (mg/kg body weight)	Baseline	19.5 ± 3.8	20.1 ± 4.4	19.7 ± 3.14	19.8 ± 4.0
	End	19.0 ± 3.6	20.7 ± 4.2	20.0 ± 3.4	19.9 ± 4.2
	p-value[c]	0.651	0.780	0.635	0.908

[1]*Data presented as Mean ± standard deviation.* [α]*Significantly higher than, the WHO recommendations for sodium, (One- Sample t-test used to compare mean with RDA = 2,300 mg/day, Significance at α = 5%.).*

[b]*Significantly lower than, the WHO recommendations for potassium, (One- Sample t-test used to compare mean with RDA = 3,510 mg/day, Significance at α = 5%.).*

[c]*Paired t-test according to time of measurements (Baseline vs. endpoint) within the same group.*

[d]*Data presented as number and frequency.* [e]*Paired t-test according to time of measurements (Baseline vs. endpoint) within the same group, each reading above than WHO recommendation earned 1, while the other zero, to estimate mean and perform paired t-test.*

3.5 ± 2.8 and 3.7 ± 2.5 out of 10, respectively for both groups at baseline. However, after 10-weeks (6-weeks of educational intervention), food related knowledge become; 8.5 ± 1.9 and 8.9 ± 1.6 out of 10 for both the WhatsApp and Electronic Brochure, respectively ($p = 0.001$) as shown in **Table 5**.

Health related knowledge for the study population was significantly improved after 10-weeks (6-weeks of educational intervention) for both WhatsApp and Electronic Brochures groups with (p-value = 0.001), as shown in **Table 5**.

Most of the study population failed to identify food rich in sodium, about 20 to 26% were able to recognize Arabic and Iranian bread as high sodium sources at baseline (**Table 6**). However, after 6-weeks of educational intervention, 80–95% of participants in the WhatsApp and Electronic Brochures groups were able to recognize Arabic and Iranian bread as high sodium sources ($p = 0.001$) as shown in **Table 6**. About 40 to 70% of study population at baseline were able to recognize canned vegetables, cheddar cheese, pickles, salad dressing oil, Ketchup, tomato paste, chicken cubes, and Instant noodle as rich food sources of sodium (**Table 6**). This percentage increased significantly up to 95% and above for intervention group after educational intervention as shown in **Table 6** ($p = 0.001$).

After 6-weeks of educational intervention using WhatsApp and Electronic Brochures, the majority of the study population were able to recognize corn takes as a rich source of sodium ($p = 0.001$) (**Table 6**). At the end of Intervention, the WhatsApp group showed a significant difference compared with baseline for 19 food items out of 19 with 100% improvement compared with baseline. Similarly, the Electronic Brochures group showed a significant difference compared with baseline for 18 food items out of 19 with 94.7% improvement. The Control group also showed a significant improvement in recognizing pickle foods as a high salt food at the endpoint after 6-weeks ($p < 0.05$) (**Table 6**). The Control group showed improvement in 1 food item compared with 19, with 5.3% improvement at the end of intervention.

Physical Activity of the Study Population Before and After Intervention

Physical activity of the study population was measured using 7-days self-reported short IPAQ for the three groups at baseline and

TABLE 3 | Salt-related attitudes among study population by intervention groups before and after the 6 weeks intervention.

Variable[1]	Stage	Control (*n*, %)	WhatsApp n (*n*, %)	Brochure (*n*, %)
How much salt do you think you consume (Just the right amount)	Baseline *n* (%)α	24 (61.5)	27 (65.8)	24 (58.5)
	Mean ± SD[b]	0.62 ± 0.51	0.66 ± 0.43	0.59 ± 0.40
	Endpoint *n* (%)	25 (64.1)	31 (70.6)	27 (65.8)
	Mean ± SD	0.64 ± 0.42	0.71 ± 0.35	0.66 ± 0.33
	p-value[c]	0.323	0.133	0.099
Are you concerned about the amount of salt/sodium in the diet (Yes)	Baseline *n* (%)	6 (15.4)	4 (9.7)	5 (12.2)
	Mean ± SD	0.15 ± 0.49	0.01 ± 0.45	0.12 ± 0.48
	Endpoint *n* (%)	6 (15.4)	9 (22.0)	7 (17.1)
	Mean ± SD	0.15 ± 0.49	0.22 ± 0.32	0.17 ± 0.46
	p-value	1.00	0.012	0.160
Reducing added salt to foods is important to you (Agree)	Baseline *n* (%)	10 (25.6)	9 (22.0)	10 (24.4)
	Mean ± SD	0.26 ± 0.35	0.22 ± 0.30	0.24 ± 0.31
	Endpoint *n* (%)	11 (28.2)	22 (53.7)	29 (70.7)
	Mean ± SD	0.28 ± 0.32	0.54 ± 0.42	0.71 ± 0.33
	p-value	0.323	0.001	0.001
Reducing consumption of processed foods is important to you (Agree)	Baseline *n* (%)	15 (38.5)	10 (24.4)	13 (31.7)
	Mean ± SD	0.39 ± 0.47	0.24 ± 0.31	0.32 ± 0.41
	Endpoint *n* (%)	14 (35.9)	28 (68.3)	30 (73.1)
	Mean ± SD	0.36 ± 0.49	0.68 ± 0.48	0.73 ± 0.36
	p-value	0.802	0.001	0.001
Reducing your sodium intake is important to you (Agree)	Baseline *n* (%)	12 (30.8)	10 (24.4)	14 (34.1)
	Mean ± SD	0.31 ± 0.36	0.24 ± 0.31	0.34 ± 0.39
	Endpoint *n* (%)	14 (35.9)	25 (61.0)	19 (46.3)
	Mean ± SD	0.36 ± 0.30	0.61 ± 0.38	0.46 ± 0.42
	p-value	0.785	0.001	0.012

[1]*Attitude was assessed based on a three-point Likert scale but only answers of "agree" are presented, each agree answer earned 1 score, while the other zero, to estimate mean and perform paired t-test.* [α]*Data presented as number and frequency.* [b]*Data presented as Mean ± standard deviation.* [c]*Paired t-test according to time of measurements (Baseline vs. endpoint) within the same group.*

intervention, showed no significant differences at baseline and after 10-weeks (6-weeks of educational intervention), as shown in **Table 7**.

DISCUSSION

To our knowledge, this is the first study in the UAE, GCC, and Arab Countries, aimed to measure the effectiveness of educational materials using social media approaches such as WhatsApp and Electronic Brochures for 6-weeks with 24-h urinary sodium excretion levels to facilitate salt reduction. Out of 148 participants, 121 participants completed the study according to urine volume and creatinine levels based on the following studies (4, 15, 16, 21–25).

The urinary sodium excretion in the current study was significantly higher than the WHO recommendations, which is (2,300 mg/day) and significantly lower for potassium (3,150 mg/day). The result of the current study showed an increase in salt consumption by 12% in a sample of UAE population compared with the study conducted in 2015, which showed level of salt intake around 6,783.5 mg (4). It is worth noting that the age group in the current study is up to 40 years, while Jarrar et al. study was up to 60 years old. The highest urinary sodium excretion was reported in age groups 20–29.9 and 30–39.9 years old compared with age groups 40–49.9 years and above and 50 years old and above (4). Therefore, the difference in the age group may explain the differences in salt intake between the current study compared with the previous study. Nevertheless, the common result between the three studies is that the mean urinary sodium excretion indicates higher than the WHO recommendation for salt intake.

There are several salt reduction strategies or approaches all over the world, these strategies were implemented as one strategy or a combination of two or more strategies or as comprehensive strategies (2, 26, 27). These reduction strategies or approaches for salt intakes may include one or more of the following such as educational approaches (individual/ group). Generally, most of the intervention's strategies are based on education or counseling lasting for 2 weeks to < 12 months (26, 28–30). The duration of the intervention varies according to the aim of the study, some interventions lasted for 2 weeks (28), or 6-weeks as reported by (30). Others have used smartphone apps as tools for educational

TABLE 4 | Salt-related practices among study population by intervention groups ($n = 121$) before and after the 6 weeks intervention, check supplementary.

Variable[1]	Stage	Control (Mean)	WhatsApp (*n*, %)	Brochure (*n*, %)
Check food labels (Often)	Baseline *n* (%)α	7 (17.9)	9 (22.0)	10 (24.4)
	Mean ± SD[b]	0.18 ± 0.33	0.22 ± 0.42	0.24 ± 0.43
	Endpoint *n* (%)	8 (20.0)	20 (48.8)	14 (34.1)
	Mean ± SD	0.20 ± 0.36	0.49 ± 0.51	0.34 ± 0.38
	p-value[c]	0.323	0.003	0.044
Information on food labels affects purchasing decisions (Often)	Baseline *n* (%)	5 (12.8)	7 (17.5)	7 (17.5)
	Mean ± SD	0.13 ± 0.35	0.18 ± 0.37	0.18 ± 0.37
	Endpoint *n* (%)	5 (12.8)	17 (41.5)	14 (34.1)
	Mean ± SD	0.13 ± 0.35	0.42 ± 0.50	0.38 ± 0.48
	p-value	1.00	0.001	0.006
Check labels specifically for salt/sodium content (Often)	Baseline *n* (%)	2 (5.1)	4 (9.8)	2 (4.9)
	Mean ± SD	0.05 ± 0.22	0.1 ± 0.28	0.05 ± 0.22
	Endpoint *n* (%)	3 (7.0)	18 (45.0)	18(45.0)
	Mean ± SD	0.08 ± 0.26	0.45 ± 0.50	0.45 ± 0.50
	p-value	0.323	0.001	0.001
Salt/sodium content on label affects purchasing decisions (Often)	Baseline *n* (%)	3 (7.5)	3 (7.3)	2 (5.0)
	Mean ± SD	0.08 ± 0.26	0.07 ± 0.26	0.05 ± 0.22
	Endpoint *n* (%)	3 (7.5)	13 (31.7)	9 (22.5)
	Mean ± SD	0.08 ± 0.26	0.32 ± 0.47	0.23 ± 0.40
	p-value	1.00	0.001	0.012
Try to buy "low salt" foods (Often)	Baseline *n* (%)	1 (2.6)	1 (2.4)	2 (4.9)
	Mean ± SD	0.03 ± 0.16	0.02 ± 0.16	0.05 ± 0.02
	Endpoint *n* (%)	1 (2.6)	10 (24.4)	4 (9.8)
	Mean ± SD	0.03 ± 0.16	0.24 ± 0.42	0.10 ± 0.30
	p-value	1.00	0.002	0.160
Add salt to food during cooking (Often)	Baseline *n* (%)	31 (79.5)	28 (68.3)	30 (73.1)
	Mean ± SD	0.80 ± 0.40	0.68 ± 0.46	0.73 ± 0.44
	Endpoint *n* (%)	32 (82.1)	15 (36.6)	18 (43.9)
	Mean ± SD	0.82 ± 0.43	0.36 ± 0.49	0. 44 ± 0.50
	p-value	0.323	0.001	0.001
Use Stock Cubes during cooking (Often)	Baseline *n* (%)	16 (41.0)	14 (34.1)	11 (26.8)
	Mean ± SD	041 ± 0.50	0.34 ± 0.48	0.27 ± 0.45
	Endpoint *n* (%)	17 (43.6)	5 (12.2)	5 (12.2)
	Mean ± SD	0.44 ± 0.50	0.12 ± 0.33	0.12 ± 0.33
	p-value	0.323	0.002	0.012
Add salt to food at the table (Often)	Baseline *n* (%)	9 (23.1)	7 (17.1)	7 (17.5)
	Mean ± SD	0.23 ± 0.42	0.17 ± 0.38	0.17 ± 0.38
	Endpoint *n* (%)	11 (27.5)	1 (2.4)	1 (2.4)
	Mean ± SD	0.28 ± 0.45	0.02 ± 0.15	0.02 ± 0.15
	p-value	0.160	0.012	0.012
Add salt before tasting the food (Often)	Baseline *n* (%)	13 (33.3)	8 (19.5)	9 (22.0)
	Mean ± SD	0.33 ± 0.47	0.20 ± 0.40	0.22 ± 0.42
	Endpoint *n* (%)	11 (27.5)	0 (0.0)	1 (2.4)
	Mean ± SD	0.28 ± 0.45	0.00 ± 0.00	0.02 ± 0.15
	p-value	0.160	0.003	0.003
Did you try to use spices to reduce salt (Yes)	Baseline *n* (%)	14 (35.9)	12 (29.3)	16 (39.0)
	Mean ± SD	0.36 ± 0.48	0.29 ± 0.46	0.39 ± 0.46
	Endpoint *n* (%)	13 (33.3)	31 (75.6)	29 (70.7)
	Mean ± SD	0.33 ± 0.47	0.76 ± 0.42	0.71 ± 0.45
	p-value	0.323	0.001	0.001

[1] *Answer options for practice questions included often, sometimes, and never. Only answers of often are presented, each often answer earn 1 score.* α*Data presented as number and frequency.* [b]*Data presented as Mean ± standard deviation.* [c]*Paired t-test according to time of measurements (Baseline vs. endpoint) within the same group.*

TABLE 5 | Food and Health related knowledge for the study population ($n = 121$), before and after the 6 weeks intervention.

Variables		Control ($n = 39$) Mean ± SD[α]	Classification[c]	WhatsApp ($n = 41$) Mean ± SD	Classification	Brochures ($n = 41$) Mean ± SD	Classification
Food related knowledge	Baseline	3.8 ± 1.8	Poor	3.5 ± 2.8	Poor	3.7 ± 2.5	Poor
	Endpoint	4.4 ± 1.5	Poor	8.5 ± 1.9	Good	8.9 ± 1.6	Good
	p-value[b]	0.142		0.001		0.001	
Medical related knowledge	Baseline	6.9 ± 1.9	Fair	6.4 ± 3.0	Fair	6.7 ± 2.7	Fair
	Endpoint	7.0 ± 2.0	Fair	9.3 ± 1.3	Good	8.9 ± 1.4	Good
	p-value	0.604		0.001		0.001	

[α]*Data presented as Mean ± standard deviation.* [b]*paired t-test according to time of measurements (Baseline vs. endpoint) within the same group.*
[c]*Score percentage for Knowledge < 60 classified as "Poor", 60–70 classified as "Fair", >70 classified as "Good" (20).*

intervention and behavioral change for 4-weeks (29, 31, 32). Some studies have also used short SMS messages and pamphlets as tools to deliver educational materials for 30-days (33, 34), or 3 months (30).

In the current study, after 10-weeks (6-weeks of educational intervention), the intervention groups (WhatsApp and Electronic Brochure) showed a significant reduction in salt intake compared with baseline. In the WhatsApp Intervention group, the reduction was 695.1 mg (∼0.7 g) with −9.2% compared with baseline, and the reduction in salt intake for Electronic Brochure group was 421.9 mg (∼0.4 g) with (−5.4%). Many other studies that used educational approach as intervention tool showed similar results. Eyles et al. used smartphone application (app) as an intervention tool for 4 weeks. The app tool, resulted in a significant reduction in salt (∼0.7 g) compared with baseline (29).

Another study conducted using Smartphone technology showed a significant reduction in salt intake after 4-weeks of intervention with (∼0.8 g) (31).

Anderson et al. (10) reported a reduction of 1.2 g/day in 24-h urinary sodium excretion for Intervention group using multicomponent-behavioral interventions for 6 months. Moreover, He et al. conducted a cluster randomized clinical trial to determine whether an education program delivered to primary school children as part of the usual curriculum could lower salt intake in children and their families (35). The mean salt intake reduction as measured by urinary excretion in children was 1.9 g/day while for families it was −2.9 g/day.

Many studies using education/counseling approach reported a reduction in salt intake with range various from 0.4 to 2.9 g/day (10, 31, 35–37). However, many studies reported the commitment toward salt reduction rely mainly on the educations of the participants and updating or maintaining education to maintain good salt reduction intake (31, 35).

Moreover, Intervention approaches/ strategies using three approaches such as education, reformulation and taxes showed a significant reduction in salt intakes of ∼4 g/day as reported in Finland and Japan, 3 g/day in Turkey and 1.3 g/day in the UK (26).

In the current study, the reduction in salt intake in the intervention groups was associated with improvement in food and health related knowledge. In food related knowledge, the WhatsApp group showed 2.4 times improvements in scores compared with baseline after 10-weeks (6-weeks of educational intervention), while the Electronic Brochure group showed 2 times improvement compared with baseline.

The health-related knowledge improved by 1.4 times in the intervention groups compared with baseline. Moreover, this improvement in food and health related knowledge reflected in an improvement in the attitudes and practices toward the selection and purchasing of low salt foods. Although this improvement increased the recognition of bread as a high source of salt, the intake of Arabic bread was reduced only by 4% which is the lowest compared with other food items that reached 10 to 30% reduction. Pickled foods showed the highest reduction after 10-weeks (6-weeks of educational intervention) with almost 32% reduction, followed by chicken cubes with 22% reduction. Moreover, Instant Indomi (Instant noodles) showed a reduction of 20%, cheeses intake was reduced by 10–20% while Tomato paste showed only 8% reduction after 10-weeks (6-weeks of educational intervention).

Several studies conducted in Arab Gulf Countries such as UAE, Qatar and Kuwait (4, 37), showed that bread and bakery products are considered as staple food in UAE, Arab Gulf Countries, Arab World and most of the Middle East countries (4, 38, 39). It is not easy to reduce the intake of bread and other baked products even if it is one of the main sources of salt in the diet. However, reduction of salt content in bread may can contribute to reduce salt intake (38).

A study conducted in Jordan aimed to measure salt contents of Arabic bread. Sixty-eight bread samples were collected from 13 different bakeries from Amman, mean salt content was 1.19 ± 0.21 g /100 g bread, while other local bread "Shrak" was 2.06 ± 0.19 1.19 ± 0.21 g /100 g (39). Therefore, one of the best approaches to reduce salt intake is to provide low salt bread or place a regulation standard to control salt in the bread. Emirates Authority for Standardization & Metrology (ESMA), initiative for voluntary salt reduction in bread began in February 2020 and it will be obligatory on 2022 (40), this aimed to reduce

TABLE 6 | The number and percentage of participants who correctly answered food related knowledge, before and after the 6 weeks intervention, check supplementary.

Sodium content in the following foods is[1]	Stage	Control ($n = 39$)	WhatsApp ($n = 41$)	Brochure ($n = 41$)
Arabic bread (High)	Baseline *n (%)*α Mean ± SD[b]	10 (25.6) 0.26 ± 0.43	10 (24.3) 0.24 ± 0.43	8 (19.5) 0.20 ± 0.40
	Endpoint *n (%)* Mean ± SD	11 (28.2) 0.28 ± 0.45	34 (82.9) 0.83 ± 0.46	38 (95.0) 0.95 ± 0.22
	p-value[c]	0.323	0.001	0.001
Iranian bread (High)	Baseline *n (%)* Mean ± SD	12 (30.8) 0.31 ± 0.36	13 (31.7) 0.32 ± 0.47	14 (34.1) 0.34 ± 0.48
	Endpoint *n (%)* Mean ± SD	13 (33.3) 0.33 ± 0.47	37 (92.5) 0.93 ± 0.27	36 (90.0) 0.90 ± 0.26
	p-value	0.323	0.001	0.001
Rice- Egyptian (Low)	Baseline *n (%)* Mean ± SD	21 (53.8) 0.54 ± 0.49	20 (48.8) 0.49 ± 0.50	22 (53.7) 0.54 ± 0.50
	Endpoint *n (%)* Mean ± SD	23 (0.59) 0.59 ± 0.50	24 (58.5) 0.59 ± 0.49	35 (85.4) 0.85 ± 0.33
	p-value	0.160	0.044	0.001
Rice-Basmati (Low)	Baseline *n (%)* Mean ± SD	19 (48.7) 0.49 ± 0.50	22 (53.7) 0.54 ± 0.50	20 (48.8) 0.49 ± 0.50
	Endpoint *n (%)* Mean ± SD	21 (53.8) 0.54 ± 0.50	31 (75.6) 0.76 ± 0.42	21 (51.2) 0.51 ± 0.40
	p-value	0.160	0.002	0.323
Milk/yogurt (Low)	Baseline *n (%)* Mean ± SD	19 (48.7) 0.49 ± 0.50	18 (43.9) 0.44 ± 0.50	17 (41.4) 0.41 ± 0.50
	Endpoint *n (%)* Mean ± SD	18 (43.9) 0.44 ± 0.50	30 (73.1) 0.73 ± 0.43	35 (85.4) 0.85 ± 0.33
	p-value	0.323	0.001	0.001
Fresh red meat (Low)	Baseline *n (%)* Mean ± SD	13 (33.3) 0.33 ± 0.47	11 (26.8) 0.27 ± 0.45	13 (31.7) 0.32 ± 0.47
	Endpoint *n (%)* Mean ± SD	15 (38.5) 0.39 ± 0.49	21 (51.2) 0.51 ± 0.50	33 (80.5) 0.85 ± 0.38
	p-value	0.160	0.001	0.001
Fresh poultry (Low)	Baseline *n (%)* Mean ± SD	15 (38.5) 0.39 ± 0.49	11 (26.8) 0.27 ± 0.45	12 (29.3) 0.29 ± 0.46
	Endpoint *n (%)* Mean ± SD	14 (35.8) 0.36 ± 0.38	21 (51.2) 0.51 ± 0.50	20 (48.8) 0.49 ± 0.50
	p-value	0.3232	0.001	0.003
Fruits (Low)	Baseline *n (%)* Mean ± SD	25 (64.1) 0.64 ± 0.49	23 (57.5) 0.58 ± 0.50	24 (58.5) 0.59 ± 0.49
	Endpoint *n (%)* Mean ± SD	22 (53.7) 0.54 ± 0.50	37 (92.5) 0.93 ± 0.27	38 (95.0) 0.95 ± 0.22
	p-value	0.083	0.001	0.001
Fresh vegetables (Low)	Baseline *n (%)* Mean ± SD	26 (66.6) 0.67 ± 0.49	28 (68.3) 0.68 ± 0.46	26 (63.4) 0.63 ± 0.48
	Endpoint *n (%)* Mean ± SD	24 (61.5) 0.62 ± 0.48	41 (100) 100 ± 0.00	39 (95.1) 0.95 ± 0.16
	p-value	0.160	0.001	0.001
Canned vegetables (High)	Baseline *n (%)* Mean ± SD	28 (71.8) 0. 72 ± 0.46	24 (58.5) 0.59 ± 0.50	28 (68.3) 0.68 ± 0.46
	Endpoint *n (%)* Mean ± SD	27 (69.2) 0.69 ± 0.47	37 (92.5) 0.93 ± 0.27	39 (95.1) 0.95 ± 0.16
	p-value	0.323	0.001	0.001
Cheddar cheese (High)	Baseline *n (%)* Mean ± SD	29 (74.4) 0.74 ± 0.45	27 (65.9) 0.66 ± 0.47	28 (68.3) 0.68 ± 0.46
	Endpoint *n (%)* Mean ± SD	28 (71.8) 0. 72 ± 0.46	39 (95.1) 0.95 ± 0.16	39 (95.1) 0.95 ± 0.16
	p-value	0.323	0.001	0.001

(Continued)

TABLE 6 | Continued

Sodium content in the following foods is[1]	Stage	Control ($n = 39$)	WhatsApp ($n = 41$)	Brochure ($n = 41$)
Pickles (High)	Baseline *n (%)* Mean ± SD	28 (71.8) 0. 72 ± 0.46	30 (73.1) 0.73 ± 0.43	28 (68.3) 0.68 ± 0.46
	Endpoint *n (%)* Mean ± SD	33 (84.6) 0.85 ± 0.38	39 (95.1) 0.95 ± 0.16	38 (95.0) 0.95 ± 0.22
	p-value	0.023	0.002	0.001
Olive oil (Low)	Baseline *n (%)* Mean ± SD	18 (43.9) 0.44 ± 0.50	20 (48.8) 0.49 ± 0.50	16 (39.0) 0.39 ± 0.49
	Endpoint *n (%)* Mean ± SD	22 (53.7) 0.54 ± 0.50	35 (85.4) 0.85 ± 0.33	24 (58.5) 0.59 ± 0.49
	p-value	0.044	0.001	0.003
Salad dressing oil (High)	Baseline *n (%)* Mean ± SD	25 (64.1) 0.64 ± 0.49	24 (58.5) 0.59 ± 0.49	22 (53.7) 0.54 ± 0.50
	Endpoint *n (%)* Mean ± SD	26 (66.6) 0.67 ± 0.49	38 (95.0) 0.95 ± 0.22	37 (92.5) 0.93 ± 0.27
	p-value	0.323	0.001	0.001
Ketchup (High)	Baseline *n (%)* Mean ± SD	21 (53.8) 0.54 ± 0.49	20 (48.8) 0.49 ± 0.50	22 (53.7) 0.54 ± 0.50
	Endpoint *n (%)* Mean ± SD	23 (0.59) 0.59 ± 0.50	39 (95.1) 0.95 ± 0.16	39 (95.1) 0.95 ± 0.16
	p-value	0.160	0.001	0.001
Tomato paste (High)	Baseline *n (%)* Mean ± SD	21 (53.8) 0.54 ± 0.49	22 (53.7) 0.54 ± 0.50	21 (51.2) 0.51 ± 0.50
	Endpoint *n (%)* Mean ± SD	22 (53.7) 0.54 ± 0.50	39 (95.1) 0.95 ± 0.16	38 (95.0) 0.95 ± 0.22
	p-value	0.323	0.001	0.001
Corn flakes (High)	Baseline *n (%)* Mean ± SD	8 (20.5) 0.21 ± 0.40	8 (19.5) 0.20 ± 0.40	10(24.4) 0.24 ± 0.43
	Endpoint *n (%)* Mean ± SD	7 (17.9) 0.18 ± 0.38	33 (80.5) 0.81 ± 0.38	35 (85.4) 0.85 ± 0.33
	p-value	0.323	0.001	0.001
Chicken cubes (High)	Baseline *n (%)* Mean ± SD	29 (74.4) 0.74 ± 0.45	26 (63.4) 0.63 ± 0.48	28 (68.3) 0.68 ± 0.46
	Endpoint *n (%)* Mean ± SD	31 (79.5) 0.80 ± 0.42	39 (95.1) 0.95 ± 0.16	40 (97.6) 0.98 ± 0.14
	p-value	0.160	0.001	0.001
Instant noodle (High)	Baseline *n (%)* Mean ± SD	27 (69.2) 0.69 ± 0.47	29 (70.7) 0.71 ± 0.45	28 (68.3) 0.68 ± 0.46
	Endpoint *n (%)* Mean ± SD	26 (66.6) 0.67 ± 0.49	38 (95.0) 0.95 ± 0.22	39 (95.1) 0.95 ± 0.16
	p-value	0.323	0.002	0.001

[1] *The correct answers are provided in brackets next to each variable. Each correct answer earned 1 score.* [α] *Data presented as number and percentage.* [b] *Data presented as Mean ± standard deviation.*

[c] *Paired t-test according to time of measurements (Baseline vs. endpoint) within the same group.*

50% of salt content in the bread "Arabic" to be 500 g salt/100 g of bread.

Thus, make bread among main contributing sources of high salt intake in UAE similar to Kuwait, Jordan and Qatar (38, 39).

Educational intervention improved significantly the identification of foods with low sodium contents such as fresh fruits and vegetables, rice, yogurt, and fresh meat. The improvement was also reported significantly in the attitude of the intervention group. Reducing added salt and low consumption of processed foods become significantly important for the intervention groups compared with the control group after 6-weeks of educational intervention.

The improvement in knowledge and attitude contributed to improvement in practice of the intervention groups. The intervention group showed significant improvement in the practice part of the KAP questionnaire. Checking food labels specifically for salt/sodium content affected purchasing decisions. In addition to that, an increased percentage of participants tried to buy "low salt" and "no added salt" foods in the intervention groups compared with the control group.

TABLE 7 | Physical activity for study population before and after the 6 weeks intervention using IPAQ questionnaire.

	Control ($n = 39$) Mean ± SEα		WhatsApp ($n = 41$) Mean ± SE		Brochures ($n = 41$) Mean ± SE	
	Baseline	**Endpoint**	**Baseline**	**Endpoint**	**Baseline**	**Endpoint**
Low intensity (min/week)	205.8 ± 25.4	195.6 ± 26.6	198.0 ± 20.3	176.5 ± 17.1	181.4 ± 16.4	191.8 ± 20.2
p-value[b]	0.692		0.482		0.398	
Moderate intensity (min/week)	87.7 ± 13.1	79.0 ± 16.0	90.0 ± 16.5	103.7 ± 17.3	86.7 ± 9.5	82.3 ± 9.1
p-value[b]	0.679		0.476		0.743	
High intensity (min/week)	54.1 ± 12.5	41.1 ± 7.3	54.9 ± 7.1	48.8 ± 6.4	43.3 ± 6.3	47.1 ± 6.6
p-value[b]	0.369		0.414		0.415	

[α] *Data presented as Mean ± Standard error.*

[b] *Independent-Samples t-test used to assessed Significance at $p < 0.05$ according to gender.*

Moreover, addition of salt during cooking reduced significantly in the intervention groups and the use of chicken cubes reduced whilst the use of salt alternatives increased significantly, in addition to significant reduction in adding table salt and adding salt before tasting foods. This improvement in the KAP components in the intervention group was translated into reduction in salt intake by the intervention groups in the food frequency questionnaire, which reported a significant reduction in using Table salt by 13% and chicken cubes by almost 20% compared with baseline.

The intervention showed an increase in the use of spices and herbs as alternatives for salt. Therefore, the current study showed a positive relationship between KAP toward salt intake and reducing salt intake. Haron et al. (41) reported a positive correlation between high knowledge scores with more controlled blood pressure compared to those who scored less.

Multiple approach was applied in countries as a multi-component programs (consumer awareness campaign, increased availability of low-sodium foods at school, worksite and restaurants, voluntary reformulation of processed foods to lower the sodium content) (7, 32). This approach showed a positive effect in salt reduction by 15% in UK (6) and 24% reduction in South Korean (7).

The 24-h urinary potassium excretion is correlated with dietary potassium intake (23, 42). In the current study all participants failed to achieve WHO recommendations for potassium intake. In addition to that, high urinary sodium to potassium ratio can be an indicator of the need for reducing sodium intake and increasing potassium intake (14). Therefore, WHO has suggested sodium: potassium ratio of ∼1.00, which will be associated with low risk for development of CVDs (43). Although the WhatsApp group showed a significant improvement in the sodium to potassium ratio, the ratio was still above one and participants failed to achieve the recommended intake of potassium. This means promoting, the intake of foods rich in potassium is just as important as reducing the intake of foods rich in sodium/salt.

The current study proved that improving KAP through providing educational materials was associated with lowering salt intake in a sample of UAE population. Moreover, the digital platform approach such as WhatsApp and Electronic Brochure were effective in terms of salt reduction. This is considered the first step or one single element of a comprehensive approach starting with educational materials, which aimed to facilitate consumer awareness regarding low and high salt foods. In addition to reformulation of staple foods (particularly bread) to reduce salt content, building a good environment for the food industry to be part of this initiative to reduce salt intake is important in UAE and in Arab Gulf Countries, and middle east region. In addition to that, including the study population in proper decision making regarding best approaches and tools to reduce salt intake is also important to make the process of salt reduction more visible and applicable.

Despite the significant findings of this study, it could be of a better value if there is more than one follow-up to the study to measure the study population's responses toward salt reduction for longer period. Moreover, measuring salt reduction along with blood pressure will give better responses toward blood pressure in UAE. In addition to that, for the KAP part of the study, including more participants in term of age groups and number will be give more useful results.

CONCLUSION

This study proven that the UAE population respond positively to salt reduction initiative using digital platform (WhatsApp and Electronic brochures) to deliver educational materials for 6-weeks. WhatsApp group showed a significant reduction in salt intake after intervention, compared with Electronic brochures and Control groups. Moreover, this reduction in salt intake was associated with significant reduction with 10% of the participants who exceeds WHO recommendation for sodium intake for WhatsApp group. KAP toward salt intake was improved for intervention group at the end of the study. In addition to that, there was a significant reduction in the practice toward adding salt during cooking, use of table salt, and adding salt before tasting. These results indicate the study population of UAE is ready to change the consumption and practice toward salt intake. In order, to make it more durable it is requiring the industry and the policy makers in UAE to provide low salt foods/products and encourage reformulation of some staple foods such as bakery products particularly bread.

This is the first intervention study conducted in UAE, that used digital platform to reduce salt intake using KAP questionnaire, and 24-h urinary sodium, potassium and creatinine excretion as a tool for measurement.

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 University Research Ethics Committee at Oxford Brookes University (UREC), Number: 191337. In addition to, ethical approval from United Arab Emirates University (UAEU) Research Ethics Committee (ERS_2020_6107). The patients/participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

AJ: conceptualization, methodology, investigation, data curation, formal analysis, and writing original draft. ASA, LC, and HL: conceptualization, methodology, and investigation. FA-M: investigation and formal analysis. AA, MA, SA, and NA: investigation. MB: data curation and formal analysis. PT: conceptualization, methodology, investigation, and writing review and editing. All authors contributed to the article and approved the submitted version.

REFERENCES

1. Mozaffarian D, Fahimi S, Singh GM, Micha R, Khatibzadeh S, Engell RE, et al. Global sodium consumption and death from cardiovascular causes. *NEJM*. (2014) 371:624–34. doi: 10.1056/NEJMoa1304127
2. Al-Jawaldeh A, Taktouk M, Chatila A, Naalbandian S, Al-Thani A-AM, Alkhalaf MM, et al. Salt reduction initiatives in the Eastern Mediterranean region and evaluation of progress towards the 2025 global target: a systematic review. *Nutrients.* (2021) 13:2676. doi: 10.3390/nu13082676
3. WHO. *Global Action Plan for the Prevention and Control of NCDs 2013–2020.* (2013). Available online at: https://www.who.int/publications/i/item/9789241506236 (accessed November 27, 2021).
4. Jarrar AH, Stojanovska L, Apostolopoulos V, Cheikh Ismail L, Feehan J, Ohuma EO, et al. Assessment of sodium knowledge and urinary sodium excretion among regions of the United Arab Emirates: a cross-sectional study. *Nutrients.* (2020) 12:1–14. doi: 10.3390/nu12092747
5. WHO. *Noncommunicable Diseases Country Profiles 2018*. (2018). Available online at: https://apps.who.int/iris/handle/10665/274512 (accessed November 27, 2021).
6. Bhat S, Marklund M, Henry ME, Appel LJ, Croft KD, Neal B, et al. A systematic review of the sources of dietary salt around the world. *Adv Nutr.* (2020) 11:677–86. doi: 10.1093/advances/nmz134
7. Ide N, Ajenikoko A, Steele L, Cohn J, Curtis CJ, Frieden TR, et al. Priority actions to advance population sodium reduction. *Nutrients.* (2020) 12:2543. doi: 10.3390/nu12092543
8. Nasreddine L, Akl C, Al-Shaar L, Almedawar MM. Isma'eel H. Consumer knowledge, attitudes and salt-related behavior in the Middle-East: the case of Lebanon. *Nutrients.* (2014) 6:5079–102. doi: 10.3390/nu6115079
9. 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. doi: 10.1016/S0140-6736(19)30041-8
10. Anderson CAM, Appel LJ, Okuda N, Brown IJ, Chan Q, Zhao L, et al. Dietary sources of sodium in China, Japan, the United Kingdom, and the United States, women and men aged 40 to 59 years: the INTERMAP study. *J Am Die Assoc.* (2010) 110:736–45. doi: 10.1016/j.jada.2010.02.007
11. Trieu K, Neal B, Hawkes C, Dunford E, Campbell N, Rodriguez-Fernandez R, et al. Salt reduction initiatives around the world—a systematic review of progress towards the global target. *PLoS ONE.* (2015) 10:e0130247. doi: 10.1371/journal.pone.0130247
12. Cheikh Ismail L, Hashim M, H Jarrar A, N Mohamad M, T Saleh S, 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. doi: 10.3390/nu11050941
13. Campbell N, Cappuccio F, Hennis A, Barquera S, Rotter RC, Dary O, et al. *Protocol for Population Level Sodium Determination In 24-Hour Urine Samples*. (2010). Available online at: https://www.paho.org/hq/dmdocuments/2013/24h-urine-Protocol-eng.pdf (accessed November 31, 2021).
14. WMA. World Medical Association declaration of Helsinki: ethical principles for medical research involving human subjects. *JAMA.* (2013) 310:2191–4. doi: 10.1001/jama.2013.281053
15. Altman DG, Bland JM. Statistics notes: variables and parameters. *BMJ.* (1999) 318:1667. doi: 10.1136/bmj.318.7199.1667
16. Chernecky CC, Berger BJ. *Laboratory Tests and Diagnostic Procedures*. 6th ed. Philadelphia, PA: Elsevier Health Sciences (2012).
17. Goldman L, Schafer AI. *Goldman's Cecil Medicine*. 24th ed. Philadelphia, PA: Elsevier Health Sciences (2011).
18. Lee RD, Nieman DC. *Nutritional Assessment*. Boston, MA: McGraw-Hill (2019).
19. Dolan SP, Capar SG. Multi-Element analysis of food by microwave digestion and inductively coupled plasma-atomic emission spectrometry. *J Food Composit Anal.* (2002) 15:593–615. doi: 10.1006/jfca.2002.1064
20. Slot C. Plasma creatinine determination a new and specific jaffe reaction method. *Scand J Clin Lab Inv.* (1965) 17:381–7. doi: 10.3109/00365516509077065
21. Land M-A, Webster J, Christoforou A, Johnson C, Trevena H, Hodgins F, et al. The association of knowledge, attitudes and behaviours related to salt with 24-hour urinary sodium excretion. *Int J Behav Nutr Phys Act.* (2014) 11:1–8. doi: 10.1186/1479-5868-11-47
22. Derouiche A, El-Kardi Y, Mohtadi K, Jafri A. Salt intake assessed by 24 hour urinary sodium excretion of Moroccan adults: a pilot study. *Nutr Clin Metab.* (2017) 31:207–11. doi: 10.1016/j.nupar.2017.07.001
23. Chen SL, Dahl C, Meyer HE, Madar AA. Estimation of salt intake assessed by 24-hour urinary sodium excretion among Somali adults in Oslo, Norway. *Nutrients.* (2018) 10:900. doi: 10.3390/nu10070900
24. Mansuri N, Moorjani R. Impact of dietary protein intake, lean body mass percentage, body mass index, physical activity on urinary creatine, and urinary creatinine excretion in a team- sport. *Act Sci Nutr Health.* (2019) 3:188–95. doi: 10.31080/ASNH.2019.03.0427
25. Othman F, Ambak R, Siew Man C, Mohd Zaki NA, Ahmad MH, Abdul Aziz NS, et al. Factors associated with high sodium intake assessed from 24-hour urinary excretion and the potential effect of energy intake. *J Nutr Metab.* (2019) 2019:6781597. doi: 10.1155/2019/6781597
26. Hyseni L, Elliot-Green A, Lloyd-Williams F, Kypridemos C, O'Flaherty M, McGill R, et al. Systematic review of dietary salt reduction policies: evidence for an effectiveness hierarchy? *PLoS ONE.* (2017) 12:e0177535. doi: 10.1371/journal.pone.0177535
27. WHO. *Noncommunicable Diseases Country Profiles 2018*. (2018). Available online at: https://apps.who.int/iris/handle/10665/274512 (accessed November 27, 2021).
28. Enkhtungalag B, Batjargal J, Chimedsuren O, Tsogzolmaa B, Anderson CS, Webster J, et al. Developing a national salt reduction strategy for Mongolia. *Cardiovasc Diagn Ther.* (2015) 5:229–37. doi: 10.3978/j.issn.2223-3652.2015.04.11
29. Eyles H, McLean R, Neal B, Jiang Y, Doughty RN, McLean R, et al. A salt-reduction smartphone app supports lower-salt food purchases for people with

cardiovascular disease: findings from the saltswitch randomised controlled trial. *Eur J Prev Cardiol.* (2017) 24:1435–44. doi: 10.1177/2047487317715713
30. Riches SP, Piernas C, Aveyard P, Sheppard JP, Rayner M, Jebb SA, et al. The salt swap intervention to reduce salt intake in people with high blood pressure: protocol for a feasibility randomised controlled trial. *Trials.* (2019) 20:1–11. doi: 10.1186/s13063-019-3691-y
31. Ipjian ML, Johnston CS. Smartphone technology facilitates dietary change in healthy adults. *Nutrition*. (2017) 33:343–7. doi: 10.1016/j.nut.2016.08.003
32. Ahn Y, Bae J, Kim H-S. The development of a mobile u-Health program and evaluation for self-diet management for diabetic patients. *Nutr Res Pract.* (2016) 10:342–51. doi: 10.4162/nrp.2016.10.3.342
33. Nundy S, Razi RR, Dick JJ, Smith B, Mayo A, O'Connor A, et al. A text messaging intervention to improve heart failure self-management after hospital discharge in a largely African-American population: before-after study. *J Med Internet Res*. (2013) 15:e53. doi: 10.2196/jmir.2317
34. Golshahi J, Ahmadzadeh H, Sadeghi M, Mohammadifard N, Pourmoghaddas A. Effect of self-care education on lifestyle modification, medication adherence and blood pressure in hypertensive adults: randomized controlled clinical trial. *Adv Biomed Res.* (2015) 4:204. doi: 10.4103/2277-9175.166140
35. He FJ, Brinsden HC, MacGregor GA. Salt reduction in the United Kingdom: a successful experiment in public health. *J Hum Hypertens.* (2014) 28:345–52. doi: 10.1038/jhh.2013.105
36. Takahashi Y, Sasaki S, Okubo S, Hayashi M, Tsugane S. Blood pressure change in a free-living population-based dietary modification study in Japan. *J Hypertens.* (2006) 24:451–8. doi: 10.1097/01.hjh.0000209980.36359.16
37. Hooper L, Bartlett C, Smith GD, Ebrahim S. Systematic review of long term effects of advice to reduce dietary salt in adults. *BMJ.* (2002) 325:628. doi: 10.1136/bmj.325.7365.628
38. Alhamad N, Almalt E, Alamir N, Subhakaran M. An overview of salt intake reduction efforts in the Gulf Cooperation Council countries. *Cardiovasc Diagn Ther.* (2015) 5:172–7. doi: 10.3978/j.issn.2223-3652.2015.04.06
39. Hussain FMA, Takruri HR. A study of salt content of different bread types marketed in Amman, Jordan. *J Agric Sci.* (2016) 8:169–78. doi: 10.5539/jas.v8n4p169
40. UAE Government. *National Nutrition Strategy 2017–2021*. (2017). Available online at: https://u.ae/en/about-the-uae/strategies-initiatives-and-awards/federal-governments-strategies-and-plans/national-nutrition-strategy-2017-2021 (accessed June 29, 2021).
41. Haron H, Kamal NF, Yahya HM, Shahar S. Knowledge, Attitude and Practice (KAP) of malay elderly on salt intake and its relationship with blood pressure. *Front Public Health.* (2021) 8:559071. doi: 10.3389/fpubh.2020.559071
42. WHO. *Guidelines on Potassium Intake for Adults and Children*. (2012). Available online at: https://www.who.int/publications/i/item/9789241504829 (accessed December 6, 2021).
43. Taylor EN, Stampfer MJ, Mount DB, Curhan GC. DASH-style diet and 24-hour urine composition. *Clin J Am Soc Nephrol.* (2010) 5:2315–22. doi: 10.2215/CJN.04420510

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Lifestyle, Eating Habits, and Health Behaviors Among Dietary Supplement Users in Three European Countries

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Dietary supplements (DS) are used by about 30–50% of adults in developed countries. However, only a few studies have compared the characteristics of DS users in different nations. This study aimed to identify and compare selected health-related behaviors of DS users from three European countries. A total of 3,588 adults (32.08 ± 8.04 years) from Poland (1,030 females, 287 males), Germany (994 females, 190 males), and the United Kingdom (911 females, 176 males) were included in the analysis. The study was based on a self-administered survey consisting of 70 questions regarding baseline characteristics, lifestyle, eating, and health habits. The associations of the obtained results were compared using the Kruskal–Wallis test, Pearson Chi-Square test, and Cramer's V value. The highest percentage of DS users (56.98%, $n = 2,044$) had a correct body weight, while higher body weight values were observed in 39.19% ($n = 1,406$). In terms of lifestyle, statistically significant differences ($p < 0.05$) were noted for alcohol consumption and the level of physical activity. Fruit and vegetables were most often consumed a few times a weeks (34.67%, $n = 1,244$). A similar result was observed for the consumption of whole grain (37.76%, $n = 1,355$), dairy (39.99%, $n = 1,435$), eggs (49.67%, $n = 1,782$), and meat (51.45%, $n = 1,846$). Most DS users did not have a chronic disease (66.72%, $n = 2,394$). Among the other conditions, a frequent occurrence (a few times a weeks) of gastrointestinal problems (28.29%, $n = 1,015$) and concentration disorders (29.15%, $n = 1,046$) was noted. Cramer's V values (<0.3) indicated a weak (but significant $p < 0.05$) relationship between the country of residence and most of the analyzed variables. In conclusion, DS users were characterized by a healthy lifestyle with appropriate behaviors but not healthy eating habits.

Keywords: dietary supplements, dietary supplement users, lifestyle, dietary habits, health behaviors, characteristics, consumer surveys

INTRODUCTION

According to the European Food Safety Authority (EFSA), dietary supplements (DS) can be defined as foodstuffs that are consumed for improving the standard diet. DS contain one or more concentrated ingredients such as minerals, vitamins, amino acids, herbal extracts, dietary fiber, and/or other substances with a nutritional or physiological effect. These can be easily taken orally, and are most often available in the form of capsules, tablets, pills, powders, and liquid (1). Studies indicate that at present, nearly half of the adult population in developed countries, such as the United States and Denmark, use DS (2, 3). While in other high-income countries such as Australia, South Korea, and United Arab Emirates, the proportion of DS users is around 30% (4–6). A rapid increase in the use of DS has been observed in most regions of the world over the last 35 years (7). Moreover, it has been documented that the Coronavirus pandemic has contributed to developing the DS market (8).

Following the definition, DS cannot replace a balanced healthy diet, and their consumption should depend on the nutritional status and nutrition type of individuals and populations. Results from analyzing the intake of 17 basic micronutrients in adult's diets across different European countries (including Poland, the United Kingdom, and Germany), revealed an extremely low intake of vitamin D_3. Moreover, zinc, iron in women of childbearing age, vitamin A, and folic acid was consumed at an insufficient level (9). For this reason in some countries, recommendations regarding vitamin D supplementation have been published. National Health Service England (NHS) recommends that adults require an average of 10 μg of vitamin D3 per day and should consider taking a daily supplement during the autumn and winter months (10). The Polish expert panel represents a similar position (11). Better understanding the scope of nutrient intake adequacy across Europe is still a significant challenge.

DS are used not only to correct nutritional deficiencies but also to improve cognitive performance and overall health, prevent diseases, increase the body's efficiency, or even to extend the expected lifetime (12–14). The effectiveness of dietary supplementation in the treatment of chronic diseases is still under debate. Evidence supporting the use of vitamin and mineral supplements for the treatment or prevention of non-communicable diseases, such as cardiovascular disorders or cancer, is inadequate (15, 16). However, supplementation has been shown to be beneficial in the treatment of various commonly occurring diseases such as diabetes, obesity, and mental illness (17–19). The effect of DS can be determined by several factors, such as the type, dose, and chemical composition of the preparation, usage period, and regularity.

An important issue that gives rise to doubts both among specialists and patients regarding the use of DS is their safety. Due to the lack of a universal regulatory system, these products may contain components that are not declared on the nutrition label, such as contaminants, illegal substances, or other active ingredients capable of interacting with prescription medications or food (20, 21). Moreover, DS may affect the metabolic or physiological functions of the body. Therefore, the decision to use them should be well-considered, justified, and discussed with a health care professional. The users should routinely check the chosen products to avoid potential threats associated with their intake (20, 21).

Previous surveys on the determinants of DS have compared participants using DS and non-users (22, 23) and indicated that supplement users are more likely to be women, non-smokers, older, and have higher educational levels and incomes than people who do not use DS. Studies have shown that supplement users are typically characterized by a more healthy lifestyle, with proper eating habits, a high level of physical activity (PA), greater consumption of fruit and vegetables, and limited consumption of alcoholic beverages (24–27).

The use of DS is of interest to scientists, clinicians, and patients because these easily accessible products have a huge influence on human health. Researchers have been emphasizing the need for studies on large groups of people to understand the impact of DS on health (22). Unfortunately, the comparison of DS users within diverse populations is challenging due to the varying definitions of DS, periods of DS use, or methods of data collection (28, 29). Thus far, studies analyzing the characteristics of DS users have mostly focused on only one population (e.g., from the same country) (5, 30–33). An exception is the SENECA project (34, 35), and studies conducted by Skeie (36) and Foote (37). However, due to the rapid development of the DS market in recent years, more than 20-year-old research results need to be updated. Knowledge about the characteristics of DS users from different European countries can help to develop effective public health interventions and universal protocols for the administration of supplements (38). This study aimed to identify and compare selected health-related behaviors among the population of DS users from three European countries.

MATERIALS AND METHODS

Study Design and Participants

This survey-based research was conducted among 3,588 DS users. A self-administered questionnaire, which was available online, was used for the study. The participants were asked to fill in the questionnaire only once. Employees of Sundose sp. z o.o. participated in the data collection and encryption.

The data for the study were collected between January 2021 and November 2021. Women and men who were using DS and filled in the survey questionnaire were eligible for the study. Additional inclusion criteria were as follows: age ≥18 years, lack of mental disorders, and willingness to provide informed consent for participation and personal data. Incomplete, unreal, or conflicting responses were rejected during the data cleaning stage ($n = 1{,}728$). The assumption of the data collection stage was to obtain a minimum of 1,000 results from each country. These sample size was sufficient to perform a reliable statistical analysis.

Research Instrument

The self-administrated questionnaire consisted of 70 questions, divided into four categories:

a. Baseline information: gender (female, male); age group (18–30, 31–45, 46–60, 61–75, or >75 years); weight, height, body mass index (BMI); city population (<10.000, 10.000–50.000,

TABLE 1 | Characteristics of the study group.

