UNIVERSITAT ROVIRA I VIRGILI

RESTAURANT-BASED INTERVENTIONS: A NEW APPROACH TO PROMOTE HEALTHIER AND ALLERGY-ADAPTED MEALS

Floriana Mandracchia

UNIVERSITAT
ROVIRA i VIRGILI

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FLORIANA MANDRACCHIA

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Floriana MANDRACCHIA

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Supervised by:

PhD Elisabet LLAURADÓ RIBÉ

PhD Lucia TARRO SÁNCHEZ

MD, PhD Rosa SOLÀ ALBERICH

To

Department of Medicine and Surgery

Universitat Rovira i Virgili

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FACULTY OF MEDICINE AND HEALTH SCIENCES
DEPARTMENT OF MEDICINE AND SURGERY

Carrer Sant Llorenç, 21
43201 Reus
Telf. 977 759 306
Fax. 977 759 352

I STATE that the present study entitled "**Restaurant-based interventions: a new approach to promote healthier and allergy-adapted meals**" presented by **Floriana Mandracchia** for the award of the degree of Doctor has been carried out under my supervision at the Department of Medicine and Surgery of this university and that this thesis meets the requirements to be eligible for the title of Doctor with International Mention.

Reus, 30 July 2021

Doctoral Thesis Supervisor/s

Dra. Rosa SOLÀ ALBERICH

Dra. Lucia TARRO SÁNCHEZ

Dra. Elisabet LLAURADÓ RIBÉ

ABBREVIATIONS

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AMed criteria: criterios de Alimentación Mediterránea (Mediterranean diet criteria)

CSUQ: Computer System Usability Questionnaire

eHealth: Electronic Health application

EU: European Union

FAO: The Food and Agriculture Organization of the United Nations

FDA: US Food and Drug Administration

FOOD: Fighting Obesity through Offer and Demand

FOP: Front-Of-Pack logo system

GDAs: Guideline Daily Amounts

ICTs: Information and Communication Technologies

MARS: Mobile App Rating Scale

mHealth: Mobile Health application

MTL: Multiple Traffic-light Labelling system

NCDs: Noncommunicable Diseases

NEMS-R: Nutrition Environment Measures Study Restaurant assessment

PREDIMED: Prevención con Dieta Mediterránea (Prevention with Mediterranean Diet)

RCT: Randomized Controlled Trial

SD: Standard Deviation

SDGs: Sustainable Development Goals

SMAP criteria: criteria for gluten management designed by the Catalan celiac association

UNESCO: United Nations Educational, Scientific and Cultural Organization

WHO: World Health Organization

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ABSTRACT

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BACKGROUND: The daily meals consumed outside of the home has increased substantially in recent years among adults and children; however, these meals are associated with an unhealthy diet that may increase predisposal to obesity and other related chronic diseases in the long term.

Thus, health promotion in community settings such as restaurants is fundamental to encourage healthier dietary habits when eating out.

HYPOTHESIS: The use of innovative strategies and the inclusion of digital technologies such as mobile and web apps in restaurant-based interventions could offer new opportunities to improve restaurant meal offerings and food allergen management.

OBJECTIVE: This thesis aims to provide evidence about potential innovative strategies and technologies to be used in restaurant-based interventions to increase healthy meal offerings and food choices and improve restaurant food allergen management.

SPECIFIC OBJECTIVES

Study 1: To assess the Mediterranean diet adherence, healthiness, nutritional quality, and food allergen management of meals at restaurants in Tarragona Province (Catalonia, Spain) using a cross-sectional study.

Study 2: To elucidate the effectiveness of independent full-service restaurant- and canteen-based interventions targeting children, adolescents and adults in increasing the availability, purchase and intake of healthy meals using a systematic review and meta-analysis.

Study 3: To assess the potential of self-monitoring mobile phone health (mHealth) apps to increase fruit and vegetable intake using a systematized review.

Study 4: To assess the food allergy or intolerance apps in app stores. The multidimensional Mobile App Rating Scale (MARS) was used to rate these apps' objective and subjective

quality and to identify critical points for future improvements using a systematic search and quality assessment.

Study 5: To describe the development of the Healthy Meals web app and evaluate its usability, quality, and validity according to a panel of restaurateurs and nutritionists.

METHODS

Study 1: This cross-sectional analysis had the following primary outcomes: (1) adherence to criteria for the Mediterranean diet (AMed) and gluten management (SMAP); (2) the nutritional quality of dishes indicated by a green traffic light rating; and (3) meal nutrient content and allergen-free options. Secondary outcomes included restaurant staff knowledge about the Mediterranean diet and food allergens.

Study 2: This systematic review and meta-analysis included studies from 2000–2020 searched in Medline, Scopus, and the Cochrane Library using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist. Randomized Controlled Trials (RCTs) and non-RCTs were included in the systematic review, but only RCTs were included in the meta-analysis. Studies were analysed using the following criteria: (1) outcome category (dietary intake, food availability and food purchase); (2) strategies applied (consumer- and/or establishment-based); and (3) intervention setting (school, community, and workplace) reflecting the age of the target population, i.e., children and/or adults.

Study 3: In this systematized review, searches in PubMed and the Web of Science were conducted and had the following inclusion criteria: RCTs evaluating mobile phone apps (mHealth) focused on increasing fruit and/or vegetable intake as a primary or secondary outcome performed from 2008 to 2018.

Study 4: This systematic search identified apps through the keywords “food allergy,” “food intolerance,” and “allergens” in English, Spanish, and Italian in the Apple App Store (iOS) and Google Play Store (Android). The inclusion criteria were a user star rating of ≥3 (of 5 stars) to limit the selection to the most highly rated apps; ≥1000 reviews identified on the presenting page of the app in the app store to identify the apps that were most commonly used and experienced; and the most recent update performed from 2017 to present. Then, the identified apps were divided according to their purpose: a) searching for allergen-free "food products," b) "restaurants," or c) recipes in "meal planners". Then, apps were evaluated on a scale from 1 to 5 points using the MARS in terms of the following: (1) app subjective and objective quality categories, comprising various sections such as engagement, functionality, aesthetics, and information (Medline was searched for eligible apps to check whether they had been tested in trials); and (2) an optional app-specific MARS section to collect further information about the perceived impact of the app on the user (awareness, knowledge, attitudes, intention to change, help-seeking, and behavioural change). Furthermore, the output and input features of the included apps were evaluated. Differences between MARS sections and app purposes were assessed. Additionally, correlations among MARS sections, star ratings, and numbers of reviews were evaluated.

Study 5: The Healthy Meals web app was based on the nutritional content of restaurant meals assessed in the form of Multiple Traffic Light (MTL) labels and the detection of 14 recognized food allergens. App evaluation included the following: 1) usability evaluation, by 6 restaurateurs and 10 nutritionists who entered a recipe sheet into the web app, and then completed the Computer System Usability Questionnaire (CSUQ), which assessed four factors (system, interface, information, and overall usability) with a maximum score of 7 points; 2) quality evaluation, by the same 10 nutritionists who performed the usability evaluation, and then completed the Mobile App Rating Scale (MARS), with a maximum score of 5 points in the following domains: (a) objective app quality (engagement, functionality, aesthetics, and information), (b) subjective app quality, and (c) user's impacts on the app; 3) validation evaluation, according to the differences in nutrient contents between 2 different nutritionists who entered the same 10 recipe sheets into the web app. Reliability of the ratings was assessed by the Interclass Correlation Coefficient (ICC) to measure the replicability of ratings and was considered moderate (ICC 0.50 to 0.75), good (ICC 0.75 to 0.90) or excellent (ICC >0.90). Furthermore, nutritionists and restaurateurs were asked two open-ended questions to identify critical points to improve.

RESULTS

Study 1: This cross-sectional study included forty-four restaurants and analysed 297 restaurant dishes. Regarding the Mediterranean-adherent diet and food allergen management, restaurants fulfilled an average (mean±Standard Deviation (SD)) of 5.1±1.6 of 9 compulsory AMed criteria and 12.9±2.8 of 18 SMAP criteria, respectively. Dishes were mainly rated green for sugar (n=178/297, 59.9%) but not for calories (n=23/297, 7.7%) or total fat (n=18/297, 6.1%). Waiters and cooks received passing scores for food allergen knowledge (5.8±1.7 and 5.5±1.5 out of 10 points, respectively).

Study 2: A total of 35 RCTs and 6 non-RCTs were included in the systematic review. The meta-analysis included 16 RCTs (excluding non-RCTs to obtain higher quality results). The results for the assessed outcome categories were the following: a) For dietary intake, the included RCTs increased healthy foods (+0.20 servings/day, 0.12 to 0.29, $p<0.001$) and decreased fat intake (-9.90 g/day, -12.61 to -7.19, $p<0.001$), favouring the intervention group; b) For food availability, intervention in schools reduced the risk of offering unhealthy menu items by 47% (RR 0.53, 0.34 to 0.85, $p=0.008$); and c) For food purchases, the systematic review of RCTs and non-RCTs showed that interventions could be partially effective in improving healthy foods.

Study 3: This systematized review included eight RCTs evaluating mobile phone apps focused on increasing fruit and/or vegetable intake. The interventions described in six of these RCTs were effective in increasing fruit and/or vegetable intake. The key aspects identified for the effectiveness of the intervention were the following: a) targeting stratified populations and b) using long-lasting interventions.

Study 4: In this systematic search of the 1376 apps identified, 14 apps were included for the quality assessment: 12 apps were related to food allergies and intolerances that detect 2-16 food allergens and 2 apps were related only to gluten intolerance. The mean (SD) MARS scores (maximum of 5 points) were 3.8/5 (SD 0.4) for objective quality, highlighting whether any app had been tested in trials; 3.5/5 (SD 0.6) for subjective quality; and 3.6/5 (SD 0.7) for the app-specific section. Therefore, a rating ≥3 out of 5 points indicated overall acceptable quality. From the between-section comparison, engagement (mean 3.5/5, SD 0.6) obtained significantly lower scores than functionality (mean 4.1/5, SD 0.6), aesthetics (mean 4/5, SD 0.5), and information (mean 3.8/5, SD 0.4). However, when the apps were compared by purpose, significantly higher engagement was identified for meal planner apps (mean 4.1/5, SD 0.4) than for food product (mean 3.0/5, SD 0.6; *p*=.05) and restaurant (mean 3.2/5, SD 0.3; *p*=.02) apps.

Study 5: Users agreed with the web app usability according to the CSUQ (mean 5.6/7 points, SD 0.9), with moderate reliability among ratings (ICC=0.57; 95% CI, 0.18 to 0.82). Factors with lower scores were interface and information usability (mean 5.6/7 points, SD 1.2; mean 5.5/7 points, SD 1.2, respectively). The web app showed good objective quality according to the MARS (mean 4.0/5 points, SD 0.4), with excellent reliability among nutritionists (ICC=0.91; 95% CI, 0.85 to 0.96). Sections with lower scores were engagement, information and subjective quality (mean 3.4/5 points, SD 0.7; mean 3.9/5 points, SD 0.6; mean 3.1/5, SD 0.4, respectively). For web app validation, no significant differences were observed between the two nutritionists' data, with excellent reliability (ICC=0.98; 95% CI, 0.97 to 0.99). Regarding the points for improvement identified, users proposed ameliorating app data entry by improving the availability of the food database.

CONCLUSIONS

Study 1: Restaurants partially met the AMed and SMAP criteria, demonstrating that further efforts are needed to improve Mediterranean diet-adherent menu offerings and food allergen management. Increasing fibre and decreasing saturated fat are necessary to improve the nutritional content of restaurant meals and consequently consumers' adherence to a healthy diet. Additionally, for restaurant staff, training courses should be considered as a way to reinforce adequate food allergen management in restaurants.

Study 2: Restaurant- and canteen-based interventions improved the dietary intake of healthy foods, reduced fat intake, and increased the availability of healthy menus, mainly in schools. However, higher-quality RCTs are needed to strengthen these results. Moreover, from our results, intervention strategy recommendations are provided.

Study 3: The present review demonstrates that mHealth app-based interventions, lasting from two to nine months and characterized by a stratified population that shares the same motivation to achieve better dietary habits, are effective in increasing fruit and vegetable consumption. Furthermore, the inclusion of behavioural change techniques, such as dietary feedback together with self-monitoring and remote coaching support, has been identified as a key element that can definitively facilitate the adoption of new dietary habits. This issue strongly suggests that behavioural theory-based strategies must be considered when designing dietary mHealth interventions. Further research on mHealth apps is needed to design more effective interventions and to determine their efficacy over the long term.

Study 4: Food allergy or intolerance apps showed acceptable MARS quality (≥3 out of 5 points), although the engagement section for food product and restaurant purpose apps should be improved, and the effectiveness of the applications has yet to be tested in trials. The critical points identified can help improve the innovativeness and applicability of future food allergy and intolerance apps.

Study 5: The Healthy Meals web app was demonstrated to be usable, of good quality and a valid tool for the nutritional assessment and food allergen identification of dishes. Points to improve were identified, while the effectiveness of the app should be tested in scientific trials.

GLOBAL CONCLUSION

In conclusion, innovative strategies have been identified and evaluated, obtaining tailored recommendations for restaurants to improve the healthiness and the Mediterranean diet-adherent offering of their menus and to ameliorate allergen management.

Regarding the inclusion of digital technologies, mHealth and eHealth technologies have been demonstrated to be innovative strategies that can be included in restaurant-based interventions. Existing apps for food allergies or intolerances have shown acceptable quality. Additionally, the Healthy Meals web app has proven its usability, quality, and validity to help restaurateurs assess dish nutritional content and the presence of food allergens.