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
	n = 3,588	1,030 (78.21)^{B}	287 (21.79)^{a}	994 (83.95)^{A}	190 (16.05)^{b}	911 (83.81)^{A}	176 (16.19)^{b}
Age ± SD (years)	32.08 ± 8.04	30.99^{B} ± 8.17	33.33^{b} ± 8.68	32.41^{A} ± 8.55	34.44^{ab} ± 8.35	31.67^{A} ± 6.96	34.20^{a} ± 6.69
18–30	1,778 (49.55)	580 (56.31)^{A}	132 (45.99)^{a}	482 (48.49)^{B}	70 (36.84)^{a}	456 (50.05)^{AB}	58 (32.95)^{a}
31–45	1,595 (44.45)	393 (38.16)^{B}	129 (44.95)^{b}	441 (44.37)^{A}	97 (51.05)^{ab}	425 (46.65)^{A}	110 (62.50)^{a}
46–60	183 (5.10)	46 (4.47)^{A}	22 (7.67)^{a}	61 (6.14)^{A}	22 (11.58)^{a}	24 (2.63)^{A}	8 (4.55)^{a}
61–75	29 (0.81)	10 (0.97)^{A}	4 (1.39)^{a}	8 (0.80)^{A}	1 (0.53)^{a}	6 (0.66)^{A}	0 (0.00)^{a}
>75	3 (0.08)	1 (0.10)^{A}	0 (0.00)^{a}	2 (0.20)^{A}	0 (0.00)^{a}	0 (0.00)^{A}	0 (0.00)^{a}
Weight ± SD (kg)	71.75 ± 16.99	66.50^{C} ± 14.09	85.09^{a} ± 13.62	70.84^{A} ± 17.27	87.35^{a} ± 15.61	68.50^{B} ± 16.07	85.77^{a} ± 13.27
High ± SD (cm)	169.32 ± 8.14	166.97^{A} ± 5.90	180.48^{a} ± 6.49	167.62^{A} ± 6.38	181.02^{a} ± 6.41	166.13^{B} ± 6.12	179.59^{a} ± 7.28
BMI value ± SD (kg/m^2)	24.91 ± 5.24	23.80^{B} ± 4.59	26.11^{a} ± 3.97	25.21^{A} ± 5.96	26.64^{a} ± 4.41	24.80^{A} ± 5.56	26.57^{a} ± 3.68
<18.5	138 (3.84)	58 (5.63)^{A}	2 (0.70)^{a}	37 (3.72)^{A}	2 (1.05)^{a}	38 (4.17)^{A}	1 (0.57)^{a}
18.5–24.9	20,44 (56.98)	663 (64.37)^{A}	127 (44.25)^{a}	573 (57.65)^{B}	76 (40.00)^{a}	545 (59.82)^{AB}	60 (34.09)^{a}
25.0–29.9	899 (25.06)	199 (19.32)^{A}	118 (41.11)^{a}	204 (20.52)^{A}	75 (39.47)^{a}	216 (23.71)^{A}	87 (49.43)^{a}
>30.0	507 (14.13)	110 (10.68)^{B}	40 (13.94)^{a}	180 (18.11)^{A}	37 (19.47)^{a}	112 (12.29)^{AB}	28 (15.91)^{a}
City population (thous.)							
<10	692 (19.29)	238 (23.11)^{A}	58 (20.21)^{a}	271 (27.26)^{A}	51 (26.84)^{a}	63 (6.92)^{B}	11 (6.25)^{b}
10–50	673 (18.76)	185 (17.96)^{AB}	39 (13.59)^{b}	230 (23.14)^{A}	51 (26.84)^{a}	144 (15.81)^{B}	24 (13.64)^{ab}
51–200	841 (23.44)	198 (19.22)^{B}	61 (21.25)^{a}	206 (20.72)^{B}	37 (19.47)^{a}	281 (30.85)^{A}	58 (32.95)^{a}
201–500	498 (13.88)	122 (11.84)^{B}	36 (12.54)^{a}	88 (8.85)^{B}	16 (8.42)^{a}	199 (21.84)^{A}	37 (21.02)^{a}
>500	884 (24.64)	287 (27.86)^{A}	93 (32.40)^{a}	199 (20.02)^{B}	35 (18.42)^{b}	224 (24.59)^{AB}	46 (26.14)^{ab}
Supplementation purpose							
Health improvement	1,563 (43.56)	387 (37.57)^{B}	95 (33.10)^{b}	463 (46.58)^{A}	96 (50.53)^{a}	443 (48.63)^{A}	79 (44.89)^{ab}
Improvement of wellbeing	1,774 (49.44)	576 (55.92)^{A}	150 (52.26)^{a}	461 (46.38)^{B}	76 (40.00)^{b}	434 (47.64)^{B}	77 (43.75)^{ab}
Maintaining current state	53 (1.48)	12 (1.17)^{A}	4 (1.39)^{a}	19 (1.91)^{A}	7 (3.68)^{a}	5 (0.55)^{A}	6 (3.41)^{a}
Treatment support	65 (1.81)	33 (3.20)^{A}	2 (0.70)^{a}	15 (1.51)^{A}	0 (0.00)^{a}	15 (1.65)^{A}	0 (0.00)^{a}
Better results in sport	133 (3.71)	22 (2.14)^{A}	36 (12.54)^{a}	36 (3.62)^{A}	11 (5.79)^{a}	14 (1.54)^{A}	14 (7.95)^{a}

^{ABC}Values with different letters in the same row are significantly different at $p < 0.05$ in the female group (Kruskal–Wallis test). ^{abc}Values with different letters in the same row are significantly different at $p < 0.05$ in the male group (Kruskal–Wallis test).
BMI, body mass index.

51.000–200.000, 201.000–500.000, or >500.000 people); and the purpose of supplementation (improvement of health, improvement of wellbeing, maintaining the current health state, treatment support, or better outcomes in sports).

b. Lifestyle: activity (from a few times a year to 6+ times during the week) and sport level; sleep problems and duration (from <5 to >10 h); work hours (from I don't work to >12 h); and use of drugs and stimulants.

c. Eating habits: meals quantity; snacks; most popular food categories (fruit and vegetables, whole grain, dairy, eggs, fish, meat, etc.); and food products rich in specific nutrients (e.g., avocado, fermented foods, legumes). The options provided for every question were daily, a few times a week, a few times a month, a few times a year, or no.

d. Health: use of antibiotics and medicaments; presence of skin, hair, and nail problems; diagnosis of immune disorders; diagnosis of gastrointestinal problems; and diagnosis of the most common chronic diseases such as diabetes, hypertension, anemia, osteoporosis, thyroid disease, and others.

Most of the questions required a single selection, while questions regarding age, weight, height, and stimulants required a numeric value. The survey was accessible online directly before the purchase of DS. The participants were aware that their answers define the composition of the purchased product, which made it difficult to obtain reliable data.

Other Covariates

BMI was determined based on the World Health Organization (WHO) classification for adults (39). The value was calculated using the body weight (kg) and height (m) declared by the respondents. Based on the BMI value, the participants were categorized into the following groups: underweight, <18.50 kg/m^2; healthy weight, 18.51–24.99 kg/m^2; overweight, 25.00–29.99 kg/m^2; and obese, >30.00 kg/m^2.

Ethical Considerations

The research protocol was approved by the Ethics Committee of Medical University of Lublin, Poland (no. KE-0254/273/2021). All subjects provided informed consent for participation in

TABLE 2 | Lifestyle characteristics of DS users.

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
	n = 3,588	1,030 (78.21)^{B}	287 (21.79)^{a}	994 (83.95)^{A}	190 (16.05)^{b}	911 (83.81)^{A}	176 (16.19)^{b}
Activity amount							
< 1x/week	1,070 (29.82)	355 (34.47)^{A}	74 (25.78)^{a}	274 (27.57)^{B}	43 (22.63)^{a}	268 (29.42)^{AB}	56 (31.82)^{a}
1x/week	623 (17.36)	196 (19.03)^{AB}	56 (19.51)^{a}	209 (21.03)^{A}	29 (15.26)^{ab}	120 (13.17)^{B}	13 (7.39)^{b}
2–3x/week	1,087 (30.29)	307 (29.81)^{A}	74 (25.78)^{a}	313 (31.49)^{A}	61 (32.11)^{a}	279 (30.63)^{A}	53 (30.11)^{a}
4–5x/week	626 (17.45)	126 (12.23)^{B}	62 (21.60)^{a}	158 (15.89)^{AB}	38 (20.00)^{a}	199 (21.84)^{A}	43 (24.43)^{a}
6+/week	182 (5.07)	46 (4.47)^{A}	21 (7.32)^{a}	40 (4.02)^{A}	19 (10.00)^{a}	45 (4.94)^{A}	11 (6.25)^{a}
Training sport							
Yes	1,957 (54.54)	518 (50.29)^{A}	178 (62.02)^{a}	539 (54.23)^{A}	120 (63.16)^{a}	507 (55.65)^{A}	95 (53.98)^{a}
No	1631 (45.46)	512 (49.71)^{A}	109 (37.98)^{a}	455 (45.77)^{A}	70 (36.84)^{a}	404 (44.35)^{A}	81 (46.02)^{a}
Sport level							
Amateur	851 (23.72)	228 (22.14)^{A}	87 (30.31)^{a}	202 (20.32)^{A}	55 (28.95)^{a}	242 (26.56)^{A}	37 (21.02)^{a}
Recreational	1,023 (28.51)	275 (26.70)^{A}	77 (26.83)^{a}	319 (32.09)^{A}	55 (28.95)^{a}	249 (27.33)^{A}	48 (27.27)^{a}
Competitive	83 (2.31)	15 (1.56)^{A}	14 (4.8)^{a}	18 (1.81)^{A}	10 (5.26)^{a}	16 (1.76)^{A}	10 (5.68)^{a}
Sleep problems							
Daily	431 (12.01)	120 (11.65)^{A}	32 (11.15)^{a}	125 (12.58)^{A}	17 (8.95)^{a}	120 (13.17)^{A}	17 (9.66)^{a}
A few/week	914 (25.47)	252 (24.47)^{A}	69 (24.04)^{a}	240 (24.14)^{A}	41 (21.58)^{a}	263 (28.87)^{A}	49 (27.84)^{a}
A few/month	710 (19.79)	209 (20.29)^{A}	48 (16.72)^{a}	207 (20.82)^{A}	38 (20.00)^{a}	181 (19.87)^{A}	27 (15.34)^{a}
A few/year	56 (1.56)	14 (1.36)^{A}	7 (2.44)^{a}	15 (1.51)^{A}	1 (0.53)^{a}	18 (1.98)^{A}	1 (0.57)^{a}
No	1,477 (41.16)	435 (42.23)^{A}	131 (45.64)^{a}	407 (40.95)^{A}	93 (48.95)^{a}	329 (36.11)^{A}	82 (46.59)^{a}
Sleep hours							
< 5 h	81 (2.26)	20 (1.94)^{A}	7 (2.44)^{a}	22 (2.21)^{A}	3 (1.58)^{a}	25 (2.74)^{A}	4 (2.27)^{a}
5–6 h	1,107 (30.85)	299 (29.03)^{A}	96 (33.45)^{a}	293 (29.48)^{A}	60 (31.58)^{a}	287 (31.50)^{A}	72 (40.91)^{a}
7–8 h	2,161 (60.23)	634 (61.55)^{A}	167 (58.19)^{a}	612 (61.57)^{A}	121 (63.68)^{a}	534 (58.62)^{A}	93 (52.84)^{a}
9–10 h	223 (6.22)	74 (7.18)^{A}	14 (4.88)^{a}	62 (6.24)^{A}	5 (2.63)^{a}	61 (6.70)^{A}	7 (3.98)^{a}
>10 h	16 (0.45)	3 (0.29)^{A}	3 (1.05)^{a}	5 (0.50)^{A}	1 (0.53)^{a}	4 (0.44)^{A}	0 (0.00)^{a}
Work hours							
I don't work	361 (10.06)	142 (13.79)^{A}	10 (3.48)^{a}	115 (11.57)^{AB}	1 (0.53)^{a}	90 (9.88)^{B}	3 (1.70)^{a}
<8	585 (16.30)	167 (16.21)^{A}	31 (10.80)^{a}	202 (20.32)^{A}	16 (8.42)^{a}	154 (16.90)^{A}	15 (8.52)^{a}
8	1,271 (35.42)	429 (41.65)^{A}	88 (30.66)^{a}	341 (34.31)^{B}	65 (34.21)^{a}	300 (32.93)^{B}	48 (27.27)^{a}
9–10	877 (24.44)	188 (18.25)^{B}	99 (34.49)^{a}	238 (23.94)^{AB}	70 (36.84)^{a}	225 (24.70)^{A}	57 (32.39)^{a}
11–12	354 (9.87)	79 (7.67)^{A}	37 (12.89)^{a}	75 (7.55)^{A}	27 (14.21)^{a}	98 (10.76)^{A}	38 (21.59)^{a}
12+	140 (3.90)	25 (2.43)^{A}	22 (7.67)^{a}	23 (2.31)^{A}	11 (5.79)^{a}	44 (4.83)^{A}	15 (8.52)^{a}
Daily cigarettes intake							
No	2,848 (79.37)	848 (82.33)^{A}	203 (70.73)^{a}	798 (80.28)^{A}	130 (68.42)^{a}	740 (81.23)^{A}	129 (73.30)^{a}
<5	280 (7.80)	81 (7.86)^{A}	32 (11.15)^{a}	65 (6.54)^{A}	13 (6.84)^{a}	78 (8.56)^{A}	11 (6.25)^{a}
5–10	250 (6.97)	65 (6.31)^{A}	18 (6.27)^{a}	74 (7.44)^{A}	17 (8.95)^{a}	57 (6.26)^{A}	19 (10.80)^{a}
11–20	174 (4.85)	32 (3.11)^{A}	29 (10.10)^{a}	46 (4.63)^{A}	16 (8.42)^{a}	35 (3.84)^{A}	16 (9.09)^{a}
20+	36 (1.00)	4 (0.39)^{A}	5 (1.74)^{a}	11 (1.11)^{A}	14 (7.37)^{a}	1 (0.11)^{A}	1 (0.57)^{a}
Alcohol consumption							
Yes	2,254 (62.82)	632 (61.36)^{A}	230 (80.14)^{a}	556 (55.94)^{B}	135 (71.05)^{a}	575 (63.12)^{A}	126 (71.59)^{a}
No	1,334 (37.18)	398 (38.64)^{AB}	57 (19.86)^{a}	438 (44.06)^{A}	55 (28.95)^{a}	336 (36.88)^{B}	50 (28.41)^{a}
Weekly alcohol intake*							
Beer (bottle 500 ml)	1.58 ± 2.80	0.65^{A} ± 1.53	2.21^{a} ± 3.03	0.43^{B} ± 1.29	2.90^{a} ± 4.77	0.69^{A} ± 1.62	2.80^{a} ± 4.80
Wine (glass 175 ml)	1.06 ± 2.38	1.20^{A} ± 2.21	1.12^{a} ± 2.64	1.13^{A} ± 2.26	1.15^{ab} ± 3.12	1.06^{A} ± 2.18	0.57^{b} ± 1.40
Vodka (glass 50 ml)	1.20 ± 2.93	0.58^{A} ± 2.09	2.60^{a} ± 4.84	0.31^{B} ± 1.31	1.52^{b} ± 3.93	0.53^{A} ± 1.74	1.30^{b} ± 2.55
Daily coffeecups intake							
No	608 (16.95)	169 (16.41)^{A}	51 (17.77)^{a}	182 (18.31)^{A}	27 (14.21)^{a}	153 (16.79)^{A}	26 (14.77)^{a}
Occasionally	281 (7.83)	82 (7.96)^{A}	25 (8.71)^{a}	73 (7.34)^{A}	13 (6.84)^{a}	71 (7.79)^{A}	17 (9.66)^{a}
1	814 (22.69)	253 (24.56)^{A}	52 (18.12)^{a}	217 (21.83)^{A}	29 (15.26)^{a}	216 (23.71)^{A}	47 (26.70)^{a}
2–3	1,603 (44.68)	466 (45.24)^{A}	121 (42.16)^{a}	435 (43.76)^{A}	86 (45.26)^{a}	423 (46.43)^{A}	72 (40.91)^{a}
4–5	236 (6.58)	56 (5.44)^{AB}	32 (11.15)^{a}	70 (7.04)^{A}	30 (15.79)^{a}	34 (3.73)^{B}	14 (7.95)^{a}
5+	46 (1.28)	4 (0.39)^{A}	6 (2.09)^{a}	17 (1.71)^{A}	5 (2.63)^{a}	14 (1.54)^{A}	0 (0.00)^{a}

^{ABC}Values with different letters in the same row are significantly different at $p < 0.05$ in the female group (Kruskal–Wallis test). ^{abc}Values with different letters in the same row are significantly different at $p < 0.05$ in the male group (Kruskal–Wallis test).

**Amount of alcohol per portion.*

the study and collecting personal data. The analyzed data did not contain any information that could reveal the identity of the participants.

The manuscript was written following the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for cross-sectional studies (40).

Statistical Analysis

The obtained results were analyzed using Statistica 13.3 software (StatSoft, Inc., Tulsa, OK, United States). Categorical variables were presented as numbers and percentages, or as mean ± standard deviation if numerical. The normal distribution of numerical data was verified using the Shapiro–Wilk test. The average values from the same gender within different countries were compared using the Kruskal–Wallis test. The association between the analyzed behaviors and the inhabited country was determined using the Pearson Chi-Square test of independence. The strength of association was analyzed by calculating Cramer's V value (41). In order to indicate predictors affecting a single DS purchase cost, a generalized linear regression model analysis was performed (GRM). Significance was set at $p < 0.05$. The random allocation of participants was performed using the Mersenne Twister algorithm.

RESULTS

A total of 2,935 women and 653 men participated in the study (**Table 1**). Most of the participants were from Poland (36.71%). The percentage of women was higher compared to men for each analyzed country.

Most DS users were in the 18–30 and 31–45-year age group, and the average age of the participants was 32.08 ± 8.04 years. Women and men from Poland were characterized by a significantly lower age than the participants of other countries. The analysis of BMI revealed that the highest percentage of respondents (56.98%, $n = 2,044$) had a correct body weight, while 39.19% ($n = 1,406$) of participants had an excessive body weight, of which 14.13% ($n = 507$) were obese and 25.06% ($n = 899$) were overweight. The Polish women had a statistically significantly lower body weight and BMI than the German and British women. A similar trend was observed for the men group. The data presented in **Table 1** proved that most of the participants were from medium-sized (with 201.000–500.000 people) or large cities (with >500.000 people). The largest agglomerations were mostly inhabited by Polish and British than German DS users. Improvement of wellbeing (49.44%, $n = 177$) and health (43.56%, $n = 1,563$) were the primary purposes of supplementation, while only 1.48% ($n = 53$) of the study group declared that they used DS for maintaining the current health state. **Table 2** presents the results of the analysis of lifestyle behaviors in the study group.

Analysis of selected lifestyle elements was also carried out. No significant differences in gender and country of residence were observed among participants in terms of playing a sport. Among DS users who were involved in sports training (54.54%, $n = 1,957$), the largest percentage declared recreational level (28.51%, $n = 1,023$). Additional PA was rarely performed (<1 time a week, 29.32%), or the frequency was average (2–3 times a week, 30.29%). The responses showed that the number of sleep hours and sleep problems did not differ among the participants. Most participants (60.23%, $n = 2,161$) indicated that they slept 7–8 h a day and did not declare sleep problems (41.16%, $n = 1,477$). The analysis of differences with respect to country revealed no statistically significant differences in cigarette smoking and daily coffee intake among participants. On the other hand, significant differences were observed for alcohol consumption. In the group of women, the largest percentage of abstainers (44.06%, $n = 438$) were from Germany, who also consumed a significantly less amount of beer and vodka than their counterparts. Similarly, British male participants consumed significantly less wine and vodka than Poles and Germans. Compared to British and German participants, Polish men and women consumed the most considerable amounts of high-percent alcohol. **Table 3** shows eating habits of the study group.

Among dietary factors, significant differences were observed in the number of meals consumed during the day. The DS users from Poland consumed statistically significantly more number of meals than others. Furthermore, participants from Germany and the United Kingdom more often consumed snacks every day. Fruit and vegetables were most often consumed a few times a week (34.67%, $n = 1,244$). Similarly, whole grain (37.76%, $n = 1,355$), dairy (39.99%, $n = 1,435$), eggs (49.67%, n=1782), and meat (51.45%, $n = 1,846$). Avocado (34.56%, $n = 1,240$), legumes (36.62%, $n = 1,314$), fish (56.44%, $n = 2,025$), nuts (38.55%, $n = 1,383$), and fermented food (43.16%, $n = 1,547$) were consumed only a few times a month. The Kruskal–Wallis test revealed single statistically significant differences within the study group for the consumption of whole grain, dairy, eggs, and nuts. **Table 4** presents the results of the analysis of health behaviors in the study group.

The results indicated that most of the DS users did not have any diagnosed chronic disease, while the remaining suffered from hypothyroidism (8.39%, $n = 309$) or anemia (2.81%, $n = 101$). The amount and type of medications used by these participants corresponded with these diagnosed conditions. A considerable number of participants declared frequent occurrence (a few times a week) of gastrointestinal problems (28.29%, $n = 1,015$) and concentration disorders (29.15%, $n = 1,046$), while headaches (40.61%, $n = 1,457$), and muscle tremors (29.40%, $n = 1,055$) were reported slightly less frequently (a few times a month). Immune disorders were relatively rare (39.13% ($n = 1,404$) did not have them in the last year), and the frequency of antibiotic use was also very less. The most frequently reported skin, hair, and nail conditions were, respectively, dry/rough (48.08%, $n = 1,725$), loss (55.21%, $n = 1,981$), and fragile/brittle (40.38%, $n = 1,449$). Regarding health characteristics, the men group was more homogeneous than females.

Table 5 presents the association between the analyzed behaviors and the country of residence in the study group.

In consonance with the Pearson Chi-Square test requirement for independence, in at least 80% of cells, the expected value should be 5 or greater (42). Accordingly, medicaments and diagnosed diseases were excluded from the analysis.

The strength of association between variables was determined through Cramer's V tests. The values of V can range from 0 to

TABLE 3 | Eating habits of the study group.

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
	n = 3,588	1,030 (78.21)^{B}	287 (21.79)^{a}	994 (83.95)^{A}	190 (16.05)^{b}	911 (83.81)^{A}	176 (16.19)^{b}
Meal frequency							
1–2	530 (14.77)	74 (7.18)^{B}	35 (12.20)^{b}	253 (25.45)^{A}	49 (25.79)^{a}	95 (10.43)^{B}	24 (13.64)^{ab}
3	1,570 (43.76)	374 (36.31)^{B}	123 (42.86)^{a}	473 (47.59)^{A}	90 (47.37)^{a}	434 (47.64)^{A}	76 (43.18)^{a}
4	1,030 (28.71)	383 (37.18)^{A}	81 (28.22)^{ab}	201 (20.22)^{B}	34 (17.89)^{b}	271 (29.75)^{C}	60 (34.09)^{a}
5	438 (12.21)	194 (18.83)^{A}	43 (14.98)^{a}	63 (6.34)^{B}	14 (7.37)^{a}	108 (11.86)^{B}	16 (9.09)^{a}
≥6	20 (0.51)	5 (0.49)^{A}	5 (1.74)^{a}	4 (0.40)^{A}	3 (1.58)^{a}	3 (0.33)^{A}	0 (0.00)^{a}
Snacks between meals							
Daily	1,277 (35.59)	329 (31.94)^{B}	68 (23.96)^{b}	407 (40.95)^{A}	50 (26.32)^{b}	346 (37.98)^{A}	77 (43.75)^{a}
A few/weeks	1,115 (31.08)	343 (33.03)^{A}	96 (33.45)^{ab}	294 (29.58)^{A}	70 (36.84)^{a}	273 (29.97)^{A}	39 (22.16)^{b}
A few/months	345 (9.62)	117 (11.36)^{A}	32 (11.15)^{a}	83 (8.35)^{A}	14 (7.37)^{a}	86 (9.44)^{A}	13 (7.39)^{a}
A few/years	21 (0.59)	4 (0.39)^{A}	0 (0.00)^{a}	11 (1.11)^{A}	0 (0.53)^{a}	4 (0.44)^{A}	0 (0.57)^{a}
No	830 (23.13)	237 (23.01)^{A}	91 (31.71)^{a}	199 (20.02)^{A}	55 (28.95)^{a}	202 (22.17)^{A}	46 (26.14)^{a}
Fruits and vegetables							
I don't eat	36 (1.00)	4 (0.39)^{A}	3 (1.05)^{a}	11 (1.11)^{A}	7 (3.68)^{a}	8 (0.88)^{A}	3 (1.70)^{a}
A few/months	285 (7.94)	87 (8.45)^{A}	42 (14.63)^{a}	69 (6.94)^{A}	32 (16.84)^{a}	46 (5.05)^{A}	9 (5.11)^{a}
A few/weeks	1,244 (34.67)	380 (36.89)^{A}	112 (39.02)^{a}	340 (34.21)^{AB}	76 (40.00)^{a}	277 (30.41)^{B}	59 (33.52)^{a}
1x/days	1,093 (30.46)	281 (27.28)^{B}	74 (25.78)^{a}	376 (37.83)^{A}	47 (24.74)^{a}	261 (28.65)^{B}	54 (30.68)^{a}
A few/days	930 (25.92)	278 (26.99)^{B}	56 (19.51)^{ab}	198 (19.92)^{C}	28 (14.74)^{b}	319 (35.02)^{A}	52 (28.98)^{a}
Avocado							
Daily	67 (1.87)	5 (0.49)^{A}	2 (0.70)^{a}	17 (1.71)^{A}	3 (1.58)^{a}	38 (4.17)^{A}	2 (1.14)^{a}
A few/weeks	470 (13.10)	85 (8.25)^{B}	16 (5.57)^{a}	137 (13.78)^{B}	11 (5.79)^{a}	198 (21.73)^{A}	23 (13.07)^{a}
A few/months	1,240 (34.56)	326 (31.65)^{B}	74 (25.78)^{a}	366 (36.82)^{AB}	54 (28.42)^{a}	370 (40.61)^{A}	50 (28.41)^{a}
A few/years	782 (21.79)	282 (27.38)^{A}	87 (30.31)^{a}	215 (21.63)^{A}	36 (18.95)^{b}	128 (14.05)^{B}	34 (19.32)^{b}
No	1,029 (28.60)	332 (32.23)^{A}	108 (37.63)^{a}	259 (26.06)^{B}	86 (45.26)^{a}	177 (19.43)^{C}	67 (38.07)^{a}
Legumes							
Daily	80 (2.23)	28 (2.72)^{A}	4 (1.39)^{a}	12 (1.21)^{A}	5 (2.63)^{a}	29 (3.18)^{A}	2 (1.14)^{a}
A few/weeks	527 (14.69)	127 (12.33)^{B}	35 (12.20)^{a}	137 (13.78)^{AB}	24 (12.63)^{a}	174 (19.10)^{A}	30 (17.05)^{a}
A few/months	1,314 (36.62)	351 (34.08)^{B}	108 (37.63)^{a}	402 (40.44)^{A}	70 (36.84)^{a}	322 (35.35)^{AB}	61 (34.66)^{a}
A few/years	980 (27.31)	324 (31.46)^{A}	80 (27.87)^{a}	262 (26.36)^{AB}	45 (23.68)^{a}	216 (23.71)^{B}	53 (30.11)^{a}
No	687 (19.15)	200 (19.42)^{A}	60 (20.91)^{a}	181 (18.21)^{A}	46 (24.21)^{a}	170 (18.66)^{A}	30 (17.05)^{a}
Whole grain							
Daily	889 (24.78)	266 (25.83)^{A}	63 (21.95)^{a}	249 (25.05)^{A}	54 (28.42)^{a}	215 (23.60)^{A}	42 (23.86)^{a}
A few/weeks	1,355 (37.76)	378 (36.70)^{A}	97 (33.80)^{a}	390 (39.24)^{A}	65 (34.21)^{a}	360 (39.52)^{A}	65 (36.93)^{a}
A few/months	907 (25.28)	276 (26.80)^{A}	78 (27.18)^{a}	240 (24.14)^{A}	42 (22.11)^{a}	228 (25.03)^{A}	43 (24.43)^{a}
A few/years	273 (7.61)	79 (7.67)^{A}	28 (9.76)^{a}	70 (7.04)^{A}	13 (6.84)^{a}	67 (7.35)^{A}	16 (9.09)^{a}
No	164 (4.57)	31 (3.01)^{A}	21 (7.32)^{a}	45 (4.53)^{A}	16 (8.42)^{a}	41 (4.50)^{A}	10 (5.68)^{a}
Dairy							
Daily	1,400 (39.02)	381 (36.99)^{B}	93 (32.40)^{a}	449 (45.17)^{A}	63 (33.16)^{a}	339 (37.21)^{B}	75 (42.61)^{a}
A few/weeks	1,435 (39.99)	434 (42.14)^{A}	129 (44.95)^{a}	372 (37.42)^{A}	89 (46.84)^{a}	341 (37.43)^{A}	70 (39.77)^{a}
A few/months	504 (14.05)	150 (14.56)^{A}	50 (17.42)^{a}	107 (10.76)^{A}	26 (13.68)^{a}	148 (16.25)^{A}	23 (13.07)^{a}
A few/years	51 (1.42)	11 (1.07)^{A}	3 (1.05)^{a}	15 (1.51)^{A}	6 (3.16)^{a}	15 (1.65)^{A}	1 (0.57)^{a}
No	198 (5.52)	54 (5.24)^{A}	12 (4.18)^{a}	51 (5.13)^{A}	6 (3.16)^{a}	68 (7.46)^{A}	7 (3.98)^{a}
Eggs (two pieces)							
Daily	269 (7.50)	69 (6.70)^{A}	22 (7.67)^{a}	51 (5.13)^{A}	8 (4.21)^{a}	99 (10.87)^{A}	20 (11.36)^{a}
A few/weeks	1,782 (49.67)	530 (51.46)^{A}	153 (53.31)^{a}	443 (44.57)^{A}	89 (46.84)^{a}	467 (51.26)^{A}	100 (56.82)^{a}
A few/months	1,230 (34.28)	360 (34.95)^{A}	102 (35.54)^{a}	393 (39.54)^{A}	71 (37.37)^{a}	258 (28.32)^{B}	46 (26.14)^{a}
A few/years	140 (3.90)	32 (3.11)^{A}	6 (2.09)^{a}	62 (6.24)^{A}	13 (6.48)^{a}	23 (2.52)^{A}	4 (2.27)^{a}
No	167 (4.65)	39 (3.79)^{A}	4 (1.39)^{a}	45 (4.53)^{A}	9 (4.74)^{a}	64 (7.03)^{A}	6 (3.41)^{a}

(Continued)

TABLE 3 | Continued

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
Fish							
Daily	17 (0.47)	3 (0.29)^{A}	1 (0.35)^{a}	6 (0.60)^{A}	1 (0.53)^{a}	6 (0.66)^{A}	0 (0.00)^{a}
A few/weeks	503 (14.02)	93 (9.03)^{B}	25 (8.71)^{a}	154 (15.49)^{A}	24 (12.63)^{a}	180 (19.76)^{A}	27 (15.34)^{a}
A few/months	2,025 (56.44)	607 (58.93)^{A}	171 (61.67)^{a}	534 (53.72)^{A}	110 (57.89)^{a}	495 (54.34)^{A}	102 (57.95)^{a}
A few/years	648 (18.06)	238 (23.11)^{A}	56 (19.51)^{a}	177 (17.81)^{AB}	30 (15.79)^{a}	114 (12.51)^{B}	33 (18.75)^{a}
No	395 (11.01)	89 (8.64)^{A}	28 (9.76)^{a}	123 (12.37)^{A}	25 (13.16)^{a}	116 (12.73)^{A}	14 (7.95)^{a}
Meat							
Daily	790 (22.02)	202 (19.61)^{A}	125 (43.55)^{ab}	118 (11.87)^{B}	63 (33.16)^{b}	196 (21.51)^{A}	86 (48.86)^{a}
A few/weeks	1,846 (51.45)	558 (54.17)^{A}	119 (41.46)^{a}	532 (53.52)^{A}	95 (50.00)^{a}	473 (51.92)^{A}	69 (39.20)^{a}
A few/months	510 (14.21)	142 (13.79)^{B}	25 (8.71)^{a}	206 (20.72)^{A}	14 (7.37)^{a}	111 (12.18)^{B}	12 (6.82)^{a}
A few/years	80 (2.23)	19 (1.84)^{A}	4 (1.39)^{a}	32 (3.22)^{A}	5 (2.63)^{a}	19 (2.09)^{A}	1 (0.57)^{a}
No	362 (10.09)	109 (10.58)^{A}	14 (4.88)^{a}	106 (10.66)^{A}	13 (6.84)^{a}	112 (12.29)^{A}	8 (4.55)^{a}
Nuts							
Daily	174 (4.85)	34 (3.30)^{A}	15 (5.23)^{a}	59 (5.94)^{A}	9 (4.74)^{a}	51 (5.60)^{A}	6 (3.41)^{a}
A few/weeks	615 (17.14)	151 (14.66)^{A}	45 (15.68)^{a}	166 (16.70)^{A}	25 (13.16)^{a}	188 (20.64)^{A}	40 (22.73)^{a}
A few/months	1,383 (38.55)	411 (39.90)^{A}	102 (35.54)^{a}	389 (39.13)^{A}	70 (36.84)^{a}	347 (38.09)^{A}	64 (36.36)^{a}
A few/years	894 (24.92)	275 (26.70)^{A}	76 (26.48)^{a}	251 (25.25)^{A}	45 (23.68)^{a}	207 (22.72)^{A}	40 (22.73)^{a}
No	522 (14.55)	159 (15.44)^{A}	49 (17.09)^{a}	129 (12.98)^{A}	41 (21.58)^{a}	118 (12.95)^{A}	26 (14.77)^{a}
Fermented food							
Daily	55 (1.53)	12 (1.17)^{A}	2 (0.70)^{a}	24 (2.41)^{A}	5 (2.63)^{a}	11 (1.21)^{A}	1 (0.57)^{a}
A few/weeks	375 (10.45)	131 (12.72)^{A}	35 (12.20)^{a}	61 (6.14)^{B}	15 (7.89)^{a}	119 (13.06)^{A}	14 (7.95)^{a}
A few/months	1,547 (43.16)	532 (51.65)^{A}	148 (51.57)^{a}	330 (33.20)^{B}	65 (34.21)^{b}	388 (42.59)^{C}	84 (47.73)^{ab}
A few/years	927 (25.84)	257 (24.95)^{A}	71 (24.74)^{a}	305 (30.68)^{AB}	54 (28.42)^{a}	197 (21.62)^{B}	43 (24.43)^{a}
No	684 (19.06)	98 (9.51)^{B}	31 (10.80)^{b}	274 (27.57)^{A}	51 (26.84)^{a}	196 (21.51)^{A}	34 (19.32)^{ab}

^{ABC}Values with different letters in the same row are significantly different at $p < 0.05$ in the female group (Kruskal–Wallis test). ^{abc}Values with different letters in the same row are significantly different at $p < 0.05$ in the male group (Kruskal–Wallis test).

1. A value of 1 or 0 indicates a strong or lack of a relationship, respectively, while values <0.3 indicate a weak relationship between the analyzed variables. The results obtained in this study showed an association between most of the analyzed behaviors and the country of residence ($p < 0.05$), whereas no association was found for sports training, sport level, sleep problems, sleep hours, and whole-grain consumption ($p > 0.05$).

A tendency to invest in DS may indirectly influence the determination to use supplementation. An average single cost of a purchased DS in a study group was 15.6 €. In order to indicate predictors affecting this value, a generalized linear regression model analysis was performed. The significant ($p < 0.05$) effects and their interactions are specified in **Table 6**. The results indicate that the cost of single DS purchase variability depends on diverse factors—related to health characteristics, eating habits, lifestyle or demographic parameters.

The SS-test for the presented complete model in relation to SS-test for the residues indicates that the model describes medium-well the dependent variable, as it is evidenced by a value of the determination coefficient. The R^2 of 0.518 indicates that 51.8% of the variance of the dependent variable cost is explained by this model. Therefore, the remaining 48.2% of the variation is explained by other unidentified factors.

DISCUSSION

A rapid increase in the use of DS in recent years prompted us to compare selected health-related behaviors in DS users. Furthermore, only a few studies have been conducted so far among DS users from different nationalities (34–37). Thus, the present study is the first to provide detailed information on personalized DS users from Poland, Germany, and the United Kingdom.

Several research teams have compared the users and non-users of DS (5, 23, 24, 43–48). In terms of gender, the results obtained in this study are consistent with most scientific reports, in which it has been shown that DS are more often used by women. Some reports (5, 24, 44, 45, 49) suggest women predominance in the range of 5–10 percentage points, while other studies (22, 23, 34, 47, 49), including ours, indicate more significant gender discrepancy. Few studies have shown more frequent consumption of DS by men (47). The average age of the participants in the present study was 32.08 ± 8.04 years, and the largest percentage of DS users were in the age group of 18–30 years (49.55%). The obtained values are lower compared to those presented in most of the earlier studies. This may be due to the fact that in our study, the purchase of DS was mainly *via*

TABLE 4 | Health characteristics of the study group.

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
	n = 3,588	1,030 (78.21)^{B}	287 (21.79)^{a}	994 (83.95)^{A}	190 (16.05)^{b}	911 (83.81)^{A}	176 (16.19)^{b}
Diagnosed disease							
No	2,394 (66.72)	637 (61.84)^{B}	201 (70.03)^{a}	653 (65.69)^{AB}	135 (71.05)^{a}	633 (69.48)^{A}	135 (76.70)^{a}
Anemia	101 (2.81)	26 (2.52)^{A}	1 (0.35)^{a}	30 (3.02)^{A}	2 (1.05)^{a}	42 (4.61)^{A}	0 (0.00)^{a}
Atherosclerosis	4 (0.11)	3 (0.29)^{A}	0 (0.00)^{a}	1 (0.10)^{A}	0 (0.00)^{a}	0 (0.00)^{A}	0 (0.00)^{a}
Diabetes	23 (0.64)	5 (0.49)^{A}	2 (0.70)^{a}	9 (0.91)^{A}	2 (1.05)^{a}	3 (0.33)^{A}	2 (1.14)^{a}
Hypertension	59 (1.64)	10 (0.97)^{A}	12 (4.18)^{a}	13 (1.31)^{A}	13 (6.84)^{a}	6 (0.66)^{A}	5 (2.84)^{a}
Hyperthyroidism	10 (0.28)	3 (0.29)^{A}	0 (0.00)^{a}	3 (0.30)^{A}	1 (0.53)^{a}	3 (0.33)^{A}	0 (0.00)^{a}
Hypothyroidism	301 (8.39)	118 (11.46)^{A}	5 (1.74)^{a}	103 (10.36)^{AB}	8 (4.21)^{a}	65 (7.14)^{B}	2 (1.14)^{a}
Liver disease	15 (0.42)	1 (0.10)^{A}	4 (1.39)^{a}	0 (0.00)^{A}	4 (2.11)^{a}	4 (0.44)^{A}	2 (1.14)^{a}
Osteoporosis	7 (0.20)	1 (0.10)^{A}	2 (0.70)^{a}	2 (0.20)^{A}	0 (0.00)^{a}	2 (0.22)^{A}	0 (0.00)^{a}
Rheumatism	30 (0.84)	11 (1.07)^{A}	1 (0.35)^{a}	10 (1.01)^{A}	1 (0.53)^{a}	6 (0.66)^{A}	1 (0.57)^{a}
Other	644 (17.95)	215 (20.87)^{A}	59 (20.56)^{a}	170 (17.10)^{A}	24 (12.63)^{a}	147 (16.14)^{A}	29 (16.48)^{a}
Bowel disease							
No	3,227 (89.94)	903 (87.67)^{A}	262 (91.29)^{a}	905 (91.05)^{A}	177 (93.16)^{a}	812 (89.13)^{A}	168 (95.45)^{a}
Coeliac disease	24 (0.67)	7 (0.68)^{A}	2 (0.70)^{a}	10 (1.01)^{A}	0 (0.00)^{a}	5 (0.55)^{A}	0 (0.00)^{a}
Crohn's disease	15 (0.42)	3 (0.29)^{A}	0 (0.00)^{a}	8 (0.80)^{A}	0 (0.00)^{a}	4 (0.44)^{A}	0 (0.00)^{a}
Intestinal ulcers	21 (0.59)	4 (0.39)^{A}	2 (0.70)^{a}	4 (0.40)^{A}	2 (1.05)^{a}	5 (0.55)^{A}	4 (2.27)^{a}
SIBO/IBS	128 (3.57)	46 (4.47)^{A}	9 (3.14)^{a}	10 (1.01)^{A}	2 (1.05)^{a}	58 (6.73)^{A}	3 (1.70)^{a}
Other	173 (4.82)	67 (6.50)^{A}	12 (4.18)^{a}	57 (5.73)^{A}	9 (4.74)^{a}	27 (2.96)^{A}	1 (0.57)^{a}
Gastrointestinal problems (flatulence; bloating; rumbling in intestines)							
daily	510 (14.21)	153 (14.85)^{A}	43 (14.98)^{a}	145 (14.59)^{A}	22 (11.58)^{a}	121 (13.28)^{A}	26 (14.77)^{a}
a few/weeks	1,015 (28.29)	301 (29.22)^{A}	73 (25.44)^{a}	282 (28.37)^{A}	55 (28.95)^{a}	261 (28.65)^{A}	43 (24.43)^{a}
a few/months	1,004 (27.98)	322 (31.26)^{A}	91 (31.71)^{a}	260 (26.16)^{A}	38 (20.00)^{b}	258 (28.32)^{A}	35 (19.89)^{b}
a few/years	195 (5.43)	58 (5.63)^{A}	19 (6.62)^{a}	43 (4.33)^{A}	10 (5.26)^{a}	57 (6.26)^{A}	8 (4.55)^{a}
No	864 (24.08)	196 (19.03)^{B}	61 (21.25)^{b}	264 (26.56)^{A}	65 (34.21)^{a}	214 (23.49)^{AB}	64 (36.36)^{a}
Vomit/diarrhea							
Daily	31 (0.86)	10 (0.97)^{A}	2 (0.70)^{a}	9 (0.91)^{A}	2 (1.05)^{a}	7 (0.77)^{A}	1 (0.57)^{a}
a few/weeks	163 (4.54)	42 (4.08)^{A}	13 (4.53)^{a}	54 (5.43)^{A}	10 (5.26)^{a}	37 (4.06)^{A}	7 (3.98)^{a}
a few/months	567 (15.80)	173 (16.80)^{A}	42 (14.63)^{a}	161 (16.20)^{A}	32 (16.84)^{a}	141 (15.84)^{A}	18 (10.23)^{a}
a few/years	498 (13.88)	155 (15.05)^{AB}	42 (14.63)^{a}	101 (10.16)^{B}	13 (6.84)^{a}	168 (18.44)^{A}	19 (10.80)^{a}
No	2,329 (64.91)	650 (63.11)^{A}	188 (65.51)^{a}	669 (67.30)^{A}	133 (70.00)^{a}	558 (61.25)^{A}	131 (74.43)^{a}
Immune disorders (throat infection;sinusitis; flu) in the last years							
No	1,404 (39.13)	306 (29.71)^{C}	94 (32.75)^{b}	496 (49.90)^{A}	105 (55.26)^{a}	331 (36.33)^{B}	72 (40.91)^{ab}
1x/season	1,162 (32.39)	367 (35.63)^{A}	91 (31.71)^{a}	248 (24.95)^{B}	55 (28.95)^{a}	337 (36.99)^{A}	64 (36.36)^{a}
1x/quarter	758 (21.13)	259 (25.15)^{A}	80 (27.87)^{a}	186 (18.71)^{B}	23 (12.11)^{b}	179 (19.65)^{AB}	31 (17.61)^{ab}
1x/months	200 (5.57)	78 (7.57)^{A}	14 (4.88)^{a}	47 (4.73)^{A}	7 (3.68)^{a}	47 (5.16)^{A}	7 (3.98)^{a}
> 2x/months	64 (1.78)	20 (1.94)^{A}	8 (2.79)^{a}	17 (1.71)^{A}	0 (0.00)^{a}	17 (1.87)^{A}	2 (1.14)^{a}
Headaches							
Daily	103 (2.87)	30 (2.91)^{A}	4 (1.39)^{a}	31 (3.12)^{A}	4 (2.11)^{a}	27 (2.96)^{A}	7 (3.98)^{a}
a few/weeks	640 (17.84)	189 (18.35)^{A}	30 (10.45)^{a}	214 (21.53)^{A}	20 (10.53)^{a}	161 (17.67)^{A}	26 (14.77)^{a}
a few/months	1,457 (40.61)	481 (46.70)^{A}	88 (30.33)^{a}	394 (39.64)^{B}	52 (27.37)^{a}	398 (43.69)^{AB}	44 (25.00)^{a}
a few/years	415 (11.57)	128 (12.43)^{A}	47 (16.38)^{a}	97 (9.76)^{A}	22 (11.58)^{a}	100 (10.98)^{A}	21 (11.93)^{a}
No	973 (27.12)	202 (19.61)^{B}	118 (41.11)^{a}	258 (25.96)^{A}	92 (48.42)^{a}	225 (24.70)^{AB}	78 (44.32)^{a}
Concentration problems							
Daily	591 (16.47)	170 (16.50)^{A}	54 (18.82)^{a}	153 (15.39)^{A}	19 (10.00)^{a}	166 (18.22)^{A}	29 (16.48)^{a}
a few/weeks	1,046 (29.15)	323 (31.36)^{A}	85 (29.62)^{a}	285 (28.67)^{A}	47 (24.74)^{a}	265 (28.10)^{A}	50 (28.41)^{a}
a few/months	801 (22.32)	242 (23.50)^{A}	54 (18.82)^{a}	235 (23.64)^{A}	39 (20.53)^{a}	206 (22.61)^{A}	25 (14.20)^{a}
a few/years	121 (3.37)	26 (2.52)^{A}	7 (2.44)^{a}	35 (3.52)^{A}	6 (3.16)^{a}	41 (4.50)^{A}	6 (3.41)^{a}

(Continued)

TABLE 4 | Continued

Overall (%)	All participants	Poland (n = 1,317)		Germany (n = 1,184)		United Kingdom (n = 1,087)	
		Female	Male	Female	Male	Female	Male
No	1,029 (28.68)	269 (26.12)^{A}	87 (30.31)^{a}	286 (28.77)^{A}	79 (41.58)^{a}	242 (26.56)^{A}	66 (37.50)^{a}
Muscle tremors							
Daily	134 (3.73)	37 (3.59)^{A}	17 (5.92)^{a}	26 (2.62)^{A}	5 (2.63)^{a}	38 (4.17)^{A}	11 (6.25)^{a}
a few/weeks	457 (12.74)	140 (13.59)^{A}	41 (14.29)^{a}	106 (10.66)^{A}	24 (12.63)^{a}	123 (13.50)^{A}	23 (13.07)^{a}
a few/months	1,055 (29.40)	364 (35.34)^{A}	89 (31.01)^{a}	259 (26.06)^{B}	40 (21.05)^{a}	257 (28.21)^{B}	46 (26.14)^{a}
a few/years	464 (12.93)	154 (14.95)^{A}	45 (15.68)^{a}	103 (10.36)^{A}	19 (10.00)^{a}	125 (13.72)^{A}	18 (10.23)^{a}
No	1,478 (41.19)	335 (32.52)^{C}	95 (33.10)^{b}	500 (50.30)^{A}	102 (53.68)^{a}	368 (40.40)^{B}	78 (44.32)^{ab}
Skin problems(multiple choice)							
No	821 (22.88)	161 (15.63)^{A}	105 (36.59)^{b}	192 (19.32)^{A}	93 (48.95)^{a}	185 (20.31)^{A}	85 (48.30)^{ab}
Acne	1,321 (36.82)	425 (41.26)^{A}	72 (25.09)^{a}	379 (38.13)^{A}	37 (19.47)^{a}	379 (41.60)^{A}	29 (16.48)^{a}
Discoloration	1,098 (30.60)	424 (41.17)^{A}	46 (16.03)^{a}	257 (25.86)^{B}	19 (10.00)^{a}	321 (35.24)^{A}	31 (17.61)^{a}
Dry and rough	1,725 (48.08)	571 (55.44)^{A}	110 (38.33)^{a}	524 (52.72)^{A}	66 (34.74)^{a}	391 (42.92)^{B}	63 (35.80)^{a}
Flaking	428 (11.93)	124(12.04)^{A}	45 (15.68)^{a}	119 (11.97)^{A}	23 (12.11)^{a}	87 (9.55)^{A}	30 (17.05)^{a}
Perleche	312 (8.70)	111 (10.78)^{A}	28 (9.76)^{a}	105 (10.56)^{A}	7 (3.68)^{a}	52 (5.71)^{B}	9 (5.11)^{a}
Slow wound healing	504 (14.05)	163 (15.83)^{A}	17 (5.92)^{a}	147 (14.79)^{A}	14 (7.37)^{a}	146 (16.03)^{A}	17 (9.66)^{a}
Keratosis	474 (13.21)	140 (13.59)^{AB}	47 (16.38)^{a}	184 (18.51)^{A}	14 (7.37)^{a}	78 (8.56)^{B}	11 (6.25)^{a}
Other	422 (11.76)	104 (10.10)^{A}	21 (7.32)^{a}	130 (13.08)^{A}	18 (9.47)^{a}	136 (14.93)^{A}	13 (7.39)^{a}
Hair problems (multiple choice)							
No	1,082 (30.16)	211 (20.49)^{B}	167 (58.19)^{a}	284 (28.57)^{A}	111 (58.42)^{a}	210 (23.05)^{AB}	99 (56.25)^{a}
Dandruff	642 (17.89)	194 (18.83)^{A}	41 (14.29)^{a}	190 (19.11)^{A}	23 (12.11)^{a}	169 (18.55)^{A}	25 (14.20)^{a}
Dry and brittle	1,641 (45.74)	568 (55.15)^{A}	32 (11.15)^{a}	511 (51.41)^{A}	26 (13.68)^{a}	485 (53.24)^{A}	19 (10.80)^{a}
Loss	1,981 (55.21)	677 (65.73)^{B}	89 (31.01)^{a}	526 (52.92)^{A}	58 (30.53)^{a}	580 (63.67)^{B}	51 (28.98)^{a}
Matt	1,013 (28.23)	361 (35.05)^{A}	25 (8.71)^{a}	295 (29.68)^{A}	16 (8.42)^{a}	299 (32.82)^{A}	17 (9.66)^{a}
Other	337 (9.39)	94 (9.13)^{A}	19 (6.62)^{a}	103 (10.36)^{A}	14 (7.37)^{a}	92 (10.10)^{A}	15 (8.52)^{a}
Nail problems (multiple choice)							
No	1,700 (47.38)	393 (38.16)^{A}	214 (74.56)^{a}	476 (47.89)^{B}	146 (76.84)^{a}	349 (38.31)^{A}	122 (69.32)^{a}
Fragile and brittle	1,449 (40.38)	549 (53.30)^{A}	45 (15.68)^{a}	371 (37.32)^{B}	25 (13.16)^{a}	433 (47.53)^{A}	26 (14.77)^{a}
Grow slowly	520 (14.49)	155 (15.05)^{A}	6 (2.09)^{a}	168 (16.90)^{A}	11 (5.79)^{a}	172 (18.88)^{A}	8 (4.55)^{a}
Inflammations	122 (3.40)	20 (1.94)^{A}	8 (2.79)^{a}	49 (4.93)^{A}	7 (3.68)^{a}	32 (3.51)^{A}	6 (3.41)^{a}
Splitting	1,066 (29.71)	343 (33.30)^{A}	27 (9.41)^{a}	314 (31.59)^{A}	17 (8.95)^{a}	343 (37.65)^{A}	22 (12.50)^{a}
White spots	562 (15.66)	170 (16.50)^{A}	27 (9.41)^{a}	154 (15.49)^{A}	13 (6.84)^{a}	170 (18.66)^{A}	28 (15.91)^{a}
Other	148 (4.12)	26 (2.52)^{A}	12 (4.18)^{a}	51 (5.13)^{A}	7 (3.68)^{a}	40 (4.39)^{A}	12 (6.82)^{a}
Medicaments (multiple choice)							
No	2,443 (68.09)	636 (61.75)^{B}	227 (79.09)^{a}	650 (65.39)^{AB}	147 (77.37)^{a}	643 (70.58)^{A}	140 (79.54)^{a}
Anticancer	5 (0.14)	0 (0.00)^{A}	0 (0.00)^{a}	4 (0.40)^{A}	0 (0.00)^{a}	1 (0.11)^{A}	0 (0.00)^{a}
Antiepileptic	10 (0.28)	5 (0.49)^{A}	0 (0.00)^{a}	5 (0.50)^{A}	0 (0.00)^{a}	0 (0.00)^{A}	0 (0.00)^{a}
Contraceptives	367 (10.23)	135 (13.11)^{A}	0 (0.00)^{a}	128 (12.88)^{A}	0 (0.00)^{a}	104 (11.42)^{A}	0 (0.00)^{a}
Diuretics	16 (0.45)	7 (0.68)^{A}	4 (1.39)^{a}	5 (0.50)^{A}	0 (0.00)^{a}	0 (0.00)^{A}	0 (0.00)^{a}
For stomach acidity	62 (1.73)	17 (1.65)^{A}	7 (2.44)^{a}	18 (1.81)^{A}	5 (2.63)^{a}	9 (0.99)^{A}	6 (3.41)^{a}
Metformin	42 (1.17)	23 (2.23)^{A}	1 (0.35)^{a}	9 (0.91)^{A}	2 (1.05)^{a}	5 (0.55)^{A}	2 (1.14)^{a}
Salicylates	8 (0.22)	3 (0.29)^{A}	1 (0.35)^{a}	3 (0.30)^{A}	0 (0.00)^{a}	1 (0.11)^{A}	0 (0.00)^{a}
Steroids	40 (1.11)	20 (1.94)^{A}	4 (1.39)^{a}	4 (0.40)^{A}	3 (1.58)^{a}	6 (0.66)^{A}	3 (1.70)^{a}
Chelation therapy	1 (0.03)	0 (0.00)^{A}	0 (0.00)^{a}	1 (0.10)^{A}	0 (0.00)^{a}	0 (0.00)^{A}	0 (0.00)^{a}
Other	773 (21.54)	254 (24.66)^{A}	51 (17.77)^{a}	231 (23.24)^{A}	35 (18.42)^{a}	175 (19.21)^{A}	27 (15.34)^{a}
Antibiotics in the last 4 years							
No	1,306 (36.40)	285 (27.67)^{B}	92 (32.06)^{b}	367 (36.92)^{A}	93 (48.95)^{a}	373 (40.94)^{A}	96 (54.55)^{a}
1–2x	1,434 (39.97)	441 (42.82)^{A}	117 (40.77)^{a}	390 (39.24)^{A}	75 (39.47)^{a}	354 (38.86)^{A}	57 (32.39)^{a}
3–4x	575 (16.03)	199 (19.32)^{A}	47 (16.38)^{a}	158 (15.90)^{A}	13 (6.84)^{a}	139 (15.26)^{A}	19 (10.80)^{a}
5+	273 (7.61)	105 (10.19)^{A}	31 (10.80)^{a}	79 (7.95)^{A}	9 (4.74)^{a}	45 (4.49)^{A}	4 (2.27)^{a}

^{ABC}Values with different letters in the same row are significantly different at $p < 0.05$ in the female group (Kruskal–Wallis test). ^{abc}Values with different letters in the same row are significantly different at $p < 0.05$ in the male group (Kruskal–Wallis test).