PERSPECTIVES

Future perspectives rely on the performance of high-quality restaurant-based interventions, such as the Healthy Meals RCT, to evaluate the effectiveness of improving meals' healthiness and food allergen management. Mobile apps for improving nutritional behaviour, as well as for food allergies or intolerances, should be tested in RCTs and be ameliorated in terms of user engagement. Regarding the Healthy Meals web app, the identified critical points should be improved, and its effectiveness should be demonstrated in a designed RCT.

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JUSTIFICATION

JUSTIFICATION

Although unhealthy lifestyle behaviours, such as poor diet and physical inactivity, have been demonstrated to negatively impact health by increasing the risk of morbidity and mortality, they are widespread worldwide (World Health Organization, 2021). These unhealthy habits begin as early as childhood and adolescence (Moreno et al., 2014), affecting all stages of life.

In particular, the consumption of out-of-home meals has increased in recent decades. However, eating out is associated with lower consumption of fruits and vegetables (Fulkerson et al., 2014) and with higher contents of calories, fats and sodium than eating at home (Lachat et al., 2012), which may increase the prevalence of being overweight, obesity (Swinburn et al., 2004) and related chronic diseases (Jayedi et al., 2020).

In Spain, for instance, young and adult individuals have reported consuming meals away from home during weekdays because of work/study commitments and for leisure and travel-related reasons on the weekend (Diaz-Mendez & Garcia-Espejo, 2017). Sit-down restaurants are the preferred locations for 74.1% of the total out-of-home consumption (Ministerio de agricultura pesca y alimentacion, 2020).

However, with respect to customer satisfaction, from a cohort of restaurant diners from ten countries worldwide, only 18% of the consumers were satisfied with the healthy options available on menus and demanded more vegetables, fresh ingredients and light cooking (Newson et al., 2015). Thus, implementing healthier meal offerings in restaurants is an exceptional opportunity for improving consumers' dietary choices.

Furthermore, eating out can be difficult for people suffering from food allergies and intolerances since many restaurants do not make information about the presence of allergens in the meals offered available to customers. In contrast, the incidence of food allergies and intolerances is growing in developed countries, and many severe reactions also occur in restaurants (Versluis et al., 2015).

In particular, although European Legislation No. 1169/2011 requires food businesses to provide information about the presence of any of the 14 most common food allergens (gluten, crustaceans, eggs, fish, peanuts, soya, milk, nuts, celery, mustard, sesame, sulfur dioxide, lupin and molluscs) (The European Parliment and the Council of the European Union, 2011), its implementation is still scarce (Begen et al., 2018; Dano et al., 2015; Loerbroks et al., 2019).

Besides, a way to reinforce the allergen management of restaurants is through their staff. Thus, insufficient training about food allergen management, misconceptions (Ajala et al., 2010), and the feeling of not being responsible for the prevention of customers' allergic reactions (Shafie & Azman, 2015) highlight the need for restaurateurs and their staff to receive more education and awareness.

Specifically, restaurant-based interventions represent a potential strategy to improve the availability of healthier meals and allergen-free options addressed to each member of a family (Tarro et al., 2017) due to the influence that food environments have on individuals' behaviours (Valdivia Espino et al., 2015).

To address the mentioned issues focused on proposing the bases of restaurant-based interventions to improve healthy meal offerings and food allergy management, different steps were followed in the present thesis (*Figure 1*).

First, the analysis of the social context has led to the following: a) the definition of a major community topic, which is the **increase in the consumption of out-of-home meals** by all the members of a family due to the lack of time for cooking, work commitments, leisure and tourism reasons; and b) the identification of literature gaps that highlight research needs and ensure the adequacy of the approach used (Alamina et al., 2020).

Second, the literature analysis highlighted the existence of a **knowledge gap about the healthiness of the meals offered by Spanish restaurants and their management of food allergens** to ensure adequate options for food allergic and intolerant consumers.

Third, **scarce evidence about the most effective methodology to improve the healthy meals offered in restaurant-based interventions** was identified, leaving little data for the design of future interventions.

Fourth, a growing **need for technological innovation** in the form of mobile health (mHealth) and electronic health (eHealth) applications (apps), which are used for different tasks in everyday life, emerged as a result of the increasing number of people with internet access worldwide, which was approximately 4.13 billion users in 2019 (Clement, 2020).

In the context of health promotion, these technologies have already been adopted in different types of healthcare interventions (Yang & Van Steen, 2019) and represent a promising opportunity in the fields of healthy nutrition promotion (Lieffers & Hanning, 2012), self-monitoring (Çelik et al., 2014), and self-management of food allergies and intolerances.

Actually, stakeholders demand digital tools that could help provide more consistent data and other types of related food information (Kapsokefalou et al., 2019), such as meals' nutritional content and the presence of food allergens, which are necessary to ensure healthy and safe meals to consumers, respectively (Elmadfa & Meyer, 2010). Moreover, evidence about **effective apps for increasing healthy food choices and adapted allergen-free options is still scarce**, and the quality evaluation of the apps already present on the market is another fundamental issue for the design of effective future apps used in health-related interventions.

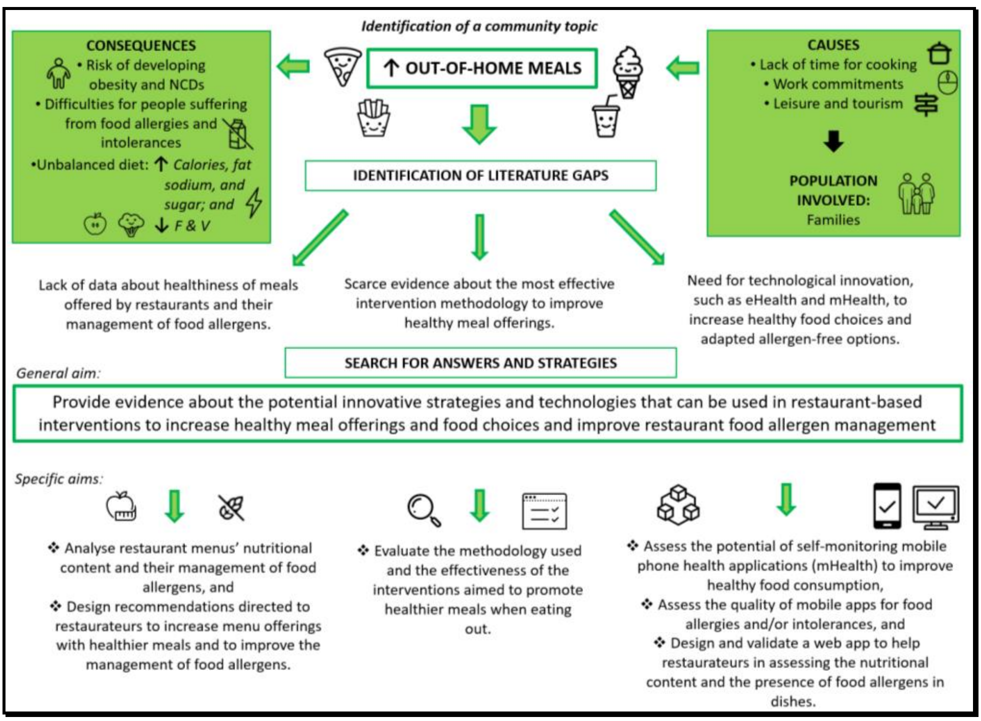
Fifth, the design of the restaurant-based intervention, as the next step, will include the assessment of the nutritional content of restaurant meals, improvement of the menu's offerings, and training of the restaurant staff about food allergen management in restaurants.

The implementation of the defined intervention represents a crucial priority since the interpretation of the resulting outcomes leads to the definition of evidence-based recommendations for the target population as restaurateurs and of implications for long-term maintenance (Rootman et al., 2001).

The improvement in the nutritional quality of restaurant meals and better management of food allergens could lead to positive changes in consumers' food choices (Story et al., 2008) and to a beneficial impact on their diet and health (Holder, 2019).

Thus, the mentioned issues will be addressed by providing evidence about the potential strategies and innovative technologies to be used in restaurant-based interventions for the promotion of healthier nutrition and better allergen management.

Figure 1: Identification of the community topic and literature gaps for the improvement of healthy meal offerings and food allergen management in restaurant-based interventions: thesis design process with specific aims to fulfill.



Source: designed by the author.

INTRODUCTION

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CHAPTER 1: PUBLIC HEALTH PROMOTION

1.1 World Health Organization definition of health, health promotion and public health

The definition of "health" according to the World Health Organization (WHO) constitution signed in 1948 is "*a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*" [..] "*the achievement of any State in the promotion and protection of health is of value to all*" (Kelley, 2014). Health is recognized as a human right, and is related to personal, physical, and social resources (World Health Organization, 1986). With the "Health for All" strategy, the WHO and its member states committed to a series of social, environmental, and economic actions to ensure "*the attainment by all the people of the world by the year 2000 of a level of health that will permit them to lead a socially and economically productive life*" (Nutbeam, 1986).

During the first international conference on health promotion, held on 21 November 1986 in Ottawa (Canada), "The Ottawa Charter" was presented as the official programme for achieving "Health for All" through health promotion, defined as "*the process of enabling people to increase control over, and to improve, their health*" (Nutbeam, 1986). The main objective of health promotion is to improve public health, which is "*the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society*"; and to enhance the concepts that go beyond healthcare, such as well-being and healthy lifestyles (Nutbeam, 1986).

In 1997, the 4th International Conference on Health Promotion held in Jakarta (Java Island, Indonesia) provided a further distinction between public health and new public health, which adds the concepts of lifestyles and living conditions as determinants of people's health status to the definition (Nutbeam, 1998). In this sense, according to the newest and latest definition of public health, supporting healthy lifestyles and environments by enhancing the creation of programmes, policies, services, and resources is necessary to preserve people's health (Nutbeam, 1998).

1.1.1 Ottawa Charter for health promotion

"The Ottawa Charter for health promotion" establishes the commitment of the WHO and the other participating members to the adoption of specific programmes related to social and ethical norms to achieve Health for All (World Health Organization, 1986). Although health promotion strategies must be designed based on the economic, social, and cultural possibilities of a country, three essential strategies for health improvement have been defined by the Ottawa Charter (World Health Organization, 1986):

1. ***Advocate*** good public health by promoting changes in political, legislative, social, and economic barriers affecting people's well-being and promoting the better use of population resources (Wise, 2001). Advocacy includes individual and social actions to create public awareness and interest through mobilization, mass media and interpersonal communications (World Health Organization, 1992).

2. ***Enable*** people with equal opportunities, information, and skills not only to achieve health goals but also to empower communities in improving environments and individuals' behaviours through partnerships (Saan & Wise, 2011).

3. ***Mediate*** to ensure coordinated action in the promotion of public health by all stakeholders such as governments, organizations, authorities, industries, professionals, and social sectors. In particular, health professionals have a greater responsibility for mediating different social interests in achieving health goals (World Health Organization, 1986).

These three strategies were presented in the health promotion emblem (*Figure 2*), created for the Ottawa International Conference and kept as the official logo for the approaches defined in the Ottawa Charter (World Health Organization, 1986). In *Figure 2*, from a central circle presenting the three above-described strategies (advocate, enable, and mediate), three wings depart from it, and a larger outside circle describing the five key action areas in health promotion delimits the emblem. These five key actions are the following (World Health Organization, 1986):

1. ***Build healthy public policy*** to keep all the actions coming from different sectors tied and coordinated to be more efficient and safer;

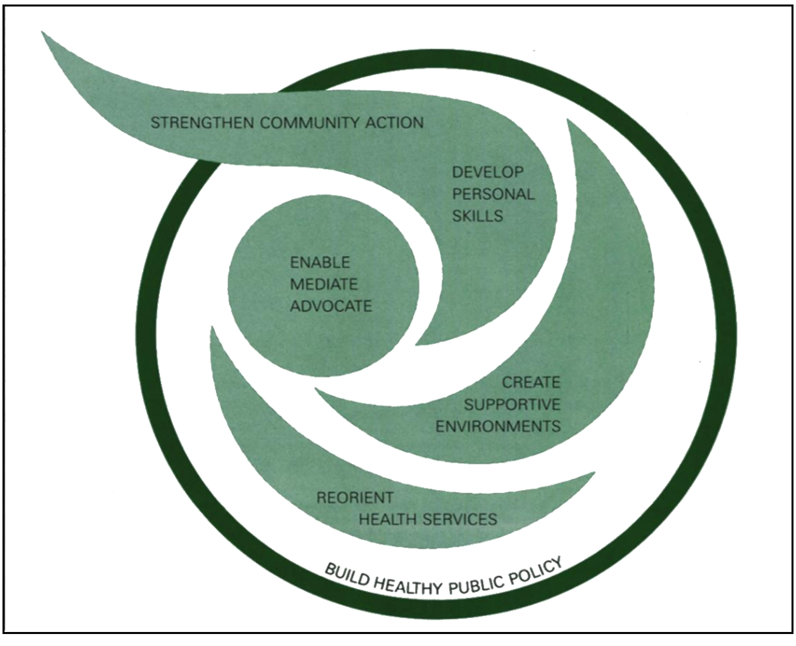
2. ***Create supportive environments*** intended as communities, living, and work environments that take care of natural resources and have a positive impact on people's health;

3. ***Strengthen community actions*** by entrusting the community in the control and management of health promotion community actions, which implies the provision of information, funding, and support;

4. ***Develop personal skill*** through education, training and developmental opportunities set in the school, work, home and community settings with the aim of enabling people to self-manage their health; and

5. ***Reorient health services*** by considering the economic, social, and cultural differences in individuals' and communities' needs and possibilities.

Figure 2: Emblem of the Ottawa International Conference on Health Promotion.



Source: World Health Organization (WHO), 1986.

The wing comprising the actions "strengthen community" (key promotion area 3) and "develop personal skills" (key promotion area 4) symbolically comes out of the larger outside circle representing the construction of public policy. This emphasizes that communities' and individuals' needs evolve with time, and a flexible healthy public policy is necessary to address these changes (World Health Organization, 1986).

Actually, health promotion actions must consider the socioeconomic, cultural, and environmental factors affecting people's health in different ways, according to age, sex, and ethnicity (Lovell & Bibby, 2018). Specifically, living and work conditions, education, diet, social relationships and individual behaviours are social health determinants whereas differences in power, money and resources are the basis of population inequalities, leading to disparities in health problems that also create gaps in health accessibility (Lovell & Bibby, 2018).

1.2 Setting-based approaches for health promotion

Health promotion requires specific setting-based approaches, described by the WHO in the Ottawa charter (1986) as the "Healthy Settings" movement, according to the concept that "*health is created and lived by people within the settings of their everyday life; where they learn, work, play and love*" (World Health Organization, 1986). Thus, a setting is defined as the environment where people spend most of their time and where they could encounter health problems and make related choices, such as cities, schools, workplaces, hospitals, homes, and communities, among others (Nutbeam, 1986) (*Figure 3*). Next, some setting-based approaches for health promotion identified by the WHO are described.

From the initial Healthy Cities programme (World Health Organization, 1986), the Healthy Settings movement has developed, addressing different settings considered health promoters, with specific projects to safeguard public health.

For example, Health Promoting Schools programmes, including multicomponent strategies directed at the school curriculum, the school environment and the entire community, are one of the most widespread setting-based approaches (World Health Organization and The United Nations Educational Scientific and Cultural Organization, 2018). School-based interventions applying the Health Promoting Schools approach have demonstrated significant effectiveness in improving students' dietary intake by increasing the consumption of healthier foods and reducing the intake of low-nutrient dense foods, as well as in ameliorating hygienic and food safety behaviours (Wang & Stewart, 2013).

The workplace environment, along with the school setting, represents another priority setting for health promotion since adults spend most of their life in their workplace and because interventions made in such settings indirectly impact workers' families, communities, and society. Multicomponent interventions based on the healthy workplace model are the most effective for improving employee health by targeting dietary behaviours and physical activity. Such interventions include food service and vending machine changes through the provision of healthier options, physical activity programmes, environmental improvements, education and health policy assumptions (World Health Organization, 2009).

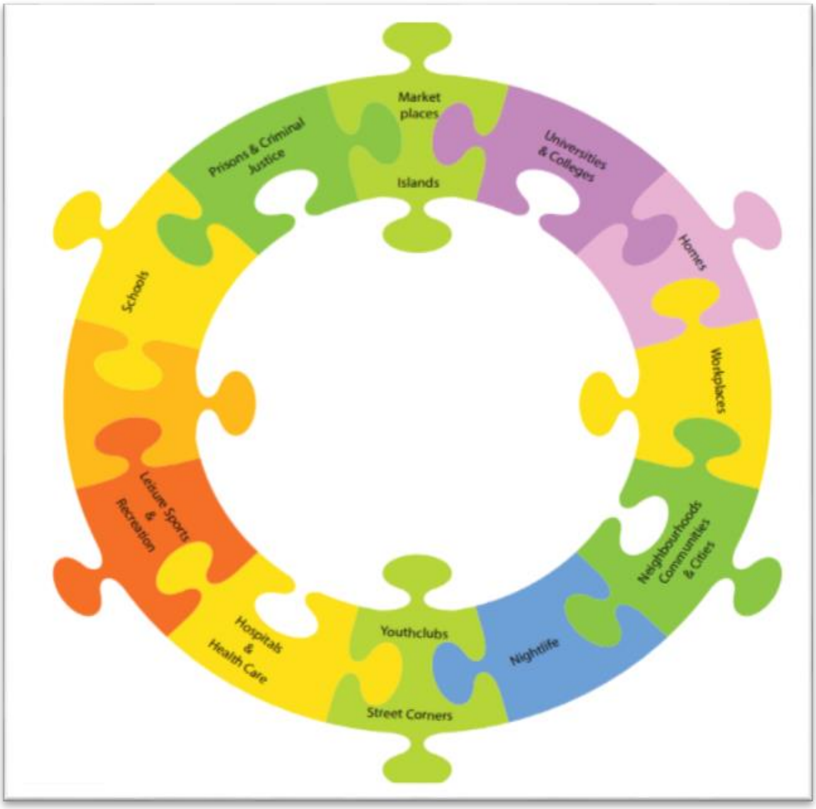
Primary care settings, such as hospitals, also represent a high-impact setting for health promotion because as research and teaching institutions, hospitals produce and disseminate knowledge that influences health structures and professional practice. Therefore, the WHO Health Promoting Hospitals movement aimed to promote health for patients, health professionals and the surrounding hospital community through actions and specific interventions (World Health Organization, 2005). However, hospital-based interventions suffer from the lack of long-term sustainability due to the absence of sufficient funding and strong implementation frameworks, which represent the current challenges faced by health care institutions (Cowie et al., 2018).

Furthermore, the home setting is a crucial environment when targeting families and children in particular. Home-based approaches have demonstrated effectiveness in improving the parental capability to promote a healthier lifestyle for all family members, including healthier eating habits and increased physical activity, contributing to the prevention of childhood obesity (West et al., 2010). Furthermore, positive results of home-based interventions also support the older population by reducing mortality rates and improving their independent activity (Tappenden et al., 2012).

Finally, another important health promotion environment is the community setting, which is the broadest setting and includes "*groups of people sharing a common characteristic or affinity, such as living in a neighbourhood, or being in a specific population group, or sharing a common faith or set of experiences*" (National Institute for Health and Care Excellence, 2016).

Communities have a fundamental role in improving public health through the active participation of individuals in activities, programmes, discussions and services (Public Health England & NHS England, 2014). Effective community-based interventions aimed at improving healthy lifestyles target multicomponent changes at the individual, social and environmental levels (Story et al., 2008). Specifically, they require the active participation of the community, implementation of the intervention in one or more community settings, use of multiple intervention strategies, and improvement of the environment through the application of policies or point-of-purchase marketing strategies in food services, retail stores and restaurants, for example (Mittelmark et al., 1993). Environmental and policy approaches could be the most effective strategies to improve population-based healthy eating habits since individual behavioural changes need to be encouraged by a healthy environment that offers accessible and affordable food choices (Story et al., 2008). Thus, possible changes are feasible through the implementation of local and national policies such as food and beverage taxes, menu labelling and market licences, among others (Bowen et al., 2015).

Figure 3: The WHO Healthy Settings.



Source: HSE National Health Promotion Office, 2012.

1.3 Promoting healthy behaviours to prevent non-communicable diseases

Individual unhealthy behaviours are relevant determinants of health and key targets in disease prevention (Mo & Winnie, 2010). Noncommunicable diseases (NCDs) such as cancer, diabetes, and heart and lung diseases caused 41 million deaths among individuals aged from 30-69 years in 2018, corresponding to 71% of global deaths. Poor nutrition, physical inactivity, smoking and alcohol abuse have been demonstrated to have significant impacts on developing NCDs (World Health Organization, 2018).

Thus, health promotion is fundamental to encouraging behavioural and environmental changes to avoid disease and relieves the increasing demand for health sector resources

(Dobe, 2012). In particular, the promotion of a healthy diet plays an important role in the prevention of diabetes, hypertension, obesity and cardiovascular diseases, among other chronic diseases (World Health Organization, 2003).

A healthy diet includes foods, nutrients and habits aimed at optimizing health. Specifically, these eating habits include the following (Willett & Stampfer, 2013; World Health Organization, 2020b):

1. Consumption of at least five portions of fruit and vegetables a day, as well as legumes, nuts and whole grains;

2. Less than 10% of the total caloric intake should come from free sugar;

3. Less than 30% of the total caloric intake should come from fats and unsaturated fats (fish, nuts, olive oils, etc.) are preferable to saturated fats (meat, butter, cheese, etc.) and should represent less than 10% of the total caloric intake;

4. Avoidance of industrially produced trans fats;

5. Consumption of less than 5g of salt a day and preferably ionized;

6. Adoption of an active lifestyle with daily physical activity; and

7. Moderate alcohol consumption and increased water intake.

Additionally, one of the globally most-known and studied healthy dietary patterns is the Mediterranean Diet recognized by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a cultural heritage of humanity (Saulle & La Torre, 2010) demonstrating preventive and protective effects towards several chronic diseases (Keys et al., 1986).

For instance, the PREDIMED (Prevención con Dieta Mediterránea) study, which is a primary prevention trial, demonstrated the protective effects of the Mediterranean diet on individuals with diabetes or other risk factors for heart disease by reducing the risk of death from stroke by 30% due to the consumption of extravirgin olive oil, nuts, and antioxidant-rich foods that characterize this particular dietary pattern (Estruch et al., 2018).

The Mediterranean dietary pattern, defined by Ancel Keys in 1986, includes the following: a) high consumption of fruits, vegetables, water, dried fruits, cereals, whole grains, fresh and local foods that are minimally processed, olive oil as the principal source of dietary fats, and dairy products; b) moderate consumption of eggs, poultry, seafood and fish; and c) low consumption of alcohol, sugars, and red and processed meat (Altomare et al., 2013).

Health promotion interventions based on the Mediterranean diet education could be effective in the prevention of different diseases among the population (Piscopo, 2009), but more evidence is needed to determine which are the best strategies and settings to encourage individuals to adopt healthier eating habits. Although individuals try to maintain healthy dietary behaviours, the modern food environment is rich in appetizing and processed foods that have addictive effects on consumers (Gearhardt et al., 2011).

The community setting, for instance, has been somewhat effective for health promotion. In the community setting, the implementation of policies and marketing strategies has limited the availability, accessibility and demand for foods and beverages high in saturated fats, trans fats, salt and sugar through taxes on sugar-sweetened drinks and the reformulation of food product contents (World Health Organization, 2016). Decreasing saturated fat intake could lead to a 17% reduction in the risk of developing cardiovascular disease (Hooper et al., 2015); and a reduction in salt content in food products, together with food labelling and marketing campaigns, had a significant impact on the prevention of NCDs (Hyseni et al., 2017).

For the prevention and control of NCDs, it is important that interventions target the entire life course, from infancy to older age; and include the natural settings where people spend their lives (Mikkelsen et al., 2019), such as schools (Singh et al., 2017), worksites (Kolbe-Alexander & Lambert, 2013), communities (Dyson et al., 2015) and restaurants (Laar et al., 2020).

In this context, in 2009, six European countries (Belgium, Spain, Italy, France, Sweden, and the Czech Republic) started the "Fighting Obesity through Offer and Demand" (FOOD) project (Soroko, 2012), which aimed to prevent obesity and improve the nutritional quality of the food offered at restaurants by proving more information to customers and making healthier choices more accessible. The findings of the FOOD project showed that employees were more interested in healthy eating habits and chose restaurants for daily lunch breaks based on their menu offerings, preferring restaurants with a greater variety of food.

Moreover, although most of the interviewed restaurants did not notice an increase in the demand for balanced meals, they were interested in making improvements in the nutritional quality of their offerings in line with the FOOD recommendations (Soroko, 2012).

1.4 Good health and well-being as one of the 17 Sustainable Development Goals

On 25 September 2015, the General Assembly of the United Nations established 17 Sustainable Development Goals (SDGs) and 169 targets (United Nations, 2015) for a healthier and fairer world by 2030 (*Figure 4*). The SDGs are a plan for action addressing people, the planet, prosperity, peace, and partnerships to be conducted by all member nations. Each government has committed to implementing these global targets into their national programmes considering their economic, social and environmental contexts (Voituriez et al., 2020).

Of the 17 SDGs, at least 13 are directly or indirectly related to health and well-being; however, only goal number 3 specifically aims to "ensure healthy lives and promote well-being for all at all ages" through 13 targets, which include decreased mortality from NCDs, improved healthcare services, education, prevention and reduced mortality, among others (Voituriez et al., 2020). To achieve SDG number 3, different implementation strategies have been proposed. For example, the WHO designed a strategic plan to extend health coverage, ensure better health services and promote health and well-being (World Health Organization, 2020a).

A practical approach for public health action, comprising five steps known as the "E4A", was proposed (Menne et al., 2020): a) Engage health and well-being related stakeholders; b) Assess the countries' contexts, challenges and potential to achieve health-related SDG targets; c) Align policies with governments and sectors to create coordinated action; d) Accelerate the entire process of identifying the most effective interventions; and e) Account for the progresses through outcome indicators and feedback.

To accelerate the implementation of these strategies and the achievement of SDG number 3, the use of Information and Communication Technologies (ICTs), in the form of e-Health and m-Health apps, is facilitating SDG 3 through direct interaction and information delivery to individuals worldwide, including those in low- and middle-income countries (International Telecommunication Union, 2017).

Figure 4: 17 Sustainable Development Goals.

Source: World Health Organization (WHO), 2016.

CHAPTER 2: MHEALTH AND EHEALTH: THE NEW INCOMING DIGITAL ERA FOR HEALTH PROMOTION

2.1 Definitions, differences, and advantages

The use of more innovative technologies, such as mHealth and eHealth in healthcare and health promotion, has rapidly increased in recent years; and most of these technologies focus on improving dietary tracking, self-monitoring and weight loss or management (*Table 1*).

A clear official definition of such tools has not yet been defined (Shorbaji, 2013). However, the most reliable definitions are those of the WHO, which consider the following: a) eHealth (short for electronic health) is "*the cost-effective and secure use of information and communications technologies in support of health and health-related fields, including health care services, health surveillance, health literature, and health education, knowledge and research*" (Shorbaji, 2013); and b) mHealth (short for mobile health) is the "*medical and public health practice supported by mobile devices, such as mobile phones, patient monitoring devices, personal digital assistants (PDAs), and other wireless devices*" (World Health Organization, 2011).