SIBO, small intestinal bacterial overgrowth; IBS, irritable bowel syndrome.

TABLE 5 | Association between the analyzed behaviors and the country of residence in the study group.

Variables	Pearson Chi-Square(X^2)	*p*-Value	Cramer's V value
BMI	34.22	0.00001	0.07
City population	291.82	0.00000	0.20
Supplementation purpose	57.46	0.00000	0.09
Activity level	55.09	0.00000	0.09
Training sport	2.43	0.29668	0.26
Sport level	11.16	0.08325	0.04
Sleep problems	12.75	0.12073	0.04
Sleep hours	6.67	0.57218	0.03
Work hours	46.91	0.00000	0.08
Daily cigarettes intake	29.06	0.00031	0.06
Alcohol consumption	15.28	0.00048	0.07
Daily coffeeintake	23.78	0.00250	0.06
Meals amount	281.88	0.00000	0.20
Snacks between meals	37.33	0.00001	0.10
Fruits and vegetables	96.90	0.00000	0.12
Avocado	189.85	0.00000	0.16
Legumes	38.42	0.00001	0.07
Whole grain	7.99	0.43438	0.33
Dairy	30.64	0.00016	0.07
Eggs	97.01	0.00000	0.12
Fish	83.87	0.00000	0.11
Meat	70.33	0.00000	0.10
Nuts	26.32	0.00093	0.06
Fermented food	206.69	0.00000	0.17
Bowel disease	58.84	0.00000	0.09
Gastrointestinal problems	32.15	0.00009	0.07
Vomit/diarrhea	31.93	0.00010	0.07
Immune disorders	124.93	0.00000	0.13
Headaches	21.76	0.00539	0.06
Concentration problems	16.76	0.03270	0.05
Muscle tremors	90.77	0.00000	0.11
Skin problems	51.88	0.00001	0.09
Hair problem	39.53	0.00002	0.07
Nail problem	107.64	0.00000	0.12
Antibiotics	76.44	0.00000	0.10

BMI, body mass index.

TABLE 6 | Generalized linear regression model (GRM) for an average cost of a purchased DS.

Variables	SS	df	MS	*F*-Value	*p*-Value
Antibiotics	1.25	3	1.25	5.94	0.01482
Avocado	3.79	4	0.95	4.50	0.00127
City population (thous.)	3.80	4	0.63	3.00	0.00628
Concentration problems	2.52	4	0.63	2.99	0.01784
Diagnosed disease	2.88	10	2.88	13.68	0.00022
Fermented food	4.43	4	1.11	5.26	0.00032
Fish	3.12	4	0.78	3.70	0.00520
Immune disorders	2.27	4	0.57	2.69	0.02946
Medicaments	567.62	10	567.62	2,694.40	0.00000
Muscle tremors	1.38	4	1.38	6.57	0.01044
Snacks between meals	1.36	4	1.36	6.45	0.01112
Work hours	2.63	5	0.53	2.50	0.02899
SS-test results for the full model	**Multiple R**		**Multiple R^2**	**Adjusted R^2**	***p*-Value**
	0.71999		0.51838	0.51008	0.00000

SS, sum of squares; MS, mean square; df, degrees of freedom; R, correlation coefficient; R^2, coefficient of determination.

the Internet, which is more often practiced by young people (50–52). A relationship between the use of DS and the correct BMI has been demonstrated in previous studies (5, 22, 23, 43, 49). Our study showed a normal BMI in most of the participants. However, significant differences were observed in terms of gender and country of residence. The average BMI of men and women from Germany indicated overweight (BMI > 25 kg/m^2). Similar results have been reported for DS users from Greece (30) and Belgium (31). It is worth emphasizing that in this study the DS users group included a low percentage of obese people (14.13%), compared to domestic populations, as around 24% in Poland (53) or Germany (54) and 28% in the United Kingdom are obese (55).

The results of our investigation showed that the main purposes for DS use are improvement of health and wellbeing. Previous studies have shown that the most frequently reported reasons for DS use are "solving or overcoming health problems"(22), "health" (43), "injury or illness" (56), or "medical need/deficiency"(47). These outcomes are in contrast with the reported overall health. The findings of the present study indicated that 66.72% of participants were not diagnosed with any chronic disease. Other studies had also well-documented that most DS users are characterized by appropriate health status. Burnett et al. (5) showed a lack of chronic disease in 91.36% of participants. Similarly, Radwan et al. (47) and Rontogianni et al. (30) revealed that the majority of DS users do not suffer from persistent illnesses. On the other hand, some reports indicated a lower percentage (around 20%) of healthy adults in the studied population (44, 45). Skin, hair, and nail problems were the most common in the group analyzed in the present study. A literature search suggested that this is the first study to report numerous dermatological disorders among DS users. Previous studies have shown that "beauty" or "skin, hair, nails" is one of the primary purposes of supplementation (14, 22, 25, 43). Taking all these into account, the results of the present study confirm the expectations that the global beauty supplement market will reach $7 billion by 2024 (57). Regarding medications, our results showed that contraceptives were the most frequently used drug among the participants (10.23%). As revealed by numerous studies, the main ingredient of DS that may reduce the effectiveness of oral contraceptives and increase the risk of breakthrough bleeding is St. John's wort (58–60). Therefore, women taking oral contraceptives should pay attention to the composition of herbal supplements.

According to the WHO (61), regular PA (at least five times a week) can contribute to an improvement in biomedical markers. Our results showed that only 25.92% of DS users followed regular PA. The highest percentage of British DS users were involved in PA for 4–5 times a week, with statistically significant differences observed among women. Additionally, 10.00% of German men and 4.94% of British women were active, involving in PA >6 times a week. These results are in line with the study of Kim et al. (44), who reported that 27.79% of DS users declared a "high" level of PA. Among Australian adults, 43.00% of DS users met the national recommendations (5). Similar results were indicated by Pouchieu et al. (22) (42.50%) and Guo et al. (32) (47.90%). Another study (33) showed that only 15.30% of male and 21.30% of female DS users in Japan undertook physical exercise for 3–7 times a week. On the other hand, as much as 57.6% of Belgium army men declared a high level of PA (31).

The recommended sleep duration for adults is 7 h/day or more (62). The obtained results proved that more than 60% of DS users met this recommendation. No statistically significant differences were observed between participants in terms of country and gender. Furthermore, most of the participants (61.16%) did not have any sleep problems. Our results confirmed those reported by Dickinson et al. (14), who showed that DS users significantly more often "had a good night's sleep" compared to non-users (70 vs. 63%). Several studies concerning lifestyle characteristics have analyzed behaviors such as cigarette smoking, alcohol use, or coffee consumption among DS users. In the current study, 79.37% of participants declared no smoking ($p > 0.05$ for country and gender). This value agrees with most of the previous works, in which 75.9–88.24% of DS users have been described as ex-smokers and/or non-smokers (5, 22, 31, 32, 37, 44, 47, 63). Former studies have indicated a significant, positive association between alcohol absence and DS use (24, 63, 64). Moreover, the association with different types of alcohol separately has been widely investigated. In contrast to beer consumption, a positive relationship has been found for wine consumption (65, 66). Scientific reports mention different percentages of abstainers among DS users. For example, Rautiainen et al. (23) showed 16.4% of the study group were non-drinkers, and Rontogianni et al. (30) reported 12.21%. On the other hand, Kim et al. (44) and Guo et al. (32) showed a higher percentage of non-drinkers (41.62 and 40.9%, respectively). Our results demonstrated that 37.18% were abstainers, of which the largest ($p < 0.05$) percentage were German females (44.06%). Few works regarding coffee intake among DS users have shown an inverse relationship between supplement use and coffee consumption in the women group (66). Our research indicated that the highest percentage of DS users (44.68%) consumed reasonable amounts of coffee (about 2–3 cups a day) in each studied country.

According to previous studies (25, 37), participants practicing correct dietary habits used DS more often than those who had not been following a proper diet. The most frequently analyzed eating habit was the consumption of fruit and vegetables. Some reports proved that more than 46.00% of DS users eat ≥5 servings of fruit and vegetables daily (32, 43). Reedy et al. (45) and Beitz et al. (66) indicated that DS users consumed adequate portions of fruit and vegetables per days (5.63 and 6.71, respectively). In contrast, only 7.49% of Australian DS users met daily guidelines (67) recommending five servings of vegetables and two servings of fruit (5). Our results revealed that 25.92% of respondents consumed a sufficient amount of vegetables and fruit (a few times a days). Significant differences were observed with respect to gender and country (the most favorable results were obtained for British DS users). The other plant-based foods (legumes, nuts, avocado) were most often consumed several times a months. It is recommended that legumes should be consumed 2–3 times a week (68) and unsalted nuts should be consumed four times a week (or 30 g daily) (69). However, our study showed that only 14.69% (for legumes) and 17.14% (for nuts) of the participants met these guidelines. Similarly, less than one-fourth of the study group (24.78%) consumed whole grain daily, as per the recommendations (70). Animal products (dairy, eggs, meat) were most often consumed a few times a week which is also in line with the guidelines (71–73). In contrast, the frequency of fish consumption by most of the studied DS users was insufficient (74).

Our results indicated that the number of meals consumed during the day significantly differed in the study group. Female DS users from Poland often consumed significantly more number [4 (37.18%) or 5 (18.83%)] of meals compared to Germans and British women. On the other hand, no differences were observed based on nationalities in the group of men. The largest percentage (over 40.00%) consumed three meals a day, which is less than the current Polish or German recommendations (4–5 meals) (75, 76) but in accordance with the British guidelines (at least three meals) (77).

The study has several strengths. First, the analysis of data from different countries allowed for a more comprehensive consideration of dietary supplementation issues. Second, all participants acquired DS from the same source and in a similar form. This enabled eliminating variations in the definition of supplement users, which was an issue in several previous studies (28, 29, 43, 66). A wide range of data was analyzed, contributing to a comprehensive assessment of the most common health behaviors. Furthermore, this research was conducted by an interdisciplinary team consisting of dietitians (KI., MM., TS.), biotechnologists (AK., MC., AP.), and pharmacists (WK.), by applying a multidimensional approach.

Although further studies on a larger number of participants are needed, the sample of DS users analyzed in this study is similar to those investigated in some previous studies on this topic (5, 30, 31, 48, 49). A limitation of the study is the use of a self-administered questionnaire, which might cause errors in data collection. Moreover, the study could not collect detailed information on the size of food portions, components of applied supplements, or health measures. However, similar results have been obtained in several previous works.

CONCLUSIONS

In summary, the obtained results demonstrate that DS users had a proper health state associated with healthy lifestyle

behaviors. Most participants were characterized by a correct BMI, limited smoking and alcohol consumption, a rare occurrence of diseases, and sufficient sleep. However, the consumption of fruit and vegetables, nuts, legumes, and fish was low and meal frequency was inadequate in the study group. Most of the analyzed behaviors showed an association with nationality.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because of ethics restrictions. Requests to access the datasets should be directed to KI, katarzyna.ilowiecka@umlub.pl.

ETHICS STATEMENT

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

AUTHOR CONTRIBUTIONS

KI: conceptualization and writing review and editing. KI and WK: methodology and writing manuscript. PW, KI, and AK: data analysis. KI, AK, WK, MC, MM, AP, TS, MG, and PW: resources. WK: supervision. All authors have made a substantial, direct, and intellectual contribution to the work and have approved to the final version of the manuscript.

REFERENCES

1. European Food Safety Authority. *Food Supplements*. Available online at: https://www.efsa.europa.eu/en/topics/topic/food-supplements (accessed December 7, 2021).
2. Tetens I, Biltoft-Jensen A, Spagner C, Christensen T, Gille M-B, et al. Intake of micronutrients among Danish adult users and non-users of dietary supplements. *Food Nutr Res.* (2011) 55:10.3402/fnr.v55i0.7153. doi: 10.3402/fnr.v55i0.7153
3. Mishra S, Stierman B, Gahche JJ, Potischman N. Dietary supplement use among adults: United States, 2017–2018. *NCHS Data Brief.* (2021) 1–8. Available online at: https://www.cdc.gov/nchs/products/databriefs/db399.html (accessed January 26, 2022).
4. Kang M, Kim DW, Baek YJ, Moon S-H, Jung HJ, Song YJ, et al. Dietary supplement use and its effect on nutrient intake in Korean adult population in the Korea National Health and Nutrition Examination Survey IV (2007–2009) data. *Eur J Clin Nutr.* (2014) 68:804–10. doi: 10.1038/ejcn.2014.77
5. Burnett AJ, Livingstone KM, Woods JL, McNaughton SA. Dietary supplement use among Australian adults: findings from the 2011–2012 National Nutrition and Physical Activity Survey. *Nutrients.* (2017) 9:e1248. doi: 10.3390/nu9111248
6. Abdulla NM, Aziz F, Blair I, Grivna M, Adam B, Loney T. Prevalence of, and factors associated with health supplement use in Dubai, United Arab Emirates: a population-based cross-sectional study. *BMC Complement Altern Med.* (2019) 19:e172. doi: 10.1186/s12906-019-2593-6
7. Messerer M, Johansson SE, Wolk A. Use of dietary supplements and natural remedies increased dramatically during the 1990s. *J Intern Med.* (2001) 250:160–6. doi: 10.1046/j.1365-2796.2001.00872.x
8. Lordan R. Dietary supplements and nutraceuticals market growth during the coronavirus pandemic – Implications for consumers and regulatory oversight. *PharmaNutrition.* (2021) 18:100282. doi: 10.1016/j.phanu.2021.100282
9. Mensink GB, Fletcher R, Gurinovic M, Huybrechts I, Lafay L, Serra-Majem L, et al. Mapping low intake of micronutrients across Europe. *Br J Nutr.* (2013) 110:755–73. doi: 10.1017/S000711451200565X
10. Mayor S. Public Health England recommends vitamin D supplements in autumn and winter. *BMJ.* (2016) 354:i4061. doi: 10.1136/bmj.i4061
11. Rusińska A, Płudowski P, Walczak M, Borszewska-Kornacka MK, Bossowski A, Chlebna-Sokół D, et al. Vitamin D supplementation guidelines for general population and groups at risk of vitamin D deficiency in Poland-recommendations of the Polish Society of Pediatric Endocrinology and Diabetes and the expert panel with participation of national specialist consultants and representatives of scientific societies-2018 update. *Front Endocrinol.* (2018) 9:e246. doi: 10.3389/fendo.2018.00246
12. Bailey RL, Gahche JJ, Miller PE, Thomas PR, Dwyer JT. Why US adults use dietary supplements. *JAMA Intern Med.* (2013) 173:355–61. doi: 10.1001/jamainternmed.2013.2299
13. Sirico F, Miressi S, Castaldo C, Spera R, Montagnani S, Di Meglio F, et al. Habits and beliefs related to food supplements: results of a survey among Italian students of different education fields and levels. *PLoS ONE.* (2018) 13:e0191424. doi: 10.1371/journal.pone.0191424
14. Dickinson A, Blatman J, El-Dash N, Franco JC. Consumer usage and reasons for using dietary supplements: report of a series of surveys. *J Am Coll Nutr.* (2014) 33:176–82. doi: 10.1080/07315724.2013.875423
15. Sunkara A, Raizner A. Supplemental vitamins and minerals for cardiovascular disease prevention and treatment. *Methodist Debakey Cardiovasc J.* (2019) 15:179–84. doi: 10.14797/mdcj-15-3-179
16. Fortmann SP, Burda BU, Senger CA, Lin JS. Whitlock EP. Vitamin and mineral supplements in the primary prevention of cardiovascular disease and cancer: an updated systematic evidence review for the US Preventive Services Task Force. *Ann Intern Med.* (2013) 159:824–34. doi: 10.7326/0003-4819-159-12-201312170-00729
17. Dinda B, Dinda M, Roy A, Dinda S. Dietary plant flavonoids in prevention of obesity and diabetes. *Adv Protein Chem Struct Biol.* (2020) 120:159–235. doi: 10.1016/bs.apcsb.2019.08.006
18. Pittas AG, Jorde R, Kawahara T, Dawson-Hughes B. Vitamin D supplementation for prevention of type 2 diabetes mellitus: to D or not to D? *J Clin Endocrinol Metab.* (2020) 105:dgaa594. doi: 10.1210/clinem/dgaa594
19. Guzek D, Kołota A, Lachowicz K, Skolmowska D, Stachoń M, Głabska D. Influence of Vitamin D supplementation on mental health in diabetic patients: a systematic review. *Nutrients.* (2021) 13:3678. doi: 10.3390/nu13113678
20. Dwyer JT, Coates PM, Smith MJ. Dietary supplements: regulatory challenges and research resources. *Nutrients.* (2018) 10:41. doi: 10.3390/nu10010041
21. Perez-Sanchez AC, Tantry EK, Burns EK, Perez VM, Prabhu S, Katta R. Skin, hair, and nail supplements: marketing and labeling concerns. *Cureus.* (2020) 12:e12062. doi: 10.7759/cureus.12062
22. Pouchieu C, Andreeva VA, Péneau S, Kesse-Guyot E, Lassale C, Hercberg S, et al. Sociodemographic, lifestyle and dietary correlates of dietary supplement use in a large sample of French adults: results from the NutriNet-Santé cohort study. *Br J Nutr.* (2013) 110:1480–91. doi: 10.1017/S0007114513000615
23. Rautiainen S, Wang L, Gaziano JM, Sesso HD. Who uses multivitamins? A cross-sectional study in the physicians' health study. *Eur J Nutr.* (2014) 53:1065–72. doi: 10.1007/s00394-013-0608-5
24. Kofoed CLF, Christensen J, Dragsted LO, Tjønneland A, Roswall N. Determinants of dietary supplement use-healthy individuals use dietary supplements. *Br J Nutr.* (2015) 113:1993–2000. doi: 10.1017/S0007114515001440
25. Dickinson A, MacKay D. Health habits and other characteristics of dietary supplement users: a review. *Nutr J.* (2014) 13:14. doi: 10.1186/1475-2891-13-14
26. Cowan AE, Jun S, Gahche JJ, Tooze JA, Dwyer JT, Eicher-Miller HA, et al. Dietary supplement use differs by socioeconomic and health-related

characteristics among U.S. Adults, NHANES 2011−2014. *Nutrients*. (2018) 10:e1114. doi: 10.3390/nu10081114
27. Reinert A, Rohrmann S, Becker N, Linseisen J. Lifestyle and diet in people using dietary supplements: a German cohort study. *Eur J Nutr*. (2007) 46:165–73. doi: 10.1007/s00394-007-0650-2
28. Dwyer J, Picciano MF, Raiten DJ, Members of the steering committee, national health and nutrition examination survery. Collection of food and dietary supplement intake data: what we eat in America-NHANES. *J Nutr*. (2003) 133:590S-600. doi: 10.1093/jn/133.2.590S
29. Brownie S, Myers S. Wading through the quagmire: making sense of dietary supplement utilization. *Nutr Rev*. (2004) 62:276–82. doi: 10.1301/nr.2004.jul.276-282
30. Rontogianni MO, Kanellopoulou A, Markozannes G, Bouras E, Derdemezis C, Doumas MT, et al. Prevalence and determinants of sex-specific dietary supplement use in a greek cohort. *Nutrients*. (2021) 13:2857. doi: 10.3390/nu13082857
31. Mullie P, Clarys P, Hulens M, Vansant G. Socioeconomic, health, and dietary determinants of multivitamin supplements use in Belgium. *Int J Public Health*. (2011) 56:289–94. doi: 10.1007/s00038-010-0210-z
32. Guo X, Willows N, Kuhle S, Jhangri G, Veugelers PJ. Use of vitamin and mineral supplements among Canadian adults. *Can J Public Health*. (2009) 100:357–60. doi: 10.1007/BF03405270
33. Ishihara J, Sobue T, Yamamoto S, Sasaki S, Tsugane S, JPHC Study Group. Demographics, lifestyles, health characteristics, and dietary intake among dietary supplement users in Japan. *Int J Epidemiol*. (2003) 32:546–53. doi: 10.1093/ije/dyg091
34. Cruz JA, Moreiras-Varela O, van Staveren WA, Trichopoulou A, Roszkowski W. Intake of vitamins and minerals. Euronut SENECA investigators. *Eur J Clin Nutr*. (1991) 45:121–38.
35. Brzozowska A, Enzi G, Amorin Cruz J. Medicine use and supplementation practice among participants of SENECA Study. *J Nutr Health Aging*. (2002) 6:34–8.
36. Skeie G, Braaten T, Hjartåker A, Lentjes M, Amiano P, Jakszyn P, et al. Use of dietary supplements in the European prospective investigation into cancer and nutrition calibration study. *Eur J Clin Nutr*. (2009) 63(Suppl. 4):S226–238. doi: 10.1038/ejcn.2009.83
37. Foote JA, Murphy SP, Wilkens LR, Hankin JH, Henderson BE, Kolonel LN. Factors associated with dietary supplement use among healthy adults of five ethnicities: the multiethnic cohort study. *Am J Epidemiol*. (2003) 157:888–97. doi: 10.1093/aje/kwg072
38. Gong W, Liu A, Yao Y, Ma Y, Ding C, Song C, et al. Nutrient supplement use among the chinese population: a cross-sectional study of the 2010–2012 china nutrition and health surveillance. *Nutrients*. (2018) 10:e1733. doi: 10.3390/nu10111733
39. WHO Expert Committee. Physical status: the use and interpretation of anthropometry, report of a WHO Expert Committee. *World Health Organ Tech Rep Ser*. (1995) 854:1–452. Available online at: https://apps.who.int/iris/handle/10665/37003
40. von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP, STROBE Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. *J Clin Epidemiol*. (2008) 61:344–9. doi: 10.1016/j.jclinepi.2007.11.008
41. Hinkle DE, Wiersma W, Jurs SG. *Applied Statistics for the Behavioral Sciences*. 5th ed. Boston: Houghton Mifflin Mass. (2003).
42. McHugh ML. The chi-square test of independence. *Biochem Med*. (2013) 23:143–9. doi: 10.11613/bm.2013.018
43. Mohd Ashri MH, Abu Saad H. Adznam SN?. Socio-demographic characteristics, body weight status and energy intake among users and non-users of dietary supplements among government employees in Putrajaya, Malaysia. *Nutrients*. (2021) 13:2248. doi: 10.3390/nu13072248
44. Kim J, Lee J-S, Shin A, Kang M-H, Shin D-S, Chung H-R, et al. Sociodemographic and lifestyle factors are associated with the use of dietary supplements in a Korean population. *J Epidemiol*. (2010) 20:197–203. doi: 10.2188/jea.JE20090064
45. Reedy J, Haines PS, Campbell MK. Differences in fruit and vegetable intake among categories of dietary supplement users. *J Am Diet Assoc*. (2005) 105:1749–56. doi: 10.1016/j.jada.2005.08.009
46. Cross AJ, George J, Woodward MC, Ames D, Brodaty H, Elliott RA. Dietary supplement use in older people attending memory clinics in australia. *J Nutr Health Aging*. (2017) 21:46–50. doi: 10.1007/s12603-016-0742-x
47. Radwan H, Hasan HA, Ghanem L, Alnajjar G, Shabir A, Alshamsi A, et al. Prevalence of dietary supplement use and associated factors among college students in the United Arab Emirates. *J Community Health*. (2019) 44:1135–40. doi: 10.1007/s10900-019-00700-2
48. Brownie S, Rolfe M. Health characteristics of older Australian dietary supplement users compared to non-supplement users. *Asia Pac J Clin Nutr*. (2004) 13:365–71.
49. Rovira M-A, Grau M, Castañer O, Covas M-I, Schröder H, REGICOR Investigators. Dietary supplement use and health-related behaviors in a mediterranean population. *J Nutr Educ Behav*. (2013) 45:386–91. doi: 10.1016/j.jneb.2012.03.007
50. Zatz LY, Moran AJ, Franckle RL, Block JP, Hou T, Blue D, et al. Comparing online and in-store grocery purchases. *J Nutr Educ Behav*. (2021) 53:471–9. doi: 10.1016/j.jneb.2021.03.001
51. Rogus S, Guthrie JF, Niculescu M, Mancino L. Online grocery shopping knowledge, attitudes, and behaviors among SNAP participants. *J Nutr Educ Behav*. (2020) 52:539–45. doi: 10.1016/j.jneb.2019.11.015
52. Jairoun AA, Al-Hemyari SS, Abdulla NM, El-Dahiyat F, Jairoun M, Al-Tamimi SK, et al. Online medication purchasing during the COVID-19 pandemic: potential risks to patient safety and the urgent need to develop more rigorous controls for purchasing online medications, a pilot study from the United Arab Emirates. *J Pharm Policy Pract*. (2021) 14:38. doi: 10.1186/s40545-021-00320-z
53. Stepaniak U, Micek A, Waśkiewicz A, Bielecki W, Drygas W, Janion M, et al. Prevalence of general and abdominal obesity and overweight among adults in Poland. Results of the WOBASZ II study (2013–2014) and comparison with the WOBASZ study (2003-2005). *Pol Arch Med Wewn*. (2016) 126:662–671. doi: 10.20452/pamw.3499
54. Effertz T, Engel S, Verheyen F, Linder R. The costs and consequences of obesity in Germany: a new approach from a prevalence and life-cycle perspective. *Eur J Health Econ*. (2016) 17:1141–58. doi: 10.1007/s10198-015-0751-4
55. Baker C. *Obesity Statistics. House of Commons Library*. (2021). Available online at: https://commonslibrary.parliament.uk/research-briefings/sn03336/ (accessed January 25, 2022).
56. Alfawaz H, Khan N, Alfaifi A, Shahrani FM, Al Tameem HM, Al Otaibi SF, et al. Prevalence of dietary supplement use and associated factors among female college students in Saudi Arabia. *BMC Womens Health*. (2017) 17:e116. doi: 10.1186/s12905-017-0475-y
57. Business Wire. *Global $7.1 Billion Beauty Supplements Market 2016-2024 - Growth Trends, Key Players, Competitive Strategies and Forecasts - Research and Markets*. Available online at: https://www.businesswire.com/news/home/20170621005635/en/Global-7.1-Billion-Beauty-Supplements-Market-2016-2024---Growth-Trends-Key-Players-Competitive-Strategies-and-Forecasts---Research-and-Markets (accessed January 26, 2022).
58. Gardiner P, Graham RE, Legedza ATR, Eisenberg DM, Phillips RS. Factors associated with dietary supplement use among prescription medication users. *Arch Intern Med*. (2006) 166:1968–74. doi: 10.1001/archinte.166.18.1968
59. Izzo AA, Ernst E. Interactions between herbal medicines and prescribed drugs. *Drugs*. (2009) 69:1777–98. doi: 10.2165/11317010-000000000-00000
60. Hall SD, Wang Z, Huang S-M, Hamman MA, Vasavada N, Adigun AQ, et al. The interaction between St John's wort and an oral contraceptive. *Clin Pharmacol Ther*. (2003) 74:525–35. doi: 10.1016/j.clpt.2003.08.009
61. Health. gov. *Physical Activity Guidelines for Americans*. Available online at: https://health.gov/our-work/nutrition-physical-activity/physical-activity-guidelines/previous-guidelines/2008-physical-activity-guidelines (accessed January 26, 2022).
62. Watson NF, Badr MS, Belenky G, Bliwise DL, Buxton OM, Buysse D, et al. Recommended amount of sleep for a healthy adult: a joint consensus statement of the american academy of sleep medicine and sleep research society. *Sleep*. (2015) 38:843–4. doi: 10.5665/sleep.4716
63. Mahdavi-Roshan M, Rezazadeh A, Joukar F, Khorshidi Y, Naghipour M, Mansour-Ghanaei F. Dietary supplements consumption and its association with socioeconomic factors, obesity and main non-communicable chronic diseases in the north of Iran: the PERSIAN Guilan Cohort Study (PGCS). *BMC Nutrition*. (2021) 7:e84. doi: 10.1186/s40795-021-00488-2

64. Peklar J, Henman MC, Richardson K, Kos M, Kenny RA. Food supplement use in the community dwelling population aged 50 and over in the Republic of Ireland. *Complement Ther Med.* (2013) 21:333–41. doi: 10.1016/j.ctim.2013.06.004
65. Radimer K, Bindewald B, Hughes J, Ervin B, Swanson C, Picciano MF. Dietary supplement use by US adults: data from the National Health and Nutrition Examination Survey, 1999–2000. *Am J Epidemiol.* (2004) 160:339–49. doi: 10.1093/aje/kwh207
66. Beitz R, Mensink GBM, Hintzpeter B, Fischer B, Erbersdobler HF. Do users of dietary supplements differ from nonusers in their food consumption? *Eur J Epidemiol.* (2004) 19:335–41. doi: 10.1023/b:ejep.0000024698.76843.3b
67. National Health and Medical Research Council. *Australian Dietary Guidelines Summary*. Available online at: https://www.eatforhealth.gov.au/guidelines (accessed January 27, 2022).
68. Recommended Amount of Legumes. *Grains & Legumes Nutrition Council.* (2013). Available online at: https://www.glnc.org.au/grains/recommended-amounts/legumes-recommendations/ (accessed January 28, 2022).
69. Brown R, Gray AR, Chua MG, Ware L, Chisholm A, Tey SL. Is a handful an effective way to guide nut recommendations? *Int J Environ Res Public Health.* (2021) 18:7812. doi: 10.3390/ijerph18157812
70. The Whole Grains Council. *U.S. Dietary Guidelines and Whole Grains*. Available online at: https://wholegrainscouncil.org/whole-grains-101/how-much-enough/us-dietary-guidelines-and-wg (accessed January 28, 2022).
71. Knowledge for policy. *Food-Based Dietary Guidelines in Europe - Table 10*. Available online at: https://knowledge4policy.ec.europa.eu/health-promotion-knowledge-gateway/food-based-dietary-guidelines-europe-table-10_en (accessed January 28, 2022).
72. Cocking C, Walton J, Kehoe L, Cashman KD, Flynn A. The role of meat in the European diet: current state of knowledge on dietary recommendations, intakes and contribution to energy and nutrient intakes and status. *Nutr Res Rev*. (2020) 33:181–189. doi: 10.1017/S0954422419000295
73. Comerford KB, Miller GD, Boileau AC, Masiello Schuette SN, Giddens JC, Brown KA. Global review of dairy recommendations in food-based dietary guidelines. *Front Nutr*. (2021) 8:e671999. doi: 10.3389/fnut.2021.671999
74. Liu C, Ralston NVC. Seafood and health: what you need to know? *Adv Food Nutr Res.* (2021) 97:275–318. doi: 10.1016/bs.afnr.2021.04.001
75. Piramida-Zdrowego-Zywienia. *Pyramid of Healthy Nutrition and Physical Activity (in Polish)*. Available online at: https://ncez.pzh.gov.pl/dzieci-i-mlodziez/piramida-zdrowego-zywienia-i-stylu-zycia-dzieci-i-mlodziezy-2/ (accessed January 28, 2022).
76. Oberritter H, Schäbethal K, Ruesten A, Boeing H. Nuthetal The DGE nutrition circle - presentation and basis of the food-related recommendations from the German Nutrition Society (DGE). *Ernaehrungs Umschau.* (2013) 60:24–9. doi: 10.4455/eu.2013.004
77. NHS. *How to Eat Well*. Available online at: https://www.nhsinform.scot/healthy-living/preventing-falls/keeping-well/how-to-eat-well (accessed January 28, 2022).

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Developing healthy eating promotion mass media campaigns: A qualitative study

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Background: Involving consumers in the development and assessment of mass media campaigns has been advocated, though research is still lacking. This study aimed to explore opinions and attitudes of citizens, health professionals, communication professionals, and digital influencers regarding the development and implementation of healthy eating promotion mass media campaigns.

Methods: We conducted five semi-structured focus groups, where participants were exposed to the first nationwide mass media campaign promoting healthy eating in Portugal. Through criteria-based purposive sampling, 19 citizens, five health professionals, two communication professionals, and four digital influencers were included. Transcripts were analyzed using Charmaz's line-to-line open coding process.

Results: Main identified themes were: considerations about informative-centered campaigns, health/nutritional issues to address, campaign formulation, target audiences, dissemination channels, and influencers' involvement. Participants favored campaigns focused on practical, transformative, and useful information with simple, innovative, activating, and exciting messages instead of strictly informative campaigns. Health and communication professionals mentioned the importance of adapting the message and dissemination channels to the target audience, addressing the most vulnerable and hard-to-reach individuals, and highlighted the importance of short video format.

Conclusions: Active involvement of the health promotion target audience is crucial for the development and effectiveness of health campaigns. Campaigns need to convey health messages on simple though exciting communication materials, targeted to the most vulnerable subgroups, including deprived, less educated, younger, and older generations.

KEYWORDS

health promotion, feeding behavior, mass media campaigns, public health, qualitative research

Introduction

Dietary risk factors, including low consumption of fruits, vegetables, and legumes, and high consumption of red and processed meats, sugar, and salt, are associated with the development of non-communicable diseases, increasing disability-adjusted life years (DALYs) and mortality. In Portugal, unhealthy eating behaviors were responsible for 7.3% of total DALYs and 11.4% of total deaths in 2019 (1).

Due to the harmful effects of unbalanced diets, improving dietary habits is a clinical and policy priority, at both individual and community levels. Individual-level and health care system-based behavioral change interventions are partly effective (2, 3). However, policy changes at organizational, community, and government levels (in addition to individual-based initiatives) can have a broader, more equitable, and sustainable impact (4). Population-based strategies for healthy eating promotion embrace a media and education domain, including mass media campaigns (4).

Mass media campaigns are being used to increase awareness about different health issues, such as smoking cessation (5), physical activity (6), and healthy eating (7, 8). These interventions may even influence behavior change, as campaigns promoting the use of healthcare services and lifestyle change have been effective in influencing the use of health care interventions (9). Indeed, the World Health Organization recommends campaigns about healthy diets as a strategy to prevent and control non-communicable diseases (10).

In general, to increase the relevance and quality of health care and research, "consumers" involvement is strongly recommended (11, 12). However, little attention has been paid to the potential contributions from diverse groups of stakeholders, such as citizens and health professionals, to the development and evaluation of health campaigns (13), especially regarding healthy eating promotion campaigns. Thus, this study aimed to explore opinions and attitudes of citizens, health professionals, communication professionals, and digital influencers regarding the development of healthy eating promotion mass media campaigns.

Methods

Design

This study followed a qualitative design. Data were collected by semi-structured focus groups (FG). Five FG were conducted: three with citizens, one with health professionals and health communication professionals, and one with digital influencers. The FG aimed to understand the perceptions about health promotion campaigns and how to develop effective healthy eating promotion mass media campaigns while discussing the specific case of the *"Eat Better"* campaign, developed by the Portuguese Directorate General of Health.

The COnsolidated criteria for REporting Qualitative research (COREQ) guidelines were followed (14).

The "*Eat Better*" campaign

The *"Eat Better"* campaign (15) was the first governmental initiative promoting healthy eating at the national level, created and implemented by the National Programme for the Promotion of Healthy Eating, of the Portuguese Directorate-General of Health. Dissemination occurred between November and December 2019. The development, dissemination, and evaluation of the campaign were completely independent, financed by public funds, without the involvement of the food industry and conflicts of interest. The target audience was people living in Portugal aged between 18 and 65 years, with special attention to younger adults as they are at higher risk for low consumption of fruit, vegetables, and legumes, and high consumption of sugary drinks. It was a multi-platform initiative, disseminated on television, radio, social media (through digital influencers), advertising outdoors, public transport, and regional media.

The general aims of the campaign were to: (a) raise awareness of the importance of healthy eating, focusing on health gains from small changes in diet, (b) increase motivation for healthy eating, by demonstrating how easy is to implement small eating changes, and (c) increase competence, by describing how the nutritional recommendations can be achieved, focusing on water, fruits, vegetables, and legumes.

Participants' inclusion criteria and recruitment

A purposive, criteria-based sampling approach was used. The sampling frame included key factors thought to influence people's perceptions and enhance group dynamics; for the FG with citizens, inclusion criteria (aiming heterogeneity) were: gender, age (between 16 to 34 and 54+ years), educational level (higher or no higher education), living in different regions of Portugal (rural and urban settings), and having being exposed or not to the *"Eat Better"* campaign; for the FG with professionals: academic background and professional activity (medical doctors, nutritionists, psychologists, nurses, and professionals working in health communication and mass media campaigns); and for the FG with digital influencers: digital platform presence, health domain (nursing, nutrition), and having or not been involved in the *"Eat Better"* campaign.

For the recruitment process, invitations by e-mail were sent to members of different organized groups of citizens, individuals who had already participated in other FG (for different research projects), and acquaintances to members of the research team. Regarding digital influencers, potential participants (content creators with ≥20 thousand followers, addressing topics related

to healthy eating, physical activity, health, and lifestyle) were identified by searching on different social media platforms and were contacted *via* e-mail. The e-mail contacts included the informed consent form with general information about the topic of the FG (not providing the FG script).

Focus groups description

The five FG were carried out between February and April 2020. Two FG were conducted at the Lisbon School of Medicine campus (with citizens), two at the Portuguese Directorate-General of Health headquarters (with professionals and digital influencers), and one online *via* Zoom® platform (with citizens) due to restrictions related to the COVID-19 pandemic, which allowed participants from different regions of the country to be included. All FG were audio-recorded and the mean discussion time was 92 min.

A total of 30 individuals participated in the FG, including 19 citizens, five health professionals, two communication professionals, and four digital influencers (three nutritionists and one nurse). The number of participants by FG varied between four and seven. The characteristics of citizens are described in Table 1 and of health and communication professionals and digital influencers in Table 2.

The FG were conducted by a moderator, a male health psychologist (MSc) with extensive training in qualitative research, together with a co-moderator (male nutritionist or female health psychologist, varying with the FG). A note-taker (female nutritionists) was always present in the room to capture the main themes discussed, as well as the non-verbal behaviors of the participants. The FG started with a brief presentation of the FG structure and aims. The moderator and co-moderator conducted the FGs according to semi-structured scripts (which differed according to the FG participants and considered previous FG emergent items and dimensions). The final FG scripts can be found in Supplementary Figure S1. The moderator disclosed that any of the elements of the research team involved in the data collection and posterior content analysis were neither involved in the development nor the implementation of the *"Eat Better"* campaign. In each FG, only the participants, the moderator, the co-moderator, and the note taker were present in the room.

To introduce the discussion regarding the "*Eat Better*" campaign, participants were exposed to the promotional materials (video, poster, and social media posts) about 20–30 min after the beginning of the FG.

Data analysis

Audio recordings were fully transcribed by an experienced researcher and writer (with extensive experience in FG transcriptions), according to a pre-defined transcription set of guidelines. The complete set of transcriptions formed the corpus and was read by two researchers independently to get familiar with and identify the main dimensions emerging from the corpus (intuitive reading). For completing the open coding process, the same authors analyzed the transcripts, line by line, using a constant comparison approach (between units of meaning—each participant occurrence—and the complete corpus: Charmaz's open coding process) (16). After this independent coding, the two researchers reached interpretative

TABLE 1 Characteristics of the study participants included in the focus groups with citizens conducted to explore opinions and attitudes regarding the development of healthy eating promotion mass media campaigns.

Focus group	*n*	Age (years), median (range)	School years completed, mean	Female, %	Setting, location
Citizens 1	6	47 (21–63)	17.8	50.0	Face-to-face, Lisbon
Citizens 2	6	31 (16–53)	14.7	50.0	Face-to-face, Lisbon
Citizens 3	7	37 (21–65)	14.3	28.6	Video conference

TABLE 2 Characteristics of the study participants included in the focus groups with health and communication professionals and digital influencers conducted to explore opinions and attitudes regarding the development of healthy eating promotion mass media campaigns.

Focus Group	*n*	Profession	Participant ID	Female, %	Setting, location
Professionals	1	Medical doctor	A	57.1	Face-to-face, Lisbon
	1	Biologist specialized in science communication	B		
	1	Specialist in strategic communication applied to science, culture, and art	C		
	2	Nurses	D, G		
	2	Nutritionists	E, F		
Influencers	3	Nutritionists	A, C, D	100.0	Face-to-face, Lisbon
	1	Nurse	B		

consensus (triangulating also with the FG moderator) and built up the code system (available in the Supplementary Material). Subsequently, the codes were grouped into themes and subthemes, according to the similarity between the identified codes (axial coding), using the constant comparison method. The relationships between themes were reviewed, by re-reading the transcripts already analyzed, to compare and develop new dimensions, from a hermeneutic perspective. Finally, the relationships between themes and subthemes were examined to define the central theme of the study and, in turn, to elaborate a conceptual framework (conceptual coding). The codes and themes that emerged were reviewed by the FG moderator and one of the co-moderators, ensuring triangulation in data interpretation. The analysis was performed in MAXQDA, version 18.0.

After content analysis, participants were contacted again and asked to provide additional feedback on the findings for validating meaning and the researchers' analysis and interpretations.

Human participant compliance statement

The study protocol was reviewed and approved by the Ethical Committee of the Lisbon Academic Medical Centre and the study was conducted according to the principles of the Declaration of Helsinki (17). Before the FG, all participants were informed that the sessions would be recorded for later transcription and that the data analysis would be carried out in a grouped manner, maintaining anonymity. All participants were asked to read and sign informed consent forms. Commuting costs were covered with a 10€ gift card delivered to each participant.

Results

During the FG, health mass media campaigns and healthy eating promotion campaigns were discussed. The main themes derived from the data are described below. Table 3 shows some of the supporting *verbatim* related to each main theme and the full list is presented in Supplementary Table S2.

Considerations about informative-centered campaigns

Some participants perceived most health mass media campaigns as impersonal and uninteresting. Campaigns were recognized, typically, as an ineffective strategy to promote behavioral changes, as they were considered a mere information vehicle, lacking narratives evoking emotions.

TABLE 3 Supporting verbatim exemplifying the six main themes emerging from the narratives of the focus groups conducted with citizens, health and communication professionals, and digital influencers to explore opinions and attitudes regarding the development of healthy eating promotion mass media campaigns.

Main theme	Supporting verbatim
Informative campaigns	"If we are thinking about informative campaigns... mass media, right?..., if this is where we are focusing on... (…) these actions should be combined with other punctual interventions (…) of more proximity..." [Professionals FG, E; Line/s 252 - 256]
Health/nutritional issues to address	"Making things maybe less…, that people like less…, into something pleasant to the palate and the sight, (…) And to associate with good experiences" [Professionals FG, G; Line/s 1119 - 1122]
Campaign formulation	"What the brand has to say, or the project has to say must be relevant, it has to be exciting, it has to be clear, true, and original. (…) The quality of the insight is measured by these five elements." [FG professionals, C; Line/s 1134 - 1161]
	"There's another level that is relevance by identification, which is where the influencers come in… It is the relevance that is like: ≪Eh, if Cristiano Ronaldo wears, I also want to wear≫. This is relevance by identification. And the other is relevance by improvement. That is ≪What you are saying to me will improve my life≫. What you told me today, I will implement it right away [?] at breakfast…" [FG professionals, C; Line/s 1136-1140]
	"But this is important (…) to simplify the message. This is... I think it is super-important to have an effect. (...) focusing only on one behavior rather than trying to change everything simultaneously." [Professionals FG, F; Line/s 243 - 247]
Targeted audiences	"Children will be the vehicle for that information, and it focuses on behavioral change that carries the message to families and, in some way, is a source of contagion." [FG professionals, E; Line/s 115 - 117]
Dissemination channels	"I think that television [to reach less urbanized areas] continues to make a lot of sense." [Citizens FG3, A; Line/s 842 - 842]
Influencers' involvement	"People identify with us; people see themselves in our place and that is what makes them follow our work. Of course (…), we take this to promote health and well-being... But that's it..., that is why people identify with us, people... ≪I've also been in this position where she's talking... I also do what she does... So, I also want to eat what she eats≫" [Influencers FG, C; Line/s 376 - 381]

FG, focus group.

To overcome this issue, one health professional suggested that campaigns should be complemented with proximity interventions (e.g., initiatives in which health professionals, as well as public figures, from sports or science, would work out the key messages of the campaigns together with citizens). Notwithstanding, nutritional (informative content-based) literacy was understood as an essential element for healthy eating choices, even though personalized information about food habits (suited to target audiences) was deemed essential, due to interindividual differences.

Health/nutritional issues to address

In all FG, participants identified barriers to healthy eating, such as the unpleasantness associated with some healthy foods and the emotional connection that influences food choices and often compromises the adherence to a healthy food pattern.

Participants suggested that healthy eating campaigns should aim to modify the perception of what is (un)pleasant, for example, by providing recipes that do not sacrifice the taste or pleasure associated with food. In parallel, the focus on emotions and feelings associated with healthy eating behaviors was also proposed as a key point to promote changes.

Campaign formulation

In the FG with health and communication professionals, it was highlighted that health campaigns need to communicate a central message—a message that creates the need to adopt a different behavior. This message should convey an insight that is based on at least four out of five key elements: relevance of the message (to the target audience), truthiness, simplicity, originality, and excitement.

It was referred that the message can be made relevant by identification or perceived improvement. The first can be present when public figures/influencers are involved in the campaign (which was advocated in all FG). It exists when the audience identifies themselves with the public figures (participating in the campaign) that they consciously or unconsciously want to follow (or even be like). For this to happen successfully, the message should absorb the acclaimed characteristics of the public figure, so that the relationship between both parties is more easily recognized and remembered. The second is present when the target public identifies a clear benefit associated with the transmitted message and recognizes that the promoted behavior can be implemented in their lives.

The insight's key element of truthiness entails interpreting statistics and facts to turn them into compelling and emotional insights that are effective at promoting behavior change, instead of just presenting them.

To clearly transmit the campaign's message, it should be simple to interpret and practical. Whenever possible, campaigns should challenge the public with concrete tasks/behaviors, and eating behavior changes ought to be addressed in a phased manner, to avoid the feeling of being overwhelmed. Campaigns should present new information to increase interest and excitement. The message also needs to be adapted to the target population, which implies a segmentation of the audience according to their values and interests.

When discussing communication formats, the use of storytelling videos conveying individuals was perceived to be the most effective approach.

The communication strategy should aim to create an identity over time, making it recognizable by the audience and perceived as trustworthy, which implies regularity and coherence in the messages transmitted.

Targeted audiences

Nutritional literacy promotion was believed to be most effective when targeted to younger audiences, when many habits are more easily formed, also considering the intergenerational influence on behavior (from youngsters to adults). Moreover, it was identified the need for healthy eating campaigns to target less urbanized areas, as participants perceived that these regions are underprovided of nutritional literacy programs.

Dissemination channels

Along with other communication channels (e.g., public transportation, clinic waiting rooms, and university campuses), television was pointed out as an advantageous channel to reach less urbanized areas. However, it was noted that this format is falling into disuse, as the preference and availability for streaming services or internet entertainment are increasing.

Influencers' involvement

Influencers' (e.g., celebrities, digital influencers) involvement was recognized as a valuable element of a health campaign, because of their wider audience reach. Digital influencers' communication channels (social media platforms) were regarded as highly personal, promoting identification and empathy with the source of the information. Nonetheless, digital influencers were also recognized as responsible for the dissemination of "eating trends".

The digital influencers participating in the FG revealed that they welcome partnerships with public health promotion

campaigns if the message conveyed is aligned with their digital influencer professional project. A preference for active partnerships, where the creator is responsible for the materials, instead of just sharing a preformatted message, was also expressed. This was reinforced as essential to the influencers' involvement success, as it is a key determinant for influencers' followers to ascertain the authenticity of the message.

Discussion

Our findings contribute to the understanding of how to develop healthy eating promotion mass media campaigns, from the perspective of citizens, health and communication professionals, and digital influencers.

Across the five FG, it was discussed that mass media health campaigns should be complemented with multi-agent proximity-based initiatives, address barriers to healthy eating, and aim to modify the target audience's perceptions through a message based on relevance, excitement, simplicity, truthiness, and originality. Campaigns targeting younger audiences, investing in dissemination channels that target more difficult-to-reach segments of the population, and involving familiar faces, such as digital influencers, were also highlighted.

Information-centered health mass media campaigns were considered an ineffective strategy to change health behavior. Although mass media health campaigns are expected to have small-to-moderate effects on individuals' health knowledge, attitudes, and behaviors, by reaching large proportions of a target population, it could translate into major population impacts (18). This type of public health strategy has been effective in improving dietary intake (19). Nevertheless, success is mainly observed when the campaign is part of a multicomponent program or comprehensive strategy (20), where health professionals play an essential role.

Indeed, health professionals (from different areas and backgrounds) should be part of the development of healthy eating promotion campaigns, following a participatory approach (11). Besides being involved in complementary actions in different contexts, as mentioned (e.g., in schools), health professionals can help define needs and priorities based on their clinical/field experience/background and develop more practical messages and activities to increase the effectiveness of the behavior change promotion (e.g., by developing recipes as suggested in the FG).

As a general consideration, health policies should promote the development of personal values that guide individuals to the healthiest possible decision-making. For this to happen, the promoted health behaviors have to be considered relevant for the short term, which is even more important for young people [who tend to have less capacity for long-term self-regulation (21)]. This can be achieved if campaigns' messages convey relevance, excitement, simplicity, truthiness, and originality, as mentioned by a communication professional in the FG. It was also stated that messages should be formulated in a simple language and should make the audience feel challenged, to improve engagement.