Specifically, eHealth technology aims to deliver health services and support and manage health systems through electronic devices such as computers (World Health Organization and International Telecommunication Union, 2012) while mHealth is derived from eHealth and supports health practices, self-monitoring, surveillance, care and information delivery through mobile technology such as apps, personal digital assistants and tablets (International Communication Union, 2014). As a result, eHealth and mHealth technologies provide different advantages in the public health promotion system, such as the following: a) the extended delivery of health services and expertise to remote areas, b) real-time data collection and monitoring, c) a patient-centred approach, d) supply chain management of equipment and products, e) friendly engagement of patients, and f) cost-effectiveness and time savings (Abolade & Durosinmi, 2018).

In particular, mHealth and eHealth technologies have allowed low-income communities to access public health services at low costs, reducing health inequalities (Bastawrous & Armstrong, 2013). However, there are several concerns about the safety and privacy of patients' information shared through mHealth and eHealth tools, which could be overcome by implementing legislative and technological measures (Azeez & Van der Vyver, 2019).

Although it is highly recommended that this technology be regulated to ensure its safety and quality for patient use, the regulatory process outlined by the European Commission in Europe only concerns medical devices for the diagnosis, prevention, monitoring, treatment or alleviation of disease; compensation for an injury or handicap; or control of conception (West of England Academic Health Science Network & University of Bristol, 2014). Similarly, the US Food and Drug Administration (FDA) only legislates apps whose aim is to provide help in decision making for the diagnosis, cure, mitigation, treatment or prevention of a disease or other conditions (US Food and Drug Administration (FDA), 2019).

Thus, apps intended to provide information and education to users, as do most of the existing apps on the market, could not actually be regulated.

Table 1: Validated mobile and web apps for dietary self-monitoring and weight loss (from 2010 to 2020).

Reference	App	Type, Focus	Characteristics	Validation/Evaluation results
Ambrosini G.L. et al., 2018.	Easy Diet Diary.	Mobile app for dietary assessment.	• Food diary and tracking from a wide country-specific database and barcode scanning, • Activity tracker, and • Calorie counter.	Participants showed higher levels of acceptance than 24-h dietary recalls. The app demonstrated good feasibility in epidemiological researches.
Azar K.M.J. et al., 2013.	Lose it.	Mobile and web app for diet tracking and weight loss.	• Food diary and tracking through barcode scanning or smart camera photography, • Reports about personal progresses, and • Personalized goals.	Lose It scored as the top-ranked in behavioural theory score and persuasive technology score. According to iTunes, Lose It was rated the most popular app in the iTunes Health and Fitness category (5/200).
Carter M.C. et al., 2013.	My Meal Mate.	Mobile app for weight loss and weight management.	• Food diary and tracking from a 40,000-item commercial food database, • Instant feedback on self-reported energy intake and estimated expenditure, and • Analysis of macronutrient intake.	My Meal Mate is a potential effective app for dietary assessment tool, as it correlates favorably with 24-h recalls.
Chaudhry B.M. et al., 2019.	Fooducate.	Mobile and web app for diet tracking and weight loss.	• Food diary and tracking through barcode scanning, • Healthiness feedback of food products, • Users community for advices and assistance, and • Tips and recipes.	Fooducate was effective in impacting some aspects of its users' lives by providing a tool that can help people understand their daily dietary intake.

Table 1 (continued): Validated mobile and web apps for dietary self-monitoring and weight loss (from 2010 to 2020).

Reference	App	Type, Focus	Characteristics	Validation/Evaluation results
Choi B.G. et al., 2019.	Vibrent Health.	Mobile app for dietary management in patients with cardiovascular diseases.	• Food diary and tracking through smart camera photography, • Weekly challenges to encourage dietary improvements, and • Dietary counseling and feedbacks.	Vibrent Health was effective in nudging participants to adhere to the Mediterranean diet even after the end of the study.
Della Torre S.B. et al., 2017.	e-CA app.	Mobile app for food records.	• Food diary and tracking from a list of categories and subcategories, • Registration or modification of eating occasions, and • Definition of sizes of food portions.	e-CA has the potential to facilitate the measurement of food intake by reducing the workload, costs, and the risk of transcription errors.
Evenepoel C. et al., 2020.	MyFitnessPal.	Mobile and web app for diet tracking and weight loss.	• Food diary and tracking from a country-specific database with over 6 million food items and brands, • Barcode scanner to insert packaged food products, and • Users community for advices and assistance.	Dietary analysis with MyFitnessPal is accurate for total energy intake, macronutrients, sugar, and, fibre but not for cholesterol and sodium. MyFitnessPal was effective in promoting weight loss when combined with dietary counseling in 100 obese subjects.
Gilliland J. et al., 2015.	SmartAPPetite.	Mobile app for health promotion.	• Push notifications abut healthy nutrition, eating tips, recipes, and local food vendors.	SmartAPPetite was effective at increasing awareness and consumption of healthy foods, and in suggesting people to buy from local food vendors.
Helander E. et al., 2014.	The Eatery.	Mobile app for dietary self-monitoring.	• Food diary and tracking through smart camera photography, • Feedbacks, and • Past behaviours reminder.	Limited adherence was demonstrated by users after the first period of use. Most of the users did not take any pictures (69%) or took only one picture (17%), which means that they only downloaded the app and experimented with it once, without starting dietary self-monitoring.

2.2 Mobile apps and web-based delivered interventions

Health promotion interventions based on the use of mobile or web apps have rapidly spread in recent years due to their cost-effectiveness and potential to reach a large target population (Soriano Marcolino et al., 2018). Specifically, their potential has been tested in supporting chronic diseases, NCDs, disease rehabilitation, mental health management, treatment adherence, and behavioural change, including smoking, alcohol consumption, dietary intake and physical activity (Soriano Marcolino et al., 2018).

mHealth and eHealth interventions have demonstrated promising results among different population ages and for different outcomes, such as the following: a) in children for the prevention or treatment of childhood obesity (Turner et al., 2016), b) in adolescents for the management of chronic diseases such as diabetes and the promotion of healthy behaviours such as increased physical activity (Fedele et al., 2017), and c) in adults and early elderly individuals for the improvement of physical activity (Haberlin et al., 2018; Kampmeijer et al., 2016), among others.

When applied in health interventions, eHealth resulted in more appreciation and usability among users and had slightly better effects than mHealth (Gomez Quiñonez et al., 2016). However, the combination of mHealth and eHealth in digital health promotion could strengthen global intervention effectiveness and improve users' motivation to achieve behavioural goals, such as healthy dietary habits and increased physical activity (Morrison et al., 2014). The favourable features of such technologies include the following: a) increasing the capability to allow patients to real-time self-monitor their health conditions; b) improving communications with health professionals in apps that offer such interaction, while others do not need such a feature; and c) increasing patients' awareness of reaching health goals through prompts and reminders (Lee et al., 2018).

Nevertheless, only a small number of the thousands of apps existing on the market have had their effectiveness in population-based interventions tested, posing the urgent need to provide more scientific evidence about the feasibility of such devices to ensure greater safety and quality for patients, especially when these apps are designed to help the self-management of a chronic condition (Byambasuren et al., 2018).

Furthermore, nonmedical apps are intended to provide only information and education to users and often lack important or complete data (Akbar et al., 2020); therefore, these apps should be validated to better help users make health-related choices (Dayton, 2013). However, medical and nonmedical apps that have been developed for scientific trials, have already been tested and have demonstrated positive results should be made available on the digital market for their use by people with or without diseases that may benefit from them (Lee et al., 2018).

2.3 Barriers encountered for digital health promotion interventions

Along with the wide range of positive opportunities that mHealth and eHealth give in the field of digital health promotion, 5 main barriers are encountered when these technologies are implemented in health interventions (Vesel et al., 2015):

1. ***Financial feasibility*** since one strong point of digital interventions is the economic benefits, which are often derived from the short-term financing that could compromise the sustainability of the intervention. This problem could be overcome if governments adopt health programmes paying for the expenses (Tamrat & Kachnowski, 2012).

2. ***Lack of knowledge, research and evidence*** about the impacts of digital interventions, which delays their progression and implies scarce standardization for study designs (Vesel et al., 2015).

3. ***The poor telecommunication infrastructure*** (Tamrat & Kachnowski, 2012), ***limited access to the internet and health inequalities*** in low-income countries, which requires actions directed not only to improve technical skills and the availability of electronic devices and internet connections but also to encourage social awareness of the importance of health (Ahmed et al., 2020).

4. ***Inadequacy of the privacy and security*** measures concerning the personal data that are communicated and exchanged on such devices (Sahama et al., 2013).

5. ***The sociocultural context***, which is based on individuals' age, education, socioeconomic status, perception and motivation, influences people's participation and interest in digital

interventions, especially among elderly individuals who are less likely than youth to use such new technology (Czaja et al., 2006).

Health promotion interventions supported by digital technologies have great potential to improve health and prevent chronic diseases in individuals and communities. Thus, the abovementioned barriers should be considered for the design of future interventions (Ren et al., 2015).

CHAPTER 3: RESTAURANT-BASED APPROACHES TO IMPROVE THE HEALTHINESS OF MEALS AND FOOD ALLERGEN MANAGEMENT

In order to design effective approaches for restaurant-based interventions, several steps are needed. The first step concerns the identification of a community topic, such as the increase in out-of-home meals (paragraph 3.1); and the assessment of societal needs (paragraph 3.2), such as the increasing demand for healthier meals (paragraph 3.2.1), allergen-free dishes (paragraph 3.2.1), and vegetarian and vegan meals (paragraph 3.2.3). The second step includes the analysis of the evidence about the healthiness of restaurant meals (paragraph 3.3), the available assessment tools for the identification of healthy food options to show consumers (paragraph 3.4), and evidence about restaurant staff knowledge about food allergen management (paragraph 3.5). Finally, the last step is the review of the evidence about effective restaurant-based interventions present in the literature (paragraph 3.6).

3.1 Identification of a community topic: the increase in out-of-home meals

The change in dietary habits among Mediterranean populations, such as the increase in the frequency of eating out due to changing lifestyles and work commitments, has turned into a real public health problem that involves poor-quality nutrition and a negative impact on health for all family members (Rotondo et al., 2021).

The nutritional intake of the Spanish population has significantly changed in the last 40 years, deviating from the traditional and healthy Mediterranean dietary pattern and therefore representing a potential risk for individuals to develop NCDs (Varela-Moreiras et al., 2010).

According to the 2021 report of the Spanish Ministry of Health, only 47% of the Spanish population >1 year old consumes vegetables daily, and 68% regularly consume fruits. Additionally, 16% of Spanish adults and 10% of Spanish children were overweight (Ministerio de Sanidad Consumo y Bienestar Social (Spanish Ministry of Health), 2021).

Regarding eating out, a recent survey conducted in Catalonia (Spain) showed that people on average consume meals away from home 3.5 times a week due to the lack of time and work necessities for adults and for leisure for youth, both on workdays and weekends (Departament d'Empresa i Coneixement de la Generalitat de Catalunya, 2018) (*Figure 5*). In general, in Spain, out-of-home eating increased by 286.39 million people in 2019; and of this eating out, 60.6% is food related and 39.4% is beverage related (Ministerio de agricultura pesca y alimentacion, 2020; Ministerio de Agricultura Pesca y Alimentación, 2019).

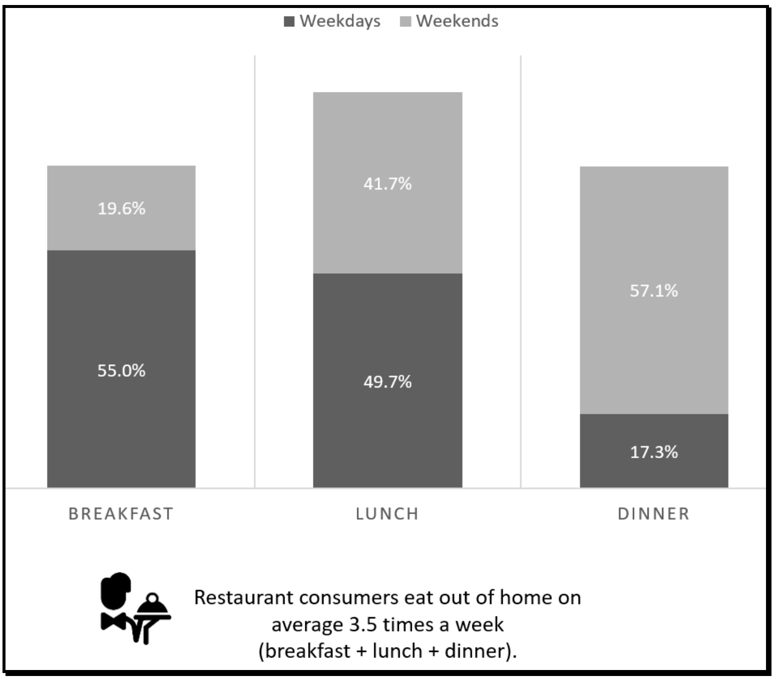
Another aspect of eating away from home is also related to the need to maintain social and familiar relationships, which means that eating away from home becomes a cultural habit and an integral part of the social life of Spaniards (Diaz-Mendez & Garcia-Espejo, 2017). Spain is one of the most visited touristic countries in the world, and its gastronomic tourism has led to a significant increase in restaurant attendance, with the aim of promoting Spanish Mediterranean characteristics through the local culinary tradition (World Tourism organization (UNWTO), 2012). Preferred locations are traditional independent restaurants and cafeterias rather than fast food restaurants, and take-out meals are mostly preferred by younger generations (Departament d'Empresa i Coneixement de la Generalitat de Catalunya, 2018).

Eating out entails increased portion sizes; greater intake of high-density caloric foods, fats, sodium and sugars; and lower varieties of fruits, vegetables, whole grains, legumes and other high-quality foods (Villacis et al., 2015). As widely recognized, long-term poor dietary habits are related to a higher risk of developing NCDs (Afshin et al., 2019) whereas the regular intake of home-cooked meals is associated with healthier nutrition and positive effects on cardiometabolic health by reducing the risk of diabetes, high cholesterol and adiposity (Mills et al., 2017).

Hence, there is a need to promote a return to compliance with the Mediterranean diet recommendations, especially in young people whose consumption of fruit, vegetables, and fish is very low compared to those of adults and elderly individuals (Partearroyo et al., 2019).

Thus, changes in the food environment, including the improvement of restaurant menu offerings by increasing the availability of healthier options, would have a positive impact on children's food choices and consumption (Anzman-Frasca et al., 2015).

Figure 5: Daily consumption of meals away from home in Catalonia (Spain).



Source: Adapted by the author from the "Study of the catering sector in Catalonia. Behavioural habits and trends", Department of Business and Knowledge of the Generalitat de Catalunya (2018).

3.2 The assessment of society's needs

3.2.1 Increase in consumers' demand for specific food options: healthier meals

Among the growing demands from consumers when eating outside the home is the need for healthier meals in restaurants.

Specifically, from an international survey of customers' satisfaction with the healthy dishes on restaurant menus, only 18% of the interviewees were completely satisfied. The expectations reported by the interviewed customers included more steamed, baked or grilled meal offerings (64%) and greater availability of fresh and low-fat ingredients (59%), especially at lunch during weekdays (Monday-Friday) (Newson et al., 2015).

Regarding the types of restaurants that people would like to have more of in their city, Spaniards mainly desire healthy restaurants (34%) and traditional cuisine (28%); however, in other countries such as the United Kingdom (UK) and Germany, consumers demand more ethnic cuisine (28%) and fast food offerings (22%), respectively (Dalia Research, 2017).

Besides, the factors influencing consumers' restaurant choices could be attributed to three main components: a) price-quality, service and marketing, referring to the combination of a low price with good quality service and reputation; b) food product quality and menu variety, related to the presence of traditional and high-valued meals; and c) seekers of healthy meals, which is the largest segment of consumers to which restaurants must begin to address in their marketing strategy (Chiciudean et al., 2019).

However, despite customers' intention to order healthier meals, there are several factors affecting consumers' choices, including convenience in terms of the following: a) time, b) affordability, c) social influencers such as families, d) friends and the community, and e) food environments (Ares et al., 2017; Davis et al., 2013).

Regarding financial aspects, regular consumers of healthy meals reported that such options are very expensive or overpriced compared to the other offerings, and the labelled healthier options are not truly healthy in their opinion, indicating the need for restaurants to provide food with a better value for the price paid (Gopaul, 2015).

Contrary to expectations, children and adolescents favour the provision of healthier side dishes, such as fruit and vegetables, to replace the most common French fries. In particular, what could limit the demand for healthier options by children is their enjoyment of/taste for new plates (Anzman-Frasca et al., 2014). However, such barriers could be overcome by restaurants through the promotion of more appetizing and creative fruit and vegetable dishes, serving as default substitutes for high calorie meals (Anzman-Frasca et al., 2014). Furthermore, 70% of parents would like restaurants to offer smaller-size meal portions adapted to the needs of children because what is offered to them on children's menus is not healthy in their opinion (Lee-Kwan et al., 2018). Thus, intervention efforts to increase the availability of healthier menu offerings for children would benefit both children's health and catering sector profits (Lee-Kwan et al., 2018).

3.2.2 Increase in consumers' demand for specific food options: allergen-free meals

The need for restaurant menu changes is particularly expressed by people with food allergies and intolerances. It has been estimated that 2-37% of European adults have allergies to any food, and 1-19% have allergies to specific foods (Lyons, 2019). For people suffering from gluten intolerance, for example, eating out is a real challenge as restaurants do not provide suitable offering or most gluten-free labelled options always contain detectable gluten traces and are not safe for their consumption (Lerner et al., 2019). Furthermore, customers with food allergies and intolerances report being very unsatisfied with the higher cost of restaurant adapted options (Newson et al., 2015).

Most restaurants do not comply with customers' demand for allergen-free meals since in most cases no suitable menu is available, insufficient information is provided on the menu (van Dam & Wiersma, 2013) and there is insufficient knowledge about the management of food allergies and intolerances among restaurant managers and their staff (Young & Thaivalappil, 2018).

However, even if compliance with EU Regulation No. 1169/2011 regarding the provision of allergen information on menus and increased offerings of allergen-free options may lead to additional costs for restaurants, allergic and intolerant consumers represent an emergent market with promising revenues for restaurants (Kronenberg, 2012).

3.2.3 Increase in consumers' demand for specific food options: vegetarian and vegan meals

Vegetarian diets mostly include plant-based foods, such as fruits, vegetables, legumes, nuts, seeds, and grains, with some vegetarians also consuming eggs and dairy products. However, a vegan diet includes not consuming any products originating from animals such as meat, fish, crustaceans, molluscs, milk, eggs, and honey (Marsh et al., 2012). An international survey stated that 5% of Europeans were vegetarians and that 2% of Spaniards followed a vegetarian diet in 2018 (Van Gelder, 2018). However, vegetarian and vegan consumers face several difficulties when eating out such as the following: a) limited and uncreative meal options, b) knowledge gaps of the restaurant staff about suitable menu items to propose, c) no menu indications of vegetarian options or meals that could be adapted by changing ingredients, and d) the presence of traces or contamination in meals that were supposed to be meat free (Shani & DiPietro, 2007).

Additionally, ethical, ecological and health-related reasons are involved in vegetarian and vegan food selections. For instance, the consumption of more fruits and vegetables in place of meat- and fish-based meals would make an important contribution to the sustainability of food production by reducing the greenhouse gas emissions, responsible for global warming, by 30% (Tilman & Clark, 2014). Furthermore, a plant-based diet has been demonstrated to positively impact people's health by reducing the risk of NCDs, such as hypertension and cardiovascular disorders (Fraser et al., 2015).

Thus, since interest in vegetarianism and veganism continues to increase and such dietary patterns have been shown to be healthy and beneficial in the prevention of certain diseases, the provision of adapted meals in restaurants and food services should be encouraged (American Dietetic Association, 2003). Furthermore, the availability of a menu with vegetarian options has been demonstrated to increase the consumption of vegetarian meals by people who are not used to consuming vegetables (Campbell-Arvai et al., 2014).

3.3 Evidence about the healthiness of restaurants and food service meals

Previous nutritional assessments of restaurants' meals were mainly focused on US chain restaurants (Bleich et al., 2020; Lesser et al., 2017), resulting in little data about European independent restaurants. *Table 2* compiles data about cross-sectional studies on the nutritional assessment of chain and independent restaurants.

Despite this, evidence from other countries such as Finland, Brazil, Ghana, India, and China suggests that meals offered in independent restaurants have very high caloric contents (Roberts et al., 2018).

Even for meals labelled healthy, the sodium and fat contents are higher than the recommended limits because no standard guidelines have been defined for the healthy option label (Auchincloss et al., 2014).

Furthermore, other studies on the meals offered in primary school canteens have been conducted; and the results showed that these lunches failed to meet the dietary guidelines for calories and nutrients as only 12.5% of the evaluated meals were adequate with respect to calories, 33.5% were adequate with respect to proteins, 11.9% were adequate with respect to carbohydrates and 57.1% were adequate with respect to lipids (Liz Martins et al., 2020). Similarly, another cross-sectional study in secondary school canteens showed the supply of poor nutritional quality products by canteens and reported that 52.8% of the analysed schools promoted unhealthy items on their menus, which were also significantly cheaper than healthier ones (Haynes et al., 2020).

Additionally, in workplace canteens, meals included 50% of the daily recommended total fats, saturated fats, and sodium intake, highlighting a similar need for improvement (Jaworowska et al., 2018).

Hence, consumers are demanding that restaurants provide nutritional labels on menus, but there are several barriers restaurateurs face, such as the following: a) the responsibility of food quality assurance and the operational challenges derived from the creation of such labels, b) the maintenance of customer confidence and marketing integrity, c) the cost effectiveness and impacts on profits, d) the lack of nutritional expertise, and e) the possibility of making assessment mistakes (Almanza et al., 1997).

However, updated nutritional assessments of out-of-home meals are required for dietary surveillance and monitoring (Lachat et al., 2012). In this sense, more practical support in the assessment of nutritional food analysis and in the provision of nutrition training to the staff by nutrition professionals to independent restaurants, are fundamental in encouraging food environment improvements and people's health behaviour changes (Thomas, 2016).

Table 2: Cross-sectional studies about the nutritional quality assessment of independent and chain restaurants' menus (from 2010-2020).

Reference	Country	Population	Setting	Aim	Tool	Results
Bernardo GL. et al., 2015.	Brazil.	N=19 restaurants and n=55 meals.	Self-service restaurants.	Assess the healthy dietary diversity of lunches in self-service restaurants.	Healthy Dietary Diversity Index for a Meal (DDI-M).	The 65.3% of the evaluated dishes obtained low diversity score indexes and were considered inadequate. A significant association between healthy diversity scores and low variety of high energy density dishes was observed.
Bleich SN. et al., 2020.	The USA.	N=66 restaurants and n=28,238 food items	Chain restaurants.	Assess the composition of newly-introduced menu items in 2018 and examine differences through 2012-2018.	MenuStat Project database for nutritional data.	Newly introduced menu items in large chain restaurants reduced menu calories content through 2018. Changes in macronutrient contents (saturated fat, trans fat, unsaturated fat, sugar, non-sugar carbohydrates, protein, sodium) were sporadic.
DuBreck CM. et al.; 2019.	Canada and the USA.	N=323 child menus in Canada and n=50 child menus in USA.	Sit-down full-service restaurants.	Assess the nutritional quality of restaurant children menus.	Children's Menu Assessment (CMA) tool.	Scores ranged from -5 to 21 points, with scores ≤0 points indicating poor nutritional quality. Canada: total menu scores ranged from −3 to 9 points; USA: total menu scores ranged from −2 to 13 points.

Table 2 (continued): Cross-sectional studies about the nutritional quality assessment of independent and chain restaurants' menus (from 2010-2020).

Reference	Country	Population	Setting	Aim	Tool	Results
Garemo M. et al., 2018.	The United Arab Emirates.	N=58 restaurants and n=209 meals.	Full-service restaurants.	Assess the nutritional quality of children meals in Abu Dhabi restaurants.	"Kids Live Well Nutritional Criteria" by the National Restaurant US Association.	The 78.9% of the assessed meals did not meet the cut-offs for healthy meals. Fruits and vegetables were included less frequently, being present in 10.6% and 15% of these meals, respectively. The 9% of the meals included desserts which were discretionary calories. Only 4% of beverage options were water.
Lesser LI. et al., 2017.	The USA.	N=200 restaurants and n=3,199 food items.	Chain restaurants.	Evaluate the nutritional quality of chain-restaurant menus through a technology-based method.	Modified Nutrient Profiling Index (MNPI) and registered dieticians analysis.	The 7% of the evaluated food items were categorized as healthy. The healthiest category was that of soups (26% of items labeled as healthy), while desserts represented the least healthy category (2% of items labeled as healthy).
Murphy SA. et al., 2020.	Canada.	N=90 restaurants and n=10,285 menu items.	Chain and fast food restaurants.	Assess the nutritional composition of fast food and sit-down restaurants' menu items.	Menu-FLIP database.	Sit-down restaurants' items had significantly higher levels of calories, saturated fat, and sodium. Entrées contained on average 52% of the total daily value for sodium and 45% of the daily value for saturated fat. Beverages and desserts had high levels of sugars.

Table 2 (continued): Cross-sectional studies about the nutritional quality assessment of independent and chain restaurants' menus (from 2010-2020).

Reference	Country	Population	Setting	Aim	Tool	Results
Roberts SB. et al.; 2018.	Brazil, China, Finland, Ghana, India, and the USA.	N=111 restaurants and n=233 meals.	Full service and fast food restaurants.	Assess the energy contents of the most frequently ordered meals.	Bomb calorimetry method.	The total energy content of fast food meals was significantly lower than meals from full-service restaurants in Brazil (34%), China (46%), and the US (29%). The 94% of meals from full-service restaurants across all sites contained at least 600 kcal, and the 3% contained at least 2000 kcal/serving.
Rüsing L. et al., 2020.	Germany.	N=500 restaurants and n=1,877 meals.	Full-service restaurants.	Evaluate menus and meals offered to children in full-service restaurants.	Children's Menu Assessment tool (CMA).	Meal variety was very limited and over 50% of the offered meals included French fries or fried potatoes. No nutritional information was present. The 81% of meals components was rated as unhealthy and none of the meals used whole grain products.
Urban LE. et al.; 2011.	The USA.	N=42 restaurants and n=269 food items.	Quick-service and sit-down restaurants.	Examine the accuracy of stated energy contents of restaurant foods.	Bomb calorimetry method.	Overall results suggest stated information on food energy content in restaurants is accurate. However, among the entrées stated with low-energy content, some meals contained more energy than the stated; on the other hand, foods with higher stated energy contents, had lower calories than the stated.
Urban LE. et al.; 2013.	The USA.	N=9 restaurants and n=157 restaurant meals.	Independent and small-chain restaurants.	Assess the energy content of the most frequently purchased restaurant meals.	Bomb calorimetry method.	Meals contained a mean of 1,327 kcal, which was twice the amount required for weight maintenance.

3.4 Nutritional assessment tools and symbols to evaluate and identify healthy meals and food environments

Several measurement tools have been developed for the nutritional assessment of meals and the evaluation of the food environment in providing healthy foods and influencing consumers' choices. Known examples are the following:

1. ***The Nutrition Environment Measures Study Restaurant assessment (NEMS-R)*** is an observation instrument designed in the US for restaurants and fast food restaurants to evaluate the relative healthiness of the foods and drinks available on restaurants' menu and children's menus; and it focuses on the availability of, facilitators of and barriers to healthy eating, pricing, and signage (Saelens et al., 2007).