Participants in this study recognized that adherence to a healthy food pattern is challenging. The main barriers identified were the unpleasantness often associated with healthy foods and the emotional connection that influences food choices. Other barriers have been identified, such as the time needed to prepare healthy food, the perceived cost of healthy eating, and social influences (22). When promoting eating behavior change, it was stressed that a stepped approach is necessary and that the health campaign should create an identity over time, which entails regularity and coherence related to the messages transmitted. In fact, broad and limited-duration health campaigns targeting the adoption of multiple behaviors are not thought to be successful (4). The campaign's identity needs to communicate who the campaign promoter is, what it stands for (regarding values and goals), how it works, and the intended relationship with the subject and the audience; it should also include the perceptions people hold about the issue of the campaign (23), which reinforces the need for formative research to adequately segment the target population before campaign development, identifying the most appropriate communication strategies (24).

Amidst other dissemination channels, television was regarded as advantageous, in particular, to reach less urbanized areas. Television has been considered the most effective media channel to reach most people (13) and the most recalled delivery channel in health campaign assessments (7, 25). One of the main reasons is that television content is consumed passively and easily, implying little effort from the audience to receive the message (13). Additionally, healthy eating has been negatively linked to watching television, meaning that it could effectively reach audiences in need of campaigns promoting healthy eating (26). Regarding difficult-to-reach population strata, and in line with participants' opinions, television is effective in reaching audiences with basic education and lower income, which could be attributed to higher consumption of television (7). These considerations are relevant when aiming to reduce health inequities. Health inequities are caused by a complex set of interrelated factors at the environmental, societal, socioeconomic, individual, and behavioral levels (27). The causes include, but are not limited to, differential exposure to environmental health agents (27) and deliberate efforts to reach underserved populations, namely when defining mass media campaigns dissemination, are necessary.

Nutritional literacy promotion was believed to be more effective when targeted to younger audiences. It has been

recognized by health professionals that social media provides a pivotal opportunity to reach and engage with young adults that may not otherwise seek out health professionals in more traditional settings (28). However, despite its growing popularity, public and non-profit sectors are underusing social media in a way that maximizes their capacity to engage with their followers (29). Social media can act as a platform to deliver and increase exposure to evidence-based key messages of health promotion campaigns and to encourage young adults to participate and engage (30). Young adults are interested in using social media for learning about nutrition-related information and recognize the usefulness of social media channels to learn about recipes and healthy eating (30). In our study, digital influencers were available to be involved in health promotion campaigns if the messages are aligned and tailored to narratives fitting their professional project.

In the present study, we sought out perspectives from different backgrounds and professional occupations that could influence the way that participants would look at the subject under study. Although this study was conducted with a diversified sample of Portuguese participants, the collected perspectives are surely not limited to Portuguese reality. As discussed, many opinions expressed in the FG agree with current literature, highlighting priorities that should be considered when dealing with communities, even outside Portugal. Nevertheless, data saturation may have not been reached due to the relatively small number of FG per type of participant, mainly with health and communication professionals and digital influencers. Additional research is needed to clarify and expand the obtained results. Nonetheless, these findings contribute to the overall knowledge in this field of research and provide valuable and useful information for informing the development of health campaigns. Despite efforts to create a comfortable environment, some opinions and attitudes perceived as rare or unpopular may not have been shared and participants may have expressed the opinions that they thought the researchers wanted to hear and future studies would benefit from a data collection methods triangulation (namely, with individual in-depth interviews).

Conclusion

The involvement of citizens, health and communication professionals, and digital influencers allowed us to understand different and complementary perspectives on how healthy eating promotion campaigns should be developed, regarding goals, messages' content and formulation, means of dissemination, and the usage of social media platforms. Our findings provide relevant insights that should be considered when developing health mass media campaigns. Actively involving the public at the different stages of public health campaigns can be a relevant determinant of success.

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 Ethical Committee of the Lisbon Academic Medical Centre. The patients/participants provided their written informed consent to participate in this study.

Author contributions

OS, RF-S, and AV designed the study and moderated the focus groups. CC and RM analyzed the data and wrote the first draft. All authors reviewed and made valuable contributions to the manuscript.

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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.

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Supplementary material

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References

1. Global Burden of Disease Collaborative Network. *Global Burden of Disease Study 2019 (GBD 2019) Results*. Seattle, WA (2020). Available from: http://ghdx.healthdata.org/gbd-results-tool (accessed September 19, 2020).

2. Artinian NT, Fletcher GF, Mozaffarian D, Kris-Etherton P, Van Horn L, Lichtenstein AH, et al. Interventions to promote physical activity and dietary lifestyle changes for cardiovascular risk factor reduction in adults: a scientific statement from the American Heart Association. *Circulation.* (2010) 122:406–41. doi: 10.1161/CIR.0b013e3181e8edf1

3. Spring B, Ockene JK, Gidding SS, Mozaffarian D, Moore S, Rosal MC, et al. Better population health through behavior change in adults: a call to action. *Circulation.* (2013) 128:2169–76. doi: 10.1161/01.cir.0000435173.25936.e1

4. Mozaffarian D, Afshin A, Benowitz NL, Bittner V, Daniels SR, Franch HA, et al. Population approaches to improve diet, physical activity, and smoking habits: a scientific statement from the American Heart Association. *Circulation.* (2012) 126:1514–63. doi: 10.1161/CIR.0b013e318260a20b

5. Bala MM, Strzeszynski L, Topor-Madry R. Mass media interventions for smoking cessation in adults. *Cochr Database Syst Rev*. (2017) 2017:CD004704. doi: 10.1002/14651858.CD004704.pub4

6. Yun L, Ori EM, Lee Y, Sivak A, Berry TR. A systematic review of community-wide media physical activity campaigns: an update from 2010. *J Phys Act Heal.* (2017) 14:552–70. doi: 10.1123/jpah.2016-0616

7. Fernandez MA, Desroches S, Marquis M, Lebel A, Turcotte M, Provencher V. Promoting meal planning through mass media: awareness of a nutrition campaign among Canadian parents. *Public Health Nutr.* (2019) 22:3349–59. doi: 10.1017/S1368980019002957

8. Morley B, Niven P, Dixon H, Swanson M, Szybiak M, Shilton T, et al. Population-based evaluation of the "LiveLighter" healthy weight and lifestyle mass media campaign. *Health Educ Res.* (2016) 31:121–35. doi: 10.1093/her/cyw009

9. Grilli R, Ramsay C, Minozzi S. Mass media interventions: effects on health services utilisation. *Cochrane Database Syst Rev*. (2002) 2002:CD000389. doi: 10.1002/14651858.CD000389

10. World Health Organization. *Tackling NCDs: "Best Buys" and Other Recommended Interventions for the Prevention and Control of Noncommunicable Diseases*. Geneva (2017).

11. Stock C, Dias S, Dietrich T, Frahsa A, Keygnaert I. Editorial: how can we co-create solutions in health promotion with users and stakeholders? *Front Public Heal.* (2021) 9:773907. doi: 10.3389/fpubh.2021.773907

12. Bastian H. Speaking up for ourselves: the evolution of consumer advocacy in health care. *Int J Technol Assess Health Care.* (1998) 14:3–23. doi: 10.1017/S0266462300010485

13. Barker KL, Minns Lowe CJ, Reid M. The development and use of mass media interventions for health-care messages about back pain: what do members of the public think? *Man Ther.* (2007) 12:335–41. doi: 10.1016/j.math.2006.07.010

14. Tong A, Sainsbury P, Craig J. Consolidated criteria for reporting qualitative research (COREQ): a 32-item checklist for interviews and focus groups. *Int J Qual Heal Care.* (2007) 19:349–57. doi: 10.1093/intqhc/mzm042

15. PNPAS. *Campanha para a promoção da alimentação saudável "Comer melhor, uma receita para a vida"*. Direção-Geral da Saúde (2019). Available from: https://nutrimento.pt/noticias/campanha-para-a-promocao-da-alimentacao-saudavel/ (accessed July 8, 2022).

16. Charmaz K. *Constructing Grounded Theory: A Practical Guide Through Qualitative Analysis*. London: SAGE (2006).

17. World Medical Association. World Medical Association Declaration of Helsinki: Ethical Principles for Medical Research Involving Human Subjects. *JAMA*. (2013) 310:2191–4. doi: 10.1001/jama.2013.281053

18. Wakefield MA, Loken B, Hornik RC. Use of mass media campaigns to change health behaviour. *Lancet.* (2010) 376:1261–71. doi: 10.1016/S0140-6736(10)60809-4

19. Afshin A, Penalvo J, Del Gobbo L, Kashaf M, Micha R, Morrish K, et al. CVD prevention through policy: a review of mass media, food/menu labeling, taxation/subsidies, built environment, school procurement, worksite wellness, and marketing standards to improve diet. *Curr Cardiol Rep*. (2015) 17:98. doi: 10.1007/s11886-015-0658-9

20. Torok M, Calear A, Shand F, Christensen H. A systematic review of mass media campaigns for suicide prevention: understanding their efficacy and the mechanisms needed for successful behavioral and literacy change. *Suicide Life Threat Behav.* (2017) 47:672–87. doi: 10.1111/sltb.12324

21. Moilanen KL, Padilla-Walker LM, Blaacker DR. Dimensions of short-term and long-term self-regulation in adolescence: associations with maternal and paternal parenting and parent-child relationship quality. *J Youth Adolesc.* (2018) 47:1409–26. doi: 10.1007/s10964-018-0825-6

22. Dale R, Hanbury A. A simple methodology for piloting and evaluating mass media interventions: an exploratory study. *Psychol Heal Med.* (2010) 15:231–42. doi: 10.1080/13548501003623971

23. Health Communication Unit. *Overview of Health Communication Campaigns*. Toronto (2007).

24. Rootman I, Goodstadt M, Hyndman B, McQueen D, Potvin L, Springett J, et al. *Evaluation in Health Promotion. Principles and Perspectives*. Copenhagen: World Health Organization Regional Office for Europe (2001).

25. Wardle J, Rapoport L, Miles A, Afuape T, Duman M. Mass education for obesity prevention: the penetration of the BBC's "Fighting Fat, Fighting Fit" campaign. *Health Educ Res.* (2001) 16:343–55. doi: 10.1093/her/16.3.343

26. Dutta-Bergman MJ. Reaching unhealthy eaters: applying a strategic approach to media vehicle choice. *Health Commun.* (2004) 16:493–506. doi: 10.1207/s15327027hc1604_6

27. Hagger MS, Cameron LD, Hamilton K, Hankonen N, Lintunen T. The *Handbook of Behaviour Change*. Cambridge: Cambridge University Press (2020).

28. Balatsoukas P, Kennedy CM, Buchan I, Powell J, Ainsworth J. The role of social network technologies in online health promotion: a narrative review of theoretical and empirical factors influencing intervention effectiveness. *J Med Internet Res.* (2015) 17:e141. doi: 10.2196/jmir.3662

29. Neiger BL, Thackeray R, Burton SH, Giraud-Carrier CG, Fagen MC. Evaluating social media's capacity to develop engaged audiences in health promotion settings: use of twitter metrics as a case study. *Health Promot Pract.* (2013) 14:157–62. doi: 10.1177/1524839912469378

30. Klassen KM, Douglass CH, Brennan L, Truby H, Lim MSC. Social media use for nutrition outcomes in young adults: a mixed-methods systematic review. *Int J Behav Nutr Phys Act.* (2018) 15:70. doi: 10.1186/s12966-018-0696-y

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Lifestyle habits among Najran University students, Najran, Saudi Arabia

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Background: Unhealthy lifestyles have been linked to increased cardiovascular disease, diabetes, and other non-communicable diseases. University students have been reported to adopt unhealthy lifestyles and undesirable eating choices.

Objectives: The study aimed to estimate the prevalence of healthy eating habits; determine the prevalence of physical activity habits; to estimate the smoking habits among male health sciences college students at Najran University, Najran, Saudi Arabia.

Methods: The present questionnaire-based descriptive cross-sectional study (convenient sample) was carried out among undergraduate male students enrolled in the health sciences colleges at Najran University, Najran, Saudi Arabia, from 1st May to 31st May, 2019. Around 500 students were recruited and were requested to answer a self-administered questionnaire about eating habits, physical activity, and tobacco smoking habits. Descriptive results were summarized in percentage and frequency. Cross tabulation using chi-square test was performed to measure the impact of demographic variable on eating pattern, physical activity and smoking behavior. Pearson's correlation was done using two tailed tests to determine the type of relationship between different variables. The SPSS (version 26) was used to perform statistical analysis.

Results: A total of 454 complete responses from the male students from Najran University were obtained. The majority (74%) were aged 21 years and above, unmarried (94.9%), had healthy BMI (47.4%), and suffered mild (41.4%) to moderate (32.4%) levels of stress during the previous month. The study findings showed a low daily frequency of consumption of vegetables and fruits. There was a low prevalence of daily consumption of vegetables (16%) and fruits (9%). More than 10% of all students reported no consumption of fruits and vegetables. Students who felt severely stressed during the previous month were significantly not eating any vegetables ($p = 0.022$) and fruits ($p < 0.001$), and had high salt intake ($p = 0.045$). Married participants had a significantly ($p = 0.03$) higher servings of vegetables per day. Furthermore, 32.15% of participants were not practicing 30 min of physical activity 5 days per week. The study showed a low prevalence (47.57%) of physical activity among the participants. However, none of the participants' variables were significantly associated with routine physical activity. In addition, the study showed a relatively high prevalence of smoking (25.77%) among Najran university male students. The participants' age (p 0.01), overall health ($p = 0.02$) and level of stress ($p = 0.001$) experienced during the last month were significantly associated with

the length of exposure to secondhand smoke. Whereas, smoking any kind of tobacco daily (25.77%) was significantly ($p = 0.005$) related to the age of participants. A high number of participants aged 21 years and above (52.72%) were significantly ($p = 0.019$) exposed to secondhand smoke.

Conclusion: To conclude, the study findings showed a low daily frequency of consumption of vegetables and fruits, a relatively high prevalence of smoking and a low level of awareness regarding the health risks of smoking; and a large number of participants were physically inactive among male university students. Intervention programs in university students should concentrate on improving nutrition attitudes and knowledge toward good diet, tobacco-smoking cessation strategies, and structured intervention programs to encourage physical activity. However, these interventions should be pilot-tested for feasibility and acceptability before implementation.

KEYWORDS

university students, dietary habits, smoking behaviors, physical activity, Saudi Arabia

Introduction

In light of significant lifestyle changes, young individuals are prepared to negatively modify their eating habits regarding diversity, consumption of fruits and vegetables, and frequency and timing of intake. University years are a crucial period that can influence both the quality of lifestyle and food habits of subsequent adults and, in the long run, the health of individuals. A student's health can significantly impact high school and college academic performance. As a result, increasing the health and wellbeing of all students and faculty at a university or college requires supporting healthy eating habits and lifestyle behaviors (1–4). Overweight and obesity are common in Saudi Arabia, with prevalence rates as high as 37 and 41%, respectively. As a result, there has been an increase in nutrition-related health issues and other linked disorders because of a significant shift in dietary intake, lower physical activity levels, and a hastened nutrition transition. The Western-style diet, with its high consumption of calorie-dense foods, fats and sugars, and low fiber intake, has replaced the traditional healthy balanced diet, which included dates, milk, vegetables, fruits, fish, and whole wheat grains. Obesity is rising, especially in Saudi Arabia, because of a sedentary lifestyle and cheap and readily available junk food. These factors and dietary shifts have contributed to the problem (5).

Obesity is not just a problem for adults but also a concern for children and adolescents. Obesity and adult diseases are more likely to occur in those who are overweight or obese as children or teenagers. Obesity is most commonly seen in childhood, but university students also experience a vital period in which their behaviors are receptive to change, often increasing weight. Overweight and obese students comprise 72 of the 240 clinical students at Malaysia's International Medical University clinical students (6).

Previous research in Saudi Arabia found that university students have adopted a sedentary lifestyle, a cigarette-smoking behavior, and other unhealthy eating habits (7–9).

Students at universities make up a sizable proportion of the young adult population (10). They tend to enter an evolving transition phase of new liberation from their families, which is characterized by increased, interconnected effects on the body, mind, and social relationships (11) and discover a new atmosphere with more significant work overload, as well as altered life patterns, all of which contribute to unhealthy lifestyles. The short-term benefits of a balanced diet can boost a student's energy levels, support a healthy immune system, enhance stress management skills, and improve concentration and academic performance. The advantages of maintaining a regularly healthy diet really pile up over the course of one's life. Cancer, arthritis, memory loss, dementia, and macular degeneration are less likely to happen. There is a lower risk of developing diabetes, heart attacks, blood clots, falls and fractures, obtaining diabetes, and nutritional deficiencies that would otherwise get harder to manage as one ages. In comparison to others who have had a less healthier diet, people with a healthy diet pattern are likely to live longer, be happier, and be more active (12). A healthy eating strategy that includes more plant-based foods appears to be essential in preventing long-term diseases such as cancer, CVD, diabetes, stroke, cataracts, Alzheimer's disease, and age-related function loss (13, 14). This indicates that diet and lifestyle changes, such as boosting vegetable and fruit consumption and ensuring a much more balanced consumption of plant foods and meat, are a viable and effective strategy for reducing chronic disease incidence in the general population, especially among young students.

Physical inactivity has increased risk of cardiovascular disease, cancer, obesity, and other illnesses (15, 16). Physical activity has been shown to have numerous health benefits. Physical activity is essential to many countries' health promotion plans and international initiatives aimed at both developed and developing countries (17, 18). Previous surveys have found that adequate physical activity is comparatively higher in children and teenagers (19, 20), but considerably lower in adults, suggesting that late adolescence and early adulthood may be a critical transitional phase (21, 22). As a result, it's critical to track young adults' physical activity trends and understand characteristics like attitudes and health advantages linked to physical activity levels.

Furthermore, research indicates that students, preteens, and teenagers increasingly use many media sites and platforms. People spending more screen time are significantly associated with obesity, lesser physical activity, and health issues (23).

Smoking is a primary behavioral public health concern that affects people worldwide. It has a high yearly mortality rate, with many millions of deaths recorded yearly, and it is expected to reach ten million by 2030 (24). Like other Middle Eastern countries, Saudi Arabia is not immune to this practice, and smoking is widespread among the Saudi people. Saudi Arabia ranked eighth in an international list of countries based on their smoking prevalence (25). The number of studies on Saudi smoking behavior is limited. There is a pressing need to learn more about this phenomenon in a typical Muslim country where most residents/citizens are Muslim, and Islam forbids smoking.

Since 2005, Saudi Arabia has been a signatory to the Framework Convention on Tobacco Control (FCTC) initiative of the World Health Organization, with strict prohibitions on all forms of tobacco advertising in the national media (26). Other measures, such as prohibiting cigarette companies from sponsoring sporting events and raising tobacco taxes, were also implemented (27).

Smoking is prohibited in the kingdom's workplaces, governmental institutions, public transportation, cultural institutions, and banks (28). There are no research results available in Saudi Arabia that illustrate the legal measures' influence on the Saudi people's smoking behavior. The existing smoking research results were based on descriptive studies that focused on smoking prevalence without any follow-up on smoking practices or an emphasis on quitting (29). The demographic and social situation can significantly influence college students in the kingdom to start smoking. Students are transitioning from a more conservative parental setting with stricter controls to a more open social atmosphere at university. To better restrict the spread of smoking among the Saudi populace, governmental authorities established legislation prohibiting smoking in all public places, including educational institutions.

The Saudi Arabian National Education Policy recognizes the connection between academic achievement and student health. The following are some of its directives: (1) Students should begin school with the healthy psychological, physical, and mental alertness required for learning; (2) A safe and disciplined school environment is required to ensure students' psychological and physical well-being; (3) A chance for all students to learn healthy living skills and receive health education. (4) In the school setting, the student's development and growth "psychosocially, mentally, and physically" should be maintained in conditions similar to those governed by Islamic teachings at home. (5) All students should have access to free health care (both preventative and curative) (30).

Today's students are the future citizens of a nation. As a result, their protection, survival, and development are essential for developing the country's future. National development should prioritize providing knowledge and resources to the younger generation to meet their fundamental imperatives and pursue excellence. Children's health, nutrition, and education are critical for national development because their individual growth and social contributions will shape the country's future and assist in achieving the Saudi Vision-2030's primary goals.

Thus, the objectives of this study were as follows: (1) to estimate the prevalence of plant based eating habits (fruits and vegetables); (2) to determine the prevalence of routine physical activity; (3) to estimate the smoking habits among male health sciences students at Najran University, Najran, Saudi Arabia. The findings of this study will aid policymakers in making decisions and encouraging schools to embrace and maintain proper healthcare programs, and addressing problems that may occur during the implementation of education and health programs at the national and regional levels.

Methodology

Study design and participants

The present questionnaire-based descriptive cross-sectional study was carried out among undergraduate male students enrolled in the health sciences colleges at Najran University, Najran, Saudi Arabia, from 1st May to 31st May, 2019. Male students who were free of diet-related health problems, did not follow any special diet, and consumed the usual mixed diet were included. Students from other universities, graduated and students from non-health sciences programs were excluded from the participation. Study purpose and informed consent were obtained from all participants before filling of paper-based questionnaires. Participation in this study was completely voluntary. The study was approved by the ethical committee of Najran University (NU/2019/12/3).

Sample size and sampling technique

A total of 500 male students (Approx.) are enrolled in the health sciences colleges in Najran University. Sample size was

calculated using Raosoft sample size (http://www.raosoft.com/samplesize.html) calculator by presuming a 95% confidence level, 5% margin of error, and response distribution of 50%, yielding a sample size of 218. We adopted convenience sampling techniques to collect the data. However, to represent the better response rate, and assuming few incomplete and inconsistent responses, the total samples collected were 454.

Study tool and validation

The detailed review of relevant literature was carried out to develop the initial questionnaire draft (31–40). Study tool was validated for its content from experts in the field of community health, dieticians, and pharmacist. Some of the items from questionnaire were removed from the initial draft based on recommendations from these experts. These questionnaires were tested for the face validity among 25 male undergraduate students of Najran University. The reliability of found to be satisfactory upon calculating alpha Cronbach factor (0.76). The final questionnaires were categorized into following sections: section one noted participants' demographic details such as age, marital status, BMI, presence of chronic disease, perceived level of stress experienced in last month (No, mild, moderate and severe) and self-declared overall health status. We collected the Height (cm) and weight (kg) from students to calculate the BMI. The BMI was categorized to underweight (<18.5), healthy (18.5 to <25), overweight (25.0 to <30) and obese (30.0 or higher) using BMI index chart from CDC (The Centers for Disease Control and Prevention). Second section was designed to record the pattern (Do you eat fruits daily) and frequency (how many pieces of fruits you eat per day) of consumption of vegetables, fruits and addition of salt to regular food among study participants. Third section explored the engagement of students in routine physical activity of 30 mins or above at least 5 days per week, followed by perception about benefits of performing routine physical activity and factor preventing them from exercising. The last section noted students smoking pattern (do you smoke daily), exposure to secondhand smoke, diseases caused by active and passive smoking and opinion about harmful effects of smoking.

Data collection

The paper-based questionnaire was distributed to all the participants at the entrance of university campus. The study purpose, eligibility criteria was briefed to every participant. Students were ensured about the confidentiality of their identity. A designated area with sitting arrangement and writing material was arranged for the participants to complete the questionnaire without any disturbances. Participants were encouraged to complete all the items of survey. The liker scale (Strongly agree to strongly disagree) was used to explore the students perception about benefits of daily routine exercise. Awareness about negative impact of active and passive smoking was documented using yes, no and don't options.

Statistical analysis

All the collected responses were checked for their completeness and consistency. Pilot study, incomplete and repeat responses were excluded from the final data analysis. Then responses were entered into Microsoft excel sheets and coded before subjecting them for analysis. The SPSS (version 26) was used to perform statistical analysis. Results were summarized in percentage, frequency, tabular and graphical forms. Cross tabulation using chi-square test was performed to measure the impact of demographic variable on eating pattern, physical activity and smoking behavior. Pearson's correlation was executed (using two tailed p value tests at a significance of <0.05 and 0.01) to determine the type of relationship between addition of salt to regular meal, physical activity, smoking of tobacco with opinions about harmful effects of smoking.

Results

Participants' details

A total of 454 male students from Najran University participated in this study. Majority (74%) of respondents were aged 21 years and above, unmarried (94.9%), having healthy BMI (47.4%). More than half of students have suffered mild (41.4%) to moderate (32.4%) level of stress during last month. About half of students have self-reported their overall health condition as good (21.8%) and very good (38.1%) as depicted in Table 1.

Vegetable, fruits eating pattern and adding salt to food among male students of Najran University

Addition of salt, consumption of vegetables and fruits weekly was not significantly associated with the participants' age, marital status, BMI, presence of chronic disease and self-declared overall health status. However, the stress felt during the last month had significantly affected addition of salt to food ($p = 0.045$), vegetable consumption per week ($p = 0.022$) and fruits consumption per week ($p < 0.001$). The participants with severe (76.2%) and moderate (69.4%) stress have significantly added salt to their food always compared to participants with no or mild stress. Similarly, consumption of vegetables and fruits was significantly low among participants who felt stressed during last

TABLE 1 Socio-demographic characteristics of the study participants ($n = 454$).

Demographic variables		Frequency	Percentage (%)
Age	20 years and below	118	26.0
	21 years and above	336	74.0
Marital Status	Single	431	94.9
	Married	22	4.8
	Divorced/separated	1	0.2
BMI	Underweight	47	10.4
	Healthy	215	47.4
	Overweight	115	25.3
	Obese	77	17.0
Do you suffer from chronic disease	Yes	61	13.4
	No	393	86.6
Did you feel stressed last month (Percieved level of stress)?	No	77	17.0
	Mild	188	41.4
	Moderate	147	32.4
	Severe	42	9.3
How to you rate your overall health	Very bad	7	1.5
	Bad	28	6.2
	Average	89	19.6
	Good	99	21.8
	Very good	173	38.1
	Excellent	58	12.8

month. About 21.4 and 23.8% of participants who felt severely stressed during last month were significantly not eating any vegetables and fruits respectively compared to the students who were not stressed and mildly stressed (Table 2).

Pattern of consumption of fruits and vegetables per day among male students of Najran University

In this section, we evaluated the student's pattern and frequency of consumption of vegetables and fruits per day. Eating pattern of fruits and vegetables was not significantly associated with any of the participants' variable except level of stress felt during last month. Participants who experienced severe stress in last month were significantly ($p = 0.002$) higher (31%) in not eating any fruit pieces per day compared to the ones who didn't experience ay stress or felt mild stress (Table 3).

Engagement of daily 30 mins' physical activity among male students of Najran University

This section evaluated the duration of student's engagement in performing routine physical activity of 30 mins or above for at least 5 days a week. We observed that nearly half of students (47.5%) were performing daily 30 mins physical activity. None of the participants' variables were significantly associated with routine physical activity. However, overweight students were non-significantly higher (31%) in performing routine physical activity of 30 mins per day for since more than 6 months compared to underweight, healthy ad obese students. Likewise, students who were planning to start routine physical activity were higher number (26%) from obese category. Students who felt severely stressed ding last month, were non-significant higher (14.3%) in not performing any physical activity compared to their counterparts (Table 4).

Perception about the benefits of performing 30 mins of regular physical activity or exercise for 5 days/week

This domain assessed the student's perception about the benefits of performing routine physical activity. More than 80% of students believe (strongly agree and agree) that performing 30 mins of regular physical activity or exercise for 5 days/week, would improve health and protect from diseases (87.7%), improve physical fitness (87.7%), develop body muscles (82.1%) and helps in doing better job (80.6%). Impact of physical activity on psychological health was noted using two statements. About 77.5% and 68.7% of students believe (strongly agree and agree) that performing routine physical activity of 30 mins will make the person feel less stressed and depressed respectively. However, 8.5% of students disagree that routine physical activity was not impact on losing body weight (Figure 1).

Factors preventing exercising among students

Students mentioned some of the important factors which discourage them from performing routine physical activity or exercise. Nearly, half of students (46.03%) of students stated weak health as most common discouraging factor, followed by lack of interest and entertainment (21.36%), busy with social and family life (20.92%) and feeling of tiredness (15.63%). The other (work requirement, fear of harm, obese and pain) reasons preventing from regular exercise accounted for 15.52%. The least

TABLE 2 Vegetable, fruits eating pattern and adding salt to food among male students of Najran University.

Demographic variables		Do you add salt to your food				Usually how many days a week do you eat vegetables					Usually how many days a week do you eat fruits				
		Always	Sometimes	No	*p* value	No	1–3 days	4–6 days	Everyday	*p* value	No	1–3 days	4–6 days	Everyday	*p* value
Age	20 years and below	88 (74.6%)	26 (22%)	4 (3.4%)	0.115	15 (12.7%)	55 (46.6%)	33 (28%)	15 (12.7%)	0.581	11 (9.3)	67 (56.8%)	27 (22.9%)	13 (11%)	0.520
	21 years and above	217 (64.6%)	108 (32.1%)	11 (3.3%)		33 (9.8%)	158 (47%)	87 (25.9%)	58 (17.3%)		35 (10.4%)	176 (52.4%)	97 (28.9%)	28 (8.3%)	
Marital status	Single	287 (66.6%)	131 (30.4%)	13 (3%)	0.270	46 (10.7%)	201 (46.6%)	117 (27.1%)	67 (15.5%)	0.563	44 (10.2%)	228 (52.9%)	120 (27.8%)	39 (9%)	0.867
	Married	17 (77.3%)	3 (13.6%)	2 (9.1%)		2 (9.1%)	11 (50%)	3 (13.6%)	6 (27.2%)		2 (9.1%)	14 (63.6%)	4 (18.2%)	2 (9.1%)	
	Divorced/separated	1 (100%)	Zero	Zero		Zero	1 (100%)	Zero	Zero		Zero	1 (100%)	Zero	Zero	
BMI	Underweight	30 (63.8%)	15 (31.9%)	2 (4.3%)	0.747	5 (10.6%)	21 (447%)	12 (25.5%)	9 (19.1%)	0.978	2 (4.3%)	31 (66%)	11 (23.4%)	3 (6.4%)	0.100
	Healthy	147 (68.4%)	61 (28.4%)	7 (3.3%)		23 (10.7%)	102 (47.4%)	56 (26.1%)	34 (15.8%)		20 (9.3)	114 (53%)	58 (27%)	23 (10.7%)	
	Overweight	72 (62.6%)	40 (34.8%)	3 (2.6%)		11 (9.6%)	58 (50.4%)	31 (27%)	15 (13%)		16 (13.9%)	55(47.8%)	39 (33.9%)	5 (4.4%)	
	Obese	56 (72.7%)	18 (23.4%)	3 (3.9%)		9 (11.7%)	32 (41.6%)	21 (27.3%)	15 (19.5%)		8 (10.4%)	43 (55.8%)	16 (20.8%)	10 (13%)	
Do you suffer from Chronic disease	Yes	41 (67.2%)	19 (31.2%)	1 (1.6%)	0.681	4 (6.6%)	27 (44.3%)	16 (26.2%)	14 (23%)	0.363	4 (6.6%)	34 (55.7%)	13 (21.3%)	10 (16.4%)	0.133
	No	264 (67.2%)	115 (29.3%)	14 (3.6%)		44 (11.2%)	186 (47.3%)	104 (26.5%)	59 (15%)		42 (10.7%)	209 (53.2%)	111 (28.2%)	31 (7.9%)	
Did you feel stressed last month?	No	48 (62.3%)	26 (33.8%)	3 (3.9%)	0.045*	6 (7.8%)	26 (33.8%)	30 (39%)	15 (19.5%)	0.022*	6 (7.8%)	30 (39%)	30 (39%)	11 (14.3%)	<0.001*
	Mild	123 (65.4%)	54 (28.7%)	11 (5.9%)		19 (10.1%)	91 (48.4%)	45 (23.9%)	33 (17.6%)		10 (5.3%)	108 (57.5%)	52 (27.7%)	18 (9.6%)	
	Moderate	102 (69.4%)	44 (29.9%)	1 (0.7%)		14 (9.5%)	80 (54.4%)	36 (24.5%)	17 (11.6%)		20 (13.6%)	88 (59.9%)	32 (21.8%)	7 (4.8%)	
	Severe	32 (76.2%)	10 (23.8%)	Zero		9 (21.4%)	16 (38.1%)	9 (21.4%)	8 (19.1%)		10 (23.8%)	17 (40.5%)	10 (23.8%)	5 (11.9%)	
How to you rate your overall health	Very bad	7 (100%)	Zero	Zero	0.199	4 (57.1%)	3 (42.9%)	Zero	Zero	0.039	2 (28.6%)	2 (28.6%)	3 (42.9%)	Zero	0.144
	Bad	21 (75%)	7 (25%)	Zero		5 (17.9%)	14 (50%)	6 (21.4%)	3 (10.7%)		4 (14.3%)	16 (57.1%)	6 (21.4%)	2 (7.1%)	
	Average	56 (62.9%)	29 (32.6%)	4 (4.5%)		7 (7.9%)	42 (47.2%)	22 (24.7%)	18 (20.2%)		8 (9%)	46 (51.7%)	24 (27%)	11 (12.4%)	
	Good	62 (62.6%)	31 (31.3%)	6 (6.1%)		12 (12.1%)	42 (42.4%)	35 (35.4%)	10 (10.1%)		9 (9.1%)	62 (62.6%)	26 (26.3%)	2 (2%)	
	Very good	117 (67.6%)	53 (30.6%)	3 (1.7%)		15 (8.7%)	81 (46.8%)	46 (26.6%)	31 (17.9%)		19 (11%)	85 (49.1%)	52 (30.1%)	17 (9.8%)	
	Excellent	42 (72.4%)	14 (24.1%)	2 (3.5%)		5 (8.6%)	31 (53.5%)	11 (19%)	11 (19%)		4 (6.9%)	32 (55.2%)	13 (22.4%)	9 (15.5%)	

* p value < 0.05.

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TABLE 3 Pattern of consumption of fruits and vegetables per day among male students of Najran University.

Demographic variables		How many pieces of fruit do you eat per day			*p* value	Usually how many servings of vegetables do you eat per day			*p* value
		Don't eat	1–4 pieces	5 and more pieces		Don't eat	1–4 serving	5 and more serving	
Age	20 years and below	17 (14.4%)	94 (79.7%)	7 (5.9%)	0.751	15 (12.7%)	92 (78%)	11 (9.3%)	0.16
	21 years and above	40 (11.9%)	273 (81.3%)	23 (6.9%)		25 (7.4%)	269 (80.1%)	42 (12.5%)	
Marital status	Single	54 (12.5%)	349 (81%)	28 (6.5%)	0.229	40 (9.3%)	344 (79.8%)	47 (10.9%)	0.03
	Married	3 (13.6%)	18 (81.8%)	1 (4.6%)		Zero	17 (77.3%)	5 (22.7%)	
	Divorced/ separated	Zero	Zero	1 (100%)		Zero	Zero	1(100%)	
BMI	Underweight	6 (12.8%)	39 (83%)	2 (4.3%)	0.620	5 (10.6%)	41 (87.2%)	1 (2.1%)	0.10
	Healthy	21 (9.8%)	178 (82.8%)	16 (7.4%)		16 (7.4%)	177 (82.3%)	22 (10.2%)	
	Overweight	19 (16.5%)	90 (78.3%)	6 (5.2%)		11 (9.6%)	87 (75.7%)	17 (14.8%)	
	Obese	11 (14.3%)	60 (77.9%)	6 (7.8%)		8 (10.4%)	56 (72.7%)	13 (16.9%)	
Do you suffer from chronic disease	Yes	7 (11.5%)	48 (78.7%)	6 (9.8%)	0.544	5 (8.2%)	44 (72.1%)	12 (19.7%)	0.11
	No	50 (12.7%)	319 (81.2%)	24 (6.1%)		35 (8.9%)	317 (80.7%)	41 (10.4%)	
Did you feel stressed last month?	No	8 (10.4%)	63 (81.8%)	6 (7.8%)	0.002*	5 (6.5%)	63 (81.8%)	9 (11.7%)	0.25
	Mild	13 (6.9%)	166 (88.3%)	9 (4.8%)		15 (8%)	150 (79.8%)	23 (12.2%)	
	Moderate	23 (15.7%)	113 (76.9%)	11 (7.5%)		11 (7.5%)	118 (80.3%)	18 (12.2%)	
	Severe	13 (31%)	25 (59.5%)	4 (9.5%)		9 (21.4%)	30 (71.4%)	3 (7.1%)	
How to you rate your overall health	Very bad	2 (28.6%)	4 (57.1%)	1 (14.3%)	0.667	1 (14.3%)	6 (85.7%)	Zero	0.76
	Bad	6 (21.4%)	21 (75%)	1 (3.6%)		4 (14.3%)	22 (78.6%)	2 (7.1%)	
	Average	12 (13.5%)	71 (79.8%)	6 (6.7%)		9 (10.1%)	70 (78.7%)	10 (11.2%)	
	Good	10 (10.1%)	84 (84.9%)	5 (5.1%)		8 (8.1%)	81 (81.8%)	10 (10.1%)	
	Very good	20 (11.6%)	138 (79.8%)	15 (8.7%)		11 (6.4%)	139 (80.4%)	23 (13.3%)	
	Excellent	7 (12.1%)	49 (84.5%)	2 (3.5%)		7 (12.1%)	43 (74.1%)	8 (13.8%)	

*P value < 0.05.

common factor mentioned were shortage of time (7.95%), lack of money (11%) and believing that exercise is hard work (12.77%) (Figure 2).

Tobacco smoking and exposure to secondhand smoke among male students of Najran University

The nature of smoking and exposure to secondhand smoke was noted in this section. The participants' age, overall health and level of stress experienced during last month was significantly associated with the length of exposure to secondhand smoke. Whereas smoking any kind of tobacco on daily basis was significantly related to age of participants. High number of participants aged 21 years and above were significantly ($p = 0.019$) exposed to secondhand smoke. Exposure to secondhand smoke daily for 1–20 mins (11.9%) and 21–60 mins (15.2%) was higher among students aged 21 years and above, which is twice the students aged below 20 years (6.8% and 8.5%). Students aged 21 years and above were significantly ($p = 0.005$) higher (29.2%) in smoking any kind of tobacco compared to younger students (16.1). Moreover, older students were significantly ($p = 0.031$) high (25.9%) in daily smoking compared to their younger counterparts (16.1%). Participants wo experienced severe stress durn last month were significantly ($p < 0.001$) highly exposed to secondhand smoke for 1–20 mins (23.8%) and 21–60 mins (23.8%). Students who

TABLE 4 Engagement into daily 30 mins physical activity 5 days/week among male students of Najran University.

Demographic variables		Duration of daily 30 mins physical activity 5 days/week					*p* value
		Never	Not in last 6 months	I'm planning to involve	Yes, but less than 6 months	Yes, more than 6 months	
Age	20 years and below	9 (7.6%)	35 (29.7%)	23 (19.5%)	33 (28%)	18 (15.3%)	0.52
	21 years and above	29 (8.6%)	73 (21.7%)	69 (20.5%)	103 (30.7%)	62 (18.5%)	
Marital status	Single	36 (8.4%)	103 (23.9%)	86 (20%)	128 (29.7%)	78 (18.1%)	0.84
	Married	2 (9.1%)	5 (22.7%)	6 (27.3%)	7 (31.8%)	2 (9.1%)	
	Divorced/separated	Zero	Zero	Zero	1 (100%)	Zero	
BMI	Underweight	6 (12.8%)	10 (21.3%)	12 (25.5%)	14 (29.8%)	5 (10.6%)	0.10
	Healthy	16 (7.4%)	45 (20.9%)	32 (14.9%)	73 (34%)	49 (22.8%)	
	Overweight	10 (8.7%)	31 (27%)	28 (24.4%)	31 (27%)	15 (31%)	
	Obese	6 (7.8%)	22 (28.6%)	20 (26%)	18 (23.4%)	11 (14.3%)	
Do you suffer from Chronic disease	Yes	8 (13.1%)	14 (23%)	12 (19.7%)	18 (29.5%)	9 (14.8%)	0.68
	No	30 (7.6%)	94 (23.9%)	80 (20.4%)	118 (30%)	71 (18.1%)	
Did you feel stressed last month?	No	7 (9.1%)	23 (29.9%)	12 (15.6%)	21 (27.3%)	14 (18.2%)	0.54
	Mild	14 (7.5%)	37 (19.7%)	35 (18.6%)	66 (35.1%)	36 (19.2%)	
	Moderate	11 (7.5%)	38 (25.9%)	35 (23.8%)	39 (26.5%)	24 (16.3%)	
	Severe	6 (14.3%)	10 (23.8%)	10 (23.8%)	10 (23.8%)	6 (14.3%)	
How to you rate your overall health	Very bad	Zero	5 (71.4%)	Zero	2 (28.6%)	Zero	0.43
	Bad	5 (17.9%)	7 (25%)	5 (17.9%)	8 (28.6%)	3 (10.7%)	
	Average	7 (7.9%)	16 (18%)	21 (23.6%)	27 (30.3%)	18 (20.2%)	
	Good	8 (8.1%)	23 (23.2%)	21 (21.2%)	34 (34.3%)	13 (13.1%)	
	Very good	15 (8.7%)	42 (24.3%)	34 (19.7%)	47 (27.2%)	35 (20.2%)	
	Excellent	3 (5.2%)	15 (25.9%)	11 (19%)	18 (31%)	11 (19%)	

stated their health as very bad (42.9%) and bad (21.4%) were significantly ($p = 0.029$) highly exposed to secondhand smoke for 1–20 and 21–60 mins respectively. Other variables didn't affect the smoking pattern and exposure to secondhand smoke significantly (Table 5).

Student's belief about the diseases caused by active and passive smoking

More than 90% of students believe that active smoking causes lung cancer (94.3%) and heart attack (90.3%) followed by abortion (79.3%) and low birth weight (77.3%) in pregnant females and stroke (72.2%). Whereas, about 61.5% students mentioned active smoking could also lead to cataract. Likewise, participants stated their agreement with the diseases caused by passive smoking. Majority of participants believe that passive smoking causes lung cancer (82.4%) and heart attack (81.7%) in elderly people followed by respiratory distress in children (86.3%) and sudden death in infants (67.4%) as depicted in Figure 3.

Correlation between opinions with smoking, physical activity, and salt addition to food

Bivariate Pearson analysis was performed to find out the correlation and its nature among various variables (Table 6). The analysis revealed significant ($p = 0.039$) positive correlation

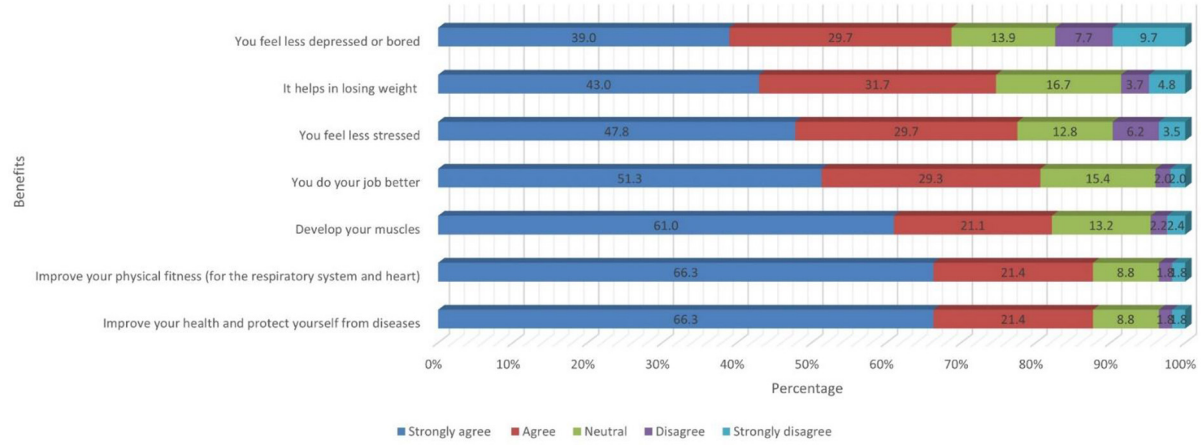

FIGURE 1
Perception about the benefits of performing 30 mins of regular physical activity or exercise for 5 days/week.

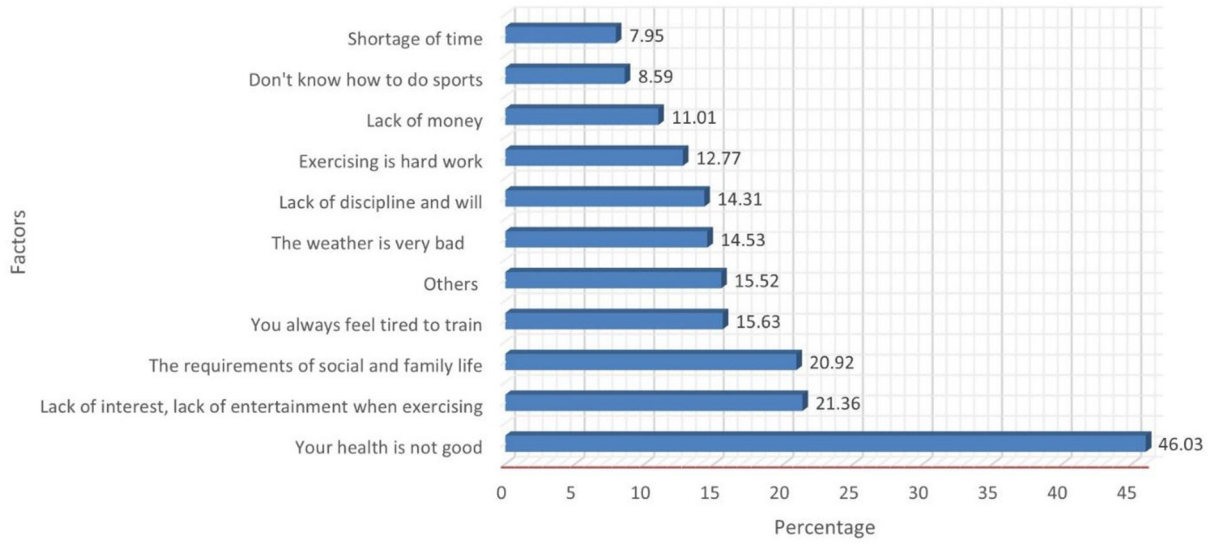

FIGURE 2
Factors preventing from exercising.

(r = 0.097) between addition of salt to food with 30 mins or more of physical activity or exercise 5 days per week, indicating that those who add salt to their food are most likely performing routine physical activity. Likewise, tobacco smoking was significantly positively associated with daily smoking (r = 0.865, $p < 0.001$), opinion 2 (smoking is addictive, r = 0.163, $p < 0.001$) and opinion 3 (smoking shisha is harmful to health, r = 0.133, $p = 0.005$). This indicates that those who smoke any form of tobacco (cigarette, cigar, hookah, pipe) are more likely to smoke daily and agree with the opinion 2 and 3. A significant positive correlation was observed among the opinions. Whereas opinion 1 (light cigarettes are less harmful than regular cigarettes) was non-significantly negatively related to addition of salt to food, routine physical activity, tobacco smoking and daily smoking.

Opinion regarding the harmful effects of smoking

Three statements were used to record the participants' opinion toward harmful effects of smoking. We noted a

TABLE 5 Tobacco smoking and exposure to secondhand smoke among male students of Najran University.

Demographic variables		On a typical day, how long are you exposed to secondhand smoke				*p* value	Currently, do you smoke any type of tobacco		*p* value	Do you currently smoke daily		*p* value
		No	1–20 min	21–60 min	More than 60 min		Yes	No		Yes	No	
Age	20 years and below	94 (79.7%)	8 (6.8%)	10 (8.5%)	6 (5.1%)	0.01*	19 (16.1%)	99 (83.9%)	0.005*	19 (16.1%)	99 (83.9%)	0.03*
	21 years and above	220 (65.5%)	40 (11.9%)	51 (15.2%)	25 (7.4%)		98 (29.2%)	238 (70.8%)		87 (25.9%)	249 (74.1%)	
Marital status	Single	300 (69.6%)	47 (10.9%)	58 (13.5%)	26 (6%)	0.44	108 (25.1%)	323 (74.9%)	0.212	98 (22.7%)	333 (77.3%)	0.28
	Married	13 (59.1%)	1 (4.6%)	3 (13.6%)	5 (22.7%)		9 (40.9%)	13 (59.1%)		8 (36.4%)	14 (63.6%)	
	Divorced/separated	1 (100%)	0	0	0		0	1 (100%)		0	1 (100%)	
BMI	Underweight	31 (66%)	9 (19.2%)	3 (6.4%)	4 (8.5%)	0.24	15 (31.9%)	32 (68.1%)	0.402	12 (25.5%)	35 (74.5%)	0.45
	Healthy	158 (73.5%)	19 (8.8%)	28 (13%)	10 (4.7%)		50 (23.3%)	165 (76.7%)		47 (21.9%)	168 (78.1%)	
	Overweight	79 (68.7%)	10 (8.7%)	15 (13%)	11 (9.6%)		28 (24.4%)	87 (75.7%)		24 (20.9%)	91 (79.1%)	
	Obese	46 (59.7%)	10 (13%)	15 (19.5%)	6 (7.8%)		24 (31.2%)	53 (68.8%)		23 (29.9%)	54 (70.1%)	
Do you suffer from chronic disease	Yes	42 (68.9%)	5 (8.2%)	8 (13.1%)	6 (9.8%)	0.79	15 (24.6%)	46 (75.4%)	0.821	14 (23%)	47 (77.1%)	0.93
	No	272 (69.2%)	43 (10.9%)	53 (13.5%)	24 (6.1%)		102 (26%)	291 (74.1%)		92 (23.4%)	301 (76.6%)	
Did you feel stressed last month?	No	62 (80.5%)	1 (1.3%)	11 (14.3%)	3 (3.9%)	0.001*	15 (19.5%)	62 (80.5%)	0.155	16 (20.8%)	61 (79.2%)	0.69
	Mild	147 (78.2%)	17 (9%)	14 (7.5%)	10 (5.3%)		44 (23.4%)	144 (76.6%)		41 (21.8%)	147 (78.2%)	
	Moderate	87 (59.2%)	20 (13.6%)	26 (17.7%)	14 (9.5%)		43 (29.3%)	104 (70.8%)		37 (25.2%)	110 (74.8%)	
	Severe	18 (42.9%)	10 (23.8%)	10 (23.8%)	4 (9.5%)		15 (35.7%)	27 (64.3%)		12 (28.6%)	30 (71.4%)	
How to you rate your overall health	Very bad	3 (42.9%)	3 (42.9%)	1 (14.3%)	Zero	0.029*	2 (28.6%)	5 (71.4%)	0.887	1 (14.3%)	6 (85.7%)	0.91
	Bad	14 (50%)	5 (17.9%)	6 (21.4%)	3 (10.7%)		9 (32.1%)	19 (67.9%)		8 (28.6%)	20 (71.4%)	
	Average	68 (76.4%)	7 (7.9%)	8 (9%)	6 (6.7%)		23 (25.8%)	66 (74.2%)		21 (23.6%)	68 (76.4%)	
	Good	65 (65.7%)	16 (16.2%)	10 (10.1%)	8 (9.1%)		24 (24.2%)	75 (75.8%)		24 (24.2%)	75 (75.8%)	
	Very good	114 (65.9%)	15 (8.7%)	33 (19.1%)	11 (6.4%)		47 (27.2%)	126 (72.8%)		41 (23.7%)	132 (76.3%)	
	Excellent	50 (86.2%)	2 (3.5%)	3 (5.2%)	3 (5.2%)		12 (20.7%)	46 (79.3%)		11 (19%)	47 (81%)	

* p value < 0.05.