2. ***The Mediterranean diet criteria (AMed)*** of the Spanish Public Health Agency consist of 9 mandatory and 8 optional criteria for restaurants to accomplish, to achieve official certification that guarantees a gastronomic menu offering based on the Mediterranean diet. In particular, the nine mandatory criteria are the following (Agencia de Salud Pública de Cataluña, 2007):

a) olive oil for dressing and olive oil or high oleic sunflower oil for cooking;

b) 25% of the first course offerings are vegetables or legumes;

c) the presence of integral products;

d) 50% of the second course offerings are based on fish, seafood and lean meat;

e) 50% of the dessert offerings are based on fresh fruit;

f) dairy desserts without added sugar;

g) free nonbottled drinking water;

h) the availability of alcohol in individual units; and

i) culinary preparations that do not require the addition of large amounts of fat.

3. ***The Multiple Traffic-Light*** (MTL) labelling system, developed in the UK by the Food Standards Agency (FSA), labels nutrients using three colours according to their high (red), medium (orange) or good (green) content (Food Standards Agency et al., 2016).

4. ***The Nutri-Score*** labelling model, adopted by France in 2017 and by Belgium in 2019, classifies foods according to their nutritional quality and labels them with five possible colours (dark green, light green, yellow, light orange and dark orange) corresponding to a letter (A, B, C, D and E, respectively), where letter A indicates the highest quality and letter E indicates the lowest quality (Julia & Hercberg, 2017).

5. ***The NutrInform Battery***, recently applied in Italy for packaged foods only, displays the percentages of the recommended daily intake of calories, fats, saturated fats, sugars and salt per portion using a battery (Mazzù et al., 2020).

6. ***Healthier choice symbols*** include the “Nordic Keyhole” introduced by the Swedish National Food Agency in 1989, which was the first Front-Of-Pack (FOP) logo system to be implemented in the EU to identify healthier food products (with fewer and healthier fats, less sugar and salt, and more fibre and whole grains) (Swedish National Food Agency, 2013); the "Heart symbol-better choice" introduced in 2000 in Finland and granted by the Finnish Heart and Diabetes Associations to identify nine main healthy food groups (Kinnunen, 2000); and the “Healthy Choice” logo (tick), owned by the Choices International Foundation and used in the Czech Republic, Poland and Germany (Choices International Foundation, 2020).

3.5 Evidence regarding food allergen knowledge and management by restaurants

Among restaurant staff, there is still a knowledge gap in the identification and management of the most common food allergens, as well as a poor attitude towards customers asking for more information (Loerbroks et al., 2019; Sogut et al., 2015; van Dam & Wiersma, 2013).

For instance, in a US survey conducted in independent restaurants and fast food restaurants, 24% of the 100 interviewed restaurant staff personnel reported that consuming a small amount of food allergen or removing an allergen from a finished meal is safe and that fryer heat could eliminate the food allergens present in meals (Ahuja & Sicherer, 2007). Similarly, in another survey in US fast food restaurants, none of the interviewed restaurant employees (n=187) were able to name all seven best practices for food allergen management, designed by the Food Allergy Research & Education (FARE) to prevent food allergy reactions in restaurants; and few participants knew to manage anaphylaxis by administering epinephrine and calling for emergency transport (16.6% of 187 employees) (Dupuis et al., 2016).

The lack of menu information is another important gap (Radke et al., 2016), and the ideal eating out experience for allergic consumers requires the provision of written allergen information together with proactive staff within an allergy-aware environment (Begen et al., 2018).

To date, 21-31% of accidental allergen ingestion occurs in restaurants due to cross-contamination or no information provision (Versluis et al., 2015). In a study on peanut and nut allergic reactions that occurred in restaurants, 22% of 106 reactions were caused by cross-contamination due to shared cooking and serving supplies; and 50% of these incidents were derived from hidden ingredients of sauces, dressings, etc. (Furlong et al., 2001).

Thus, evidence suggests the need for more training, education and increased awareness regarding how to manage food allergens among restaurant staff and managers and the need to provide more information to customers.

In European countries, Regulation (EU) No. 1169/2011 established the obligation for food services to inform consumers about the presence of the 14 most common food allergens causing allergies and intolerances (The European Parliment and the Council of the European Union, 2011).

In Catalonia (Spain), for instance, the Catalan celiac association has also provided eighteen recommendations for restaurants, known as the SMAP criteria, in order to obtain the official SMAP certification for gluten-free food preparation. SMAP recognition is intended to encourage restaurateurs to implement correct practices for allergen-free cooking, avoid gluten cross-contamination, and guarantee safe meals to consumers (Associació Celíacs de Catalunya, 2014).

Moreover, the Spanish federation of coeliac associations (FACE), which includes other associations present in the Spanish territory, in the framework of the "Gluten Free Restaurants Project" helps restaurants apply a standard protocol for the preparation of gluten-free meals and provides training to restaurant staff about allergen management to prevent potential cross-contamination and preserve consumers' safety (Federación de Asociaciones de Celiacos de España (FACE), 2018).

Likewise, the Food and Agriculture Organization of the United Nations (FAO) and the WHO developed the "code of practice on food allergen management for food business operators" as part of the Codex Alimentarius, with internationally recognised food standards and guidelines for food business operators to manage food allergens (World Health Organization and The Food and Agriculture Organization, 2020). Nevertheless, education programmes for food service staff must be promoted and implemented in every type of food establishment for the safety of allergic and intolerant consumers and to improve restaurant management of food allergens (National Academies of Science Engineering and Medicine; Health and Medicine Division; Food and Nutrition Board, 2016).

3.6 Effective strategies applied in restaurant-based interventions to promote healthier meals

Although different restaurant- and food service-based interventions were designed to evaluate the change in consumers' selections following the implementation of restaurants' marketing and choice architecture actions, strong evidence regarding the most effective strategies is still scarce (Valdivia Espino et al., 2015).

However, there are some strategies that have been identified to be effective:

1. Menu labelling, including food information with the list of ingredients, was demonstrated to positively influence consumers' healthy food choices at the point of selection (Oliveira et al., 2018); and the inclusion of healthy symbols or logos on the menu could encourage the purchase of healthier options while symbolising the benefits coming from more nutritious meals (Sharma et al., 2011).

2. Reduced portion sizes of meals were shown to be preferred by consumers when available in both restaurants and cafeterias to reduce the excessive caloric intake and plate waste (Berkowitz et al., 2016).

3. Point-of-purchase messages, including table tents, posters and advertisements, have shown moderate effectiveness in improving restaurant food choices by increasing customers' awareness of the availability of healthier menu items (Fitzgerald et al., 2004).

4. Promotional marketing activities, such as community events and media advertising, were effective in the "TrEAT Yourself Well" Randomized Controlled Trial (RCT) study aimed to promote healthier menu items in US chain restaurants. This communication campaign increased the probability of customers purchasing healthier menu items by 3.7% by influencing consumers' beliefs and attitudes towards healthier nutrition (Acharya et al., 2006).

5. The provision of nutritional information on a restaurant menu, increased availability of healthier food options, and training the restaurant staff on healthy nutritional concepts based on the Mediterranean diet model were demonstrated to improve restaurants' healthy offerings and increase customers' satisfaction (Tarro et al., 2017).

However, since the majority of the existing interventions were mainly focused on fast food restaurants or restaurant chains, there is limited evidence on the effective strategies applied in independent restaurants (Lindberg et al., 2018), especially in the European context. Moreover, existing evidence reports different findings or limited effectiveness and weak study designs (Valdivia Espino et al., 2015).

Thus, further research is needed to design the best restaurant-based intervention studies for the promotion of healthy eating habits, such as the Healthy Meals RCT, by considering restaurant barriers and factors influencing consumers' out-of-home food choices (D'Addezio et al., 2014).

CHAPTER 4: THE "HEALTHY MEALS" RESTAURANT-BASED INTERVENTION STUDY

4.1 Intervention design and implementation of the Healthy Meals RCT as part of the "PECT-TurisTIC en familia" European project

To meet the request for more restaurant setting health promotion interventions, the Healthy Meals RCT was designed as part of a European funded project named PECT-TurisTIC en Familia, aimed to improve familiar tourism in the province of Tarragona (Catalonia, Spain). The main objective was the promotion of healthier menu offerings addressed to each member of a family and better restaurant management of food allergens.

The Healthy Meals study has been implemented for two years, but due to the SARS-CoV-2 pandemic, intervention and data collection have been delayed.

The Healthy Meals design was a randomized, parallel, and controlled study. Restaurants were randomized into intervention and control groups for the final evaluation of the intervention effectiveness. The protocol was approved by the Ethics Committee of the Institut d'Investigació Sanitaria Pere Virgili (ref CEIM: 179/2018), and the trial was registered at the international registry of clinical trials (ClinicalTrials.gov) with the project identification code NCT03826576.

The participants in the Healthy Meals study consisted of full-service restaurants located in the province of Tarragona (Catalonia, Spain) fulfilling specific inclusion criteria: a) willing to sign an informed consent form; b) full-service restaurants; c) possessing a minimum of 5 tables for service; d) offering Mediterranean and traditional cuisine dishes; e) possessing dishes' recipes, with ingredients and cooking details; and f) available to share food product information for the study research.

Restaurant exclusion criteria were the following: a) being an ethnic restaurant, a fast food restaurant or a restaurant with a unique meal offering such as pizza, sushi, etc.; and b) lack of one of the abovementioned inclusion criteria.

The multicomponent intervention design was defined according to evidence-based effective strategies and demanded innovative technologies and considering the needs of the modern restaurant community. The multicomponent intervention consisted of five main actions (*Figure 6*):

1. ***Analysis of the restaurant menu***, including the assessment of the fulfilled AMed and SMAP criteria for Mediterranean diet adherence and allergen management, respectively. Moreover, meals' nutritional content and identification of food allergens is conducted through a web app designed for the study. The app is able to calculate the nutrient content per meal serving in the form of a traffic light label according to the cut-offs of the UK Food Standards Agency (Food Standards Agency et al., 2016).

2. ***Provision of appropriate training to the restaurant staff*** (cookers and waiters) regarding Mediterranean diet as a model of healthy nutritional patterns and food allergen management, provided to the intervention group only through digital and streaming course sessions.

3. ***Improvement of the restaurant offerings*** according to the AMed criteria designed by the Spanish Public Health Agency (Agencia de Salud Pública de Cataluña, 2007) and according to the SMAP criteria proposed by the Catalan Celiac Association (Associació Celíacs de Catalunya, 2014) through tailored paper-based reports provided to the intervention group after attending the planned training.

4. ***Communication of results*** to disseminate the importance of healthy nutrition and allergen prevention when eating out.

The expected primary outcomes were the following:

a) Increase in the number of AMed criteria for Mediterranean diet adherence and SMAP criteria for gluten management to be fulfilled by restaurants;

b) Increase in the number of dishes with green ratings in the traffic light analysis as an indication of better nutritional quality;

c) Increase in menu offerings adapted for allergic and intolerant customers, as well as for vegetarians and vegans; and

d) Changes in the nutritional content of the meals offered, including reductions in salt, saturated fat and sugar and an increase in the fibre content.

Furthermore, expected secondary outcomes included the increase in the knowledge of the restaurant staff regarding healthy nutrition and food allergen management.

Findings of the Healthy Meals RCT will provide more evidence regarding effective strategies to promote healthy nutrition and food allergen management in restaurant community settings through the use of modern innovative technologies such as eHealth and mHealth apps.

Figure 6: Multicomponent study design of the Healthy Meals RCT.

1. ANALYSIS OF THE RESTAURANT MENU

- Assessment of the fulfilled compulsory AMed criteria,
- Assessment of the fulfilled SMAP criteria for gluten management, and
- Assessment of the nutritional contents of restaurants' offered dishes through the Healthy Meals web-based application.

2. PROVISION OF APPROPRIATE TRAINING TO RESTAURANT STAFF

- Training courses on healthy nutrition and the Mediterranean dietary pattern, and
- Training courses on food allergens and their management in kitchens and dining rooms.

3. IMPROVEMENT OF THE RESTAURANT OFFERINGS

- Proposed improvements to the dishes offered by restaurants through a nutritional report, with the aim of implementing Mediterranean offerings on the menu according to the AMed criteria,
- Proposed improvements to food allergen management by restaurants through a tailored report, with the aim of increasing the number of fulfilled SMAP criteria, and
- Identification of the food allergens contained in the restaurants' dishes through the Healthy Meals web-based application, as well as of the suitable dishes for vegetarian and vegan customers.

4. COMMUNICATION OF RESULTS

- Promotion of the Mediterranean and healthy diet when eating out of home,
- Promotion of food safety recommendations for allergic and intolerant people, and
- Design and development of a report with tailored recommendations and suggestions for restaurants.

Source: designed by the author.

HYPOTHESIS AND OBJECTIVES

HYPOTHESIS

The use of innovative strategies and the inclusion of digital technologies such as mobile and web apps in restaurant-based interventions could offer new opportunities to improve restaurant meal offerings and food allergen management.

OBJECTIVES

This thesis aims to provide evidence about the potential innovative strategies and technologies to be used in restaurant-based interventions to increase healthy meal offerings and food choices and improve restaurant food allergen management. In particular, the individual objectives are:

Objective 1: To assess the Mediterranean diet adherence, healthiness, nutritional quality, and food allergen management of meals at restaurants in Tarragona Province (Catalonia, Spain) using a cross-sectional study.

Objective 2: To elucidate the effectiveness of independent full-service restaurant- and canteen-based interventions targeting children, adolescents and adults in increasing the availability, purchase and intake of healthy meals using a systematic review and meta-analysis.

Objective 3: To assess the potential of self-monitoring mobile phone health (mHealth) apps to increase fruit and vegetable intake using a systematized review.