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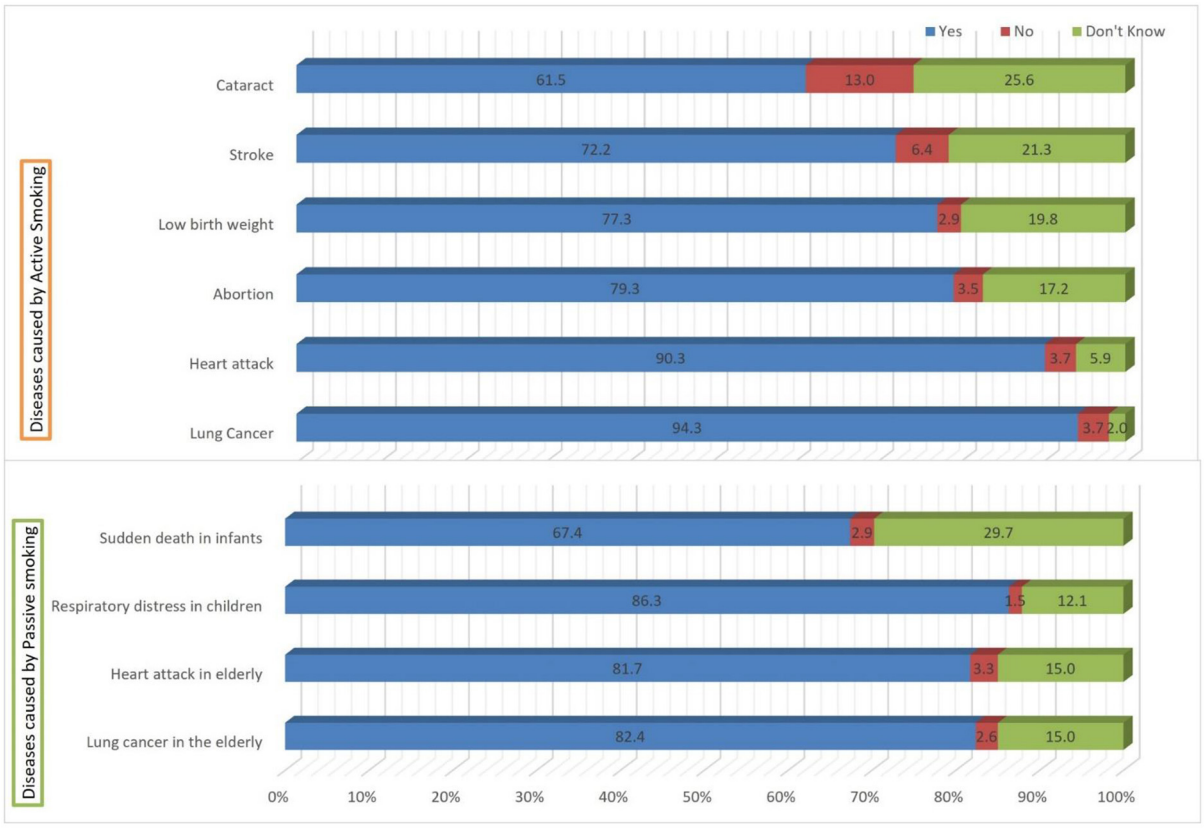

FIGURE 3
Student's belief about the diseases caused by active and passive smoking.

TABLE 6 Pearson correlation between opinions with smoking, physical activity, and salt addition to food.

Variable	Adding salt to food		Physical activity 5 days a week		Smoking tobacco		Daily smoking		Opinion 1		Opinion 2		Opinion 3	
	r	*p* value	r	*p* value	r	*p* value	r	*p* value	r	*p* value	r	*p* value	r	*p* value
Adding salt to food	–	–	0.097*	0.039	0.030	0.521	0.041	0.383	−0.017	0.715	0.037	0.435	0.002	0.973
Physical activity 5 days a week			–	–	0.049	0.302	0.085	0.070	−0.022	0.647	0.007	0.879	0.019	0.688
Smoking tobacco					–	–	0.865**	<0.001	−0.014	0.771	0.163**	<0.001	0.133**	0.005
Daily smoking							–	–	−0.034	0.464	0.159**	0.001	0.130**	0.006
Opinion 1									–	–	0.162**	0.001	0.108*	0.021
Opinion 2											–	–	0.642**	<0.001

r = correlation coefficient.
*Significant correlation at the 0.05 level (2-tailed).
**Significant correlation at the 0.01 level (2-tailed).
Opinion 1: Light cigarettes are less harmful than regular cigarettes.
Opinion 2: Smoking is addictive.
Opinion 3: Smoking shisha is harmful to health.

significant ($p = 0.036$) impact of marital status toward harmful effect of light cigarette compared to regular cigarettes. Unlike unmarried students, married students (40.9%) disagree that "Light cigarettes are less harmful than regular cigarettes." Conversely, more than 80% of students agree that smoking is addictive and smoking shisha is harmful to health. No significant impact of marital status was observed on the addictive nature of smoking and harmful effects of shisha smoking (Table 7). We noted significant ($p = 0.05$) impact of health status on the harmful effect of light cigarette compared to regular cigarettes. About 40% of students with bad health status disagree that "Light cigarettes are less harmful than regular cigarettes," whereas, students with good and excellent health agree with this. No significant impact of health status was noted on addictive nature of smoking and harmful effects of shisha smoking.

Discussion

A healthy lifestyle is incomplete without good eating habits. Vitamin A deficiency, iron deficiency anemia, and excess body weight are just a few of the health problems that young people face that can be avoided with proper nutrition. Eating habits, physical activity and smoking can also have a long-term impact on one's health. Unhealthy eating patterns, such as skipping breakfast and snacking foods high in carbohydrate and fat, are the leading causes of nutritional deficiencies. Heart disease, obesity, atherosclerosis, osteoporosis, and malignancies are all chronic diseases that can be aggravated by poor nutrition (31).

The current study findings showed a low daily frequency consumption of vegetables and fruits. It's varied from 16.07% of daily vegetable consumption to 11.23% of daily fruits consumption. More than 10% of all students reported no consumption of fruits and vegetables. A low prevalence of regular consumption of fruits and vegetables by undergraduates was reported in several studies conducted in various countries (33–38). Only 14% of 863 students in a recent study conducted at the University of Acre in Brazil's northern region consumed fruits and vegetables on a regular basis (38). The prevalence of inadequate fruit and vegetable intake among Turkish college students was 66.1 percent for men and 63.1% for women (36). Greek students' eating habits were also found to be particularly poor in terms of fruit and vegetable consumption, with 68.1% of men and 53.9% of women consuming fiber at levels below international guidelines (36). In addition, the current study revealed that when compared to students who were not stressed or mildly stressed during the previous month, those who were severely stressed did not eat any vegetables or fruits. Thus stress can act as factor which can influence the eating behaviors and negatively impact the students' health. These findings are consistent with the another study conducted in Saudi Arabia by Aljaber et al. (39), who reported that students with high levels of stress eat unhealthier foods than students with low levels of stress. A previous study conducted among Saudi Medical Students at University of Dammam, Saudi Arabia revealed that majority of the students (91.3%) were consuming fast foods, and were aware of the advantages of fruits and vegetables and the drawbacks of soft drinks, but they nevertheless tend to drink more soft drinks and consume less vegetables and fruits. And 65% of the male medical students did not routinely engage in physical activity (9). Similarly, another study conducted among Mutah University students in Jordan revealed a high prevalence of unhealthy eating behaviors with 59% of participants engaged in fast-food consumption $\geq$2 times per week (40).

The results of our study will serve as a basic documentation for regional health authorities and university managers to implement an intervention program to improve healthy eating habits and healthy lifestyle among students at Najran University. The benefits of such kind of nutrition interventions were shown elsewhere. For example, according to a Brazilian study, nutrition education initiatives on fruit and vegetable consumption that combined information and motivation were successful in impoverished environments (41). The actions included spreading awareness about the benefits of eating fruits and vegetables for good health and improving skills for incorporating them into daily eating. It implies that students would benefit from nutritional education programs.

Another important finding of the study showed a relatively high prevalence of smoking 25.77% among Najran university male students. This result was based on the self-reporting of students without any invasive investigation to identify objectively the smoking status. Otherwise, to overcome this limitation more precautions were taken during the study by using anonymous questionnaires and informing the students about the confidentiality of the results.

Similar range of prevalence (37%) were observed in Jeddah, in a study conducted among secondary school male students (42). Palestine (52.7%), Jordan (56.9%), and Egypt (61.2%) had the highest male smoking rates, according to a systemic review conducted in Arab countries (43). A prospective cohort multi-center international study of university students showed a high smoking prevalence among both male (34%) and female (27%) students. The highest prevalence was found in south European countries reaching 44% among male students, a lower prevalence was reported in Western Europe University male students about 31% (44).

Our study also showed a low level of awareness regarding health risks of smoking among Saudi male university students. Similar findings also revealed in another study conducted in Eastern Saudi secondary school adolescents, which showed that the prevalence of current smokers was 21.7% (45). Similarly, a research conducted in Botswana, South Africa, revealed that 10% of students were active tobacco smokers, with 29% of respondents having tried smoking (46). Another study conducted in Jordan revealed that the students started smoking to cope with course and exam stress. Students appreciated the

TABLE 7 Opinion regarding the harmful effects of smoking.

Statement	Opinions	Marital Status			*p* value	How do you rate your overall health (Health status)						*p* value
		Single	Married	Widowed/ Separated		Very bad	Bad	Average	Good	Very good	Excellent	
Light cigarettes are less harmful than regular cigarettes	Strongly agree	134 (31.1%)	2 (9.1%)	1 (100%)	0.036*	Zero	8 (28.6%)	18 (20.2%)	33 (33.3%)	51 (29.5%)	27 (46.6%)	0.005*
	Agree	152 (35.3%)	5 (22.7%)	Zero		6 (85.7%)	5 (17.9%)	40 (44.9%)	29 (29.3%)	64 (37%)	13 (22.4%)	
	Neutral	42 (9.7%)	6 (27.3%)	Zero		Zero	4 (14.3%)	11 (12.4%)	11 (11.1%)	18 (10.4%)	4 (6.9%)	
	Disagree	25 (5.8%)	1 (4.5%)	Zero		Zero	1 (3.6%)	6 (6.7%)	2 (2%)	12 (6.9%)	5 (8.6%)	
	Strongly Disagree	78 (18.1%)	8 (36.4%)	Zero		1 (14.3%)	10 (35.7%)	14 (15.7%)	24 (24.2%)	28 (16.2%)	9 (15.5%)	
Smoking is addictive	Strongly agree	205 (47.6%)	13(59.1%)	1 (100%)	0.427	2 (28.6%)	15 (53.6%)	40 (44.9%)	49 (49.5%)	77 (44.5%)	36 (62.1%)	0.33
	Agree	172 (39.9%)	7 (31.8%)	Zero		5 (71.4%)	7 (25%)	39 (43.8%)	40 (40.4%)	71 (41%)	17 (29.3%)	
	Neutral	24 (5.6%)	Zero	Zero		Zero	3 (10.7%)	3 (3.4%)	5 (5.1%)	12 (6.9%)	1 (1.7%)	
	Disagree	13 (3%)	2 (9.1%)	Zero		Zero	Zero	3 (3.4%)	2 (2%)	7 (4%)	3 (5.2%)	
	Strongly Disagree	17 (3.9%)	Zero	Zero		Zero	3 (10.7%)	4 (4.5%)	3 (3%)	6 (3.5%)	1 (1.7%)	
Smoking shisha is harmful to health	Strongly agree	269 (62.4%)	13 (59.1%)	1 (100%)	0.691	3 (42.9%)	17 (60.7%)	56 (62.9%)	65 (65.7%)	100 (57.8%)	42 (72.4%)	0.08
	Agree	127 (29.5%)	5 (22.7%)	Zero		3 (42.9%)	5 (17.9%)	28 (31.5%)	27 (27.3%)	56 (32.4%)	13 (22.4%)	
	Neutral	17 (3.9%)	3 (13.6%)	Zero		1 (14.2%)	3 (10.7%)	2 (2.2%)	6 (6.1%)	8 (4.6%)	Zero	
	Disagree	9 (2.1%)	Zero	Zero		Zero	Zero	1 (1.1%)	1 (1%)	6 (3.5%)	1 (1.7%)	
	Strongly disagree	9 (2.1%)	1 (4.5%)	Zero		Zero	3 (10.7%)	2 (2.2%)	Zero	3 (1.7%)	2 (3.4%)	

*p value < 0.05.

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feeling and flavor of cigarettes, especially with friends, and reported daily smoking of 10–40 cigarettes (47).

Anti-smoking education that does not include a discussion of mortality linked to smoking habits is ineffective. In fact, many international studies have shown that people who are aware of the mortality risks associated with smoking habits smoke less than those who believe smoking has reversible consequences (48). It was reported in other studies that students had personal justification and compensatory behavior to continue their smoking and to be protected from blame from themselves or from others (49). More behavioral studies are needed in the future to investigate these complex aspects.

Another important aspect of this study was determining the students' physical activity levels. This study revealed that 32.15% of participants were not practicing a 30 min of physical activity during 5 days per week, which is a little lower than the 45.8% of college students in a Saudi Arabian study (50). Our findings are consistent with previous research, which found that ∼26.4% of university students in a Lebanese study engaged in physical activity (51). Physical inactivity was observed in approximately one-third of Chinese and Brazilian college students (52, 53). According to Makrides et al. (54), nearly half of Canadian university students exercise three or more times each week. A prior study in the United States (55) discovered that just 39% of students exercised three or more times per week. According to another American research, 47% of college students do not participate in intense exercise, and 17% were not physically active (56). According to the National College Health Risk Behavior Survey (NCHRBS) in the United States, 42% of the participants engaged in strenuous physical activity at least three times per week, whereas an additional 20% engaged in moderate—intensity activity (57). According to Staten et al., 41 and 39% of college students were moderately and vigorously physically active, respectively (58). Government statistics indicate that in many regions of the world, at least a quarter of all youths are physically inactive (59). The incidence of lack of activity in recreational time among college students in 23 countries varied with economic development and cultural factors, averaging 30% (central and eastern Europe), 23% (northwestern Europe and the United States), 42% (Pacific Asia), 39% (Mediterranean), and 44% (emerging economies) (60). This variation in physical inactivity levels between countries tends to reflect economic and social development, urbanization, and technological excellence. In the current study, 47.57% of students were physically active, of which 17.62% were engaged in daily 30 mins' physical activity for more than 6 months, which reflects the consistency and focus of the students on maintaining their physical fitness and wellbeing.

Also, the students' perceptions and beliefs about the benefits of performing 30 mins of regular physical activity was assessed in this study. Majority of students stated that physical activity has one or more benefits, particularly in terms of health promotion and maintenance. These findings were in contrast to the findings of Haase et al. (60), who found that awareness about activity and health was lacking, with only 40–60% of people knowing that physical activity was linked to the risk of cardiovascular disease.

Physical activity at the university should be encouraged as a preventive measure against chronic diseases and to improve quality of life in adult and elderly life, given the importance of the college years as a transition from adolescence to adulthood. University students require explicit, practical guidelines for participating in physical activity and staying fit and healthy.

Conclusion

To conclude, the study findings showed a low daily frequency consumption of vegetables and fruits. More than 10% of the students did not consume vegetables and fruits at all. Another important finding of the study showed a relatively high prevalence of smoking and a low level of awareness regarding health risks of smoking among Saudi male university students. In addition, a large number of male university students were physically inactive, and could benefit from a structured intervention program, motivating the college students to engage in more vigorous exercise programs.

Recommendations

University years is a time when the large majority of college students are entirely liable for their own eating patterns. Healthy eating habits developed during this time of transition may persist into adulthood, reducing the risk of many chronic diseases later down the line. Long-term nutrition intervention strategies should target enhancing nutrition attitudes and knowledge toward healthy eating amongst university students. In addition to this, there is a pressing need to enforce a tobacco-smoking-reduction strategies among students. As part of these strategies, medical schools and residency training programs could include training, lectures, and educational materials about smoking health risks. Urgent interventions such as setting boundaries and limits on technology and gadgets at school and home and encouraging healthy eating and physical activity are required. Officials at the university should also consider giving students free time slots to engage in physical activities. Students may benefit from mandatory physical activity classes at least three times per week.

Limitations of the study

There are a few limitations worth mentioning for this study. It was a single centered, observational study involving solely male students from the health sciences colleges of Najran University, Saudi Arabia. Hence the results from this study cannot be generalized to other colleges in Saudi Arabia. Apart from that, the participants' self-reporting was used to measure

the lifestyle behaviors. Hence, data could be skewed due to over-reporting or under-reporting.

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 Scientific Ethical Committee of Najran University (NU/2019/12/3). The patients/participants provided their written informed consent to participate in this study.

Author contributions

The author confirms being the sole contributor of this work and has approved it for publication.

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Conflict of interest

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

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References

1. Jenkins JM. Healthy and ready to learn: effects of a school-based public health insurance outreach program for kindergarten-aged children. *J Sch Health.* (2018) 88:44–53. doi: 10.1111/josh.12579

2. Suárez-Reyes M, Muñoz Serrano M, Van den Broucke S. How do universities implement the Health Promoting University concept? *Health Promot Int.* (2019) 34:1014–24. doi: 10.1093/heapro/day055

3. Langford R, Bonell CP, Jones HE, Pouliou T, Murphy SM, Waters E, et al. The WHO Health Promoting School framework for improving the health and well-being of students and their academic achievement. *Cochrane Database Syst Rev.* (2014) 4:CD008958. doi: 10.1002/14651858.CD008958.pub2

4. Papadaki A, Hondros G, Scott JA, Kapsokefalou M. Eating habits of university students living at, or away from home in Greece. *Appetite.* (2007) 49:169–76. doi: 10.1016/j.appet.2007.01.008

5. Alzeidan RA, Rabiee F, Mandil AA, Hersi AS, Ullah AA. Changes in dietary habits, physical activity and status of metabolic syndrome among expatriates in Saudi Arabia. *East Mediterr Health J.* (2018) 23:836–44. doi: 10.26719/2017.23.12.836

6. Tamim H, Tamim R, Almawi W, Rahi A, Shamseddeen W, Ghazi A, et al. Risky weight control among university students. *Int J Eating Disorders.* (2006) 39:80–3. doi: 10.1002/eat.20205

7. Alghamdi SA, Alqarni AA, Alghamdi AF, Alghamdi TK, Hasosah NM, Aga SS, et al. Knowledge, attitude, and practices regarding dietary habits among medical and non-medical university students. *J Family Med Prim Care.* (2021) 10:3436–43. doi: 10.4103/jfmpc.jfmpc_2227_20

8. Alharbi N, Alshowibi R, Aljabri N, Alamri F, Alali F, Alajmi N, et al. Comparative study of dietary habits and sedentary lifestyle among the female medical and non-medical students in a Saudi Arabia University. *Adv Hum Biol.* (2021) 11:51. doi: 10.4103/aihb.aihb_77_21

9. Al-Qahtani MH. Dietary Habits of Saudi Medical Students at University of Dammam. *Int J Health Sci* (Qassim). (2016) 10:353–62. doi: 10.12816/0048729

10. Pullman AW, Masters RC, Zalot LC, Carde LE, Saraiva MM, Dam YY, et al. Effect of the transition from high school to university on anthropometric and lifestyle variables in males. *Appl Physiol Nutr Metab.* (2009) 34:162–71. doi: 10.1139/h09-007

11. Willett WC. Balancing lifestyle and genomics research for disease prevention. *Science.* (2002) 296:695–8. doi: 10.1126/science.1071055

12. Hanly L. Short-term and long-term effects of a healthy diet. Livestrong.com (2010). Available online at: https://www.livestrong.com/article/289568-short-term-long-term-effects-of-a-healthy-diet/ (accessed July 8, 2022).

13. Liu RH. Potential synergy of phytochemicals in cancer prevention: mechanism of action. *J Nutr.* (2004) 134:3479S–85S. doi: 10.1093/jn/134.12.3479S

14. U.S. Department of Health and Human Services. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, GA: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (1996).

15. Vainio H, Bianchini F. IARC handbooks of cancer prevention: weight control and physical activity. Lyons: IARC (2002).

16. U.S. Department of Health and Human Services. Healthy people 2010. US Department of Health and Human Services. Washington, DC (2000).

17. World Health Organization. *WHO Mega Country Health Promotion Network: Behavioural Risk Factor Surveillance Guide*. Geneva: World Health Organization. (2002).

18. Currie C, Hurrelmann K, Settertobulte W, Smith R, Todd J. *Health and Health Behaviour Among Young People*. Copenhagen: World Health Organization (2000).

19. Pate RR, Freedson PS, Sallis JF, Taylor WC, Sirard J, Trost SG, et al. Compliance with physical activity guidelines: prevalence in a population of children and youth. *Ann Epidemiol.* (2002) 12:303–8. doi: 10.1016/S1047-2797(01)00263-0

20. Caspersen CJ, Pereira MA, Curran KM. Changes in physical activity patterns in the United States, by sex and cross-sectional age. *Med Sci Sports Exerc.* (2000) 32:1601–9. doi: 10.1097/00005768-200009000-00013

21. Leslie E, Fotheringham MJ, Owen N, Bauman A. Age-related differences in physical activity levels of young adults. *Med Sci Sports Exerc.* (2001) 33:255–8. doi: 10.1097/00005768-200102000-00014

22. Rosen LD, Lim AF, Felt J, Carrier LM, Cheever NA, Lara-Ruiz JM, et al. Media and technology use predicts ill-being among children, preteens and teenagers independent of the negative health impacts of exercise and eating habits. *Comput Human Behav.* (2014) 35:364–75 doi: 10.1016/j.chb.2014.01.036

23. Jha P, Chaloupka F, editors. *Tobacco Control in Developing Countries*. Washington: World Bank (2012). Available online at: http://documents.worldbank.org/curated/en/602821468330954036/pdf/709670WP0tobac00Box370064B00PUBLIC0.pdf (accessed March 14, 2022).

24. Alnohair SF. Prevalence of smoking and its related behaviors and beliefs among secondary school students in Riyadh, Saudi Arabia. *Int J Health Sci.* (2011) 5:57–63.

25. WHO. *WHO Framework Convention on Tobacco Control*. Geneva: World Health Organization (2005). Available online at: http://apps.who.int/iris/bitstream/10665/42811/1/9241591013.pdf (accessed February 17, 2022).

26. Jarallah JS, al-Rubeaan KA, Al-Nuaim ARA, Al-Ruhaily AA, Kalantan KA. Prevalence and determinants of smoking in three regions of Saudi Arabia. *Tob Control*. (1999) 8:53–6.

27. Alshibrawi A. *Smoking Ban in Public Areas Takes Effect*. Saudi Gazette (2016). Available online at: https://english.alarabiya.net/en/variety/2016/06/13/Smoking-ban-in-public-areas-takes-effect-in-Saudi-Arabia.html (accessed June 13, 2016).

28. Uyar M, Filiz A, Bayram N, Elbek O, Herken H, Topcu A, et al. A randomized trial of smoking cessation. Medication versus motivation. *Saudi Med J.* (2007) 28:922–6.

29. Mason WM, Wolfinger NH. Cohort Analysis. In: Smelser J, Baltes PB, editors. *International Encyclopaedia of the Social and Behavioral Sciences*. Oxford: Oxford University Press (2001). p. 2189–94.

30. Al-Shehri SN. Healthy students—healthy nation. *J Family Community Med.* (2002) 9:15–7.

31. Hernández-González V, Arnau-Salvador R, Jové-Deltell C, Mayolas-Pi C, Reverter-Masia J. Physical activity, eating habits and tobacco and alcohol use in students of a Catalan university. *Rev Facultad Med.* (2018) 66:537–41. doi: 10.15446/revfacmed.v66n4.61896

32. Wahlqvist ML. Nutrition and prevention of chronic diseases: a unifying eco-nutritional strategy. *Nutr Metab Cardiovasc Dis.* (2004) 14:1–5. doi: 10.1016/S0939-4753(04)80040-1

33. Farias SC, de Castro IRR, da Matta VM, Castro LMC. Impact assessment of an intervention on the consumption of fruits and vegetables by students and teachers. *Rev Nutr*. (2014) 27: 55–65. doi: 10.1590/1415-52732014000100006

34. Franco Ada S, Castro IR, Wolkoff DB. Impact of the promotion of fruit and vegetables on their consumption in the workplace. *Rev Saude Publ.* (2013) 47:29–36. doi: 10.1590/S0034-89102013000100005

35. Cooke R, Papadaki A. Nutrition label use mediates the positive relationship between nutrition knowledge and attitudes towards healthy eating with dietary quality among university students in the UK. *Appetite.* (2014) 83:297–303. doi: 10.1016/j.appet.2014.08.039

36. Neslişah R, Emine AY. Energy and nutrient intake and food patterns among Turkish university students. *Nutr Res Pract.* (2011) 5:117–23. doi: 10.4162/nrp.2011.5.2.117

37. Cervera Burriel F, Serrano Urrea R, Daouas T, Delicado Soria A, García Meseguer MJ. Hábitos alimentarios y evaluación nutricional en una población universitaria tunecina (Food habits and nutritional assessment in a Tunisian university population). *Nutr Hosp.* (2014) 30:1350–8. doi: 10.3305/nh.2014.30.6.7954

38. Ramalho AA, Dalamaria T, Souza OF. Regular consumption of fruits and vegetables by university students in Rio Branco, Acre State, Brazil: prevalence and associated factors. *Cad Saude Publica.* (2012) 28:1405–13. doi: 10.1590/S0102-311X2012000700018

39. AlJaber MI, Alwehaibi AI, Algaeed HA, Arafah AM, Binsebayel OA. Effect of academic stressors on eating habits among medical students in Riyadh, Saudi Arabia. *J Family Med Prim Care.* (2019) 8:390–400. doi: 10.4103/jfmpc.jfmpc_455_18

40. Mwafi NR, Al-Rawashdeh IM, Al-Kubaisy WA, Ezzat WR, Al-Qazaqi RA, Salameh MH. Prevalence and factors related to obesity and fast food consumption among Mutah University students, Jordan. *J Pak Med Assoc.* (2021) 71:1608–12. doi: 10.47391/JPMA.274

41. Reis LC, Correia IC, Mizutani ES. Stages of changes for fruit and vegetable intake and their relation to the nutritional status of undergraduate students. *Einstein (São Paulo)*. (2014) 12:48–54. doi: 10.1590/S1679-45082014AO2926

42. Fida HR, Abdelmoneim I. Prevalence of smoking among male secondary school students in Jeddah, Saudi Arabia. *J Fam Commun Med.* (2013) 20:168–72. doi: 10.1186/1471-2458-13-1010

43. Nasser AMA, Geng Y, Al-Wesabi SA. The prevalence of smoking (cigarette and waterpipe) among University Students in Some Arab Countries: a systematic review. *Asian Pac J Cancer Prev.* (2020) 21:583–91. doi: 10.31557/APJCP.2020.21.3.583

44. Steptoe A, Wardle J. Health behavior, risk awareness and emotional well-being in students from Eastern Europe and Western Europe. *Soc Sci Med.* (2001) 53:1621–30. doi: 10.1016/S0277-9536(00)00446-9

45. Amin TT, Amr MAM, Zaza BO, Kaliyadan F. Predictors of waterpipe smoking among secondary school adolescents in Al Hassa, Saudi Arabia. *Int J Behav Med.* (2012) 19:324–35. doi: 10.1007/s12529-011-9169-2

46. Mbongwe B, Tapera R, Phaladze N, Lord A, Zetola NM. Predictors of smoking among primary and secondary school students in Botswana. *PLoS ONE.* (2017) 12:e0175640. doi: 10.1371/journal.pone.0175640

47. Al-Natour A, Gillespie GL, Alzoubi F. "We cannot stop smoking": Female university students' experiences and perceptions. *Appl Nurs Res.* (2021) 61:151477. doi: 10.1016/j.apnr.2021.151477

48. Carbone JC, Kverndokk S, Røgeberg OJ. Smoking, health, risk, and perception. *J Health Econ.* (2005) 24:631–53. doi: 10.1016/j.jhealeco.2004.11.001

49. Heikkinen H, Patja K, Jallinoja P. Smokers' accounts on the health risks of smoking: why is smoking not dangerous for me? *Soc Sci Med.* (2010) 71:877–83. doi: 10.1016/j.socscimed.2010.05.036

50. Al-Hazzaa H. Physical activity patterns of college male subjects. *King Saud University J.* (1990) 2:383–96.

51. Musharrafieh U, Tamim HM, Rahi AC, El-Hajj MA, Al-Sahab B, El-Asmar K et al. Determinants of university students physical exercise: a study from Lebanon. *Int J Public Health.* (2008) 53:208–13. doi: 10.1007/s00038-008-7037-x

52. Abdullah AS, Wong CM, Yam HK, Fielding R. Factors related to non-participation in physical activity among the students in Hong Kong. *Int J Sports Med.* (2005) 26:611–5. doi: 10.1055/s-2004-821315

53. Fontes ACD, Vianna RPT. Prevalence and factors related to low level physical activity among university students in a public university in the northeast region of Brazil. Brasil. *Rev Bras Epidemiol.* (2009) 12:20–9. doi: 10.1590/S1415-790X2009000100003

54. Makrides L, Veinot P, Richard J, McKee E, Gallivan T. A cardiovascular health needs assessment of university students living in residence. *Can J Public Health.* (1998) 89:171–5. doi: 10.1007/BF03404468

55. Haberman S, Luffey D. Weighing in college students' diet and exercise behaviors. *J Am Coll Health.* (1998) 46:189–91. doi: 10.1080/07448489809595610

56. Suminski RR, Petosa R, Utter AC, Zhang JJ. Physical activity among ethnically diverse college students. *J Am Coll Health.* (2002) 51:75–80. doi: 10.1080/07448480209596333

57. Youth Risk Behavior Surveillance. National College Health Risk Behavior Survey–United States, 1995. *MMWR CDC Surveill Summ*. (1997) 46:1–56.

58. Staten RR, Miller K, Noland MP, Rayens MK. College students' physical activity: application of an ecological perspective. *Am J Health Stud.* (2005) 20:58–65.

59. CDC. *National Youth Risk Behavior Survey 1991–2005: Trends in the Prevalence of Physical Activity*. Atlanta, Georgia: Centers for Disease Control and Prevention (2006).

60. Haase A, Steptoe A, Sallis JF, Wardle J. Leisure-time physical activity in university students from 23 countries: associations with health beliefs, risk awareness, and national economic development. *Prev Med.* (2004) 39:182–90. doi: 10.1016/j.ypmed.2004.01.028

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The effect of unhealthy dietary habits on the incidence of dental caries and overweight/obesity among Egyptian school children (A cross-sectional study)

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Background: Obesity and dental caries are public health problems in Egypt. Factors such as unhealthy diet, poor oral hygiene, and physical inactivity can play a major role in both problems. This study was carried out to illuminate the mutual unhealthy dietary risk factors associated with the incidence of both health conditions.

Methods: Between 1 October 2020 and 1 July 2021, 369 Egyptian children (5–10 years) were examined. Dental status was assessed using decayed, missing/extracted, and filled tooth indices (dmft, deft, and DMFT) for deciduous, mixed, and permanent dentitions, respectively. Moreover, the lifestyle, food habits, and body mass index (BMI) were recorded.

Results: A total of 342 (93.7%) of the included subjects suffered from caries, and only 27(7.3%) were caries-free. Based on BMI percentiles, 247 (66.9%) of the youngsters were overweight/obese, while 122 (33.1%) had normal weight. The mean dmft was 6.9 (±4.6), deft 4.2 (±3.3), and DMFT 0.1 (±1.7). In the primary dentition, a significant positive correlation was detected between dmft and BMI, legumes, sweetened milk and juice, soft drinks, and desserts, while a significant negative correlation was detected between dmft/deft, meat/poultry/fish, fresh fruits, and vegetables. A significant positive correlation was detected between deft and BMI, sweetened milk and juice, ice cream, candies, and crackers. In the permanent dentition, a significant positive correlation was detected between age, soft drinks, sweetened juice, desserts, and DMFT, while a significant negative correlation was detected with fresh fruits and vegetables. BMI was significantly negatively correlated with a healthy lifestyle, meat/poultry/fish consumption, and fresh fruits and vegetables while positively correlated with legumes, ice cream, soft drinks, granulated sugars, desserts, fast food, and caffeinated drinks.

Conclusion: Overweight/obesity was positively correlated with primary dentition dental caries. Desserts (sweetened snacks) and soft drinks could be the common risk factors associated with high caries and overweight/obesity incidence among Egyptian school children; conversely, consumption of fruits and vegetables could hinder both health conditions. Moreover, sweetened juices were associated with primary and permanent dental caries.

KEYWORDS

unhealthy diet, dental caries, school children, overweight, obesity

Introduction

Dental caries and obesity are considered worldwide growing public health problems that significantly impact children's lives and impose an enormous cost on society (1, 2). The Global Burden of Disease Study 2017 revealed that oral diseases affect 3.5 billion people around the world (3). Dental caries is considered the most common chronic disease affecting 2.43 billion people globally (4). Caries in deciduous teeth affects more than 530 million children worldwide (3). Despite the global spread of the disease, its incidence exhibits geographical diversity across developing and developed countries. It has been asserted that dental caries is decreasing in most industrialized nations due to enhanced prevention programs and expanded access to dental health services. Even so, contradictory results suggest that dental caries is still prevalent among underprivileged communities in many of these nations (5–7). In most developing countries, dental caries levels were low until recent years. An increase was observed due to rising sugar consumption, inadequate fluoride exposure, and limited access to oral healthcare services (5, 6, 8). The Egyptian Ministry of Health and the World Health Organization (WHO) in 2014 conducted an oral health survey in Egypt and revealed that approximately 70% of children had untreated caries (9). In 2022, the comparison between different governorates showed that the highest dental caries prevalence was in children living in Cairo (85%), while for those living in upper Egypt and Deltas was lower (82% and 83.5, respectively) (10).

Children with dental caries have significantly impaired social and psychological functioning. Pain in the teeth, mouth, or jaws, irritation or frustration, difficulty in eating, and sleeping are the most common effects reported by parents in the literature (11–15). Poor dental hygiene greatly impacts the child's growth and cognitive development over time by interfering with the child's nutrition which results in reduced body mass and stature (16–20). Subsequently, the impacts include school absences, inability to concentrate in school, decreased self-esteem, poor social relations, impaired speech development, sleep problems, and inadequate nutrition (21). Family members also suffer when a child has untreated dental caries, including the caretaker's inability to get enough rest, the caretaker missing time at work, and the caretaker's stress and financial hardship due to the time and money required to get the child to the dentist (11, 12, 14, 15).

The WHO in 2003 established global goals for oral health to guide health planners and policymakers in improving the oral health status of their populations (22). Subsequently, the WHO published its global action plan for preventing and controlling non-communicable diseases (NCDs) 2013–2020 (23). The action plan has two goals; the first is to start reducing risk factors for NCDs and underlying social determining factors through developing health-promoting environments; second, to strengthen and direct health systems to prevent and control NCDs and the social factors that cause them through people-centered primary healthcare and universal health coverage. The WHO resolution on Oral Health in 2021 reinforces these goals regarding oral diseases and dental caries. This occurs by encouraging countries to abandon the traditional curative approach in favor of a "preventive promotional approach with risk identification for timely, comprehensive, and inclusive care, taking into account all stakeholders in contributing to the improvement of the population's oral health with a positive impact on overall health" (24, 25).

Obesity is a major public health concern affecting over 650 million people globally (26). According to WHO, Egypt ranks 18th globally in the prevalence of obesity (27). The prevalence of overweight among children and adolescents aged 5–19 has significantly risen in Egypt from 22.6% in 2000 to 36.7% in 2016. Among EMR countries that suffer from a high incidence of overweight among children, Egypt has been ranked third after Kuwait and Qatar. In addition, the prevalence of obesity among children and adolescents aged 5–19 in Egypt has nearly doubled between 2000 and 2016 from 9 to 17.6% (28). The WHO in 2016 reported that more than 340 million children and adolescents between the ages of 5 and 19 are classified overweight or obese (26). Moreover, a report by WHO in 2018 revealed that the worldwide prevalence of obesity in children and adolescents had increased more than 10-fold in the last four decades (29). Despite the WHO efforts, the expanded utilization of unhealthy diets led to an increased prevalence of dental caries and childhood overweight/obesity worldwide in the past decades (30–32).

Dietary sugar specifically becomes a significant public health issue with concerns regarding its contribution to increased obesity prevalence and its negative impact on oral health (33, 34). Sweetened foods and soft drinks are the first choice of children as snacks between meals (35). These food items are rich in carbohydrates and thus result in an increased risk for caries development (36).

Both dental caries and obesity possess common characteristics of being chronic and highly prevalent conditions (5, 37, 38). They are also thought to have the same contributing factors, including genetic, biological, dietary, socioeconomic, cultural, and lifestyle predisposing factors (39, 40). Diet plays an essential role in the development of dental caries and obesity where a high consumption of sugar-sweetened beverages, junk foods, and fermentable carbohydrates influences their incidence (41, 42). Moreover, lifestyle may contribute to the development of obesity and dental caries also by increasing the time spent on social media and watching TV while consuming unhealthy snacks, which can lead to a reduction in physical activity time (43, 44).

Furthermore, both conditions are more prevalent in specific communities with low socioeconomic status in association with the low education level of the parents, unhealthy diet consumption, and the difficulty in acquiring adequate healthcare and services (41, 45, 46). The results of our previous study emphasize this assumption as SES, parental educational, and oral hygiene measures were significantly inversely correlated with primary teeth dental caries, whereas permanent teeth caries revealed non-significant correlations (47). Conversely, low and high socioeconomic status were demonstrated to increase the risk of dental caries, while a middle socioeconomic status had a 20% lesser chance in low- and middle-income countries. It was reported that 44% of the children had access to dental care services, which implies the role of numerous socioeconomic constraints in addition to geographical restrictions (48). Moreover, the relation between obesity and socioeconomic status depends on the stage of the nutrition transition (49). In nutrition, the concept of "transitions" has been used to describe trends in significant population health parameters to provide insight into underlying determinants, positive deviations, and future directions (50). Analysis of Egypt's Demographic and Health Survey data between 1992-1995 and 2005-2008 revealed that the greatest relative increases in the prevalence of obesity occurred among women with no/primary education and in the lowest income quintile (25).

The correlation between dental caries and obesity is a controversial issue. In literature, being overweight has been linked to an increased incidence of dental caries (51) due to the upregulated intake frequency of sugary foods and snacks (52). This correlation was supported by a systematic review that reported a significant relationship between childhood obesity and dental caries (53). On the contrary, being underweight has also been associated with high caries prevalence (54, 55), as the pain resulting from dental caries could make the child eat less food (17, 56). Other studies reported that dental caries was not correlated with obesity (57, 58).

Estimating the burden of the unhealthy diet that could contribute to the incidence of dental caries and obesity is crucial in determining the public health intervention priorities. It also helps educate the public about the negative effects of dental caries and obesity and provides health policy decision makers with information about the scope of health problems. The impact of unhealthy diets in correlation to dental caries and obesity among the Egyptian population is not well–established. Therefore, this study aims to evaluate the impact of unhealthy dietary habits on the incidence of dental caries and overweight/obesity among children aged 5 to 10 years to guide parents to be more conscious of their role in preventing these related health problems. Moreover, the need for high-quality and comparable data is a key component for the healthcare ministry to take essential actions regarding major health problems.

Subjects and methods

The research was conducted following the Research Ethics Committee of Cairo University's Faculty of Dentistry's requirements (Approval: 24,920). The parents or guardians of the children gave their written informed consent to participate in the study. From 1 October 2020 to 1 July 2021, individuals were recruited from the Pedodontic outpatient clinics of Cairo University's Faculty of Dentistry. The criteria for the included children were as follows: age: ranges from 5 to 10 years old; Gender: males and females; Ethnicity: Egyptians. Children with visible disorders, physical or mental abnormalities, diabetes, or other systemic ailments or having orthodontic treatment were not included in the study. Children and parents who refused to participate were also excluded.

The sample size was calculated to be 369 using the basic formula (59). For dental caries, the prevalence in Egypt was estimated at 60% according to the WHO Regional Office for the Eastern Mediterranean (WHO EMRO) report in 2014 (9). Abbass et al. reported 74 % among children aged 3–18 years while reported 93.2 % among children aged 5–10 years (47). In EMR, caries was estimated by 66% (59–73%) for children aged 6–15 years (60). Moreover, 51.6% was reported among different Australian refugees (61). The average of the previously mentioned percentages was utilized in calculations; accordingly, the estimated sample size was 330. For overweight/obesity, Egypt's population of children aged (5–10) years was estimated at 30,000,000 (62), and the prevalence of overweight and obesity in this population was estimated at 40.2 % according to WHO data (63), and the estimated sample size was 369.

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TABLE 1 Description of investigated dietary elements.

Dietary item	Full description
Protein food	Meats/poultry and fish
Carbohydrates	Bread, rice, macaroni, mahshi, potatoes and sweet potatoes
Fruits/Vegetables	Fresh
Legumes	Favabeans, homos, wheat and peas
Sweetened cereals	Sweetened belyla, sweetened oats
Dairy products	Unsweetened milk, yogurt and cheese (all types) (butter is not included)
Sweetened milk	With or without flavors
Diary based ice cream	—
Soft drinks	pespsi, coke, fanta, 7up, sprite, etc.….
Fruits/Vegetables	Fresh
Sweetened juices	fresh/canned
Sugar	Sugar added to drinks (hot or cold), eaten sugar granules.
Candies	Hard, Sticky, lollipops
Jam, molasses and honey	Jam, molasses, honey and halawa
Crackers	Biscuits and chips
Desserts (sweetened snacks)	Cakes, doughnuts, sweetened pies, baklawa, basbosa, konafa
Junk food	Any of the following food items prepared outside home (ready to eat food): burgers, pizza, fried (potatoes, chicken, falafal), favabeans, koshary, shawarma sandwiches.
Chocolate	Bars, chocolate cakes
Soda	Sweetened carbonated drinks
Juices	Fresh, canned and citric,
Caffeinated drinks	Tea, coffee, Nescafe sachets (commonly known in Egypt as 3 in 1)

Data collection and grouping

Name, age, gender, address, and type of education (government, experimental, or private) were among the sociodemographic data obtained from children's guardians. The children's lifestyle habits were documented, and the dietary habits were thoroughly reported using a food frequency questionnaire. The first two parts of the questionnaire that included the sociodemographic data and the dentition status were validated in WHO-oral health surveys (64), while the third part that included the lifestyle habits was validated in (65, 66). Finally, the part of the dietary habits was validated by Abbass et al. and the diet history questionnaire (47, 67–69). The assessed 18 dietary elements are included in Table 1.

The authors filled out the questionnaire according to parents' answers on behalf of their children. The frequencies used in the questionnaire were once per month; 1–2 times per week; 3–4 times per week; 5–6 times per week; once per day; 2–3 times per day; 4–5 times per day; and 6 or more times per day. To facilitate the comparison and statistical analysis, these frequencies were merged into the three frequencies displayed: $\leq$ 2 times/week; 3–6 times/week; 1–6 times/day. According to WHO (1995) (70), body weights were measured using a Beurer scale (Ulm, Germany) with the participants wearing clothes but without shoes. Standing heights were measured to the nearest 0.1 cm utilizing a stadiometer. Body mass index (BMI) was calculated from the measured heights and weights. The obtained BMI values were plotted on the WHO percentile body mass index (BMI/age) charts for boys and girls (71). The children were divided into four categories based on their BMI percentiles: the underweight group (<5th percentile); the normal group ($\geq 5^{th}$-$< 85^{th}$ percentile); the overweight group ($\geq 85^{th}$-$< 95^{th}$ percentile); and the obese group ($\geq$ 95th percentile). Moreover, children were divided into three groups based on their age: group I (5–<7 years old), group II (7–<9 years old), and group III (9, 10).

Furthermore, participants' responses to questions regarding lifestyle habits were marked, and a total score was calculated for each participant as previously described (72–75). Participants with a cumulative score of (0–3) were categorized into unhealthy lifestyle habits, while those with a cumulative score of (4–5) were categorized into moderate lifestyle habits, while participants with a cumulative score of (6–7) were categorized into healthy lifestyle habits.

Oral examination

Examiners were trained and calibrated over 3 days in 3 sessions, with disparities in observations discussed among the examiners for reassessment and consensus (76, 77). Following the WHO guidelines, oral examination was performed on a dental chair in artificial light using a plain mouth mirror and a dental probe (78). During the clinical examination, all of the teeth that were present were considered (77).

Any lesion with a detectably softened floor, undermined enamel, or softened wall in a pit or fissure or on a smooth tooth surface, tooth surface containing a temporary filling requiring further treatment, and tooth surface containing a permanent restoration with an area of decay were all considered carious (either primary or secondary caries). The DMFT index, which measures the number of D (decayed tooth), M (missing tooth), and F (filled tooth), was used to determine the severity of caries in permanent teeth. The dmft index was employed for primary teeth: d (decayed teeth), m (missing teeth), and f (filled tooth). The deft index was employed for mixed dentition: d (decayed tooth indicated for filling), e (decayed tooth advised for extraction), and f (filled tooth) (64). The DMFT, dmft, and deft indices were divided into three categories: caries index zero (no carious teeth), caries index 1–3 (number of carious teeth 1–3),

and caries index ≥4 (number of carious teeth ≥ 4) for statistical analysis (79).

Statistical analysis

Data were statistically described as frequencies (number of cases) and percentages. Since data were non-parametric, the Kruskal–Wallis test was used for comparing more than two groups, while the Mann–Whitney test was used for comparing two groups. Spearman's rank correlation was used for the detection of correlation between different variables. Multivariate logistic regression analysis was used to test for the preferential effect of each food item on caries index and obesity after adjusting the effect of age and gender. *P*-values of < 0.05 were considered statistically significant. All statistical calculations were done using the computer program IBM SPSS (Statistical Package for the Social Science; IBM Corp, Armonk, NY, United States), release 22 for Microsoft Windows.

Results

Population profile

The study included 180 (48.8%) boys and 189 (51.2%) girls. About 172(46.6%) participants fell into the first age group AI (5–6.9 years), 97(26.3%) fell into the second age group AII (7–8.9 years), while 100 (27.1%) fell into the third age group AIII (9–10 years). The majority of participants 162 (43.9%) attended governmental schools. A total of 122 (33.1%) of the participants had normal weight, while 247 (67.0%) were overweight or obese. No underweight participants have been reported in this work; therefore, this category is not presented in the result section. About 342 (93.7%) of the included subjects suffered from dental caries, and only 27 (7.3%) individuals were caries-free (Table 2).

Lifestyle habits

Most of the parents stated that their children had breakfast meal most of the time. In addition, 162 (43.9%) of the parents mentioned that their child would watch TV while eating, 159 (43.1%) of the parents stated that their children sometimes eat outside their home, and 131 (35.5%) of the participants would have their dinner 1 h before bedtime. Most of the parents 286 (77.5%) mentioned that the whole family had their meals together, and 227 (61.5%) acknowledged that their child does not perform any sort of physical exercise. A total of 175 (47.4%) of the participating children used the internet more than 2 h per day, while 178 (48.2%) did not. The majority of the participants 190 (51.5%) were categorized as moderate regarding lifestyle habits (Table 2).

Dietary habits

Most of the participants consumed meat, legumes (fava beans/ hommos), sweetened cereals/ belela, sweetened milk, ice cream, soft drinks, sweetened juice, granulated sugars, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, chocolate, and caffeinated drinks (coffee, tea) less than or equal to 2 times/week, while the majority consumed carbohydrates, fresh fruits, and vegetables, dairy products (unsweetened milk/ cheese/ yogurt), candies, and crackers (biscuits/ chips), 1 to 6 times per day (Table 2).

Mean decayed, missing/extracted, filled teeth (Dmft, deft, and DMFT)

The mean dmft recorded for the participants was 6.8 (±4.5), the mean deft was 4.2 (±3.3), while the mean DMFT was 0.9 (±1.7). The highest mean DMFT 1.8 (±2.0) was detected within AIII age group. In contrast, AI age group showed the highest mean dmft and deft of 6.9 (±4.5) and 5.5 (±3.9), respectively (Table 3).

Correlation between caries indices and different risk factors

Correlation between dmft index and different risk factors

The majority of participants had dmft more than 4. The highest percentage of participants with dmft more than 4 were overweight or obese. The highest percentage of participants with dmft more than 4 were males. Most of the participants with dmft more than 4 had unhealthy life habits. No significant correlation was detected between dmft and gender or age, a statistically significant positive correlation was detected between dmft and BMI, while a statistically significant negative correlation was detected between dmft and healthy lifestyle habits (Table 4).

The highest percentage of participants with dmft more than 4 consumed meat, sweetened cereals/ belela, sweetened milk, dairy ice cream, soft drinks, granulated sugar, halawa/ honey, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, and caffeinated drinks (coffee, tea), less than or equal to 2 times/week, while carbohydrates, fresh fruits and vegetables, legumes (fava beans/ hommos), dairy products unsweetened milk/ cheese/ yogurt, candies (sticky or not), crackers (biscuits/ chips), and chocolate were consumed 1–6 times/day by the majority of participants with dmft more than 4.

A statistically significant positive correlation was detected between dmft and legumes, sweetened milk, soft drinks, sweetened juice, and desserts (cakes/ doughnuts/

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TABLE 2 Demographics, lifestyle habits and dietary habits.

Parameter	Categories number (%)				
1- Age (years)	**AI (5–6.9 years)**	**AII (7-8.9 years)**	**AIII (9-10 years)**		
	172 (46.6%)	97 (26.3%)	100 (27.1%)		
2- Gender	**Boys**	**Girls**			
	180 (48.8%)	189 (51.2%)			
3-Children education	**Governmental**	**Private**	**Experimental**	**Others**	
	162 (43.9%)	100 (27.1%)	36 (9.8%)	71(19.2%)	
4- Body Mass Index	**Normal (≥5-<85)**	**Overweight (≥85–<95) and Obese (≥ 95)**			
	122 (33.1%)	247 (66.9%)			
5- Dental status	**Caries free**	**Caries**			
	342 (93.7%)	27 (7.3%)			
6- Lifestyle habits	**Unhealthy habits**	**Moderate**	**Healthy habits**		
	152 (41.2%)	190 (51.5%)	27 (7.3%)		
a. **Breakfast meal**	**No**	**Sometimes**	**Most of the times**	**Rare**	**Unknown**
	34 (9.2%)	105 (28.5%)	207 (56.1%)	21(5.7%)	2(0.5%)
b. **Watching TV while eating**	**No**	**Sometimes**	**Most of the times**	**Rare**	**Unknown**
	62 (16.8%)	133 (36.0 %)	162 (43.9%)	9(2.4%)	3(0.8%)
c. **Eating outside home**	**No**	**Sometimes**	**Most of the times**	**Rare**	**Unknown**
	133 (36.0%)	159 (43.1%)	29 (7.9%)	46(12.5%)	2(0.5%)
d. **Eating before bedtime**	**Don't eat at night**	**One hour**	**2 hours**	**3 hours**	**Just before bed time**
	17 (4.6%)	131 (35.5%)	97 (26.3%)	52(14.1%)	72(19.5%)
e. **Family meals**	**Alone**	**All/some family**	**Other**	**Unknown**	
	36 (9.8%)	286 (77.5%)	30 (8.1%)	17 (4.6%)	
f. **Exercise /physical activity**	**No**	**Yes**	**Unknown**		
	227 (61.5%)	122 (33.1%)	20 (5.4%)		
g. **Using internet more than 2 hours per day**	**Yes**	**No**	**Unknown**		
	175 (47.4%)	178 (48.3%)	16 (4.3%)		
7- Food consumption	**≤ 2 times/week**	**3-6 times/week**	**1-6 times/day**		
a. **Meat/poultry/fish**	130 (35.2%)	127 (34.4%)	112 (30.4%)		
b. **Carbohydrates**	26 (7.1%)	73 (19.8%)	270 (73.2%)		
c. **Fresh fruits and vegetables**	96 (26.0%)	80 (21.7%)	193 (52.3%)		
d. **Legumes (fava beans/ hommos)**	164 (44.4%)	72 (19.5%)	133 (36.1%)		
e. **Sweetened cereals/ belela**	229 (62.1%)	44 (11.9%)	96 (26.0%)		
f. **Dairy products (unsweetened milk/ cheese/ yogurt**	85 (23.0%)	66 (17.9%)	218 (59.1%)		
g. **Sweetened milk**	183 (49.6%)	54 (14.68%)	132 (35.8%)		
h. **Dairy ice cream**	234 (63.5%)	71 (19.2%)	64 (17.3%)		
i. **Soft drinks**	243 (65.9%)	50 (13.6%)	76 (20.6%)		
j. **Sweetened juice**	175 (47.4%)	86 (23.3%)	108 (29.3%)		
k. **Granulated sugars**	270 (73.2%)	28 (7.6%)	71 (19.2%)		
l. **Candies (sticky or not)**	123 (33.3%)	67 (18.2%)	179 (48.5%)		
m. **Halawa/ honey**	202(54.7%)	60(16.3%)	107 (29.0%)		
n. **Crackers (biscuits/ chips)**	80 (21.7%)	62 (16.8%)	227 (61.5%)		
o. **Cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa**	250 (67.8%)	66 (17.9%)	53 (14.3%)		
p. **Fast food**	244 (66.1%)	67 (18.2%)	58 (15.7%)		
q. **Chocolate**	163 (44.1%)	70 (19.0 %)	136 (36.9%)		
r. **Caffeinated drinks (coffee, tea)**	268 (72.6%)	31 (8.4%)	70 (19.0 %)		

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TABLE 3 Mean (±SD) of dmft, deft, and DMFT indices.

Variable mean (±SD)	AGE	N	Mean (±SD)	Variable mean (±SD)	AGE	N	Mean (±SD)	Variable mean (±SD)	AGE	N	Mean (±SD)
dmft 6.829 (±4.541)	**AI**	105	6.9 (±4.6)	deft4.2 (±3.3)	**AI**	67	5.5 (±3.9)	DMFT 0.1 (±1.7)	**AI**	67	0.09 (±0.4)
	AII	0			**AII**	97	4.7 (±3.1)		**AII**	97	0.8 (±1.4)
	AIII	0			**AIII**	100	2.8 (±2.5)		**AIII**	100	1.8 (±2.1)

sweetened pies/ baklawa/ basbosa/ konafa), while a statistically significant negative correlation was detected between dmft and meat/poultry/fish, fresh fruits and vegetables, and dairy products (unsweetened milk/ cheese/ yogurt).

After adjusting the effect of age and gender, the following items were found to be significantly associated with high dmft: legumes, sweetened milk, soft drinks, sweetened juice, granulated sugars, and desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa). Conversely, meat/poultry/fish, fresh fruits and vegetables, and dairy products, including unsweetened milk/ cheese/ yogurt, were significantly associated with low dmft (Table 5).

Correlation between deft index and different risk factors

Most of the studied population 145 (54.9%) had a deft index of more than 4. The highest percentage of participants with deft index of more than 4 fell into the AII age group. The highest percentage of participants with deft index of more than 4 were females. The highest percentage of participants with deft index of more than 4 were overweight or obese. A statistically significant negative correlation was detected between age and deft also between deft and healthy lifestyle habits. A statistically significant positive correlation was detected between deft and BMI (Table 6).

The highest percentage of participants with deft index of more than 4 consumed meat/poultry/fish, sweetened cereals/ belela, dairy ice cream, soft drinks, sweetened juice, granulated sugars, halawa/ honey, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, chocolate, and caffeinated drinks less than or equal to 2 times/week, while carbohydrates, fresh fruits and vegetables, dairy products, sweetened milk, candies, and crackers were consumed 1 to 6 times daily.

A statistically significant positive correlation was detected between deft and sweetened milk, dairy ice cream, sweetened juice, candies, and crackers. In contrast, a statistically significant negative correlation was detected between deft and meat/poultry/fish, fresh fruits, and vegetables.

After adjusting the effect of age and gender, the following items were found to be significantly associated with high deft, sweetened milk, dairy ice cream, soft drinks, candies, and crackers. On the contrary, meat/poultry/fish, fresh fruits, and vegetables were associated with low deft (Table 7).

Correlation between dmft index and different risk factors

The majority of participants 173 (65.5%) had DMFT = 0. The highest percentage of participants with DMFT index of more than 4 fell into the AIII age group. The highest percentage of participants with DMFT index of more than 4 were females. The highest percentage of participants with DMFT index of more than 4 were overweight or obese. A statistically significant positive correlation was detected between age and DMFT, while a non-significant positive correlation was detected between gender, BMI, and DMFT (Table 8).

The highest percentage of participants with DMFT more than 4 consumed meat/poultry/fish, legumes, sweetened cereals, dairy ice cream, soft drinks, granulated sugars, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, and caffeinated drinks less than or equal to 2 times/week, while carbohydrates, fresh fruits and vegetables, dairy products, sweetened juice, candies, halawa/ honey, crackers, and chocolate were consumed 1–6 times/day.

A statistically significant positive correlation was detected between DMFT and soft drinks, sweetened juice, and desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), while a statistically significant negative correlation was detected between DMFT and fresh fruits and vegetables.

After adjusting the effect of age and gender, the following items were found to be significantly associated with high DMFT: soft drinks, sweetened juice, and desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa). In contrast, fresh fruits and vegetables were significantly associated with low DMFT (Table 9).

Correlation between BMI and different risk factors

Most of the studied population 247 (66.9%) were overweight (≥ 85–< 95) and obese (≥ 95), while 122(33.1%) of the participants had normal BMI (≥ 5–< 85). The highest percentage of overweight/obese participants fell into AII age

TABLE 4 Correlation between dmft index and different risk factors (Total number 105).

Parameter and categories		Number (%)			M-W test	Correlation		Logistic regression			
		dmft = 0 7 (6.7%)	dmft = 1-321 (20%)	dmft > 4 77 (73.3%)	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
										Lower	Upper
Age (years)	AI 105 (100%)	7 (6.7%)	21 (20.2%)	77 (73.3%)	<0.05*	0.059	0.553				
	AII 0	0	0	0							
	AIII 0	0	0	0							
Gender	Boys 56 (53.3%)	2 (3.6%)	9 (16.1%)	45 (80.4%)	<0.05*	−0.177	0.071				
	Girls 49 (46.6%)	5 (10.2%)	12 (24.5%)	32 (65.3%)							
BMI	Normal (≥5-<85) 34 (32.38%)	7 (20.5%)	13 (38.2%)	14 (41.1%)	0.576	0.523	<0.05*				
	Overweight (≥85-<95)	0	8 (11.3%)	63 (88.7%)							
	and Obese (≥ 95) 71 (67.61%) Lifestyle habits										
Lifestyle habits	Unhealthy habits 44(41. 9%)	0	7 (33.33%)	37 (48%)	<0.05*	−0.273	0.005*				
	Moderate 50(47.6%)	4 (57.1%)	11 (52.4%)	35 (45.5%)							
	Healthy habits 11(10.5%)	3 (42.8%)	3 (14.3%)	5 (6.5%)							

*Statistically significant.

group. The highest percentage of overweight/obese participants were males. Overweight/obese participants had the highest percentages of unhealthy lifestyle habits.

A non-statistically positive correlation was detected between BMI and age. Moreover, a non-statistically negative correlation was detected between BMI and gender. On the contrary, a statistically significant negative correlation was detected between BMI and healthy lifestyle habits (Table 10).

The highest percentage of overweight/obese participants consumed meat/poultry/fish, carbohydrates, fresh fruits and vegetables, dairy products, and chocolate less than or equal to 2 times/week and consumed sweetened milk 3 to 6 times per week. Legumes, sweetened cereals/ belela, dairy ice cream, soft drinks, sweetened juice, granulated sugars, halawa/honey, crackers, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, and caffeinated drinks were consumed 1 to 6 times per day within overweight/obese participants, while candies were nearly equally consumed less than or equal to 2 times/week and 1–6 times/day.

A statistically significant positive correlation was detected between BMI and legumes, dairy ice cream, soft drinks, granulated sugars, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, and caffeinated drinks, while a statistically significant negative correlation was detected between BMI and meat/poultry/fish, fresh fruits, and vegetables.

After adjusting the effect of age and gender, the following items were found to be associated with high BMI: legumes, dairy ice cream, soft drinks, granulated sugars, desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa), fast food, and caffeinated drinks. While meat/poultry/fish, fresh fruits, and vegetables were significantly associated with low BMI (Table 11).

Discussion

Dental caries is considered the most prevalent non-communicable chronic disease worldwide, affecting all ages, from infants to old adults. It is a biofilm-mediated, sugar-induced, multifactorial, dynamic disease that leads to a cyclic demineralization and remineralization of dental hard tissues (80). This study examined the correlation between caries prevalence and malnutrition (overweight/obesity) in association with unhealthy food consumption patterns.

The strengths of our study include the collection of data representative to the whole nation since the patients come to the clinics of the Faculty of Dentistry, Cairo University from all the Egyptian governorates, and the high-quality outcome data. An additional strength is the use of a questionnaire validated by the WHO. Despite these strengths, the exposure measurement used in our study has several weaknesses including the sampling technique, where a non-random sampling technique was used as all the participants were recruited from the outpatient clinics of

TABLE 5 Correlation between dmft index and frequency of intake of different food items (Total number 105).

Dietary habits											
Parameter and categories		Number (%)			M-W test	Correlation			Logistic regression		
		dmft = 0	dmft = 1–3	dmft > 4	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
		7 (6.7%)	21 (20 %)	77 (73.3%)						Lower	Upper
a. **Meat/poultry/fish**	**≤ 2 times/week 37 (35.2%)**	0	3 (8.1%)	34 (91.9%)	<0.05*	−0.415	<0.05*	<0.05*	0.269	0.141	0.515
	3–6 times/week 33 (31.4%)	1 (3.07%)	6 (18.2%)	26 (78.8%)							
	1–6 times/day 35 (33.3%)	6 (17.1%)	12 (34.3%)	17 (48.6%)							
b. **Carbohydrates**	**≤ 2 times/week 4 (3.8%)**	0	1 (25%)	3 (75%)	0.094	−0.110	0.264	0.359	0.623	0.227	1.713
	3–6 times/week 14 (13.3%)	0	2 (14.3%)	12 (85.7%)							
	1–6 times/day 87 (82.8%)	7 (8.1%)	18 (20.7%)	62 (71.3%)							
c. **Fresh fruits and vegetables**	**≤ 2 times/week 19 (18%)**	0	1 (5.3%)	18 (94.7%)	0.010*	−0.378	<0.05*	0.001*	0.197	0.073	0.536
	3–6 times/week 25 (23.8%)	0	2 (8%)	23 (92%)							
	1–6 times/day 61 (58.1%)	7 (11.5%)	18 (29.5%)	36 (59.0%)							
d. **Legumes (fava beans/ hommos)**	**≤ 2 times/week 47 (44.8%)**	5 (10.6%)	12 (25.5%)	30 (63.8%)	<0.05*	0.219	0.025*	0.029*	1.775	1.062	2.966
	3–6 times/week 20 (19%)	2 (10%)	3 (15%)	15 (75%)							
	1–6 times/day 38 (36.2%)	0	6 (15.79%)	32 (84.2%)							
e. **Sweetened cereals/ belela**	**≤ 2 times/week 62 (59%)**	2 (3.2%)	11 (17.7%)	49 (79.0%)	<0.05*	−0.145	0.140	0.180	0.714	0.436	1.168
	3–6 times/week 17 (16.2%)	2 (11.8%)	5 (29.4%)	10 (58.8%)							
	1–6 times/day 26 (24.8%)	3 (11.5%)	5 (19.2%)	18 (69.2%)							
f. **Dairy products un sweetened milk/ cheese/ yoghurt**	**≤ 2 times/week 23 (21.9%)**	1 (4.3%)	2 (8.7%)	20 (87%)	0.006*	−0.236	0.015*	0.025*	0.475	0.247	0.911
	3–6 times/week 21 (20%)	1 (4.7%)	2 (9.5%)	18 (85.7%)							
	1–6 times/day 61(58.1%)	5 (8.19%)	17 (27.86%)	39 (63.93%)							
g. **Sweetened milk**	**≤ 2 times/week 58 (55.2%)**	7 (12.1%)	16 (27.6%)	35 (60.3%)	<0.05*	0.326	0.001*	0.003*	2.775	1.422	5.417
	3-6 times/week 18 (17.1%)	0	2 (11.1%)	16 (88.8%)							
	1–6 times/day 29 (27.6%)	0	3 (10.3%)	26 (89.7%)							
h. **Dairy ice cream**	**≤ 2 times/week 76 (72.4%)**	6 (7.9%)	15 (19.7%)	55 (72.4%)	<0.05*	0.059	0.547	0.434	1.299	0.674	2.506
	3–6 times/week 16 (15.2%)	1 (6.3%)	4 (25%)	11 (68.7%)							
	1–6 times/day 13 (12.4%)	0	2 (15.4%)	11 (84.6%)							
i. **Soft drinks**	**≤ 2 times/week 67 (63.8%)**	7 (10.5%)	18 (26.9%)	42 (62.7%)	<0.05*	0.330	0.001*	0.004*	3.770	1.531	9.285
	3–6 times/week 15 (14.3%)	0	2 (13.3%)	13 (86.7%)							
	1–6 times/day 23 (21.9%)	0	1 (4.4%)	22 (95.6%)							
j. **Sweetened juice**	**≤ 2 times/week 46 (43.8%)**	3 (6.5%)	14 (30.4%)	29 (63.0%)	<0.05*	0.237	0.015*	0.016*	2.029	1.142	3.606
	3–6 times/week 27 (25.7%)	2 (7.4%)	6 (22.2%)	19 (70.4%)							
	1–6 times/day 32 (30.5%)	2 (6.3%)	1 (3.1%)	29 (90.6%)							

(Continued)

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TABLE 5 Continued

Dietary habits											
Parameter and categories		Number (%)			M-W test	Correlation			Logistic regression		
		dmft = 0	dmft = 1–3	dmft > 4	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
		7 (6.7%)	21 (20 %)	77 (73.3%)						Lower	Upper
k. **Granulated sugars**	**≤ 2 times/week 72 (68.6%)**	5 (6.9%)	18 (25%)	49 (68.1%)	<0.05*	0.188	0.055	0.047*	1.943	1.008	3.744
	3–6 times/week 10(9.5%)	2 (20%)	1 (10%)	7 (70%)							
	1–6 times/day 23 (21.9%)	0	2 (8.70%)	21 (91.30%)							
l. **Candies (sticky or not)**	**≤ 2 times/week 25 (23.8%)**	1 (4%)	8 (32%)	16 (64%)	0.003*	0.162	0.099	0.125	1.470	0.899	2.404
	3–6 times/week 20 (19%)	3 (15%)	4 (20%)	13 (65%)							
	1–6 times/day 60 (57.1%)	3 (5%)	9 (15%)	48 (80%)							
m. **Halawa/ honey**	**≤ 2 times/week 54 (51.4%)**	4 (7.4%)	11 (20.4%)	39 (72.2%)	<0.05*	0.098	0.320	0.239	1.368	0.812	2.304
	3–6 times/week 21 (20%)	2 (9.5%)	7 (33.3%)	12 (57.2%)							
	1–6 times/day 30 (28.6%)	1 (3.3%)	3 (10%)	26 (86.7%)							
n. **Crackers (biscuits/ chips)**	**≤ 2 times/week 24 (22.9%)**	1 (4.2%)	4 (16.7%)	19 (79.2%)	0.023*	0.020	0.839	0.972	0.991	0.593	1.657
	3–6 times/week 16 (15.2%)	2 (12.5%)	5 (31.3%)	9 (56.3%)							
	1–6 times/day 65 (61.9%)	4 (6.2%)	12 (18.5%)	49 (75.4%)							
o. **Cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa**	**≤ 2 times/week 70 (66.7%)**	6 (8.6%)	19 (27.1%)	45 (64.3%)	<0.05*	0.290	0.003*	0.009*	3.299	1.346	8.085
	3–6 times/week 15 (14.3%)	1 (6.7%)	1 (6.6%)	13 (86.7%)							
	1–6 times/day 20 (19%)	0	1 (5.0%)	19 (95.0%)							
p. **Fast food**	**≤ 2 times/week 76 (72.4%)**	7 (9.2%)	16 (21.1%)	53 (69.7%)	<0.05*	0.158	0.108	0.100	1.940	.881	4.273
	3–6 times/week 17 (16.2%)	0	4 (23.5%)	13 (76.5%)							
	1–6 times/day 12 (11.4%)	0	1 (8.3%)	11 (91.7%)							
q. **Chocolate**	**≤ 2 times/week 41 (39%)**	1 (2.4%)	8 (19.5%)	32 (78.1%)	<0.05*	−0.028	0.775	0.748	0.926	0.577	1.485
	3–6 times/week 18 (171%)	2 (11.1%)	6 (33.3%)	10 (55.6%)							
	1–6 times/day 46 (43.8%)	4 (8.7%)	7 (15.2%)	35 (76.1%)							
r. **Caffeinated drinks (coffee, tea)**	**≤ 2 times/week 72 (68.6%)**	7 (9.7%)	16 (22.2%)	49 (68.1%)	<0.05*	0.180	0.066	0.095	1.669	0.914	3.048
	3–6 times/week 10 (9.5%)	0	1 (10%)	9 (90.0%)							
	1–6 times/day 23 (21.9%)	0	4 (17.4%)	19 (82.6%)							

*Statistically significant.

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TABLE 6 Correlation between deft index and different risk factors (Total number 264).

Parameter and categories		Number (%)			M-W test	Correlation		Logistic regression			
		deft = 0 33 (12.5%)	deft = 1-386 (32.57%)	deft >4 145 (54.92%)	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
										Lower	Upper
Age (years)	AI 67 (25.4%)	5 (7.5%)	16 (23.9%)	46 (68.6%)	<0.05*	−0.278	<0.05*				
	AII 97 (36.7%)	7 (7.2%)	28 (28.9%)	62 (63.9%)							
	AIII 100 (37.9%)	21 (21.0%)	42 (42.0%)	37 (37.0%)							
Gender	Boys 124 (47.0%)	17 (13.7%)	41 (33.1%)	66 (53.2%)	<0.05*	0.037	0.549				
	Girls 140 (53.0%)	16 (11.4%)	45 (32.1%)	79 (56.5%)							
BMI	Normal (≥5-<85) 88 (33.3%)	16 (18.9%)	36 (40.9%)	36 (40.1%)	<0.05*	0.203	0.001*				
	Overweight (≥85-<95) and Obese (≥ 95) 176 (66.7%)	17 (9.7%)	50 (28.4%)	109 (61.9%)							
Lifestyle habits											
Lifestyle habits	Unhealthy habits 108 (40.9%)	6 (5.6%)	37 (34.3%)	65 (60.1%)	<0.05*	−0.173	0.005*				
	Moderate 140 (53%)	23 (16.4%)	42 (30%)	75 (53.1%)							
	Healthy habits 16 (6.1%)	4 (25%)	7 (43.7%)	5 (31.3%)							

*Statistically significant.

the Faculty of Dentistry, Cairo University. In addition, another major limitation is the cross-sectional study design, as the exposure and outcome are concurrently assessed. Finally, this study did not include questions about participants' oral hygiene and socioeconomic status which can be justified by the inclusion of such questions in a previous study among Egyptian adults (69) and children (47) conducted by our group. As per our previous study, poor oral hygiene was one of the risk factors significantly associated with caries prevalence among Egyptian adults (69) and children (47).

Study participants were recruited from the pediatrics dental clinics, Faculty of Dentistry, Cairo University. Hence, the majority of participants 342 (93.7%) suffered from dental caries, while only 27(7.3%) were caries-free. The highest mean dmft 6.9(± 4.6) and deft 5.5(± 3.9) were detected in an age group ranging from 5 to 6.9 years. This result could be attributed to lack of parental education, which affects their attitude regarding dental healthcare, with subsequent negligence toward maintaining a healthy primary dentition. Parents' ignorance can result in neglecting seeking dental treatment for their children as they regard primary teeth as unimportant and replaceable by permanent teeth (47, 81). On the contrary, the highest mean DMFT 1.8 (± 2.1) was detected in age group ranging from 9 to 10 years. A statistically significant positive correlation was detected between age and DMFT. Early loss of primary teeth due to a lack of parental education, with subsequent early eruption of their permanent successors, subjects permanent teeth to poor oral environment and to multiple caries-promoting factors (81).

The absence of dental services within the primary healthcare centers in Egypt leads to limited or no access to effective dental care (82). According to a WHO-sponsored epidemiological study on the state of oral health in Egypt, dental services were not being used to their full potential, and 40% of the included individuals stated that they had dental problems at the time of the study but chose not to seek dental care. According to the subjects' visitation patterns, roughly 20% had not seen a dentist in more than 2 years, and another 20% had never visited a dentist (9).

Diet and diet-related risks play a significant role in the incidence of obesity and dental caries. These diet factors include dietary habits frequencies, consumption of large amounts of fermentable carbohydrates, junk foods, and highly cariogenic diets (41).

Sugars are the most important and the most studied dietary factor in developing dental caries. In this study, there was a significant positive correlation between both dmft and DMFT with the consumption of desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa). Another significant positive correlation was found between deft and the consumption of dairy ice cream, candies, and crackers. The form (solid or liquid) of the fermentable carbohydrate directly influences the duration of exposure and retention of the food on the teeth. Thereby, prolonged retention of cariogenic components on teeth

TABLE 7 Correlation between deft index and frequency of intake of different food items (Total number 264).

Dietary habits											
		Number (%)			M-W test	Correlation			Logistic regression		
		deft = 0	deft = 1–3	deft > 4	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
		33 (12.5%)	86 (32.57%)	145 (54.92%)						Lower	Upper
a. Meat/poultry/fish	≤ 2 times/week 93 (35.2%)	6 (6.4%)	29 (31.2%)	58 (62.4%)	<0.05*	−0.186	0.002*	<0.05*	0.584	0.429	0.795
	3–6 times/week 94 (35.6%)	11 (11.7%)	28 (29.8%)	55 (58.5%)							
	1–6 times/day 77 (29.2%)	16 (20.8%)	29 (37.6%)	32 (41.6%)							
b. Carbohydrates	≤ 2 times/week 22 (8.3%)	6 (27.3%)	6 (27.3%)	10 (45.4%)	0.001*	0.002	0.973	0.983	0.996	0.680	1.458
	3–6 times/week 59 (22.4%)	3 (5.1%)	21 (35.6%)	35 (59.3%)							
	1–6 times/day 183 (69.3%)	24 (13.2%)	59 (32.2%)	100 (54.6%)							
c. Fresh fruits and vegetables	≤ 2 times/week 77 (29.2%)	7 (9.1%)	21 (27.3%)	49 (63.7%)	0.010*	−0.172	0.005*	0.002*	0.632	0.472	0.846
	3–6 times/week 55 (20.8%)	2 (3.6%)	19 (34.6%)	34 (61.8%)							
	1–6 times/day 132 (50%)	24 (18.2%)	46 (34.8%)	62 (47%)							
d. Legumes (fava beans/ hommos)	≤ 2 times/week 117 (44.3%)	18 (15.4%)	41 (35.0%)	58 (49.6%)	<0.05*	0.110	0.073	0.081	1.274	0.971	1.672
	3–6 times/week 52 (19.7%)	6 (11.5%)	17 (32.7%)	29 (55.8%)							
	1–6 times/day 95 (36%)	9 (9.5%)	28 (29.5%)	58 (61.0%)							
e. Sweetened cereals/ belela	≤ 2 times/week 167 (63.3%)	21 (12.6%)	55 (32.9%)	91 (54.5%)	<0.05*	0.022	0.726	0.485	1.103	0.837	1.453
	3–6 times/week 27 (10.3%)	4 (14.8%)	10 (37.0%)	13 (48.2%)							
	1–6 times/day 70 (26.5%)	8 (11.4%)	21 (30.0%)	41 (58.6%)							
f. Dairy products un sweetened milk/ cheese/ yogurt	≤ 2 times/week 62 (23.4%)	4 (6.5%)	23 (37.1%)	35 (56.5%)	0.828	−0.073	0.237	0.105	0.786	0.588	1.051
	3–6 times/week 45 (17.1%)	4 (8.9%)	14 (31.1%)	27 (60.0 %)							
	1–6 times/day 157 (59.5%)	25 (15.9%)	49 (31.2%)	83 (52.9%)							
g. Sweetened milk	≤ 2 times/week 125 (47.4%)	24 (19.2%)	43 (34.4%)	58 (46.4%)	<0.05*	0.185	0.003*	0.005*	1.468	1.126	1.913
	3–6 times/week 36 (13.6%)	4 (11.1%)	9 (25.0%)	23 (63.9%)							
	1–6 times/day 103 (39.0%)	5 (4.9%)	34 (33.0%)	64 (62.1%)							
h. Dairy ice cream	≤ 2 times/week 158 (59.9%)	24 (15.2%)	58 (36.7%)	76 (48.1%)	<0.05*	0.182	0.003*	0.005*	1.586	1.149	2.191
	3–6 times/week 55 (20.8%)	6 (10.9%)	16 (29.1%)	33 (60.0%)							
	1–6 times/day 51 (19.39%)	3 (5.9%)	12 (23.5%)	36 (70.6%)							
i. Soft drinks	≤ 2 times/week 176 (66.97%)	25 (14.2%)	60 (34.1%)	91 (51.7%)	<0.05*	0.118	0.055	0.003*	1.617	1.172	2.232
	3–6 times/week 35 (13.3%)	4 (11.4%)	14 (40.0%)	17 (48.6%)							
	1–6 times/day 53 (20%)	4 (7.6%)	12 (22.6%)	37 (69.8%)							
j. Sweetened juice	≤ 2 times/week 129 (48.9%)	21 (16.3%)	47 (36.4%)	61 (47.3%)	<0.05*	0.122	0.048*	0.075	1.297	0.974	1.728
	3–6 times/week 59 (22.4%)	3 (5.1%)	16 (27.1%)	40 (67.8%)							
	1–6 times/day 76 (28.8%)	9 (11.8%)	23 (30.3%)	44 (57.9%)							

(Continued)

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TABLE 7 Continued

		Number (%)			M-W test	Correlation			Logistic regression		
		deft = 0	deft = 1–3	deft > 4	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
		33 (12.5%)	86 (32.57%)	145 (54.92%)						Lower	Upper
k. Granulated sugars	≤ 2 times/week 198 (75 %)	26 (13.1%)	69 (34.9%)	103 (52.0%)	<0.05*	0.096	0.120	0.096	1.317	0.952	1.821
	3–6 times/week 18 (6.8%)	2 (11.1%)	5 (27.8%)	11 (61.1%)							
	1–6 times/day 48 (18.2%)	5 (10.4%)	12 (25.0%)	31 (64.6%)							
l. Candies (sticky or not)	≤ 2 times/week 98 (37.1%)	13 (13.3%)	40 (40.8%)	45 (45.9%)	<0.05*	0.141	0.021*	0.031*	1.340	1.027	1.750
	3–6 times/week 47 (17.8%)	7 (14.9%)	15 (31.2%)	25 (53.2%)							
	1–6 times/day 119 (45.1%)	13 (10.9%)	31 (26.1%)	75 (63.0 %)							
m. Halawa/ honey	≤ 2 times/week 148 (56.1%)	20 (13.5%)	48 (32.4%)	80 (54.1%)	<0.05*	0.013	0.833	0.844	0.973	0.744	1.273
	3–6 times/week 39 (14.8%)	6 (15.4%)	8 (20.5%)	25 (64.1%)							
	1–6 times/day 77 (29.1%)	7 (9.1%)	30 (39%)	40 (51.9%)							
n. Crackers (biscuits/ chips)	≤ 2 times/week 56 (21.2%)	7 (12.5%)	24 (42.9%)	25 (44.6%)	0.702	0.141	0.022*	0.035*	1.364	1.022	1.821
	3–6 times/week 46 (17.4%)	8 (17.4%)	17 (37%)	21 (45.6%)							
	1–6 times/day 162 (61.4%)	18 (11.1%)	45 (27.8%)	99 (61.1%)							
o. Cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa	≤ 2 times/week 180 (68.2%)	23 (12.8%)	60 (33.3%)	97 (53.9%)	<0.05*	0.051	0.411	0.165	1.285	0.902	1.830
	3–6 times/week 51 (19.3%)	6 (11.7%)	21 (41.2%)	24 (47.1%)							
	1–6 times/day 33 (12.5%)	4 (12.1%)	5 (15.2%)	24 (72.7%)							
p. Fast food	≤ 2 times/week 168 (63.6%)	20 (11.9%)	58 (34.5%)	90 (53.6%)	<0.05*	0.026	0.670	0.315	1.178	0.856	1.622
	3–6 times/week 50 (18.9%)	5 (10.0%)	18 (36.0%)	27 (54.0%)							
	1–6 times/day 46 (17.4%)	8 (17.4%)	10 (21.7%)	28 (60.9%)							
q. Chocolate	≤ 2 times/week 122 (46.2%)	14 (11.5%)	47 (38.5%)	61 (50.0%)	<0.05*	0.063	0.308	0.531	1.092	0.829	1.438
	3–6 times/week 52 (19.7%)	5 (9.6%)	17 (32.7%)	30 (57.7%)							
	1–6 times/day 90 (34.1%)	14 (15.6%)	22 (24.4%)	54 (60.0%)							
r. Caffeinated drinks (coffee, tea)	≤ 2 times/week 196 (74.2%)	25 (12.8%)	68 (34.7%)	103 (52.5%)	<0.05*	0.084	0.175	0.069	1.348	0.978	1.858
	3–6 times/week 21 (8%)	5 (23.8%)	5 (23.8%)	11 (52.4%)							
	1–6 times/day 47 (17.8%)	3 (6.4%)	13 (27.7%)	31 (65.9%)							

*Statistically significant.

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TABLE 8 Correlation between DMFT index and different risk factors (Total number 264).

Parameter and categories		Number (%)			M-W test	Correlation		Logistic regression			
		DMFT = 0 173 (65.53%)	DMFT = 1–3 54 (20.45%)	DMFT > 4 37 (14.01%)	*p*-value	rho	*p*-value	*p*-value	OR	95% CI for OR	
										Lower	Upper
Age (years)	AI 67 (25.4%)	63 (94.03%)	4 (5.97%)	0	<0.05*	0.460	<0.05*				
	AII 97 (36.7%)	70 (72.16%)	17 (17.53%)	10 (10.31%)							
	AIII 100 (37.9%)	40 (40%)	33 (33%)	27 (27%)							
Gender	Boys 124 (47%)	85 (68.55%)	24 (19.35%)	15 (12.10%)	0.012*	0.063	0.307				
	Girls 140 (53%)	88 (62.86%)	30 (21.43%)	22 (15.71%)							
BMI	Normal (≥5–<85) 88 (33.3%)	62 (70.45%)	16 (18.18%)	10 (11.36%)	<0.05*	0.075	0.225				
	Overweight (≥85–<95) and Obese (≥ 95) 176 (66.7%)	111 (63.07%)	38 (21.59%)	27 (15.34%)							
Lifestyle habits											
Lifestyle habits	Unhealthy habits 108 (40.9%)	73 (67.6%)	15 (13.9%)	20 (18.5%)	<0.05*	−0.009	0.883				
	Moderate 140 (53%)	88 (62.8%)	37 (26.4%)	15 (10.7%)							
	Healthy habits 16 (6.1%)	12 (75%)	2 (12.5%)	2 (12.5%)							

*Statistically significant.

surfaces causes acid production with subsequent early teeth demineralization and caries initiation and propagation (83).

Previous studies revealed that fluid consumption patterns have changed over the past decade with rising consumption of sugary drinks and less consumption of water and milk (84, 85). In this study, the consumption of sweetened juices was found to be associated with all caries indices: dmft, deft, and DMFT. A recent systematic review (86) declared the need to control, limit, and manage the intake of sweetened juices, as they could degenerate not only an adult's dental health but one's overall wellness. Furthermore, Kim et al. (87) recorded in their study conducted in the United States, that among the studied subjects, 26% of young adults lost one or more teeth in association with massive intake of sweetened juices. Interestingly, frequent and prolonged bottle-feeding practices, as well as high consumption of sweet drinks during weaning, could be associated with the formation of early childhood caries (88). It is important to increase the awareness among parents concerning bottle-feeding practices and weaning diet contents and highlight the potential implication for their children's oral health.

In this study, there was a significant positive correlation between dmft and DMFT with soft drinks. It was reported that children with a high consumption rate of soft drinks have undesirable eating patterns and eat high amounts of sugars from other dietary sources. Such an unhealthy diet pattern affects both the primary and permanent dentition (89–91). In contrast, this disagrees with our previous work (47), which recorded a non-significant correlation between soft drinks and dental caries.

A statistically significant negative correlation was detected between dmft and dairy products (unsweetened milk/ cheese/ yogurt). These findings are in agreement with our previous work (47). Egyptian children who consume milk more frequently possessed lower caries index. Milk has low cariogenic potential as it contains calcium, phosphorus, and casein, which are considered caries protective factors (83, 90).

The inverse significant association between fruit/vegetable consumption and caries in all age groups agrees with a study that recorded that dental caries prevalence was higher in non-vegetarians than vegetarians (92). This association could be explained by a lower tendency to consume sweets between meals in vegetarians than non-vegetarians (93). In addition, the naturally occurring sugar within whole fruits, vegetables, some grains, and dairy products is less likely to be overconsumed and is counteracted by the wide range of bioactive health-enhancing nutrients, antioxidants, fiber, and phytochemicals present in fruits/vegetables that can reduce inflammation and improve endothelial function (94).

It has been authorized that a lower risk for first permanent molars caries was found in children consuming diet rich in red meat, poultry, organs, eggs, and seafood (95). Moreover, there was an inverse significant association between meat/poultry/fish and dmft ($p<0.05$) in this study. These results are concomitant with a study carried out in Zhejiang Province, exploring the

TABLE 9 Correlation between DMFT index and frequency of intake of different food items (Total number 264).

Dietary habits											
Parameter and categories		**Number (%)**			**M-W test**	**Correlation**			**Logistic regression**		
		DMFT = 0	**DMFT = 1–3**	**DMFT > 4**	***p*-value**	**rho**	***p*-value**	***p*-value**	**OR**	**95%CI for OR**	
		173 (65.53%)	**54 (20.45%)**	**37 (14.01%)**						**Lower**	**Upper**
a. Meat/poultry/fish	≤ 2 times/week 93 (35.2%)	55 (59.1%)	24 (25.8%)	14 (15.1%)	<0.05*	−0.110	0.074	0.072	0.748	0.545	1.027
	3-6 times/week 94 (35.6%)	61 (64.9%)	20 (21.3%)	13 (13.8%)							
	1-6 times/day 77 (29.2%)	57 (74%)	10 (13%)	10 (13%)							
b. Carbohydrates	≤ 2 times/week 22 (8.3%)	13 (59.1%)	6 (27.3%)	3 (13.6%)	<0.05*	−0.058	0.349	0.368	0.841	0.577	1.226
	3-6 times/week 59 (22.4%)	36 (61.0%)	15 (25.4%)	8 (13.6%)							
	1-6 times/day 183 (69.3%)	124 (67.8%)	33 (18.0%)	26 (14.2%)							
c. Fresh fruits and vegetables	≤ 2 times/week 77 (29.2%)	45 (58.4%)	18 (23.4%)	14 (18.2%)	<0.05*	−0.128	0.038*	0.041*	0.741	0.557	0.987
	3-6 times/week 55 20.8%)	33 (60.0%)	15 (27.3%)	7 (12.7%)							
	1-6 times/day 132 (50%)	95 (72%)	21 (15.9%)	16 (12.1%)							
d. Legumes (fava beans/ hommos)	≤ 2 times/week 117 (44.3%)	78 (66.7%)	22 (18.8%)	17 (14.5%)	<0.05*	−0.050	0.414	0.367	0.879	0.664	1.163
	3–6 times/week 52 (19.7%)	26 (50.0%)	15 (28.9%)	11 (21.1%)							
	1–6 times/day 95 (34.8%)	69 (72.6%)	17 (17.9%)	9 (9.5%)							
e. Sweetened cereals/ belela	≤ 2 times/week 167 (63.3%)	110 (65.9%)	39 (23.3%)	18 (10.8%)	0.143	0.061	0.322	0.228	1.191	0.896	1.582
	3–6 times/week 27 (10.2%)	21 (77.8%)	4 (14.8%)	2 (7.4%)							
	1–6 times/day 70 (26.5 %)	42 (60.0%)	11 (15.7%)	17 (24.3%)							
f. Dairy products un sweetened milk/ cheese/ yogurt	≤ 2 times/week 62 (23.5%)	41 (66.1%)	9 (14.5%)	12 (19.4%)	<0.05*	−0.079	0.200	0.274	0.847	0.629	1.140
	3-6 times/week 45 (17.1%)	23 (51.1%)	16 (35.6%)	6 (13.3%)							
	1-6 times/day 157 (59.4%)	109 (69.4%)	29 (18.5%)	19 (12.1%)							
g. Sweetened milk	≤ 2 times/week 125 (47.4%)	84 (67.2%)	25 (20.0%)	16 (12.8%)	<0.05*	0.062	0.316	0.301	1.151	0.881	1.504
	3-6 times/week 36 (13.6%)	27 (75.0%)	4 (11.1%)	5 (13.9%)							
	1-6 times/day 103 (39.0%)	62 (60.2%)	25 (24.3%)	16 (15.5%)							
h. Dairy ice cream	≤ 2 times/week158 (59.9%)	103 (65.2%)	34 (21.2%)	21 (13.3%)	0.121	−0.017	0.783	0.668	0.933	0.680	1.281
	3–6 times/week 55 (20.8%)	34 (61.8%)	11 (20.0%)	10 (18.2%)							
	1–6 times/day 51 (19.3%)	36 (70.6%)	9 (17.7%)	6 (11.7%)							
i. Soft drinks	≤ 2 times/week 176 (66.7%)	122 (69.3%)	35 (19.9%)	19 (10.8%)	0.792	0.139	0.024*	0.018*	1.440	1.065	1.948
	3–6 times/week 35 (13.2%)	22 (62.9%)	9 (25.7%)	4 (11.4%)							
	1–6 times/day 53 (20.1%)	29 (54.7%)	10 (18.9%)	14 (26.4%)							
j. Sweetened juice	≤ 2 times/week 129 (48.8%)	95 (73.6%)	23 (17.8%)	11 (8.5%)	<0.05*	0.167	0.007*	0.008*	1.479	1.106	1.980
	3–6 times/week 59 (22.4%)	33 (55.9%)	17 (28.8%)	9 (15.3%)							
	1–6 times/day 76 (28.8%)	45 (59.2%)	14 (18.4%)	17 (22.4%)							

(Continued)

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TABLE 9 Continued

Dietary habits

Parameter and categories		Number (%)			M-W test	Correlation			Logistic regression		
		DMFT = 0	DMFT = 1–3	DMFT > 4	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
		173 (65.53%)	54 (20.45%)	37 (14.01%)						Lower	Upper
k. Granulated sugars	≤ 2 times/week 198 (75%)	137 (69.2%)	35 (17.7%)	26 (13.1%)	0.097	0.101	0.103	0.261	1.193	0.877	1.622
	3–6 times/week 18 (6.8%)	5 (27.8%)	8 (44.4%)	5 (27.8%)							
	1–6 times/day 48 (18.2%)	31 (64.6%)	11 (22.9%)	6 (12.5%)							
l. Candies (sticky or not)	≤ 2 times/week 98 (37.1%)	69 (70.4%)	16 (16.3%)	13 (13.3%)	<0.05*	0.091	0.139	0.138	1.237	0.934	1.639
	3–6 times/week 47 (17.8%)	31 (65.9%)	14 (29.8%)	2 (4.3%)							
	1–6 times/day 119 (45.1%)	73 (61.3%)	24 (20.2%)	22 (18.5%)							
m. Halawa/ honey	≤ 2 times/week 148 (56.1%)	101 (68.3%)	34 (22.9%)	13 (8.8%)	0.002*	0.094	0.128	0.132	1.240	0.937	1.642
	3-6 times/week 39 (14.8%)	24 (61.5%)	8 (20.5%)	7 (18.0%)							
	1-6 times/day 77 (29.1%)	48 (62.3%)	12 (15.6%)	17 (22.1%)							
n. Crackers (biscuits/ chips)	≤ 2 times/week 56 (21.2%)	40 (71.4%)	10 (17.9%)	6 (10.7%)	<0.05*	0.043	0.488	0.413	1.139	0.834	1.554
	3-6 times/week 46 (17.4%)	28 (60.9%)	12 (26.1%)	6 (13.0%)							
	1-6 times/day 162 (61.4%)	105 (64.8%)	32 (19.8%)	25 (15.4%)							
o. Cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa	≤ 2 times/week 180 (68.2%)	125 (69.5%)	40 (22.2%)	15 (8.3%)	0.503	0.158	0.010*	0.015*	1.538	1.089	2.172
	3–6 times/week 51 (19.3%)	29 (56.8%)	9 (17.7%)	13 (25.5%)							
	1–6 times/day 33 (12.5%)	19 (57.6%)	5 (15.1%)	9 (27.3%)							
p. Fast food	≤ 2 times/week 168 (63.6%)	115 (68.45%)	36 (21.4%)	17 (10.1%)	0.511	0.102	0.097	0.114	1.291	0.941	1.772
	3-6 times/week 50 (19%)	30 (60.0%)	10 (20.0%)	10 (20.0%)							
	1-6 times/day 46 (17.4%)	28 (60.9%)	8 (17.4%)	10 (21.7%)							
q. Chocolate	≤ 2 times/week 122 (46.2%)	78 (63.9%)	29 (23.8%)	15 (12.3%)	<0.05*	−0.001	0.981	0.997	1.001	0.754	1.328
	3–6 times/week 52 (19.7%)	35 (67.3%)	13 (25.0%)	4 (7.8%)							
	1–6 times/day 90 (34.1%)	60 (66.7%)	12 (13.3%)	18 (20.0%)							
r. Caffeinated drinks (coffee, tea)	≤ 2 times/week 196 (74.2%)	130 (66.3%)	38 (19.4%)	28 (14.3%)	0.128	0.014	0.826	0.943	1.012	0.737	1.388
	3–6 times/week 21 (8%)	12 (57.1%)	5 (23.8%)	4 (19.1%)							
	1–6 times/day 47 (17.8%)	31 (66%)	11 (23.4%)	5 (10.6%)							

*Statistically significant.

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TABLE 10 Correlation between BMI and different risk factors (Total number 369).

Parameter and categories		Number (%)		M-W test	Correlation		Logistic regression			
		Normal (≥5–<85)	Over weight (≥85–<95) and Obese (≥ 95)	*p*-value	rho	*p*-value	*p*-value	OR	95% CI for OR	
									Lower	Upper
Age (years)	AI	60 (35.1%)	111 (64.9%)	<0.05*	0.033	0.524				
	AII	30 (30.6%)	68 (69.4%)							
	AIII	32 (32%)	68 (68%)							
Gender	Boys	58 (32.2%)	122 (67.8%)	<0.05*	−0.017	0.739				
	Girls	64 (33.9%)	125 (66.1%)							
Lifestyle habits										
Lifestyle habits	Unhealthy habits	40 (26.32%)	112 (73.7%)	<0.05*	−0.146	0.005*				
	Moderate	67 (35.26%)	123 (64.7)							
	Healthy habits	15 (55.56%)	12 (44.4%)							

*Statistically significant.

prevalence of dental caries in 6- to 8-year-old children, especially their first permanent molars (95).

Obesity and dental caries are multifactorial in etiology as multiple genetic and environmental factors may impact them. Consequently, these confounding factors, including age, gender, lifestyle, and oral hygiene habits, might control their incidence (96).

Individual body weight relative to population norms was evaluated by calculating BMI using the formula BMI = weight in kilograms/height in meters squared (97). Our study found a positive correlation between increased weight represented through BMI and both dmft and deft. This finding contradicts our previous findings, where no correlation between BMI and all caries indices was reported (47). Overweight–obese children have a higher risk of developing dental caries than normal-weight children (98) as they tend to consume high levels of cariogenic and obesogenic food and drinks (26). These findings are confirmed by our results where a significant correlation was recorded between overweight/obesity and the consumption of soft drinks, fast foods, dairy ice cream, granulated sugars, and desserts (cakes/ doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa).

In this study, 66.9% of the studied population were overweight/obese. This percentage is higher than what has been reported in our previous work in 2020, as the percentage of overweight/obese children in the same age group was 44.4% (99). The small sample size for this age group (5–9 years) in the previous work as well as the change in the dietary habits with the time could explain this discrepancy. In this work, a higher percentage of male participants were overweight/obesity than females, and BMI was significantly positively correlated with soft drinks. These findings support the results of our previous work (99).

A statistically significant positive correlation was detected between BMI and legumes. This result was in disagreement with a cross-sectional study conducted by Papanikolaou et al. (100), which concluded that legume consumption is related to healthier body weights, as legumes are not considered energy-dense food, they are low in dietary fat (101) and rich in dietary fibers (102). Since bread is an important dietary constituent and legumes are usually consumed with bread in the Egyptian diet, this combination might explain the positive correlation between BMI and legumes.

A statistically significant negative correlation was detected between BMI and meat/poultry/fish, fresh fruits, and vegetable consumption. This finding supports previous report that obese children's diet is usually low in fiber (103) and proteins, with protein-deficient malnutrition, while their energy intake comprises high carbohydrates and highly processed foods (104).

The literature reports on the association of dental caries with BMI are conflicting, and three systematic reviews (53, 105, 106) found inconclusive evidence regarding the association between obesity and dental caries. The possible

TABLE 11 Correlation between BMI and frequency of intake of different food items (Total number 369).

Dietary habits										
Parameter and categories		Number (%)		M-W test	Correlation			Logistic regression		
		Normal (≥5-<85)	Over weight (≥85-<95) and Obese (≥ 95)	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
									Lower	Upper
a. Meat/poultry/fish	≤ 2 times/week	25 (19.2%)	105 (80.8%)	<0.05*	−0.270	<0.05*	<0.05*	0.478	0.358	0.637
	3–6 times/week	40 (31.5%)	87 (68.5%)							
	1–6 times/day	57 (50.9%)	55 (49.1%)							
b. Carbohydrates	≤ 2 times/week	7 (26.9%)	19 (73.1%)	0.251	0.046	0.383	0.548	1.116	.779	1.600
	3–6 times/week	30 (41.1%)	43 (58.9%)							
	1–6 times/day	85 (31.5%)	185 (68.5%)							
c. Fresh fruits and vegetables	≤ 2 times/week	6 (6.3%)	90 (93.7%)	<0.05*	−0.395	<0.05*	<0.05*	.280	.195	.403
	3–6 times/week	20 (25%)	60 (75%)							
	1–6 times/day	96 (49.7%)	97 (50.3%)							
d. Legumes (fava beans/ hommos)	≤ 2 times/week	65 (39.6%)	99 (60.4%)	<0.05*	0.164	0.002*	0.002*	1.502	1.167	1.931
	3–6 times/week	28 (38.9%)	44 (61.1%)							
	1–6 times/day	29 (21.8%)	104 (78.2%)							
e. Sweetened cereals/ belela	≤ 2 times/week	80 (34.9%)	149 (65.1%)	<0.05*	0.084	0.107	0.051	1.299	.998	1.689
	3–6 times/week	21 (47.7%)	23 (52.3%)							
	1–6 times/day	21 (21.9%)	75 (78.1%)							
f. Dairy products unsweetened milk/ cheese/ yoghurt	≤ 2 times/week	26 (30.6%)	59 (69.4%)	<0.05*	−0.035	0.500	0.537	.920	.706	1.199
	3–6 times/week	21 (31.8%)	45 (68.2%)							
	1–6 times/day	75 (34.4%)	143 (65.6%)							
g. Sweetened milk	≤ 2 times/week	70 (38.3%)	113 (61.7%)	<0.05*	0.092	0.076	0.094	1.231	0.966	1.568
	3–6 times/week	13 (24.1%)	41 (75.9%)							
	1–6 times/day	39 (29.5%)	93 (70.5%)							
h. Dairy ice cream	≤ 2 times/week	88 (37.6%)	146 (62.4%)	<0.05*	0.142	0.006*	0.005*	1.564	1.147	2.133
	3–6 times/week	22 (30.9%)	49 (69.0%)							
	1–6 times/day	12 (18.7%)	52 (81.3%)							
i. Soft drinks	≤ 2 times/week 67 (63.8%)	98 (40.3%)	145 (59.7%)	<0.05*	0.265	<0.05*	<0.05*	2.700	1.862	3.916
	3–6 times/week 15 (14.3%)	23 (46%)	27 (54%)							
	1–6 times/day	1 (1.3%)	75 (98.7%)							

(Continued)

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TABLE 11 Continued

Dietary habits										
Parameter and categories		Number (%)		M-W test	Correlation			Logistic regression		
		Normal (≥5-<85)	Over weight (≥85-<95) and Obese (≥ 95)	*p*-value	rho	*p*-value	*p*-value	OR	95%CI for OR	
									Lower	Upper
j. Sweetened juice	≤ 2 times/week	64 (36.6%)	111 (63.4%)	<0.05*	0.079	0.129	0.594	1.306	0.944	1.583
	3–6 times/week	28 (32.6%)	58 (67.4%)							
	1–6 times/day	30 (27.8%)	78 (72.2%)							
h. Granulated sugars	≤ 2 times/week	99 (36.7%)	171 (63.3%)	<0.05*	0.148	0.004*	0.001*	1.675	1.221	2.299
	3–6 times/week	13 (46.4%)	15 (53.6%)							
	1–6 times/day	10 (14.1%)	61 (85.9%)							
i. Candies (sticky or not)	≤ 2 times/week	39 (31.7%)	84 (68.3%)	<0.05*	0.006	0.901	0.902	1.016	0.795	1.297
	3–6 times/week	26 (38.8%)	41 (61.2%)							
	1–6 times/day	57 (31.8%)	122 (68.2%)							
j. Halawa/ honey	≤ 2 times/week	66 (32.7%)	136 (67.3%)	<0.05*	0.021	0.690	0.544	1.080	0.842	1.386
	3–6 times/week	26 (43.3%)	34 (56.7%)							
	1–6 times/day	30 (28.0%)	77 (72%)							
k. Crackers (biscuits/ chips)	≤ 2 times/week	26 (32.5%)	54 (67.5%)	<0.05*	0.044	0.405	0.517	1.091	0.839	1.419
	3–6 times/week	26 (41.9%)	36 (58.1%)							
	1–6 times/day	70 (30.8%)	157 (69.2%)							
l. Doughnuts/ sweetened pies/ baklawa/ basbosa/ konafa	≤ 2 times/week	91 (36.4%)	159 (63.6%)	<0.05*	0.108	0.038*	0.039*	1.399	1.017	1.925
	3–6 times/week	19 (28.8%)	47 (71.2%)							
	1–6 times/day	12 (22.6%)	41 (77.4%)							
m. Fast food	≤ 2 times/week	94 (38.5%)	150 (61.5%)	<0.05*	0.191	<0.05*	<0.05*	2.008	1.411	2.856
	3–6 times/week	23 (34.3%)	44 (65.7%)							
	1–6 times/day	5 (8.6%)	53 (91.4%)							
n. Chocolate	≤ 2 times/week	47 (28.8%)	116 (71.2%)	<0.05*	−0.035	0.502	0.587	.935	.733	1.192
	3–6 times/week	32 (45.7%)	38 (54.3%)							
	1–6 times/day	43 (31.6%)	93 (68.4%)							
o. Caffeinated drinks (coffee, tea)	≤ 2 times/week	102 (38.1%)	166 (61.9%)	<0.05*	0.178	0.001*	<0.05*	1.726	1.252	2.381
	3–6 times/week	8 (25.8%)	23 (74.2%)							
	1–6 times/day	12 (17.1%)	58 (82.9%)							

*Statistically significant.