Objective 4: To assess the food allergy or intolerance apps in app stores. The multidimensional Mobile App Rating Scale (MARS) was used to rate these apps' objective and subjective quality and to identify critical points for future improvements using a systematic search and quality assessment.

Objective 5: To describe the development of the Healthy Meals web app and evaluate its usability, quality, and validity according to a panel of restaurateurs and nutritionists.

METHODS AND RESULTS

METHODS AND RESULTS

In these sections, the five studies conducted in the present thesis are presented:

Study 1: Mandracchia, F., Llauradó, E., Valls, R. M., Tarro, L., & Solà, R. (2021). Evaluating Mediterranean Diet-Adherent, Healthy and Allergen-Free Meals Offered in Tarragona Province Restaurants (Catalonia, Spain): A Cross-Sectional Study. *Nutrients*, *13*(7), 2464, Multidisciplinary Digital Publishing Institute, 2021. https://doi.org/https://doi.org/10.3390/nu13072464.

Study 2: Mandracchia, F., Tarro, L., Llauradó, E., Valls, R. M., & Solà, R. (2021). Interventions to promote healthy meals in full-service restaurants and canteens: A systematic review and meta-analysis. *Nutrients*, *13*(4), 1350, Multidisciplinary Digital Publishing Institute, 2021. https://doi.org/10.3390/nu13041350.

Study 3: Mandracchia, F., Llauradó, E., Tarro, L., Del Bas, J. M., Valls, R. M., Pedret, A., Radeva, P., Arola, L., Solà, R., & Boqué, N. (2019). Potential use of mobile phone applications for self-monitoring and increasing daily fruit and vegetable consumption: A systematized review. *Nutrients*, *11*(3), 686, Multidisciplinary Digital Publishing Institute, 2019. https://doi.org/10.3390/nu11030686.

Study 4: Mandracchia, F., Llauradó, E., Tarro, L., Valls, R. M., & Solà, R. (2020). Mobile phone apps for food allergies or intolerances in app stores: Systematic search and quality assessment using the mobile app rating scale (MARS). *JMIR MHealth and UHealth*, *8*(9), e18339, JMIR Publications, 2020. https://doi.org/10.2196/18339.

Study 5: Mandracchia, F., Tarro, L., Llauradó, E., Valls, R. M., & Solà, R. The "Healthy Meals" web app for the assessment of nutritional content and food allergens in restaurant meals: Development, evaluation and validation. (Editor submitted).

STUDY 1:

Evaluating Mediterranean Diet-Adherent, Healthy and Allergen-Free Meals Offered in Tarragona Province Restaurants (Catalonia, Spain): A Cross-Sectional Study.

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Article

Evaluating Mediterranean Diet-Adherent, Healthy and Allergen-Free Meals Offered in Tarragona Province Restaurants (Catalonia, Spain): A Cross-Sectional Study

Floriana Mandracchia [1,†], Elisabet Llauradó [1,†], Rosa Maria Valls [1], Lucia Tarro [1,2,*] and Rosa Solà [1,2,3]

1 Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Healthy Environment Chair, Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili, 43201 Reus, Spain; floriana.mandracchia1@urv.cat (F.M.); elisabet.llaurado@urv.cat (E.L.); rosamaria.valls@urv.cat (R.M.V.); rosa.sola@urv.cat (R.S.)
2 Institut d'Investigació Sanitària Pere Virgili (IISPV), 43204 Reus, Spain
3 Hospital Universitari Sant Joan de Reus, 43204 Reus, Spain
* Correspondence: lucia.tarro@urv.cat; Tel.: +34-977-758-920
† These authors contributed equally to this work.

Abstract: Restaurant meal consumption has increased substantially, but the ability of restaurants to adhere to guidelines for the Mediterranean diet, healthiness and food allergen management is a challenge. This cross-sectional study aims to assess the Mediterranean diet adherence, healthiness, nutritional quality and food allergen management of meals at restaurants in the Tarragona province (Catalonia, Spain). Primary outcomes included adherence to criteria for the Mediterranean diet (AMed) and gluten management (SMAP), nutritional quality of dishes indicated by a green traffic light rating, meal nutrient content and allergen-free options. Secondary outcomes included restaurant staff knowledge about the Mediterranean diet and food allergens. Forty-four restaurants and 297 dishes were analysed. The restaurants fulfilled an average (mean ± SD) of 5.1 ± 1.6 of 9 compulsory AMed criteria and 12.9 ± 2.8 of 18 SMAP criteria. Dishes were mainly rated green for sugar (n = 178/297; 59.9%) but not for energy (n = 23/297; 7.7%) or total fat (n = 18/297; 6.1%). Waiters and cooks received passing scores for food allergen knowledge (5.8 ± 1.7 and 5.5 ± 1.5 out of 10 points, respectively). Restaurants partially met the AMed and SMAP criteria. Increasing fibre and decreasing saturated fat content are necessary to improve consumers' adherence to healthy diets. For restaurant staff, training courses should be considered to improve their food allergen management.

Keywords: restaurants; healthy menu choices; food allergy; Mediterranean diet; cross-sectional

Citation: Mandracchia, F.; Llauradó, E.; Valls, R.M.; Tarro, L.; Solà, R. Evaluating Mediterranean Diet-Adherent, Healthy and Allergen-Free Meals Offered in Tarragona Province Restaurants (Catalonia, Spain): A Cross-Sectional Study. *Nutrients* **2021**, *13*, 2464. https://doi.org/10.3390/nu13072464

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1. Introduction

The consumption of daily meals outside of the home, both in sit-down restaurants and as take-away foods, has increased in recent years among adults and children [1]. Lack of time and work commitments have been reported as the major reasons for the consumption of daily meals in restaurants and cafeterias. For example, in the region of Catalonia (Spain), out-of-home consumption occurs on average 3.5 times a week [2]. Additionally, according to a recent study of eleven European countries, eating frequently at restaurants was associated with a higher intake of energy, fat and alcohol [3], as well as with a lower consumption of fruits and vegetables, increasing the risk of weight gain, overweight and obesity [4].

The food environment is directly associated with the nutritional quality of the foods offered, so consumers' diets differ according to the eating location; for instance, out-of-home meals consumed in the workplace setting are nutritionally healthier and more similar to home-cooked meals than restaurant and fast-food meals, as more high energy-density foods are available at these locations [5]. In recent years, in Mediterranean countries, the frequency of restaurant meal consumption has been correlated with an obesity epidemic [6].

Furthermore, it has also been observed that restaurants' food choices are influenced by socioeconomic and demographic factors, such as financial status and population age, that impact the nutritional quality of the menu choice [7]. For instance, food poor in nutrients and high in energy is associated with lower cost and higher affordability by low-income populations and youth [8]. However, offering healthier meals [9] and reducing the price of healthier options [10] could influence consumers' food choices, leading to an increase in the purchase and consumption of out-of-home healthier items. Similarly, the provision of nutritional information on restaurant menus has been shown to be positively related to the purchase of lower-fat and healthier meals by consumers, who are willing to spend more on healthier products if nutrient labelling is provided, and the healthier choice is more visible to them [11]. On the other hand, one of the main concerns for restaurateurs in the implementation of healthier meals and nutrient information is the loss of profit that could result from it; thus, changes in community nutritional policies and norms could support restaurants through the provision of more incentives [12] for the improvement of menus offering to include meals with better nutritional quality [7]. However, the value that restaurateurs place on community health is the most important driver to encourage healthy improvements since the lack of interest by restaurants has been found to be a major barrier in the effectiveness of interventions to promote healthy eating [13].

Additionally, eating outside of the home also represents a difficulty for people suffering from food allergies and intolerances, with 21–31% of accidental allergen ingestion occurring in restaurants [14] due to the lack of adequate training of staff on the proper prevention and management of food allergens by employees [15]. Although European Union (EU) regulation No. 1169/2011 requires food businesses to declare the presence of any of the 14 specified food allergens (peanuts, tree nuts, milk, soya, mustard, lupin, eggs, fish, molluscs, crustaceans, cereals containing gluten, sesame, celery and sulphites) in the offered foods [16], allergic consumers would like to be able to count on qualified staff and on a safer food environment [17].

Previous cross-sectional studies have assessed the energy and nutrient contents of purchased [18] and served [19,20] restaurant meals, as well as the degree of knowledge of restaurant staff about food allergen management [21–23] in different countries, such as Germany, the USA, the UK, Turkey and Canada, but there is still a lack of data about the nutritional quality of Spanish restaurants. However, several studies have demonstrated the high quality of Spanish olive oil in terms of its psychochemical and sensory components [24] and its benefits for human health in reducing the risk of developing chronic diseases [25,26] and that it is the most important food element for the Mediterranean diet [27].

In this context, restaurant-based cross-sectional analysis represents the first step of assessing the characteristics and nutritional quality of the meals offered in local full-service restaurants. The obtained information will provide a basis to design an intervention aimed at increasing restaurant offerings of healthier meals, as well as of allergen-free food options adapted for people with food allergies and intolerances.

Thus, the aim of this cross-sectional analysis was to assess the healthiness and nutritional quality of meals offered and their adherence to the Mediterranean diet as well as food allergen-adapted meals and their management at restaurants of the Tarragona province (Catalonia, Spain).

2. Materials and Methods

2.1. Study Design

The present cross-sectional study is about the nutritional quality of menus offered in restaurants and the availability of allergen-free dishes of Tarragona province restaurants. It includes the baseline data of the Healthy Meals Randomized Controlled Trial (RCT), which is a multicomponent intervention applied to restaurants and their staff, including training, menu nutritional quality analysis and identification of food allergens, to promote healthier meals for each member of a family and improved management of food allergens, and to satisfy customers with specific needs (food allergies and intolerances). It was carried out from

September 2019 to March 2021, before and during the SARS-CoV-2 pandemic. This study is part of a European funded project called PECT-TurisTIC en Familia, through which the University Rovira i Virgili (Tarragona, Spain) has led the "Healthy Meals" operation, one of the twelve operations included in the project. The study was conducted in accordance with the Declaration of Helsinki [28], and the protocol was approved by the Ethics Committee of the Institut d'Investigació Sanitaria Pere Virgili (ref CEIM: 179/2018). The trial was registered in 2019 at the international registry of clinical trials (ClinicalTrials.gov) [29] with the project identification code NCT03826576. All restaurant owners gave their informed consent for inclusion before they participated in the study. Moreover, to ensure the study quality, the present study followed the STrengthening the Reporting of OBservational studies in Epidemiology (STROBE) criteria [30] for observational cross-sectional studies (Table S1).

2.2. *Study Population and Setting*

The study population consisted of full-service restaurants offering traditional and Mediterranean cuisine that were recruited from the province of Tarragona (Spain). Restaurants were searched, considering the population density of the different counties of the Tarragona province [31], through the tourism offices of each participating town and online restaurant databases, such as TripAdvisor [32]. The study researchers visited the restaurants and explained the study to the owner/responsible party of each restaurant to obtain informed consent. Then, the researchers verified whether the restaurants met the inclusion criteria: (1) being a full-service restaurant; (2) having a minimum of 5 serviced tables; (3) offering Mediterranean/traditional/local cuisine; (4) having technical details of the recipe for each dish, including ingredients and cooking details; (5) being willing to share food product information with the research team; and (6) the owner signing an informed consent form for participation in the study. On the other hand, restaurants were excluded if they (1) were ethnic or fast-food restaurants; (2) had fewer than 5 serviced tables; or (3) had not yet received the Mediterranean diet (AMed) certification.

Furthermore, restaurant owners had to (1) have a minimum of one year of experience and (2) be available to continue working during the one-year intervention. Not fulfilling any of the above inclusion criteria led to exclusion from the study.

2.3. *Outcomes and Data Collection*

The primary outcomes included the following:

(1) number of compulsory AMed criteria, which must be fulfilled by restaurants to obtain a certification that the restaurant offers a Mediterranean diet (described below), as determined through face-to-face interviews with the restaurant owner;
(2) number of SMAP criteria fulfilled by restaurants, as assessed through face-to-face interviews with the restaurant owner to determine the potential for obtaining the corresponding certification;
(3) number of dishes per restaurant with a green rating in the traffic light rating system on the Healthy Meals app for the evaluated nutrients (energy, carbohydrates, sugar, fat, saturated fat, protein, sodium and fibre), which indicates good nutritional quality, according to the analysis of the recipes of the dishes, including the ingredients, weights and cooking details;
(4) nutrient content of the restaurants' meals (kcal of energy; grams of carbohydrates, sugar, fat, saturated fat, protein and fibre; micrograms of sodium), assessed by the Healthy Meals web-based app, which was designed and developed by researchers according to the framework of the PECT-TurisTIC en Familia project;
(5) allergen content assessment, identified through the Healthy Meals web-based app;
(6) adequacy of vegetarian and vegan dishes, also evaluated through the Healthy Meals app.

As a secondary outcome, restaurant staff knowledge about the Mediterranean diet and food allergens was evaluated through paper-based questionnaires.

The primary outcomes were assessed as follows:

2.3.1. AMed Criteria

The AMed criteria were designed by the Spanish Public Health Agency as the basis for an official certification that can be provided to restaurants and the establishment of a food service that guarantees the offering of a menu based on the Mediterranean diet [33]. The criteria are divided into nine mandatory and eight optional criteria (available at www.amed.cat, accessed on 20 January 2019) [33]. All 17 criteria were evaluated, but for the purpose of achieving the primary outcome, only the nine mandatory criteria were considered: (1) olive oil is used in dressings, and olive oil or high oleic sunflower are used for cooking; (2) 25% of the first course offerings are vegetables and/or legumes; (3) whole-grain products are included; (4) 50% of the second course offerings are based on fish, seafood or lean meat; (5) 50% of the dessert offerings are based on fresh fruit (whole or prepared); (6) dairy desserts without added sugar are offered; (7) free nonpackaged drinking water is offered; (8) wine, beer and cava are measured in glasses or individual units; (9) culinary preparations that do not require the addition of large amounts of fat, and culinary techniques that use little or no fat are used.