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reason (81) for the conflicting reports is that dental caries and BMI are non–linearly related, with more dental caries occurring in individuals with either higher or lower BMI. Thereby, we suggest that methodological factors together with sample demographics, dental examination accuracy, and data analysis methodology affect whether or not the association is detected.

There is a growing evidence that emphasizes the role of physical inactivity in the development of obesity among children and adults (26, 107, 108). This comes in accordance with our results, a statistically significant negative correlation was detected between BMI and healthy lifestyle habits.

There are multiple social and environmental factors linked to the purchase and consumption of sugar-sweetened beverages and junk food. Policies aiming to reduce their consumption should be addressed. First, regulating food advertising and promotion since there is a growing evidence on the relation between food advertising and increased intake of calorie-dense products by adult populations (109) and children (110). Second, labeling of sugar-sweetened beverages and raising awareness about their health effects. A systematic review on the impact of front-of-package labeling on consumption suggested that consumers identify healthier foods more easily from nutrient-specific schemes (111). Third, school interventions and nutrition policies to restrict the availability of sugar-sweetened beverages and provide healthier food in schools (112). Finally, imposing taxes on sugar-sweetened beverages. Higher prices of sugar-sweetened beverages, food taxes, and subsidies may affect their consumption rate and improve health outcomes (113–116). Among EMR, 15 countries have developed either a policy or prepared a draft to reduce the impact of marketing of unhealthy foods and beverages to children in educational facilities and on media. These countries include all high-income countries (GCC), middle-income countries (Egypt, Iran, Jordan, Lebanon, Morocco, Pakistan, and Palestine), and a low-income country (Yemen) (110, 117). Taxes on sugar-sweetened beverages have been implemented in all high-income countries (GCC) and middle-income countries including Egypt, Iran, Morocco, Palestine, and Tunisia. Front-of-pack labeling has been applied in five countries in EMR, Saudi Arabia, UAE, Iran, Morocco, and Tunisia (117).

Taken with this findings, both overweight/obesity and dental caries have mutual determinants and require an inclusive, integrated management approach by multidisciplinary medical teams. BMI calculation should be included in the standard dental evaluation of any pediatric patient, providing a screen for prevention, timely diagnosis, and treatment of the children suffering from dental caries and malnutrition (overweight/obesity). Soft drinks, sweetened juices, and sweetened snacks, which are frequently available at schools, are associated with overweight/obesity and dental caries. Hence, health promotion activities should highlight the importance of reducing the consumption of these unhealthy food items and other sugary foods in homes and schools.

Conclusion

Investigating the dietary habits of the Egyptian school children revealed a positive correlation between desserts (sweetened snacks), soft drinks, and the incidence of dental caries and overweight/obesity; conversely, the consumption of fruits and vegetables was negatively associated. Sweetened juices were positively associated with the three caries indices. Overweight/obesity was significantly positively correlated with primary dentition caries; accordingly, BMI calculation should be included in the routine examination in dental clinics. Despite the forward step taken by the Egyptian government by applying taxes on soft drinks, more taxes need to be applied on other sweetened beverages, including juices and milk. Moreover, legislation regulating the sale of these food items and prohibiting the marketing of these unhealthy food items in school canteens is mandatorily needed. In addition, the results of this study have identified children as a target group of the population to apply interventional and preventive strategies against dental caries and obesity. The government should educate parents about healthy dietary habits, dental health practices, and the benefits of physical activity through different media approaches. Further studies assessing the level of parents' awareness in more detail are needed.

Data availability statement

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

Ethics statement

The studies involving human participants were reviewed and approved by the Research Ethics Committee of Cairo University's Faculty of Dentistry's requirements

(Approval: 24920). Written informed consent to participate in this study was provided by the participants' legal guardian/next of kin. Written informed consent was obtained from the individual(s), and minor(s)' legal guardian/next of kin, for the publication of any potentially identifiable images or data included in this article.

Author contributions

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

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.

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References

1. Gill M. Book review: the challenge of oral disease: a call for global action. *Br Dent J.* (2016) 221:687. doi: 10.1038/sj.bdj.2016.898

2. World Health Organization. *Report of the Commission on Ending Childhood Obesity: World Health Organization.* (2016). Available online at: https://www.who.int/publications/i/item/9789241510066 (accessed February 15, 2022).

3. James SL, Abate D, Abate KH, Abay SM, Abbafati C, Abbasi N, et al. Global, regional, and national incidence, prevalence, and years lived with disability for 354 diseases and injuries for 195 countries and territories, 1990–2017: a systematic analysis for the global burden of disease study 2017. *Lancet.* (2018) 392:1789–858. doi: 10.1016/S0140-6736(18)32279-7

4. Vos T, Flaxman AD, Naghavi M, Lozano R, Michaud C, Ezzati M, et al. Years lived with disability (Ylds) for 1160 sequelae of 289 diseases and injuries 1990–2010: a systematic analysis for the global burden of disease study 2010. *Lancet.* (2012) 380:2163–96. doi: 10.1016/S0140-6736(12)61729-2

5. Kassebaum N, Bernabé E, Dahiya M, Bhandari B, Murray C, Marcenes W. Global burden of untreated caries: a systematic review and metaregression. *J Dent Res.* (2015) 94:650–8. doi: 10.1177/0022034515573272

6. Petersen PE, Bourgeois D, Ogawa H, Estupinan-Day S, Ndiaye C. The global burden of oral diseases and risks to oral health. *Bull World Health Organ.* (2005) 83:661–9.

7. Tinanoff N, Baez RJ, Diaz Guillory C, Donly KJ, Feldens CA, McGrath C, et al. Early childhood caries epidemiology, aetiology, risk assessment, societal burden, management, education, and policy: global perspective. *Int J Paediatr Dent.* (2019) 29:238–48. doi: 10.1111/ipd.12484

8. Lagerweij M, Van Loveren C. Declining caries trends: are we satisfied? *Curr Oral Health Rep.* (2015) 2:212–7. doi: 10.1007/s40496-015-0064-9

9. *Who Emro Egypt Releases Results of Epidemiological Study on Oral Health Status Egypt-Events Egypt*. (2014). Available online at: http://www.emro.who.int/egy/egypt-events/results-of-epidemiological-study-on-oral-health-status-released.html (accessed February 15, 2022).

10. Mohamed Ismail AEA. Caries assessment in preschool children in relation to some socioeconomic factors. *Adv Dent J.* (2022) 4:61–73. doi: 10.21608/adjc.2022.101295.1116

11. Abanto J, Carvalho TS, Mendes FM, Wanderley MT, Bönecker M, Raggio DP. Impact of oral diseases and disorders on oral health-related quality of life of preschool children. *Community Dent Oral Epidemiol.* (2011) 39:105–14. doi: 10.1111/j.1600-0528.2010.00580.x

12. Cantekin K, Yildirim MD, Cantekin I. Assessing change in quality of life and dental anxiety in young children following dental rehabilitation under general anesthesia. *Pediatr Dent.* (2014) 36:12E–7.

13. Cunnion D, Spiro A, Jones J, Rich S, Papageorgiou C, Tate A, et al. Pediatric oral health-related quality of life improvement after treatment of early childhood caries: a prospective multisite study. *J Dent Child.* (2010) 77:4–11.

14. Ramos-Jorge J, Pordeus IA, Ramos-Jorge ML, Marques LS, Paiva SM. Impact of untreated dental caries on quality of life of preschool children: different stages and activity. *Community Dent Oral Epidemiol.* (2014) 42:311–22. doi: 10.1111/cdoe.12086

15. Sajadi FS, Pishbin L, Azhari SH, Moosazadeh M. Impact of oral and dental health on children's and parents' quality of life based on early childhood oral health impact scale (Ecohis) index. *Int J Dent Sci Res.* (2015) 3:28–31. doi: 10.12691/ijdsr-3-2-2

16. Acs G, Lodolini G, Kaminsky S, Cisneros GJ. Effect of nursing caries on body weight in a pediatric population. *Pediatr Dent.* (1992) 14:303.

17. Acs G, Shulman R, Chussid S, Ng M. The effect of dental rehabilitation on the body weight of children with early childhood caries. *Pediatr Dent.* (1999) 21:109–13.

18. Casamassimo PS, Thikkurissy S, Edelstein BL, Maiorini E. Beyond the Dmft: the human and economic cost of early childhood caries. *J Am Dent Assoc.* (2009) 140:650–7. doi: 10.14219/jada.archive.2009.0250

19. Sheiham A. Dental caries affects body weight, growth and quality of life in pre-school children. *Br Dent J.* (2006) 201:625–6. doi: 10.1038/sj.bdj.4814259

20. Thomas CW, Primosch RE. Changes in incremental weight and well-being of children with rampant caries following complete dental rehabilitation. *Pediatr Dent.* (2002) 24:109–13.

21. Low W, Tan S, Schwartz S. The effect of severe caries on the quality of life in young children. *Pediatr Dent.* (1999) 21:325–6.

22. Hobdell M, Clarkson J, Petersen P, Johnson N. Global goals for oral health 2020. *Int Dent J.* (2003) 53:285–8. doi: 10.1111/j.1875-595X.2003.tb00761.x

23. WHO Organization. *Global Action Plan for the Prevention and Control of Noncommunicable Diseases 2013–2020*. Geneva: World Health Organization (2013).

24. World Health Organization. *Oral Health*. (2021). Available online at: https://www.who.int/news-room/fact-sheets/detail/oral-health

25. Aitsi-Selmi A, Chandola T, Friel S, Nouraei R, Shipley MJ, Marmot MG. Interaction between education and household wealth on the risk of obesity in women in Egypt. *PLoS ONE.* (2012) 7:e39507. doi: 10.1371/journal.pone.0039507

26. World Health Organization. *Obesity and Overweight*. (2021). Available online at: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight (accessed February 15, 2022).

27. *Most Obese Countries in the World Procon Org*. (2020). Available online at: https://obesity.procon.org/global-obesity-levels (accessed February 15, 2022).

28. World Health Organization. *The Global Health Observatory*. Available online at: https://www.who.int/data/gho/data (accessed February 15, 2022).

29. WHO Organization. *Taking Action on Childhood Obesity*. World Health Organization (2018). Available online at: https://apps.who.int/iris/handle/10665/274792.

30. Petersen PE. The world oral health report 2003: continuous improvement of oral health in the 21st century–the approach of the who global oral health programme. *Community Dent Oral Epidemiol.* (2003) 31:3–24. doi: 10.1046/j..2003.com122.x

31. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among us children and adolescents, 1999-2010. *JAMA*. (2012) 307:483–90. doi: 10.1001/jama.2012.40

32. Bagramian RA, Garcia-Godoy F, Volpe AR. The global increase in dental caries. A pending public health crisis. *Am J Dent.* (2009) 22:3–8.

33. Allison DB, Bassaganya-Riera J, Burlingame B, Brown AW, le Coutre J, Dickson SL, et al. Goals in nutrition science 2015–2020. *Front Nutr.* (2015) 2:26. doi: 10.3389/fnut.2015.00026

34. Pyne V, Macdonald IA. Update on carbohydrates and health: the relevance of the scientific advisory committee on nutrition report for children. *Arch Dis Child.* (2016) 101:876–80. doi: 10.1136/archdischild-2015-310200

35. Drewnowski A, Mennella JA, Johnson SL, Bellisle F. Sweetness and food preference. *J Nutr.* (2012) 142:1142S—8. doi: 10.3945/jn.111.149575

36. Shenkin JD, Heller KE, Warren JJ, Marshall TA. Soft drink consumption and caries risk in children and adolescents. *Gen Dent.* (2003) 51:30–6.

37. Maffeis C, Tatò L. Long-term effects of childhood obesity on morbidity and mortality. *Horm Res Paediatr*. (2001) 55(Suppl. 1):42–5. doi: 10.1159/000063462

38. Gilchrist F, Marshman Z, Deery C, Rodd HD. The impact of dental caries on children and young people: what they have to say? *Int J Paediatr Dent.* (2015) 25:327–38. doi: 10.1111/ipd.12186

39. Spiegel KA, Palmer CA. Childhood dental caries and childhood obesity. Different problems with overlapping causes. *Am J Dent.* (2012) 25:59–64.

40. Chi DL, Luu M, Chu F, A. scoping review of epidemiologic risk factors for pediatric obesity: implications for future childhood obesity and dental caries prevention research. *J Public Health Dent.* (2017) 77:S8–31. doi: 10.1111/jphd.12221

41. Kottayi S, Bhat SS, Hegde KS, Peedikayil FC, Chandru T, Anil S, et al. cross-sectional study of the prevalence of dental caries among 12-to 15-year-old overweight schoolchildren. *Contemp Dent Pract.* (2016) 17:750–4. doi: 10.5005/jp-journals-10024-1924

42. da Silva RAB, Barreiros D, Oliveira S, da Silva LAB, Nelson-Filho P, Küchler EC. Association between body mass index and caries experience in Brazilian children and adolescents. *J Dent Child.* (2016) 83:146–51.

43. El Qomsan MAA, Alasqah MN, Alqahtani FA, Alobaydaa MA, Alharbi MM, Kola Z. Intricate evaluation of association between dental caries and obesity among the children in Al-Kharj City (Saudi Arabia). *JCDP.* (2017) 18:29–33. doi: 10.5005/jp-journals-10024-1983

44. Lobstein T, Jackson-Leach R, Moodie ML, Hall KD, Gortmaker SL, Swinburn BA, et al. Child and adolescent obesity: part of a bigger picture. *Lancet.* (2015) 385:2510–20. doi: 10.1016/S0140-6736(14)61746-3

45. Blomquist H, Bergstrøm E. Obesity in 4-year-old children more prevalent in girls and in municipalities with a low socioeconomic level. *Acta Paediatr.* (2007) 96:113–6. doi: 10.1111/j.1651-2227.2006.00018.x

46. Marshall TA, Eichenberger-Gilmore JM, Broffitt BA, Warren JJ, Levy SM. Dental caries and childhood obesity: roles of diet and socioeconomic status. *Community Dent Oral Epidemiol.* (2007) 35:449–58. doi: 10.1111/j.1600-0528.2006.00353.x

47. Abbass MM, Mahmoud SA, El Moshy S, Rady D, AbuBakr N, Radwan IA, et al. The prevalence of dental caries among egyptian children and adolescences and its association with age, socioeconomic status, dietary habits and other risk factors. a cross-sectional study. *F1000Research*. (2019) 8:243. doi: 10.12688/f1000research.17892.1

48. Yousaf M, Aslam T, Saeed S, Sarfraz A, Sarfraz Z, Cherrez-Ojeda I. Individual, family, and socioeconomic contributors to dental caries in children from low- and middle-income countries. *Int J Environ Res Public Health Monograph.* (2022) 19:7114. doi: 10.3390/ijerph19127114

49. Jaacks LM, Vandevijvere S, Pan A, McGowan CJ, Wallace C, Imamura F, et al. The obesity transition: stages of the global epidemic. *Lancet Diabetes Endocrinol.* (2019) 7:231–40. doi: 10.1016/S2213-8587(19)30026-9

50. Popkin BM. Nutritional patterns and transitions. *Popul Dev Rev.* (1993) 19:138–57. doi: 10.2307/2938388

51. Alswat K, Mohamed WS, Wahab MA, Aboelil AA. The association between body mass index and dental caries: cross-sectional study. *J Clin Med Res.* (2016) 8:147. doi: 10.14740/jocmr2433w

52. Costacurta M, DiRenzo L, Sicuro L, Gratteri S, De Lorenzo A, Docimo R. Dental caries and childhood obesity: analysis of food intakes, lifestyle. *Eur J Paediatr Dent.* (2014) 15:343–8.

53. Hayden C, Bowler JO, Chambers S, Freeman R, Humphris G, Richards D, et al. Obesity and dental caries in children: a systematic review and meta-analysis. *Community Dent Oral Epidemiol.* (2013) 41:289–308. doi: 10.1111/cdoe.12014

54. Alkarimi HA, Watt RG, Pikhart H, Sheiham A, Tsakos G. Dental caries and growth in school-age children. *Pediatrics.* (2014) 133:e616–23. doi: 10.1542/peds.2013-0846

55. Yang F, Zhang Y, Yuan X, Yu J, Chen S, Chen Z, et al. Caries experience and its association with weight status among 8-year-old children in Qingdao, China. *J Int Soc Prevent Communit Dent.* (2015) 5:52. doi: 10.4103/2231-0762.151978

56. Miller J, Vaughan-Williams E, Furlong R, Harrison L. Dental caries and children's weights. *J Epidemiol Community Health.* (1982) 36:49–52. doi: 10.1136/jech.36.1.49

57. Peng SM, Wong HM, King NM, McGrath C. Is dental caries experience associated with adiposity status in preschool children? *Int J Paediatr Dent.* (2014) 24:122–30. doi: 10.1111/ipd.12039

58. de Jong-Lenters M, van Dommelen P, Schuller AA, Verrips EH. Body mass index and dental caries in children aged 5 to 8 years attending a dental paediatric referral practice in the Netherlands. *BMC Res Notes.* (2015) 8:1–7. doi: 10.1186/s13104-015-1715-6

59. Daniel WW, Cross CL. *Biostatistics: A Foundation for Analysis in the Health Sciences.* 11th ed. Hoboken, NJ: Wiley (2018).

60. Kale S, Kakodkar P, Shetiya S, Abdulkader R. Prevalence of dental caries among children aged 5–15 years from 9 countries in the eastern mediterranean region: a meta-analysis. *East Mediterr Health J.* (2020) 26:726–35. doi: 10.26719/emhj.20.050

61. Quach A, Laemmle-Ruff IL, Polizzi T, Paxton GA. Gaps in smiles and services: a cross-sectional study of dental caries in refugee-background children. *BMC Oral Health.* (2015) 15:1–10. doi: 10.1186/1472-6831-15-10

62. World Bank. *World Bank Staff Estimates Based on Age/Sex Distributions of United Nations Population Division's World Population Prospects: 2019 Revision*. (2019).

63. World Health Organization. *Global Health Observatory Data Repository*. Available online at: http://apps.who.int/gho/data/node.main (accessed January 13, 2021).

64. WHO Organization. *Oral Health Surveys: Basic Methods*. 5th edition ed. Geneva: World Health Organization (2013).

65. Otsuka Y, Kaneita Y, Itani O, Osaki Y, Higuchi S, Kanda H, et al. Association between unhealthy dietary behaviors and sleep disturbances among Japanese adolescents: a nationwide representative survey. *Sleep Biol Rhythms.* (2019) 17:93–102. doi: 10.1007/s41105-018-0193-3

66. *Making Sense of Media*. (2019). Available online at: https://www.ofcom.org.uk/__data/assets/pdf_file/0024/134907/children-and-parents-media-use-and-attitudes-2018.pdf (accessed January 16, 2022).

67. Abbass MM, Rady D, Radwan IA, El Moshy S, AbuBakr N, Ramadan M, et al. The occurrence of periodontal diseases and its correlation with different risk factors among a convenient sample of adult Egyptian population: a cross-sectional study. *F1000Research*. (2019) 8:1740. doi: 10.12688/f1000research.20310.1

68. Diet History Questionnaire, Version 2.0 (Dhq-Ii) Snap-Ed. (2016). Available online at: https://snaped.fns.usda.gov/library/materials/diet-history-questionnaire-version-20-dhq-ii (accessed January 16, 2022).

69. Abbass MM, AbuBakr N, Radwan IA, Rady D, El Moshy S, Ramadan M, et al. The potential impact of age, gender, body mass index, socioeconomic status and dietary habits on the prevalence of dental caries among egyptian adults: a cross-sectional study. *F1000Research*. (2019) 8.

70. WHO Organization. *Physical Status: The Use of and Interpretation of Anthropometry, Report of a Who Expert Committee*. World Health Organization (1995).

71. World Health Organization. *Growth Reference 5–19 Years*. World Health Organization (2014). Available online at: https://www.who.int/tools/growth-reference-data-for-5to19-years (accessed January 16, 2022).

72. Tanaka K, Ogata S, Tanaka H, Omura K, Honda C, Hayakawa K. The relationship between body mass index and uric acid: a study on Japanese adult twins. *Environ Health Prev Med.* (2015) 20:347–53. doi: 10.1007/s12199-015-0473-3

73. Tenjin K, Sekine M, Yamada M, Tatsuse T. Relationship between parental lifestyle and dietary habits of children: a cross-sectional study. *J Epidemiol.* (2020) 5:253–9. doi: 10.2188/jea.JE2019 0015

74. Haruyama Y, Fukuda H, Arai T, Muto T. Change in lifestyle through health promotion program without face-to-face intervention in a large-scale Japanese enterprise. *J Occup Health.* (2013) 55:74–83. doi: 10.1539/joh.12-0145-OA

75. Breslow L, Enstrom JE. Persistence of health habits and their relationship to mortality. *Prev Med.* (1980) 9:469–83. doi: 10.1016/0091-7435(80)90042-0

76. Mobarak E, Shabayek M, Mulder J, Reda A, Frencken J. Caries experience of Egyptian adolescents: does the atraumatic restorative treatment approach offer a solution? *Med Princ Pract.* (2011) 20:545–9. doi: 10.1159/000329790

77. Ivančić Jokić N, Bakarčić D, Janković S, Malatestinić G, Dabo J, Majstorović M, et al. Dental caries experience in croatian schoolchildren in Primorsko-Goranska county: a pilot study. *Cent Eur J Public Health.* (2013) 21:39–42. doi: 10.21101/cejph.a3752

78. World Health Organization. *Oral Health Surveys: Basic Methods*. 4th ed. Geneva: World Health Organization (1997).

79. Lin HS, Lin JR, Hu SW, Kuo HC, Yang YH. Association of dietary calcium, phosphorus, and magnesium intake with caries status among schoolchildren. *Kaohsiung J Med Sci.* (2014) 30:206–12. doi: 10.1016/j.kjms.2013.12.002

80. Pitts NB, Zero DT, Marsh PD, Ekstrand K, Weintraub JA, Ramos-Gomez F, et al. Dental caries. *Nat Rev Dis Primers.* (2017) 3:1–16. doi: 10.1038/nrdp.2017.30

81. Yabao R, Duante C, Velandria F, Lucas M, Kassu A, Nakamori M, et al. Prevalence of dental caries and sugar consumption among 6–12-y-old schoolchildren in La Trinidad, Benguet, Philippines. *Eur J Clin Nutr.* (2005) 59:1429–38. doi: 10.1038/sj.ejcn.1602258

82. Moussa A, Ibrahim E, Esmat A, Eissa S, Ramzy M. An overview of oral health status, socio-economic and behavioral risk factors, and the pattern of tooth loss in a sample of Egyptian rural population. *Bull Natl Res Cent.* (2020) 44:1–6. doi: 10.1186/s42269-020-0268-6

83. Moynihan P, Petersen PE. Diet, nutrition and the prevention of dental diseases. *Public Health Nutr.* (2004) 7:201–26. doi: 10.1079/PHN2003589

84. Lee J, Brearley Messer L. Contemporary fluid intake and dental caries in Australian children. *Aust Dent J.* (2011) 56:122–31. doi: 10.1111/j.1834-7819.2011.01313.x

85. Feferbaum R, de Abreu LC, Leone C. Fluid intake patterns: an epidemiological study among children and adolescents in Brazil. *BMC Public Health.* (2012) 12:1–7. doi: 10.1186/1471-2458-12-1005

86. Merugu M, Kodali S, Cherian R, SanjayKumar PK. Effect of sugar sweetened beverages on dental caries among adults: a systematic review. *Eur J Mol Clin Med.* (2020) 7:2051–65.

87. Kim S, Park S, Lin M. Permanent tooth loss and sugar-sweetened beverage intake in us young adults. *J Public Health Dent.* (2017) 77:148–54. doi: 10.1111/jphd.12192

88. Rusali R, Najwa Hamali N, Muhammad Razi F, Mustafa N, Asilah Harun N, Azwani Mohd Shukri N. Early childhood feeding practices and its association with early childhood caries. *J Food Nutr Res.* (2019) 7:801–4. doi: 10.12691/jfnr-7-11-7

89. Sohn W, Burt BA, Sowers MR. Carbonated soft drinks and dental caries in the primary dentition. *J Dent Res.* (2006) 85:262–6. doi: 10.1177/154405910608500311

90. Lim S, Sohn W, Burt BA, Sandretto AM, Kolker JL, Marshall TA, et al. Cariogenicity of soft drinks, milk and fruit juice in low-income African-American children: a longitudinal study. *J Am Dent Assoc.* (2008) 139:959–67. doi: 10.14219/jada.archive.2008.0283

91. Ismail AI, Burt BA, Eklund SA. The cariogenicity of soft drinks in the United States. *J Am Dent Assoc.* (1984) 109:241–5. doi: 10.14219/jada.archive.1984.0346

92. Shah N, Sundaram KR. Impact of socio-demographic variables, oral hygiene practices, oral habits and diet on dental caries experience of indian elderly: a community-based study. *Gerodontology.* (2004) 21:43–50. doi: 10.1111/j.1741-2358.2004.00010.x

93. Sherfudhin H, Abdullah A, Shaik H, Johansson A. Some aspects of dental health in young adult indian vegetarians: a pilot study. *Acta Odontol Scand.* (1996) 54:44–8. doi: 10.3109/00016359609003508

94. Hojsak I, Colomb V, Braegger C, Bronsky J, Campoy C, Domellöf M, et al. Espghan committee on nutrition position paper. Intravenous lipid emulsions and risk of hepatotoxicity in infants and children: a systematic review and meta-analysis. *J Pediatr Gastroenterol Nutr.* (2016) 62:776–92. doi: 10.1097/MPG.0000000000001121

95. Zhu F, Chen Y, Yu Y, Xie Y, Zhu H, Wang H. Caries prevalence of the first permanent molars in 6–8 years old children. *PLoS ONE.* (2021) 16:e0245345. doi: 10.1371/journal.pone.0245345

96. Araujo D, Marquezin M, Barbosa T, Fonseca F, Fegadolli C, Castelo P. Assessment of quality of life, anxiety, socio-economic factors and caries experience in Brazilian children with overweight and obesity. *Int J Dent Hyg.* (2017) 15:e156–62. doi: 10.1111/idh.12248

97. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of overweight and obesity in the United States, 1999-2004. *JAMA.* (2006) 295:1549–55. doi: 10.1001/jama.295.13.1549

98. Hooley M, Skouteris H, Millar L. The relationship between childhood weight, dental caries and eating practices in children aged 4–8 years in Australia, 2004–2008. *Pediatr Obes.* (2012) 7:461–70. doi: 10.1111/j.2047-6310.2012.00072.x

99. Al Jawaldeh A, Radwan IA, Rady D, El Moshy S, Abu Bakr N, Abbass MMS. Food consumption patterns among children and adolescents and their correlation with overweight/obesity in Egypt: a cross-sectional study. *Piel Zdr Publ.* (2020) 10:149–57. doi: 10.17219/pzp/118081

100. Papanikolaou Y, Fulgoni III VL. Bean consumption is associated with greater nutrient intake, reduced systolic blood pressure, lower body weight, and a smaller waist circumference in adults: results from the national health and nutrition examination survey 1999-2002. *J Am Coll Nutr.* (2008) 27:569–76. doi: 10.1080/07315724.2008.10719740

101. Astrup A, Ryan L, Grunwald GK, Storgaard M, Saris W, Melanson E, et al. The role of dietary fat in body fatness: evidence from a preliminary meta-analysis of ad libitum low-fat dietary intervention studies. *Br J Nutr.* (2000) 83:S25–32. doi: 10.1017/S0007114500000921

102. Sathe SK, Deshpande S, Salunkhe D, Rackis JJ. Dry beans of phaseolus. A review part 2 chemical composition: carbohydrates, fiber, minerals, vitamins, and lipids. *Crit Rev Food Sci Nutr.* (1984) 21:41–93. doi: 10.1080/10408398409527396

103. Bailleul-Forestier I, Lopes K, Souames M, Azoguy-Levy S, Frelut ML, Boy-Lefevre ML. Caries experience in a severely obese adolescent population. *Int J Paediatr Dent.* (2007) 17:358–63. doi: 10.1111/j.1365-263X.2007.00848.x

104. Psoter WJ, Reid BC, Katz RV. Malnutrition and dental caries: a review of the literature. *Caries Res.* (2005) 39:441–7. doi: 10.1159/000088178

105. Hooley M, Skouteris H, Boganin C, Satur J, Kilpatrick N. Body mass index and dental caries in children and adolescents: a systematic review of literature published 2004 to 2011. *Syst Rev.* (2012) 1:1–26. doi: 10.1186/2046-4053-1-57

106. Silva AER, Menezes AMB, Demarco FF, Vargas-Ferreira F, Peres MA. Obesity and dental caries: systematic review. *Rev Saude Publica.* (2013) 47:799–812. doi: 10.1590/S0034-8910.2013047004608

107. El-Kassas G, Ziade F. Exploration of the risk factors of generalized and central obesity among adolescents in North Lebanon. *J Environ Public Health.* (2017) 2017:2879075. doi: 10.1155/2017/2879075

108. Winkvist A, Hultén B, Kim J-L, Johansson I, Torén K, Brisman J, et al. Dietary intake, leisure time activities and obesity among adolescents in Western Sweden: a cross-sectional study. *Nutr J.* (2015) 15:1–12. doi: 10.1186/s12937-016-0160-2

109. Mills SDH, Tanner LM, Adams J. Systematic literature review of the effects of food and drink advertising on food and drink-related behaviour, attitudes and beliefs in adult populations. *Obes Rev.* (2013) 14:303–14. doi: 10.1111/obr.12012

110. Al-Jawaldeh A, Jabbour J. Marketing of food and beverages to children in the eastern mediterranean region: a situational analysis of the regulatory framework. *Front Nutr.* (2022) 9:868937. doi: 10.3389/fnut.2022.868937

111. Hersey JC, Wohlgenant KC, Arsenault JE, Kosa KM, Muth MK. Effects of front-of-package and shelf nutrition labeling systems on consumers. *Nutr Rev.* (2013) 71:1–14. doi: 10.1111/nure.12000

112. Levy DT, Friend KB, Wang YC, A. review of the literature on policies directed at the youth consumption of sugar sweetened beverages. *Adv Nutr.* (2011) 2:182S—200. doi: 10.3945/an.111.000356

113. Ruopeng A. Effectiveness of subsidies in promoting healthy food purchases and consumption: a review of field experiments. *Public Health Nutr.* (2013) 16:1215–28. doi: 10.1017/S1368980012004715

114. Escobar MAC, Veerman JL, Tollman SM, Bertram MY, Hofman KJ. Evidence that a tax on sugar sweetened beverages reduces the obesity rate: a meta-analysis. *BMC Public Health.* (2013) 13:1–10. doi: 10.1186/1471-2458-13-1072

115. Niebylski ML, Redburn KA, Duhaney T, Campbell NR. Healthy food subsidies and unhealthy food taxation: a systematic review of the evidence. *Nutrition.* (2015) 31:787–95. doi: 10.1016/j.nut.2014.12.010

116. Thow AM, Jan S, Leeder S, Swinburn B. The effect of fiscal policy on diet, obesity and chronic disease: a systematic review. *Bull World Health Organ.* (2010) 88:609–14. doi: 10.2471/BLT.09.070987

117. Al-Jawaldeh A, Abbass MMS. Unhealthy dietary habits and obesity: the major risk factors beyond non-communicable diseases in the eastern mediterranean region. *Front Nutr.* (2022) 9:817808. doi: 10.3389/fnut.2022.817808

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Modeling the health impact of legislation to limit the salt content of bread in Portugal: A macro simulation study

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Background: Excessive salt consumption—associated with a range of adverse health outcomes—is very high in Portugal, and bread is the second largest source. Current Portuguese legislation sets a maximum limit of 1.4 g salt per 100 g bread, but imported and traditional breads are exempted. In 2017 the Ministry of Health proposed reducing the salt threshold to 1.0/100 g by 2022, however the legislation was vetoed by the European Commission on free-trade grounds.

Aims: To estimate the health impact of subjecting imported and traditional breads to the current 1.4 g threshold, and to model the potential health impact of implementing the proposed 1.0 g threshold.

Methods: We gathered bread sales, salt consumption, and epidemiological data from robust publicly available data sources. We used the open source WHO PRIME modeling tool to estimate the number of salt-related deaths that would have been averted in 2016 (the latest year for which all data were available) from; (1) Extending the 1.4 g threshold to all types of bread, and (2) Applying the 1.0 g threshold to all bread sold in Portugal. We used Monte Carlo simulations to generate confidence intervals.

Results: Applying the current 1.4 g threshold to imported and traditional bread would have averted 107 deaths in 2016 (95% CI: 43–172). Lowering the current threshold from 1.4 to 1.0 g and applying it to all bread products would reduce daily salt consumption by 3.6 tons per day, saving an estimated 286 lives a year (95% CI: 123–454).

Conclusions: Salt is an important risk factor in Portugal and bread is a major source. Lowering maximum permissible levels and removing exemptions would save lives. The European Commission should revisit its decision on the basis of this new evidence.

KEYWORDS

public health, salt, policy, NCD and risk factors, nutrition

Introduction

Cardiovascular diseases are the most common cause of death globally and constitute an important public health challenge (1). In Portugal, 29% of deaths are due to CVDs (2) and the prevalence of hypertension is 42.2% (3). As shown by the Global Burden of Disease study, poor diet is the risk factor that contributes most to the loss of healthy life years among the Portuguese population (4).

The average daily intake of salt per capita among the Portuguese is 7.4 g (5, 6), which is well above the WHO's recommended maximum (<5 g/day) (7). Portugal ranks the highest in Western Europe for salt intake, with excessive intake reported in 63.2% of women and 88.9% of men (5, 6). The problem affects also younger groups with over half of all children and adolescents exceeding daily recommendations (8–10). The World Health Organization (WHO) specifically calls for interventions to reduce salt intake as one of the most cost-effective measures to improve health (7).

Data from the latest National Food, Nutrition and Physical Activity Survey (5, 6) shows that after salt added to food (11), bread is the second largest source of salt in the Portuguese diet, constituting 18.2% of daily salt intake in Portugal. The same survey showed that the mean daily consumption of bread was 100.3 g/person/day, which is higher than the consumption of cereals, cereal products and tubers (5, 6). Another study also highlighted the high salt content of school meals which commonly, in Portugal, include an added piece of bread. The study showed that not only this bread serving portion was double the recommended values (45 g instead of 25 g) but was the major contributor of salt when compared with the main dish and soup, adding a mean value of 0.48 g of salt/serving to the school meal (11). Controlling salt consumption in bread plays a central part in Portugal's salt reduction strategy. Many other countries have also considered using the reduction of salt in bread, despite the hedonic (e.g., taste) and technical (e.g., dough handling) challenges (12–14).

On 12th of August 2009 Portugal introduced legislation that limited the salt content of bread to 1.4 g salt per 100 g bread (15). However, the legislation did not cover imported or "traditional" bread, defined as (16):

- Bread products containing added meat preparations and sausage-meat;
- Regionally produced bread classified as traditional and with protected name, which has characteristics easily recognizable by consumers;
- Special bread having very specific characteristics, for which the use of other ingredients is allowed (as specified in point 5 n° 7° of paragraph n° 425/98) and standardization of a general salt limit is not suitable;
- Products which are similar and/or related to bread.

According to Nielsen data, ∼90% of bread consumed in Portugal is unpackaged bread from bakeries (17). The remaining 10% is packaged bread—of which just over half is imported (6% of all bread). The National Association of Bread Producers (AIPAN) estimate that 45% of all bread sold in Portugal is "traditional" (18).

In 2017 the Portuguese Ministry of Health introduced non-binding self-regulation agreements with bread producers and distributors to meet a lower salt threshold. These agreements established that bread should not have salt content exceeding 1.0 g per 100 g of bread. On the 13th of July 2018, the Ministry of Health proposed a new bill to enshrine lower maximum levels in law, applying to all forms of bread, including imported products. The proposed bill was approved at the Government Secretaries' of State meeting and, therefore, notified to the European Commission by the Portuguese authorities (19). The proposed bill aimed to gradually reduce the threshold from 1.4/100 g to:

i) 1.3/100 g by the 1st of January 2019,
ii) 1.2/100 g by the 1st of January 2020,
iii) 1.1/100 g by the 1st of January 2021, and
iv) 1.0/100 g by the 1st of January 2022.

The European Commission rejected the proposed legislation on the basis that it restricted the salt content of imported bread and, consequently, restricted free-trade between member states. In response to this decision a preliminary impact assessment on mortality was developed by the WHO and shared with the European Commission. This draft evidence was not considered

sufficient to overturn the decision, and the internal market rationale prevailed over public health protection and promotion. This is despite the fact that the European Commission has adopted *The Strategy for Europe on Nutrition, Overweight and Obesity Related Health Issues* and launched the EU Salt Reduction Framework which recognized salt reformulation as a principal factor in achieving a reduction in salt intake among the member states. The same framework recognizes bread as one of the main sources of salt intake and an important target for intervention.

Objectives

In this study we aimed to conduct a formal assessment of the potential health gains of the proposed bill to lower the threshold from 1.4 g to 1.0 g salt/100 g bread, and to apply these limits to traditional and imported products.

Methods

Data sources

Bread consumption

Information about the daily bread consumption in Portugal was obtained from the latest *National Food, Nutrition and Physical Activity Survey*, which estimated the daily intake at 100.3 g per capita (8). We multiplied this by the current population size (10,300,000 people) (20) and multiplied the product by 365.25 to obtain the annual intake of bread in Portugal. Figure 1 illustrates all data sources used, formulas and final estimated values.

In Portugal bread can be sold loose (in bakeries) or pre-packaged—which includes all imported bread. Data from Nielsen, a global information and measurement company, which supplements sales data with in-store observations, was used to obtain pre-packaged bread sales. Data provided by Nielsen (17) showed that in 2016 40,040 tons of pre-packaged bread was sold in Portugal. According to the National Institute of Statistics (20), 21,764 tons of pre-packaged bread is imported. These two data sources allowed us to calculate the amount of nationally produced pre-packaged bread. Finally, the difference between the total bread sold in the country and packaged bread was used to calculate the amount of bread sold loose in bakeries.

As bread classified as traditional is exempt from current legislation, we needed to know what proportion of bread falls under this category. AIPAN (National Association of Bread Producers) declared that 45% of all bread produced in Portugal is classified as "traditional bread" (18).

Using the amount of imported and traditional bread allowed us to calculate the amount of bread which is currently exempt from legislation limiting salt contents.

Salt in bread

Next, we proceeded to estimate the salt intake from bread available on the Portuguese market. To calculate the amount of salt coming from all bread sold in Portugal, we used data from the National Food, Nutrition, and Physical Activity Survey of the Portuguese General Population (2015–2016). This data shows that 18.2% of salt intake in the population comes from bread (5, 6). According to the same survey, average daily consumption of salt per capita is 7.4 g. We multiplied the daily salt intake per capita by the population size to estimate the total salt intake per day.

Simulations

We estimated the total reduction in salt intake that would be observed if all bread sold in Portugal (including imported, domestic, and traditional bread) complied with legislation establishing salt limits, using two simulations:

Counterfactual scenario 1

We calculated the total reduction in salt consumption if all bread products (including imported and traditional) were to comply with the pre-existing legislation of 1.4 g of salt per 100 g of final product.

Counterfactual scenario 2

We calculated the total reduction in salt consumption that would be observed if the maximum salt level of <1.0 g salt/100 g bread was applied to all bread sold in Portugal (imported, domestic, and traditional).

Modeling health gains

We used the open-source PRIME NCD mortality modeling tool developed by researchers at Oxford University, and endorsed by the WHO Regional Office for Europe, which is described in detail elsewhere (21, 22) PRIME calculates how many deaths would have occurred in the baseline year if the distribution of risk factors—in our case daily salt consumption—had been different, based on relative risk figures from peer-reviewed meta-analyses. Causes included cerebrovascular disease, ischaemic heart disease, heart failure, aortic aneurism, pulmonary emboli, rheumatic heart disease and hypertensive disease. We used Monte Carlo analysis to generate confidence intervals; effectively compiling uncertainty around a deterministic result. We used the established daily salt consumption value of 7.4 g per person per day as the baseline,

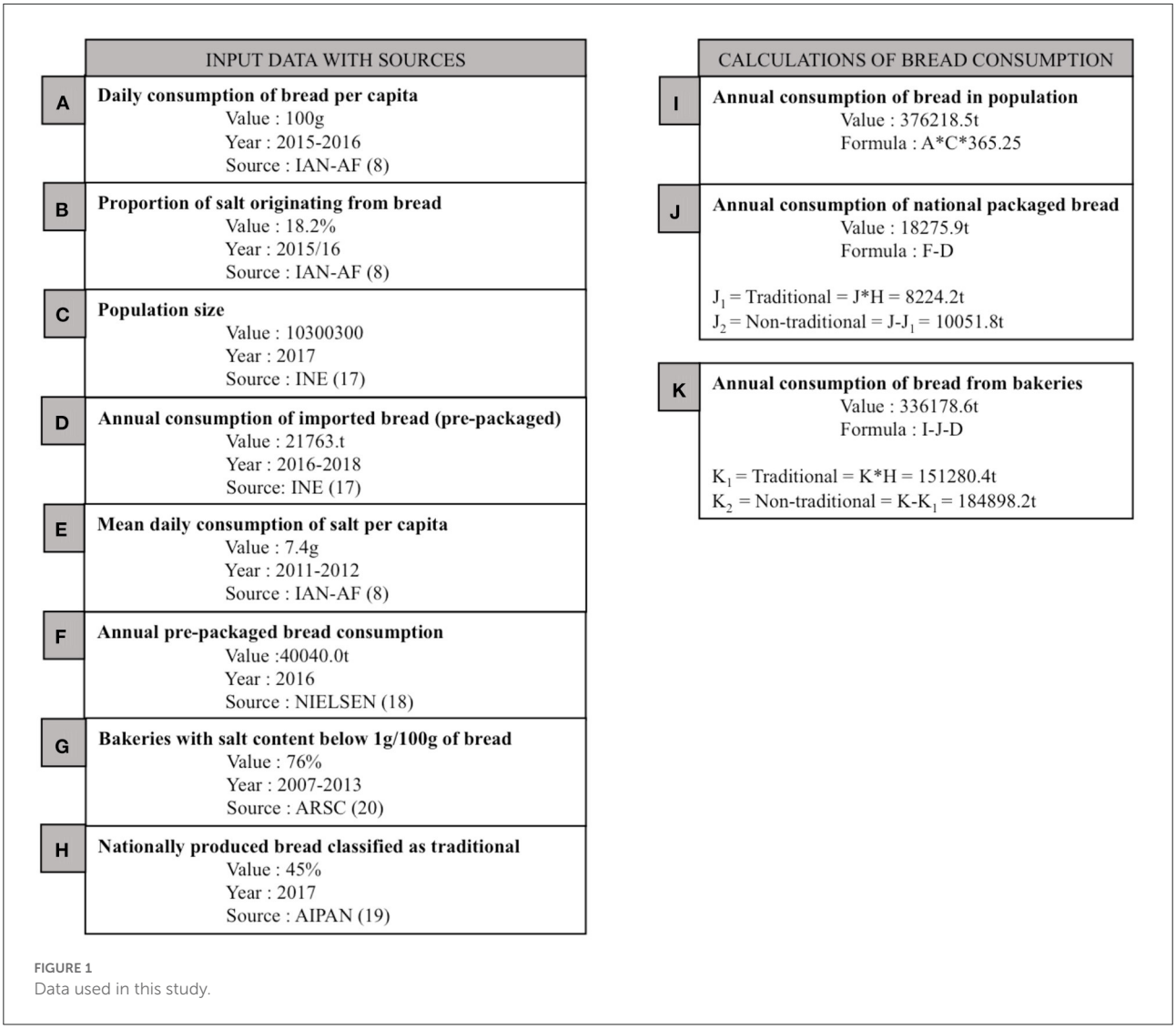

FIGURE 1
Data used in this study.

taken from the National Food, Nutrition, and Physical Activity Survey of the Portuguese General Population (5, 6). Appendix 1 presents the demographic and epidemiological data used, taken from the National Institute for Statistics (INE) and the WHO Global Health Estimates (23).

Sensitivity analyses

In order to account for potential biases on our calculations we ran several sensitivity analyses.

Sensitivity analysis 1: Proportion of bakeries with 1 g of salt per 100 g of final product

Sensitivity analysis 1a: According to the bakeries' national association, 76% of bakeries already use the 1.0 g threshold. This is built into our main model. However, to hedge against the possibility that all bakeries now comply with the 1.0 g threshold we ran a sensitivity analysis where compliance with the voluntary target was 100%.

Sensitivity analysis 1b: A more likely situation is that 76% is an overestimate. To hedge against this we performed a sensitivity analysis where compliance was 50%.

Sensitivity analysis 2: Higher salt intake baseline

The PHYSA study from 2011 to 2012 estimated average daily consumption of salt to be 10.7 g per capita using urinary sodium—a very reliable method (3). We re-ran the analyses using this higher baseline salt consumption (10.7 g/day/capita rather than 7.4/day/capita):

Sensitivity analysis 2a: Baseline value of 10.7 g/day/capita, with all products meeting the 1.4/100 g threshold.

Sensitivity analysis 2b: Baseline value of 10.7 g/day/capita, with all products meeting the 1.0/100 g threshold.

Sensitivity analysis 3: Proportion of salt coming from bread

We performed two sets of sensitivity analyses where we changed the proportion of salt consumption that comes from bread by ±1 percentage point. We did both analyses for each of the two counterfactual scenarios i.e., CF1 - with all products meeting the 1.4/100 g threshold (sensitivity analyses 3a CF1 and 3b CF1); and CF2 - with all products meeting the 1.0/100 g threshold (sensitivity analysis 3a CF2 and 3b CF2).

Sensitivity analysis 3a CF1: Proportion of salt originating from bread 1% higher with all products meeting the 1.4/100 g threshold.

Sensitivity analysis 3b CF1: Proportion of salt originating from bread 1% lower with all products meeting the 1.4/100 g threshold.

Sensitivity analysis 3a CF2: Proportion of salt originating from bread 1% higher with all products meeting the 1.0/100 g threshold.

Sensitivity analysis 3b CF2: Proportion of salt originating from bread 1% lower with all products meeting the 1.0/100 g threshold.

Sensitivity analysis 4: Lower baseline of daily salt intake

Our final set of sensitivity analyses used a 1% lower baseline salt intake, applied to the 1.4 and 1.0 g thresholds, respectively.

Sensitivity analysis 4a: Baseline of daily salt intake 1% lower, with all products meeting the 1.4/100 g threshold.

Sensitivity analysis 4b: Baseline of daily salt intake 1% lower, with all products meeting the 1.0/100 g threshold.

Results

The Portuguese population consumes ∼376, 218 tons of bread annually. The amount of nationally produced pre-packaged bread has been estimated to account for 4.86% of all bread consumed (18,276 tons/year) and 89.36% of all bread is baked fresh at national bakeries (336,179 tons/year).

We estimated that 48.18% (181,268 tons/year) of all sold bread is currently exempt from legislation defining the maximum value of salt in bread. Of this excluded bread, exactly 88% is exempt because it is traditional and the remaining 12% is exempt because it is imported. See Figure 1 for other results.

If all bread complied with the current law (1.4 g per 100 g bread salt maximum), we estimate that 1.4 fewer tons of salt would be consumed daily in Portugal. This translates to a decrease of 0.13 g of salt per day per person. Using PRIME, we estimate that an 0.13 g/day/person reduction in salt consumption would avert 107 deaths (95% CI: 43–172) per year, holding all other variables constant (Table 1). Whilst men consume more salt than women, there are many more older women in Portugal, such that 46 averted deaths were among men (95% CI: 19–74) and 61 were among women (95% CI: 25–99). If we focus exclusively on deaths averted in those aged under 75 years, we find that 16 deaths were averted among males (95% CI: 6–26) vs. 9 among women (3–14).

In our most conservative sensitivity analyses, where the proportion of salt coming from bread falls by 1%, we estimate that between 20 and 84 lives would be saved. In our analysis that used the PHYSA salt consumption baseline we estimated that 592 deaths would be averted (95% CI: 243–932)—this is five times higher than our main estimate.

If all bread products met the proposed threshold of 1.0 g of salt per 100 g of bread we estimate that this would decrease salt consumption by 3.6 tons/day, translating into a decrease of 0.35 g of salt per day per capita. Using PRIME, we estimate that a 0.35 g/day/person reduction in salt consumption would avert 286 deaths (95% CI: 123–454) per year, holding all other variables constant (Table 2). In terms of sex-specific outcomes, 127 averted deaths were in males (95% CI: 54–200) and 159 in women (95% CI: 69–254). Again, this reversed in the under-75s, with 44 male deaths averted (95% CI: 19–70) vs. 22 female deaths (95% CI: 10–35).

In our most conservative sensitivity analysis, with 1% less salt coming from bread, the number of averted deaths dropped to 221, however the confidence interval overlaps with the main estimate (95% CI: 98–351). If the actual population baseline salt consumption is 10.4 g—in line with the PHYSA study, then we estimate that 768 deaths would be averted (95% CI: 328–1,212).

Discussion

Nearly half of all bread sold in Portugal is exempt from the current legislation. Extending the existing 1.4/100 g threshold to all bread products would reduce daily salt intake by around 2% and save over 100 lives each year. Imposing the stricter 1.0/100 g threshold would cut salt intake by around 5% and prevent over 250 deaths each year.

Our sensitivity analyses highlight the fact that the total number of averted deaths is dependent on our assumptions about baseline salt intake. However, even if the proportion of salt coming from bread was 1% lower than survey data suggest, we would still observe around 99 lives saved each year with the extension of the current 1.4 g threshold to imported and traditional products, or 271 lives saved with the lower threshold.

Despite the fact that imported bread plays a relatively small role in comparison with traditional bread, Portugal's experience with the European Commission highlights an important and ubiquitous policy issue around the trade-off between health and

TABLE 1 Deaths averted by applying the established 1.4 g salt/100 g bread threshold to all bread products sold in Portugal.

	Description	Baseline salt consumption (g/day/capita)	Absolute salt reduction (g/day/capita)	Counterfactual (i.e., new) salt consumption (g/day/capita)	Deaths averted annually (95% CI)
Counterfactual scenario 1	All products < 1.4 g salt/100 g bread	7.40	0.13	7.27	107 (43–172)
Sensitivity analysis 1a	Proportion of bakeries with <1 g salt moves from 76 to 100%	7.40	0.18	7.22	148 (59–235)
Sensitivity analysis 1b	Proportion of bakeries with <1 g salt moves from 76/24% to 50%/50%	7.40	0.08	7.32	67 (26-109)
Sensitivity analysis 2a	Different baseline (10.7 g), all products < 1.4 g salt/100 g bread	10.70	0.73	9.97	592 (243–932)
Sensitivity analysis 3a	1% more salt comes from bread, all products < 1.4 salt/100 g bread	7.40	0.21	7.19	173 (71–273)
Sensitivity analysis 3b	1% less salt comes from bread, all products < 1.4 salt/100 g bread	7.40	0.06	7.34	50 (20-84)
Sensitivity analysis 4a	Different baseline (1% lower), all products < 1.4 salt/100 g bread	7.33	0.12	7.21	99 (40–160)

TABLE 2 Deaths averted by applying the mooted 1.0 salt/100 g bread threshold to all bread products sold in Portugal.

	Description	Baseline salt consumption (g/day/capita)	Absolute salt reduction (g/day/capita)	Counterfactual (i.e., new) salt consumption (g/day/capita)	Deaths averted annually (95%CI)
Counterfactual scenario 2	All products < 1.0 g salt/100 g bread	7.40	0.35	7.05	286 (123–454)
Sensitivity analysis 2b	Different baseline (10.7 g),	10.70	0.95	9.75	768 (328–1,212)
Sensitivity analysis 3a	1% more salt comes from bread	7.40	0.42	6.98	343 (139–542)
Sensitivity analysis 3b	1% less salt comes from bread	7.40	0.27	7.13	221 (98–351)
Sensitivity analysis 4b	Different baseline (1% lower)	7.33	0.33	6.99	271 (111–432)

market competition. The High Level Group on Nutrition and Physical Activity of the European Commission recommends that Member States implement national initiatives for the reduction of salt. In particular, it encouraged Member States to focus on food categories recognized as main sources of salt intake, including bread (24). This builds on the EU framework for salt reduction that was published in 2008 with the aim of promoting salt reduction and meeting national and WHO recommendations (7). This framework supports national plans, while at the same time preserving the necessary flexibility for State Members to formulate their own strategies toward salt reduction. In their systematic review, Santos and colleagues identified 57 countries that have established salt reformulation targets, including many variations of regulated limits on salt content in bread within European countries (25).

The EC salt framework supports measurable actions and assumes food groups representing the main source of salt intake (i.e., bread) should be a priority. It was based on this premise that the Portuguese Ministry of Health reached out to the European Commission to request permission to extend the national law and include imported bread.

In general, Member States are free to adopt whatever rules on food composition they consider necessary to protect public health in their territories, as long as these rules are adopted consistently with the EU internal market law and general principles of EU law as a whole (C-174/82 *Sandoz*). The European Commission rejected the government's initial proposal on the basis that it would restrict Portuguese access to bread legally produced and sold in the other Member States. It is important to note that the original estimates supplied were

draft figures. This may have played a role in influencing the Commission's decision. In its ruling, the Commission recalled case law on the regulation of salt content in bread, which established that placing limits on salt content constituted a measure with equivalent effect to a quantitative restriction, which conflicts with Article 34 TFEU (C-17/93 *Van der Veldt*; C-123/00, *Bellamy*).

A national rule that conflicts with Article 34 TFEU can be justified (and allowed to stand) if it pursues a legitimate objective of protecting public health (Article 36 TFEU; C-120/78 *Cassis*) and is proportionate to that objective. A rule is proportionate if it is appropriate to and necessary for achieving that objective, and a measure is considered unnecessary "if human life and health can be as effectively protected by measures that are less restrictive of trade within the European Union" (C-333/14 *Scotch Whisky Association*, para 41).

Member States are responsible for demonstrating that their measure is necessary for the protection of public health using the available scientific evidence (C-333/08 *Commission v France*). A consistent line of case law has established that "specific evidence" must be presented to justify trade restrictive public health rules: Member States must prove that the new law will contribute to the protection of public health (C-148/15 *Deutsche Parkinson Vereinigung*; C-456/10 *ANETT*; C-254/05 *Commission v Belgium*; C-319/05 *Commission v Germany*).

Our study provides evidence that lower maximums in bread products are likely to save lives. This aligns with modeling work from Trieu et al. who found that even small reductions in salt intake from reformulation efforts are associated with large reductions in mortality. They also used data from an Australian national nutrition survey and sales data from Nielsen (26). This work also builds on an allied review by Hyseni et al. showing that mandatory reformulation is the most effective measure for achieving population-level reduction in consumption of *trans* fats, having an impact ~3.6 times larger than labeling (27)—an alternative strategy that the CJEU has suggested would be less trade restrictive (C-17/93 *Van der Veldt*). A major advantage of reformulation over other types of nutrition intervention is that success is not dependent on personal willpower.

Given the success of the bread reformulation already achieved by the Portuguese government, the reformulation of traditional bread provides an opportunity to tackle a significant source of salt intake and save hundreds of lives annually. Registering products as "traditional" serves the purpose of preserving an important element of identity and heritage associated with traditional food. Whilst this is important, we feel that it should not come at the price of poor health and lost lives, especially considering its large representation among the consumed bakery products. Revision of the decision to protect these large group of breads from the current legislation should be a priority if the salt reduction target is to be achieved.

Given the large number of deaths that can be averted with bread reformulation, we recommend that the Portuguese Ministry of Health look to other sources such as soups and processed meats (the next largest contributors after bread and salt added to food), using the recently published WHO global sodium benchmarks (28).

Globalization and free-trade are linked to a shift toward the consumption of more processed foods and foods high in sugar, salt and fat (29). The "Health in All Policies" approach to policymaking (30) is a response to this trend, and if implemented effectively would help policymakers to recognize where trade policy might compromise health protection, and take steps to establish a better balance between these two public goods. While some might suggest that EU free movement rules favor the promotion of trade and prevent the adoption of evidence-based public health policies—thus contradicting the imperatives of Health in All Policies—EU internal market law was always framed, and has continued to develop, to accommodate the conflict between health and trade objectives. Internal market law protects the prerogative of Member States to prioritize the protection of public health objectives over trade objectives. A balance between the two objectives is struck through an examination of the evidence—a public health measure that restricts free trade is acceptable as a matter of EU law if evidence demonstrates that it secures real public health benefits and that it is more effective at securing those benefits than other less trade restrictive measures. Although including traditional bread in the current legislation would classify as such measure, we believe that these two interventions should not be exclusive but applied alongside each other to achieve an optimal public health gains and save lives of Portuguese people.

Limitations

We were unable to obtain data for all of our inputs for the same year, however most of our data years overlapped with 2015/2016. Some of our input data are already estimations such as the fraction of bread classified as traditional by AIPAN (31) and the percentage of salt intake coming from bread (5, 6). Therefore, calculated values should be treated as estimations and not as exact values. The values of the pre-packaged bread provided by Nielsen includes all the data from retail stores in Portugal where the vast majority of packed bread is sold. However, the small proportion of pre-packaged bread sold through other channels is not included which can cause an underestimation of its sales values.

The ARSC sample used to calculate the percentage of bakeries complying with 1.0/100 g of bread limits refers to the central region where projects such as pao.come worked proactively to reduce the salt amount. We predict that on the national level the fraction of bakeries following the 1 g limit may

be lower. Thus, the impact of the new legislation may be higher than the calculated in this study.

Another limitation is the lack of information about the salt content of imported and traditional bread, which frustrates estimates of the contribution of each of these groups to salt intake.

The same source was used for the daily amount of bread intake and the daily salt intake by the Portuguese population: the National Dietary Survey IAN-AF. However, salt intake levels are typically underreported by dietary surveys. This may lead to an underestimation of the number of deaths averted, and the higher baseline salt intake value from sensitivity analysis 2 may be a more accurate estimate for the impact of the two thresholds.

Changing the salt content of bread may shift consumers preferences toward other products that are high in salt. Our study does not factor-in potential substitution effects. However, while we cannot rule out this possibility, a recent meta-analysis shows that salt reduction in bread of up to 40% does not impact consumer acceptability or elasticity of demand (32). We estimate that applying the 1.4 and 1.0 g thresholds leads to respective 9.9 and 25.7% falls in the salt content of Portuguese bread, so these effects are unlikely to affect our findings.

Finally, our model only permitted the estimation of deaths averted from salt reformulation. By not including morbidity and incidence of non-fatal diseases we significantly underestimate the likely health impact of extending legislation to cover all breads and tightening the maximum threshold.

Conclusions

Despite the proven effectiveness of the mandatory reformulation in reducing population salt intake, half of the bread in the Portuguese market (traditional and imported bread) is currently exempt from national legislation. The proposed bill setting a maximum levels of 1.0 g salt per 100 g of final product aimed to address this but was initially rejected by the European Commission—partly on the basis of the level of evidence available. Here we present robust evidence that implementing this bill and extending it to all forms of bread is likely to save hundreds of lives each year.

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

FG-d-S conceived the study and drafted the initial manuscript. LA wrote the final draft. All authors contributed to methods and data analysis, reviewed, and edited the manuscript.

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Conflict of interest

Author FA was the Portuguese Secretary of State for Health until October 2018. Authors FG-d-S and DC-e-S were members of the Portuguese Secretary of State for Health office until October 2018.

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

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fpubh.2022.876827/full#supplementary-material

References

1. World Health Organization. *Cardiovascular Diseases (CVDs)*. Geneve: WHO (2017). Available online at: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds) (accessed February 10, 2020).

2. *European Observatory on Health Systems and Policies*. Portugal: Country Health Profile. Brussels: EOHSP (2017). Available online at: http://www.euro.who.int/__data/assets/pdf_file/0007/355993/Health-Profile-Portugal-Eng.pdf?ua=1 (accessed February 10, 2020).

3. Polonia J, Martins L, Pinto F, Nazare J. Prevalence, awareness, treatment and control of hypertension and saltintake in Portugal: changes over a decade. The PHYSA study. *J Hypertens.* (2014) 32:1211–21. doi: 10.1097/HJH.0000000000000162

4. Direção Geral de Saúde (Direção de Serviços de Informação e Análise), Administração Regional de Saúde doNorte (Departamento de Saúde Pública), Institute for Health Metrics and Evaluation. Portugal: The Nation's Health 1990–2016. Porto (2018). Available online at: https://comum.rcaap.pt/handle/10400.26/22502 (accessed February 10, 2020).

5. Lopes C, Torres D, Oliveira A, Severo M, Guiomar S, Alarcao V, et al. National food, nutrition, and physical activity survey of the portuguese general population (2015-2016): protocol for design and development. *JMIR Res Protocols.* (2018) 7:e42. doi: 10.2196/resprot.8990

6. Lopes C, Torres D, Oliveira A, Severo M, Alarcão V, Guiomar S, et al. Inquérito Alimentar Nacional e de Atividade Física, IAN-AF 2015-2016: Relatório de resultados. Porto Universidade do Porto (2017). Available online at: https://ian-af.up.pt/sites/default/files/IAN-AF%20Brochura%20de%20resultados.pdf (accessed February 10, 2020).

7. World Health Organization. *Salt Reduction*. Geneve: WHO (2016). Available online at: https://www.who.int/news-room/fact-sheets/detail/salt-reductio (accessed accessed February 10, 2020).

8. Gonçalves C, Abreu S, Padrão P, Pinho O, Graça P, Breda J, et al. Sodium and potassium urinary excretion and dietary intake: a cross-sectional analysis in adolescents. *Food Nutr Res.* (2016) 60:29442. doi: 10.3402/fnr.v60.29442

9. Correia-Costa L, Cosme D, Nogueira-Silva L, Morato M, Sousa T, Moura C, et al. Gender and obesity modify the impact of salt intake on blood pressure in children. *Pediatr Nephrol.* (2016) 31:279–88. doi: 10.1007/s00467-015-3210-7

10. Sardinha LB, Santos DA, Silva AM, Coelho-e-Silva MJ, Raimundo AM, Moreira H, et al. Prevalence of overweight, obesity, and abdominal obesity in a representative sample of Portuguese adults. *PLoS ONE.* (2012) 7:e47883–e. doi: 10.1371/journal.pone.0047883

11. Rito AI, Mendes S, Santos M, Goiana-da-Silva F, Cappuccio FP, Whiting S, et al. Salt reduction strategies in Portuguese school meals, from pre-school to secondary education—The Eat Mediterranean Program. *Nutrients.* (2020) 12:2213. doi: 10.3390/nu12082213

12. Pasqualone A, Caponio F, Pagani MA, Summo C, Paradiso VM. Effect of salt reduction on quality and acceptability of durum wheat bread. *Food Chem.* (2019) 289:575–81. doi: 10.1016/j.foodchem.2019.03.098

13. Antúnez L, Giménez A, Ares G. A consumer-based approach to salt reduction: case study with bread. *Food Res Int.* (2016) 90:66–72. doi: 10.1016/j.foodres.2016.10.015

14. Belz MC, Ryan LA, Arendt EK. The impact of salt reduction in bread: a review. *Crit Rev Food Sci Nutr.* (2012) 52:514–24. doi: 10.1080/10408398.2010.502265

15. Lei n° 75/2009, de 12 de agosto. Available online at: https://dre.pt/pesquisa/-/search/493513/details/maximized (accessed February 10, 2020).

16. *Autoridade de Segurança Alimentar e Económica*. O Pão. Lisboa: ASAE (2019). Available online at: https://www.asae.gov.pt/seguranca-alimentar/informacoes-sobre-actividades-economicas-na-area-alimentar/pao.aspx (accessed February 10, 2020).

17. Nielsen (2019). Available online at: http://www.nielsen.com/pt/pt (accessed February 10, 2020).

18. Associação dos Industriais de Panificação, Pastelaria e similares do Norte (AIPAN) (2019). Available online at: http://www.aipan.pt/index.html (accessed February 10, 2020).

19. European Comission. *Legislation Laying Down Maximum Levels for the Salt Content in Bread*. Brussels: European Commission (2018). Available online at: https://ec.europa.eu/growth/tools-databases/tris/en/index.cfm/search/?trisaction=search.detail&year=2018&num=363&mLang=PT (accessed February 10, 2020).

20. National Institute of Statistics, Portugal Web Portal (2019). Available online at: https://www.ine.pt/xportal/xmain?xpgid=ine_main&xpid=INE&xlang=en (accessed February 10, 2020).

21. World Health Organizarion. *Modelling the Impact of National Policies on Noncommunicable Disease (NCD) Mortality Using PRIME: A Policy Scenario Modelling Tool*. Copenhagen; WHO Europe (2019). Available online at: http://www.euro.who.int/__data/assets/pdf_file/0014/411251/PRIME-a-policy-scenario-modelling-tool.pdf?ua=1 (accessed February 10, 2020).

22. Scarborough P, Harrington RA, Mizdrak A, Zhou LM, Doherty A. The preventable risk integrated ModEl and its use to estimate the health impact of public health policy scenarios. *Scientifica.* (2014) 2014:748750. doi: 10.1155/2014/748750

23. World Health Organizarion. *Global Health Estimates*. Available online at: https://www.who.int/data/global-health-estimates (accessed May 14, 2022).

24. European Commission. *Salt campaign - Public Health*. Brussels: European Commission (2018). Available online at: https://ec.europa.eu/health/nutrition_physical_activity/high_level_group/nutrition_salt_en (accessed February 10, 2020).

25. 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

26. Trieu K, Coyle DH, Afshin A, Neal B, Marklund M, Wu JH. The estimated health impact of sodium reduction through food reformulation in Australia: a modeling study. *PLoS Med.* (2021) 18:e1003806. doi: 10.1371/journal.pmed.1003806

27. 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 Org.* (2017) 95:821–30. doi: 10.2471/BLT.16.189795

28. World Health Organization. *WHO Global Sodium Benchmarks for Different Food Categories*. Available online at: https://www.who.int/publications/i/item/9789240025097 (accessed May 14, 2022).

29. World Health Organization. *Globalization, Diets and Noncommunicable Diseases*. Switzerland: WHO (2003). Available online at: https://apps.who.int/iris/bitstream/handle/10665/42609/9241590416.pdf;sequence$=$1 (accessed February 10, 2020).

30. World Health Organization. *Health in All Policies: Framework for Country Action*. Paris: WHO (2014). Available online at: https://apps.who.int/iris/bitstream/handle/10665/112636/9789241506908_eng.pdf?sequence=1 (accessed February 10, 2020).

31. Goiana-da-Silva F, Cruz-e-Silva D, Gregório MJ, Miraldo M, Darzi A, Araujo F. The future of the sweetened beverages tax in Portugal. *Lancet Public Health.* (2018) 3:e562. doi: 10.1016/S2468-2667(18)30240-8

32. Rachael J, Federica B, Emma MM, Jacqui W, Julie B. Consumer acceptance of reformulated food products: a systematic review and meta-analysis of salt-reduced foods. *Crit Rev Food Sci Nutr.* (2017) 57:3357–72. doi: 10.1080/10408398.2015.1118009

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The magnitude of oral rehydration salt utilization in diarrhea hot spot regions of Ethiopia and its associated factors among under-five children: A multilevel analysis based on Bayesian approach

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Background: Diarrhea leads the children to severe dehydration or death as a result of the loss of water and electrolytes (namely, potassium, chloride, sodium, and bicarbonate). To compensate for the losses, ORS is given to children who experienced diarrhea.

Objective: To estimate the magnitude of ORS utilization in diarrhea hotspot regions of Ethiopia and to assess its associated factors among under-five children.

Methods: To conduct this study, we used the 2016 Ethiopian demographic and health survey data. A total of 1,079 weighted sample children were selected. Each sample was selected randomly. Then, to identify factors associated with ORS utilization in diarrhea hotspot regions of Ethiopia, a multilevel analysis based on the Bayesian approach was applied. Finally, the credible interval of AOR that does not include 1 was considered statistically significant.

Results: The magnitude of ORS utilization for children in diarrhea hotspot regions of Ethiopia was 28%. Being urban resident (AOR = 1.92; 95% CrI: 1.13–3.3), woman household head (AOR = 2.11; 95% CrI: 1.3–3.9), having higher educational level (AOR = 1.52; 95% CrI: 1.04–2.22), member of health insurance (AOR = 1.73; 95% CrI: 1.14–2.43), and being exposed for media (AOR = 1.43; 95% CrI: 1.18–2.5) increases ORS utilization for diarrhea management.

Conclusion: Residence, educational level, health insurance, and media exposure were the factors of ORS utilization. So, to increase the practice of ORS utilization for diarrhea management in Ethiopia, the Ministry of Health and the Government of Ethiopia should consider those factors when they design diarrhea prevention and control strategies.

KEYWORDS

Ethiopia, Ethiopian demographic health survey, children, ORS, diarrhea

Background

According to World Health Organization (WHO) passing loose or watery stool three or more times during 24 h is considered Diarrhea (1). An individual who experiences diarrhea has symptoms of vomiting, fever, severe watery diarrhea, and abdominal pain. This is common in children and all adults who experienced diarrhea. Those symptoms lead the children to severe dehydration or death as a result of the loss of water and electrolytes (namely, potassium, chloride, sodium, and bicarbonate). Even though the death of children over time due to diarrhea showed a significant reduction, still diarrhea remains one of the top five causes of morbidity and mortality. In Africa, it is responsible for an estimated 3,33,000 children's death and also accounts for one-fourth of all childhood deaths annually across the globe (2–6). According to different studies, lack of sanitation, poor hygiene practices, unsafe waste disposal, inadequate and unsafe water, and not being vaccinated for Rotavirus and Measles are accountable for diarrheal diseases occurrence (7–9).

The combination of electrolyte and sugar solutions was introduced in 1960 to treat water and electrolyte losses due to diarrhea (10). This combination is known as Oral Rehydration Salt (ORS). This salt is simple, affordable, and can be given at home by mothers or caregivers when the child experiences diarrhea (11, 12). Different studies showed that after the introduction of ORS, morbidity and mortality of children over time due to diarrhea have declined significantly (13–15). Even though ORS is very crucial to replace the lost fluid due to diarrhea, its utilization is still low in low- and middle-income countries (16). In 2017, the overall ORS utilization coverage in middle and low-income countries was below 50% (about 6.52 million children out of 13.34 million children with diarrhea, were not taking ORS to treat dehydration) (16).

Despite the Ethiopian ministry of health and the government collaboratively making an effort to increase the utilization of ORS for diarrhea management, only 46% of children with diarrhea received ORS (17). Also, according to the reports of the International Vaccine Access Center (IVAC), despite Ethiopia being one of the top countries in under-five children death by diarrhea, they achieved only 30% of ORS treatment targets from 90% of treatment targets in 2020 (18). According to the study conducted in Ethiopia, among the nine regional states and two city administrations, four regions (namely, Amhara, Oromia, SNNP, and Benishangul Gumuz) and one city administration (Addis Ababa) were the hotspot regions for diarrhea (19). But there are no studies conducted at the national level which show the magnitude of ORS utilization to manage diarrhea and its associated factors in diarrhea hotspot regions of Ethiopia. So, the identification of risk factors is crucial to increase the utilization of ORS for diarrhea management and to prevent and control diarrhea in diarrhea hotspot regions of Ethiopia using an appropriate statistical method of analysis. The Bayesian analysis approach is one of the data analysis approaches independent of the classical analysis approach and the parameters are estimated from the posterior distribution which is the combination of the prior information and the likelihood of the data. A prior distribution of a parameter is the probability distribution that represents our uncertainty about the parameter before the current data are examined and the likelihood function (often simply called the likelihood) expresses how probable a given set of observations is for different values of the statistical parameters. Therefore, this study aimed to estimate the magnitude of ORS utilization and to identify its associated factors among under-five children in diarrhea hotspot regions of Ethiopia by considering the clustering effect using the Bayesian analysis approach.

Abbreviations: AOR, Adjusted Odds Ratio; CrI, Credible interval; DHS, Demographic Health Survey; EA, Enumeration Area; EDHS, Ethiopian Demographic and Health Survey; ICC, Intraclass Correlation Coefficient; ORS, Oral Rehydration Salt; SNNP, South Nation Nationality and People; WAIC, Widely Applicable Information Criteria; WHO, World Health Organization.

Methods

Data source and population

This study was performed based on the 2016 Ethiopian Demographic and Health Survey (EDHS) data. To access the data, we requested the Measure DHS center online by explaining the objective of our study. Then, after permission was granted, the data were accessed from the Measure DHS website (http://www.dhs_program.com). In Ethiopia, the DHS data are nationally representative and collected from 9 regions and 2 city administrations in the country every 5 years cross-sectionally. Before the data were collected, stratified two-stage sampling of clusters was carried out in each of the surveys. Each region of the country was stratified into urban and rural areas. For the 2016 survey, a total of 645 enumeration areas (EA) were selected randomly proportional to the EA size. In the second stage, on average 27–32 households per EA were selected (20–22). All under-five children in diarrhea hotspot regions of Ethiopia were the source population. In this region, all under-five children who experienced diarrhea within 2 weeks before the survey in the selected enumeration households were included in the study. Finally, a total of 1,079 weighted samples under-five children were used to conduct this study. The comprehensive procedure for sampling and sample size determination technique, in general, about the survey, is described in the complete EDHS report (20–22).

Variables

The dependent variable is the utilization of ORS for under-five children who have diarrhea. The response was coded as "Yes = 1" and "No = 0". The EDHS asked respondents to answer the question "Did you give ORS to your children who have diarrhea?" So, the response is binary with possible values Y_i = Yes if i^{th} child get ORS and Y_i = No, if the i^{th} child had not gotten ORS.

The independent variables were classified as community- and individual-level variables. Region and place were considered as community-level factors. The number of under-five children, family size, educational level of the mother, working status of the mother, wealth status, exposure to media, sex of household head, health insurance, distance to the health facility, age and gender of the child, being twin, and the weight of the child at birth were considered as individual-level factors.

Data processing and analysis

After the data set was downloaded from the Measure DHS website, the variables of the study were extracted from Ethiopian Demographic and Health Survey kid record (KR) data set using the software STATA version 14.2. The extracted data were weighted using sampling weight before any statistical analysis was performed to restore the representativeness of the survey and get reliable statistical estimates. Then, based on the diarrhea status (hot or cold spot) of the country, regions were categorized into a hotspot and cold spot region for diarrhea. Cold spot regions for diarrhea were excluded from the analysis. The data (data from diarrhea hotspot regions) were exported to the R software version 4.0 for further analysis. Then the data were coded, edited, and cleaned for analysis.

A multilevel model based on the Bayesian statistical approach was fitted to identify factors associated with not utilizing ORS for under-five children who have diarrhea in Ethiopia. In this study, two levels of data hierarchy were considered to fit the multilevel models. Children in the household were nested to the EA and were considered as level one units, whereas the EAs were considered as level two units.

The category of the dependent variable was dichotomous and represented as follows:

$$Y_{ij} = \begin{cases} Yes,\ if\ they\ utilized\ ORS\ for\ diarrhea \\ No,\ if\ they\ didn't\ utilized\ ORS\ for\ diarrhea \end{cases}$$

So, this variable hass Bernoulli distribution with successes when the child utilized ORS for diarrhea and the failure when the child did not utilize ORS for diarrhea.

The probability of utilizing ORS for diarrhea for i^{th} children in the j^{th} cluster is π_{ij}

$$P(X_{ij} = x) = \binom{n}{x} p^x (1-p)^{n-x}, if\ \ X = \sum_{i=1}^{n} Y_{ij}$$

Let π_{ij} be modeled using a logit link function. The two-level model is given as follows:

$$Logit(\pi_{ij}) = \beta_0 + \sum_{h=1}^{h} \beta_{hj} X_{hj} + \mu_{0j} + \sum_{h=1}^{h} \mu_{hj}$$

$$\begin{aligned} \text{Where,} \beta_{0j} &= \beta_0 + \mu_{0j} \\ \beta_{1j} &= \beta_1 + \mu_{1j} \\ \beta_{hj} &= \beta_h + \mu_{hj} \end{aligned}$$

$\beta_0 + \sum_{h=1}^{h} \beta_{hj} X_{hj}$, is called fixed part of the model

$\mu_{0j} + \sum_{h=1}^{h} \mu_{hj}$, is called random effect of the model

X_{ij}, are the covariates in the model

β, is the regression coefficient of the parameter

μ_{hj}, is the estimate of random intercept.

We used the recently developed R package called Brms (23) to fit multilevel models. This package uses No-U-Turn Sampler (NUTS) to estimate the extent of random variations between clusters and parameters of the variable. No-U-Turn Sampler (NUTS) is an extension of HMC and it uses a recursive algorithm to build a set of likely candidate points that spans a wide swath of the target distribution, stopping automatically when it starts to double back and retrace its steps (23). When multilevel models based on the Bayesian approach are fitted using NUTS, they converge to high-dimensional target distributions much more quickly as compared with the Gibbs sampler (23).

Four models are fitted by considering flat prior with beta distribution (1, 1) for regression coefficients and gamma distribution (0.001, 0.001) for the variance, cores = 2, iteration = 8,000, burn-in iterations = 1,000, number of chains = 2, to control the divergent transition, alpha delta = 0.95, and initials = 0.

The first model (fitted without covariate) is nested into the second model (fitted with individual-level factors), the third model (fitted with community-level factors), and the fourth model (fitted with both individual- and community-level factors). Again, the second and the third models are also nested into the fourth model. A multicollinearity test was conducted and there was no multicollinearity among variables (all variables had no tolerance of <0.1 and variance inflation factor (VIF) of >10, with a maximum VIF of 1.34). Those

four models were compared based on their widely applicable information criteria (WAIC). Finally, the fourth model was selected since it has the smallest WAIC value as compared with the rest three fitted models. Therefore, we made all interpretations and inferences based on the fourth model. The intraclass correlation coefficient (ICC) value >5% was considered to determine the variation of ORS utilization for diarrhea among under-five children between the enumeration areas of diarrhea hotspot regions. Also, to declare statistically significant, we used the 95% posterior credible interval. The credible interval of AOR that included 1 was not considered statistically significant.

Finally, the convergence of the algorithms was checked using Rhat value = 1, Bulk_ESS and Tail_ESS >1,000, chains of the time series plots mixed well and smooth density plot. Because the estimates of the posterior distribution might not be reliable unless the chain of distribution has reached its stationary (24).

Results

Study participant characteristics

Based on the sociodemographic characteristics, 91.4% of participants were rural residents. Among the total, the majority of the study participants were from Oromia regional state (44.5%) followed by SNNP (27.9%) and Amhara regional (25%) state. Based on the birth interval, 20.2% of the children were born with narrow birth intervals (<23 months interval). Regarding the media exposure status of the respondents, 78.3% of the participants were not exposed to the media (Table 1).

TABLE 1 Characteristic's frequency and percentage distribution of study participants in Ethiopia in 2016.

Variables	Categories	Frequency	Percent
Sex of child	Male	566	52.5
	Female	513	47.5
Twin	Yes	28	2.6
	No	1,051	97.4
Birth order	First	220	20.4
	2–3	337	31.2
	4–5	265	24.6
	≥6	257	23.8
Birth interval	≤23 month	174	20.2
	≥24 month	686	79.8
Child weight at birth	Normal	369	34.4
	Small	342	31.9
	Big	363	33.8
Working status of mothers	Had work	740	68.6
	Had no working	339	31.4
Wealth status	Poor	455	42.2
	Medium	250	23.1
	Rich	375	34.7
Distance to health facility	Not long	443	41.1
	Long	636	58.9
Health insurance	Yes	33	3
	No	1,047	97
Region	Amhara	270	25
	Oromia	481	44.5
	B/Gumuz	10	0.9
	SNNP	301	27.9
	Addis Ababa	18	1.6
Residence	Rural	986	91.4
	Urban	93	8.6
Sex of household head	Male	972	90
	Female	108	10
Number of U-5 children	≤2	953	88.3
	≥3	126	11.7
Family members	≤5	534	49.5
	≥6	545	50.5
Mother's educational level	No formal education	672	62.2
	Primary	335	31
	Secondary	56	5.2
	Higher	17	1.6
Media exposure	No	845	78.3
	Yes	235	21.7

Magnitude of ORS utilization among under-five children in diarrhea hotspot regions of Ethiopia

The overall magnitude of ORS utilization for children in diarrhea hotspot regions of Ethiopia was 28%. The utilization of ORS for diarrhea management in diarrhea hotspot regions of Ethiopia is almost comparable based on different sociodemographic variables. Based on the residence, 35.5% of the rural and 27.4% of the urban residents utilize ORS for diarrhea management. Based on the regional state, Addis Ababa city administration is the highest regional state (55.6%), followed by B/Gumuz (54.5%), SNNP (33.2%), Amhara (28.5%), and Oromia (22.9%), respectively among diarrhea hotspot regions to utilize ORS for diarrhea. Regarding wealth status, 26.6%, 31.6%, and 27.5% of the households utilize ORS for diarrhea management whose wealth status is poor, medium, and rich, respectively. Similarly, based on educational level of the mothers, 26.5% of mothers who had no formal education

level, 30.2% of mothers who had primary education level, 26.8% of mothers who had secondary education level, and 47.1% of mothers who had higher education level utilize ORS for diarrhea management in diarrhea hotspot regions of Ethiopia (Table 2).

Multilevel analysis

As shown in Table 3, the variance between enumeration areas and the utilization of ORS for children who have diarrhea in diarrhea hotspot regions of Ethiopia. Therefore, the utilization of ORS across the cluster is different. In addition, the ICC in this study is 12.1%. This means roughly 12.1% of the variability of the utilization of ORS for children with diarrhea in diarrhea hotspot regions of Ethiopia was attributable to the enumeration areas. The model fitted by using community and individual variables has the smallest WAIC (3,124) among the four fitted models. Since models which have the smallest WAIC value are considered the best-fitted model (25), we made a report and interpretation based on this model.

Among the factors included in a model which contains both community- and individual-level factors, residence, wealth status, being a member of health insurance, gender of household head, educational level, and media exposure status were significantly associated with ORS utilization for children who have diarrhea in diarrhea hotspot regions of Ethiopia (Table 2). Being an urban resident, the odds of utilizing ORS is 1.92 times (AOR = 1.92; 95% CrI: 1.13–3.3) more likely as compared with rural residents. The odds of ORS utilization for children with diarrhea among middle and rich wealth status households is 1.9 and 1.28 times (AOR = 1.9; 95% CrI: 1.4–2.1), and 1.28 (AOR = 1.28; 95% CrI: 1.12–1.92) more likely as compared with poor wealth status households, respectively. Being a woman household head, the utilization of ORS for children with diarrhea is 2.11 times (AOR = 2.11; 95% CrI: 1.3–3.9). Also, the odds of the utilization of ORS for children with diarrhea among households who are exposed to the media is 1.43 times (AOR = 1.43; 95% CrI: 1.18–2.5) more likely as compared with households who are not exposed to the media.

Discussion

Diarrhea leads an individual to many watery stools, vomiting, fever, and abdominal pain. Finally, all those manifestations may lead an individual to severe dehydration or death depending on its severity. So, to replace the lost body fluids, ORS is given to individuals who experienced diarrhea (11, 12). Of the factors included

TABLE 2 The magnitude of ORS utilization based on different characteristics among under five children in diarrhea hotspot regions of Ethiopia in 2016.

Variables	Categories	Percentage
Sex of child	Male	29
	Female	26.9
Twin	Yes	17.9
	No	28.3
Birth order	First	26.8
	2–3	29.9
	4–5	27.2
	≥6	27.6
Birth interval	≤23 month	20.8
	≥24 month	30.2
Child weight at birth	Normal	32.8
	Small	24.5
	Big	26.4
Working status of mothers	Had work	32.4
	Had no working	26
Wealth status	Poor	26.6
	Medium	31.6
	Rich	27.5
Distance to health facility	Not big problem	28.4
	Big problem	27.8
Health insurance	Yes	27.6
	No	39.4
Region	Amhara	28.5
	Oromia	22.9
	B/Gumuz	54.5
	SNNP	33.2
	Addis Ababa	55.6
Residence	Rural	35.5
	Urban	27.4
Sex of household head	Male	26.4
	Female	42.6
Number of U-5 children	≤2	28.2
	≥3	26.2
Family members	≤5	27.9
	≥6	28.3
Mother's educational level	No formal education	26.5
	Primary	30.2
	Secondary	26.8
	Higher	47.1
Media exposure	No	27.7
	Yes	28.9
Overall magnitude		28

TABLE 3 Factors associated with ORS utilization among under-five children in diarrhea hotspot regions of Ethiopia in 2016.

Variables	Categories	AOR [95% CrI]	Rhat	Bulk_ESS	Tail_ESS
$\beta 0$ intercept*		0.14 [0.06, 0.32]	1	8,894	9,120
Sex of child	Male				
	Female	0.83 [0.61, 1.13]	1	7,867	8,567
Twin	Yes	0.64 [0.22,1.84]	1	8,934	8,645
	No				
Birth order	First				
	2–3	1.20 [0.80, 1.70]	1	9,234	9,345
	4–5	1.02 [0.68, 1.52]	1	6,784	6,657
	≥6	1.04 [0.70, 1.50]	1	7,689	7,653
Birth interval	≤23 month	0.60 [0.39, 0.93]	1	7,856	7,980
	≥24 month				
Child weight at birth	Normal				
	Small	0.60 [0.41, 1.03]	1	9,745	10,123
	Big	1.13 [0.71, 1.78]	1	10,231	10,545
Working status of mothers	Had work				
	Had no working	1.07 [0.76, 1.53]	1	11,234	11,543
Wealth status	Poor				
	Medium*	1.90 [1.40, 2.10]	1	9,764	9,985
	Rich *	1.28 [1.12, 1.92]	1	8,674	8,874
Distance to health facility	Not big problem	1			
	Big problem	0.77 [0.54, 1.10]	1	6,575	6,789
Health insurance	Yes*	1.73 [1.14, 2.43]	1	7,123	6,997
	No				
Residence	Rural				
	Urban*	1.92 [1.13, 3.30]	1	8,892	9,012
Sex of household head	Male				
	Female*	2.11 [1.30, 3.90]	1	9,177	9,457
Number of U-5 children	≤2				
	≥3	1.06 [0.66, 1.71]	1	8,141	8,272
Family members	≤5				
	≥6	1.40 [0.91, 2.22]	1	7,459	7,359
Mother's educational level	No formal education				
	Primary*	1.52 [1.04, 2.22]	1	5,989	5,747
	Secondary	1.12 [0.52, 2.30]	1	6,852	6,743
	Higher*	3.5 [1.30, 5.00]	1	7,457	7,792
Media exposure	No				
	Yes*	1.43 [1.18, 2.50]	1	8,932	9,089
$\sigma^2_{\mu 0}$ *		0.22 [0.05, 1.22]	1	4,896	5,231
ICC		12.1 [6.20, 18.74]			
WAIC		3,124			

* = Significant at 95% CrI.

in the selected model, residence, educational level of mothers, wealth status, being a member of health insurance, sex of household head, and media exposure status were significantly associated with ORS utilization for children who have diarrhea in diarrhea hotspot regions of Ethiopia.

This study revealed that the odds of utilizing ORS among urban residents are more likely as compared with rural residents. This finding is concurrent with a study conducted in Ethiopia (26). This might be due to urban residents having a better health care service access and good knowledge about ORS in response to diarrhea as compared with Ethiopian rural

residents. Since urban residents have more media exposure (such as Television, Radio, Internet, Newspaper…) than rural residents, they might have more information about ORS utilization and seek healthcare services early when their child experiences diarrhea.

The odds of utilizing ORS for children who experienced diarrhea among the mothers who have primary and higher education levels are more likely as compared with the mothers who did not have formal education. This finding is evidenced by studies conducted in Cameroon (27) and Kenya (28). This might be due to educated mothers having good knowledge about diarrhea and its complications (29–31). Therefore, educated mothers might go to health facilities early and obtain health education from healthcare professionals about the appropriate treatment of their children, including the importance, preparation, and utilization of ORS. Similarly, households whose wealth status is rich and medium utilize ORS more likely as compared with households whose wealth status is poor for their children who experienced diarrhea. This finding is concurrent to the findings of the studies conducted in India (32, 33). This is the fact that in developing countries, such as in Ethiopia, poor households cannot afford the costs of healthcare services including ORS (34). So, children of poor households might not get ORS when they experienced diarrhea. Also, the odds of utilizing ORS for children who experienced diarrhea among mothers who are member of health insurance is more likely to utilize ORS as compared with mothers who are not member of health insurance. This might be due to the fact that households who are not member of health insurance and who had no health facilities close to their area of residence may not access health care services easily. The utilization of ORS among women headed households is more likely as compared with men headed households. This finding is supported by the study conducted in Gondar town (35). This might be due to women having more health seeking behavior as compared with men (36). In addition to the above, since women are close to children care (35), they might see their child when he or she experiences diarrhea. Therefore, women headed households might use ORS more likely as compared with men headed households. The odds of the utilization of ORS for children with diarrhea among households who are exposed to media are more likely as compared with households who are not exposed to media. The finding is supported by the studies conducted in sub-Saharan countries and Bangladesh (namely, Nigeria, Burkina Faso, and Niger) (37–41). This might be due to individuals who have media exposure might get more information about the advantages of using ORS during diarrhea episode and complications of diarrhea if they did not use ORS during diarrhea episode as compared with individuals who are not exposed to media.

Strengths and limitations of the study

Conducting a study by considering the data of all diarrhea hotspot regions of Ethiopia and fitting a multilevel model using the Bayesian approach to get fine estimates of the parameters was the strength of this study. Also, as a limitation, we cannot get some variables (for example, availability and accessibility of ORS, knowledge and attitude of the participants toward ORS) to identify risk factors of ORS utilization.

Conclusion and recommendations

The magnitude of ORS utilization for children in diarrhea hotspot regions of Ethiopia is very low. Not utilizing ORS for diarrhea management had been a major public health problem if the problem continues in this way in the study area. Therefore, all individuals whose children are experiencing diarrhea should give priority attention to utilize ORS. Being an urban resident, wealthy, educated, exposed to media, a member of health insurance, and women headed household increases the utilization of ORS for children who have diarrhea in diarrhea hotspot regions of Ethiopia. Therefore, to increase the utilization of ORS for diarrhea management in diarrhea hotspot regions of Ethiopia, all the concerned bodies including the Ethiopian Ministry of Health and Government should consider those factors when they design diarrhea prevention and control strategies specifically in diarrhea hotspot regions of Ethiopia.

Data availability statement

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

Ethics statement

Ethical clearance for the EDHS data was given by the Ethiopian Health and Nutrition Research Institute (EHNRI) Review Board; the National Research Ethics Review Committee (NRERC) at the Ministry of Science and Technology (34). To collect the data, the respondents were informed about the survey and a verbal consent was taken for their participation (34). Before the data collection, all the procedures were reviewed and approved by the ICF Institutional Review Board (34).

Author contributions

YN, GFA, AA, MSA, and DA were participated in this study from the initial till the end, participated in design, acquisition of data, data cleaning, coding, data analysis, interpretation, drafting, and finally revising of the manuscript. All authors contributed to the article and approved the submitted version.

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Conflict of interest

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

Publisher's note

References

1. WHO/UNICEF. *Progress on Sanitation and Drinking Water: 2015 Update and Mdg Assessment.* Geneva: World Health Organization (2015).

2. Jin Y, Mankadi PM, Rigotti JI, Cha S. Cause-specific child mortality performance and contributions to all-cause child mortality, and number of child lives saved during the Millennium Development Goals era: a country-level analysis. *Glob Health Action.* (2018) 11:1546095. doi: 10.1080/16549716.2018.1546095

3. World Health Organization, UNICEF. *Ending preventable child deaths from pneumonia and diarrhoea by 2025: The integrated Global Action Plan for Pneumonia and Diarrhoea (GAPPD).* Geneva: World Health Organization (2013).

4. World Health Organization. *Diarrhoea: Why Children are Still Dying and What Can be Done*. (2009).

5. Reiner RC, Graetz N, Casey DC, Troeger C, Garcia GM, Mosser JF, et al. Variation in Childhood Diarrheal Morbidity and Mortality in Africa, 2000–2015. *New England J Med.* (2018) 379:1128–38. doi: 10.1056/NEJMoa1716766

6. Troeger C, Forouzanfar M, Rao PC, Khalil I, Brown A, Reiner Jr RC, et al. Estimates of global, regional, and national morbidity, mortality, and aetiologies of diarrhoeal diseases: a systematic analysis for the Global Burden of Disease Study 2015. *Lancet Infect Dis.* (2017) 17:909–48.

7. Gebru T, Taha M, Kassahun W. Risk factors of diarrhoeal disease in under-five children among health extension model and non-model families in Sheko district rural community, Southwest Ethiopia: comparative cross-sectional study. *BMC Public Health.* (2014) 14:395. doi: 10.1186/1471-2458-14-395

8. Fayfman M, Flint K, Srinivasan S. Obesity, motility, diet, and intestinal microbiota-connecting the dots. *Curr Gastroenterol Rep.* (2019) 21:15. doi: 10.1007/s11894-019-0680-y

9. Negesse Y, Taddese AA, Negesse A, Ayele TA. Trends and determinants of diarrhea among under-five children in Ethiopia: cross-sectional study: multivariate decomposition and multilevel analysis based on Bayesian approach evidenced by EDHS 2000–2016 data. *BMC Public Health.* (2021) 21:1–16. doi: 10.1186/s12889-021-10191-3

10. Pierce NF, Sack RB, Mitra RC, Banwell JG, Brigham KL, Fedson DS, et al. Replacement of water and electrolyte losses in cholera by an oral glucose—electrolyte solution. *Ann Intern Med.* (1969) 70:1173–81. doi: 10.7326/0003-4819-70-6-1173

11. WHO. *Diarrhoeal Disease.* Available online at: https://www.who.int/news-room/fact-sheets/detail/diarrhoeal-disease (accessed May 2, 2017).

12. UNICEF. *One is Too Many: Ending Child Deaths from Pneumonia and Diarrhoea*. New York: UNICEF. (2016).

13. Black R, Fontaine O, Lamberti L, Bhan M, Huicho L, El Arifeen S, et al. Drivers of the reduction in childhood diarrhea mortality 1980–2015 and interventions to eliminate preventable diarrhea deaths by 2030. *J Global Health.* (2019) 9. doi: 10.7189/jogh.09.020801

14. Munos MK, Walker CLF, Black RE. The effect of oral rehydration solution and recommended home fluids on diarrhoea mortality. *Int J Epidemiol.* (2010) 39:i75–i87. doi: 10.1093/ije/dyq025

15. Victora CG, Bryce J, Fontaine O, Monasch R. Reducing deaths from diarrhoea through oral rehydration therapy. *Bull World Health Organ.* (2000) 78:1246–55.

16. Wiens KE, Lindstedt PA, Blacker BF, Johnson KB, Baumann MM, Schaeffer LE, et al. Mapping geographical inequalities in oral rehydration therapy coverage in low-income and middle-income countries, 2000–17. *Lancet Global Health.* (2020) 8:e1038–e60.

17. Csa I. Central Statistical Agency (CSA) [Ethiopia] and ICF. *Ethiopia Demographic and Health Survey.* Addis Ababa (2016).

18. (IVAC) IVAC. *Pneumonia and Diarrhea Progress Report 2020*. Johns Hopkins Bloomberg School of Public Health (2020).

19. Atnafu A, Sisay MM, Demissie GD, Tessema ZT. Geographical disparities and determinants of childhood diarrheal illness in Ethiopia: further analysis of 2016 Ethiopian Demographic and Health Survey. *Trop Med Health.* (2020) 48:64. doi: 10.1186/s41182-020-00252-5

20. CSAEaOM. *Ethiopia Demographic and Health Survey 2000*. Addis Ababa, Ethiopia and Calverton, Maryland, USA Central Statistical Authority and ORC Macro (2001).

21. CSACEaI. *Ethiopia Demographic and Health Survey 2016*. AddisAbaba, Ethiopia, and Rockville, Maryland, USA: CSA and ICF (2016).

22. OMC. *Ethiopia demographic and health survey 2005*. Addis Ababa,Ethiopia and Calverton, Maryland USA: central statistics agency and ORC Macro (2005).

23. Hoffman MD, Gelman A. The No-U-Turn sampler: adaptively setting path lengths in Hamiltonian Monte Carlo. *J Mach Learn Res.* (2014) 15:1593–623.

24. Kynn M. *Eliciting Expert Knowledge for Bayesian Logistic Regression in Species Habitat Modelling*. Brisbane: Queensland University of Technology (2005).

25. Watanabe S. Asymptotic equivalence of Bayes cross validation and widely applicable information criterion in singular learning theory. *J Mach Learn Res.* (2010) 11:3571–94.

26. Dodicho T. Knowledge and practice of mothers/caregivers on home management of diarrhea in under five children in Mareka district, Southern Ethiopia. *J Health Med Nurs.* (2016) 27:71–9.

27. Essomba NE, Koum DK, Adiogo D, Ngwe M, Coppieters Y. Use of oral rehydration therapy in the treatment of childhood diarrhoea in Douala, Cameroon. *Malawi Med J.* (2015) 27:60–4. doi: 10.4314/mmj.v27i2.6

28. Njeri G, Muriithi M. Household choice of diarrhea treatmens for children under the age of five in Kenya: evidence from the Kenya demographic and health survey 2008–09. *Eur Sci J.* (2013) 9:77–91.

29. Adane M, Mengistie B, Mulat W, Kloos H, Medhin G. Utilization of health facilities and predictors of health-seeking behavior for under-five children with acute diarrhea in slums of Addis Ababa, Ethiopia: a

community-based cross-sectional study. *J Health Populat Nutr*. (2017) 36:1–12. doi: 10.1186/s41043-017-0085-1

30. Apuleni G, Jacobs C, Musonda P. Predictors of health seeking behaviours for common childhood illnesses in poor resource settings in Zambia, a community cross sectional study. *Front Public Health*. (2021) 9:519. doi: 10.3389/fpubh.2021.569569

31. Lee H-Y, Huy NV, Choi S. Determinants of early childhood morbidity and proper treatment responses in Vietnam: results from the Multiple Indicator Cluster Surveys, 2000–2011. *Glob Health Action*. (2016) 9:29304. doi: 10.3402/gha.v9.29304

32. Bawankule R, Singh A, Kumar K, Pedgaonkar S. Disposal of children's stools and its association with childhood diarrhea in India. *BMC Public Health*. (2017) 17:12. doi: 10.1186/s12889-016-3948-2

33. Pinzón-Rondón ÁM, Zárate-Ardila C, Hoyos-Martínez A, Ruiz-Sternberg ÁM. Vélez-van-Meerbeke A. Country characteristics and acute diarrhea in children from developing nations: a multilevel study. *BMC Public Health*. (2015) 15:811. doi: 10.1186/s12889-015-2120-8

34. EDHS E. Demographic and health survey 2016: key indicators report. *DHS Program ICF*. (2016) 363:364.

35. Yimenu DK, Kasahun AE, Chane M, Getachew Y, Manaye B, Kifle ZD. Assessment of knowledge, attitude, and practice of child caregivers towards oral rehydration salt and zinc for the treatment of diarrhea in under 5 children in Gondar town. *Clin Epidemiol Global Health*. (2022) 14:100998. doi: 10.1016/j.cegh.2022.100998

36. Thompson AE, Anisimowicz Y, Miedema B, Hogg W, Wodchis WP, Aubrey-Bassler K. The influence of gender and other patient characteristics on health care-seeking behaviour: a QUALICOPC study. *BMC Fam Pract*. (2016) 17:38. doi: 10.1186/s12875-016-0440-0

37. Tambe AB, Nzefa LD, Nicoline NA. Childhood diarrhea determinants in sub-Saharan Africa: a cross sectional study of Tiko-Cameroon. *Challenges*. (2015) 6:229–43. doi: 10.3390/challe6020229

38. Caruso B, Stephenson R, Leon JS. Maternal behavior and experience, care access, and agency as determinants of child diarrhea in Bolivia. *Revista Panamericana de Salud Pública*. (2010) 28:429–39. doi: 10.1590/S1020-49892010001200004

39. Bado AR, Susuman AS, Nebie EI. Trends and risk factors for childhood diarrhea in sub-Saharan countries (1990–2013): assessing the neighborhood inequalities. *Glob Health Action*. (2016) 9:30166. doi: 10.3402/gha.v9.30166

40. Messelu Y, Trua K. Application of multilevel binary logistic regressionsanalysis in determining risk factors of diarrhealmorbidity among under five children in Ethiopia. *Public Health Res*. (2016) 6:110–8.

41. Melese B, Paulos W, Astawesegn FH, Gelgelu TB. Prevalence of diarrheal diseases and associated factors among under-five children in Dale District, Sidama zone, Southern Ethiopia: a cross-sectional study. *BMC Public Health*. (2019) 19:1235. doi: 10.1186/s12889-019-7579-2

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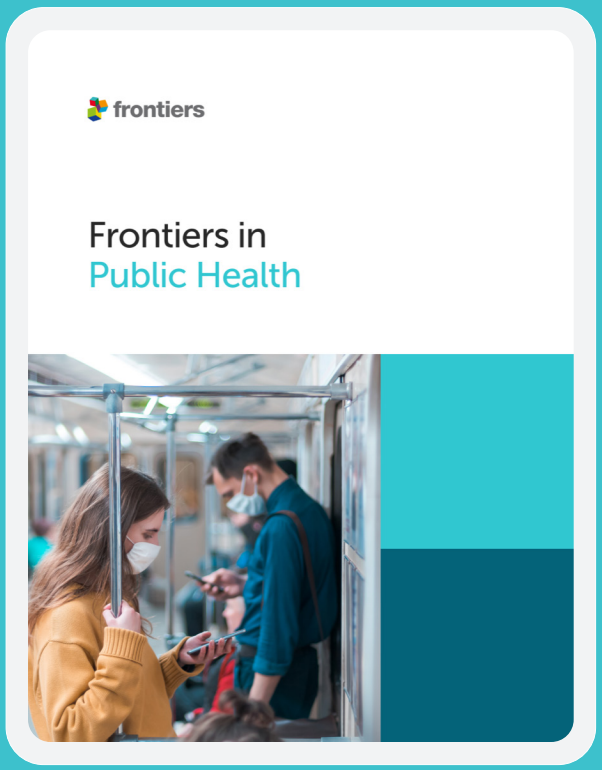

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