2.3.2. Gluten Management (SMAP) Criteria

The SMAP criteria were developed by the Catalan Celiac Association [34] as the basis for obtaining the official SMAP certification for gluten-free food preparation. This recognition is intended to encourage restaurateurs to implement correct practices for allergen-free cooking and to avoid cross-contamination. The SMAP criteria include 18 recommendations that were evaluated in this study for assessing one of the primary outcomes [34].

2.3.3. Nutritional Content Assessment of Restaurant-Offered Dishes

Dishes offered by the included restaurants were classified as starters, main dishes and desserts.

The nutritional quality of each meal was analysed through the Healthy Meals app using the recipes for each dish, including the ingredients used, their quantities and the cooking process. Home-spun ingredient measurements were converted to the equivalent quantity in grams. A food composition database for the extraction of the necessary nutritional data was generated from the nutritional information of commercial food products and data from different public databases [35–39]. The food ingredient database was used for the development of the Healthy Meals web-based app, which was used for the nutritional assessment of the restaurants' dishes. The information obtained for each dish included the energy (Kcal), protein (g), total carbohydrates (g), sugar (g), total fat (g), saturated fat (g), fibre (g) and sodium (mg).

From the nutritional information calculated, a traffic light rating system for a single-plate portion was created; the system classified the content of each nutrient according to three colours, namely red (high), orange (medium) or green (good), in agreement with the cut-offs of the UK Food Standards Agency [40]. Based on a single-plate portion, nutrients were classified as (a) green when the dish contained <7.5% of the European Guideline Daily Amount (GDA); (b) orange when the dish contained between 7.5–20% of the GDA; (c) red when the dish contained >20% of the GDA recommended daily nutrient amounts for a healthy adult diet of 2000 Kcal [41]. However, the fibre content was classified inversely so that a red label corresponded to a low fibre content according to the recommendations.

Single dishes from the included restaurants were then evaluated through the traffic light system, and a number of healthy meals were identified as green-light dishes.

2.3.4. Allergen Assessment

For each of the 297 dishes, the following 14 most common food allergens that should be declared according to European Regulation 1169/2011 [16] were identified taking into account the ingredients used and the cooking process: (1) cereals containing gluten, (2) milk, (3) eggs, (4) fish, (5) crustaceans, (6) tree nuts, (7) peanuts, (8) soya, (9) celery, (10) mustard, (11) sesame, (12) sulphites, (13) lupin and (14) molluscs.

2.3.5. Adequacy for Vegetarian and Vegan Diet

According to the ingredients used, vegetarian- and vegan-adapted meals were identified. In particular, plant-based meals not containing animal products were labelled vegetarian, while meals not containing animal products or their derivates were marked vegan [42].

2.3.6. Restaurant Staff Knowledge about the Mediterranean Diet and Food Allergens

Restaurant staff were divided into cooks and waiters, and their knowledge was evaluated according to two topics: Mediterranean diet and food allergens. The questionnaires used were adapted from AMed to evaluate Mediterranean diet knowledge [33] and from those designed by McAdams B. et al. to evaluate food allergy knowledge; however, these questionnaires have not been validated [43]. The information collected about the waiters' knowledge on the Mediterranean diet included the identification of foods adhering to the Mediterranean diet (10 items), and regarding food allergens, the waiters had to identify the following: (1) the presence of food allergens in common traditional meals (14 items), (2) the critical points of food allergen management (13 items), and (3) food allergy and intolerance reactions (20 items). The information collected about the knowledge of kitchen staff about the Mediterranean diet included their identification of (1) foods adhering to the Mediterranean diet (10 items), (2) healthy food (8 items), and (3) the AMed criteria (8 items). On the other hand, regarding food allergens, the kitchen staff had to identify (1) food allergens in common traditional meals (14 items) and (2) critical points of food allergen management (11 items).

Staff knowledge was evaluated on a 10-point scale for the two evaluated themes (Mediterranean diet and food allergens) and for a total knowledge score.

2.4. Additional Data

The following information about the included restaurants' general characteristics and offered meals were collected: (1) type of restaurant; (2) capacity; (3) location; (4) years in operation; (5) frequency of menu changes over a year; (6) restaurant administration (owner and his/her family, owner and recruited staff, or a recruited manager); (7) type of cuisine; (8) menu labelling; (9) availability of child/daily/weekend menu; (10) number of employees; (11) quality of the foods by purchases cooks and owners (fish, meat, fruit, vegetable, eggs, oil) according to the store and the type of products purchased; (12) type and management of the training provided to employees; (13) weaknesses, points to be improved and differences from other restaurants; (14) availability of healthy meals on the menu according to the owner; (15) staff knowledge about the restaurant's menu offerings; (16) methods to avoid cross-contamination. Moreover, the following information about the restaurant's owner and employees (waiters and cooks) was collected: (1) years of experience of the owner and (2) gender, education and age of the employees.

2.5. Statistical Analysis

Data are presented as the mean ± standard deviation (SD) for continuous variables and as percentages for categorical variables. Student's t-tests for continuous variables were used to calculate the cooks' and waiters' knowledge. Moreover, the chi^2 test was used for categorical variables to calculate the difference in green- vs. red-light dishes, among starters, main dishes and desserts. Bonferroni tests were conducted for differences among restaurant employees (owners, cooks and waiters) with their education degree and gender, and type of dishes (starters, main dishes and desserts) with gluten-free and allergen-free options.

The Pearson (r) correlation coefficient for variables with normal distribution and the Spearman (ϱ) correlation coefficient for not normally distributed variables [44] were used to analyse the correlations between staff knowledge and restaurant compliance with the AMed and SMAP criteria and between the presence of green-light nutrients according to the traffic light system and AMed criteria. Statistical analysis was performed using SPSS software (version 26), and the significance level was fixed at $p \leq 0.05$.

3. Results

A total of 61 restaurants were recruited for the present cross-sectional analysis; however, 17 restaurants were excluded before the collection of the baseline data because of problems encountered due to the COVID-19 pandemic (n = 3), restaurant internal problems (n = 6), loss of interest or time to participate (n = 4), and nonresponse (n = 4) (Figure 1). As a result, 44 restaurants were analysed, as shown in Figure 1, and 297 dishes were analysed from 32 restaurants. A total of 47 questionnaires on staff Mediterranean diet and food allergen knowledge were collected from waiters, and 53 were collected from cooks.

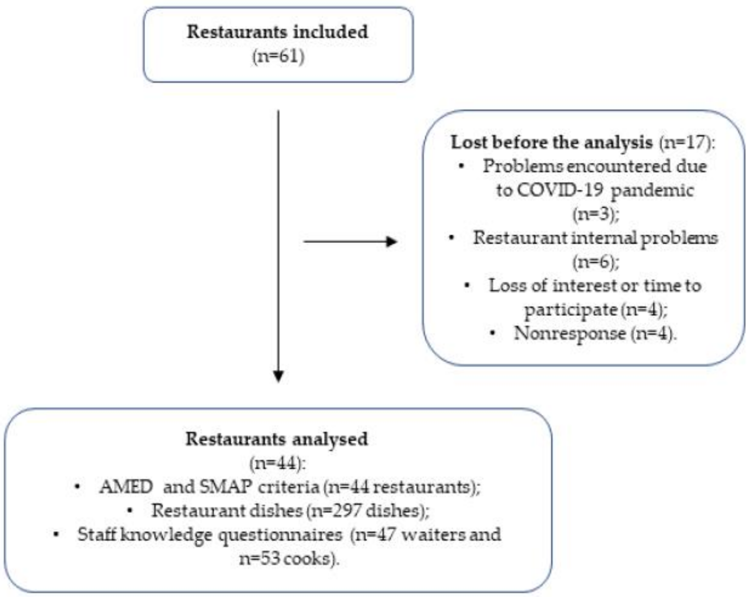

Figure 1. Study flow diagram according to the STROBE statement.

3.1. General Characteristics of the Included Restaurants

Of the 44 included restaurants, the majority were urban (68.2%; n = 30) and coastal (18.2%; n = 8), offering dishes from both menus and daily specials (54.5%; n = 24). Restaurants had a medium average size of 134.1 ± 86.8 m^2 with 17.7 ± 10.8 tables available to receive 61.7 ± 38.7 customers (Table 1). Twenty-two of the included restaurants were located in Tarragonès County which has the highest population density, including the cities of Tarragona, Salou and Torredembarra (50.0%); 17 were located in Baix Camp, which is the second most populated county [31], including the cities of Reus, Cambrils, Prades and Vinyols (38.6%); the others were located in different counties of the Tarragona Province with the least population density (Table 1). The restaurants had been open for 13.2 ± 18.9 years, offering the same menus throughout the entire year (25.0%; n = 11) or changing their offered dishes two or more times a year (68.1%; n = 30). Half of the included restaurants were run by the owner and his/her family (50.0%; $n = 22$) or by the owner with recruited staff (38.6%; $n = 17$), with an average of 5.4 ± 4.2 employees (Table 1).

Table 1. General characteristics of the included restaurants.

	N = 44% **(*n*)**
Restaurant type:	
Rural	13.6 (6)
Urban	68.2 (30)
Coastal	18.2 (8)
Restaurant offer:	
Daily menu	22.7 (10)
Menu	22.7 (10)
Daily menu + menu	54.5 (24)
Location:	
Tarragonès	50.0 (22)
Baix Camp	38.6 (17)
Montsià	7.0 (3)
Baix Penedès	2.3 (1)
Conca de Barberà	2.3 (1)
Time of restaurant activity in years [2]:	13.2 ± 18.9
Frequency of menu changes:	
Twice a year (winter/summer)	22.7 (10)
More than twice a year	22.7 (10)
It is the same throughout the year	25.0 (11)
Other	22.7 (10)
Not answered	6.8 (3)
Administration of the restaurant:	
The owner with his/her family	50.0 (22)
The owner with recruited staff	38.6 (17)
Recruited manager	4.5 (2)
The owner with his family and the recruited staff	4.5 (2)
Not answered	2.3 (1)
Number of recruited employees [2]:	5.4 ± 4.2
Type of cuisine [1]:	
Traditional	54.5 (24)
Spanish	36.4 (16)
Catalan	43.2 (19)
Mediterranean	72.7 (32)
Author	18.2 (8)
Italian	13.6 (6)
Fusion	15.9 (7)
Tapas	31.8 (14)
Other	11.4 (5)
Presence on the menu of [1]:	
Nutritional information	0.0 (0)
Traffic light labels	0.0 (0)
GDAs	0.0 (0)
Healthier choice indicators	0.0 (0)
Colours	6.8 (3)
Other (allergens, vegan/vegetarian/celiac options, typical cuisine meals, prepared with local products)	29.5 (13)

Table 1. *Cont.*

	N = 44% (*n*)
Availability of a children's menu:	
Yes	29.5 (13)
No	70.5 (31)
Availability of daily menu:	
Yes	77.3 (34)
No	22.7 (10)
Availability of a weekend menu:	
Yes	56.8 (25)
No	43.2 (19)

[1]: Total percentage of respondents is higher than 100% due to the multiple-option responses given by the restaurateurs and cooks; [2]: data are expressed in Mean ± SD.

The included restaurants reported offerings of Mediterranean cuisine (72.7%; $n = 32$), traditional cuisine (54.5%; $n = 24$), Catalan cuisine (43.2%; $n = 19$) and Spanish cuisine (36.4%; $n = 16$). In particular, 79.5% ($n = 35$ of 42 respondents) considered their menus to offer healthy meal options. None of the restaurants presented nutritional information, such as the traffic light labels, GDAs or healthier choice indicators, on the menu, while 29.5% ($n = 13$) identified the presence of allergens or gluten-free options, vegan/vegetarian options or traditional dishes prepared using local food. Only 29.5% ($n = 13$) offered children's menus; on the other hand, 77.3% ($n = 34$) had a daily menu, and 56.8% ($n = 25$) had weekend menu offerings (Table 1). The majority of the included restaurants recognized that there were points that could be improved regarding the availability of allergen-adapted options (38.6%; $n = 17$ of 20 respondents) and menu offerings (29.6%; $n = 13$ of 17 respondents), and most did not see the lack of allergen-free options as a point of weakness or an area of competition with other restaurants (81.8%; $n = 36$ of 41 respondents). Meanwhile, the quality of restaurant service (72.7%; $n = 32$ of 41 respondents) and the quality of gastronomic offerings (63.6%; $n = 28$ of 41 respondents) were meant to be competitive differences with respect to other restaurants.

A significant positive correlation was observed between restaurateurs who considered their menu to be based on healthy offerings and the total AMed number of criteria fulfilled ($\varrho = 0.32$; p-value = 0.04) [44]. Although the association was weak, when the restaurateur's perception of the healthiness of the menu was positive, the number of AMed criteria fulfilled was higher.

3.2. General Characteristics of the Included Restaurant Owners and Their Employees

As shown in Table 2, the restaurant owners had an average of 18.0 ± 10.6 years of experience in the catering sector. Most of the restaurant owners were men (59.1%; $n = 26$), had primary (25.0%; $n = 11$) or secondary (52.3%; $n = 23$) education and were 44.0 ± 8.6 years old. Similarly, employees such as cooks and waiters were mainly men (67.9%, $n = 36$, and 53.2%, $n = 25$, respectively), had secondary education (60.4%, $n = 32$, and 59.6%, $n = 28$, respectively) and were 40.0 ± 11.4 and 38.3 ±12.1 years old, respectively. However, differences in gender and education among owners, cooks and waiters were not statistically significant ($p > 0.05$) (Table 2).

Table 2. General characteristics of the included restaurant owners and employees.

	Total [1] (N = 144) % (n)	Owners [2] (N = 44) % (n)	Cooks [2] (N = 53) % (n)	Waiters [2] (N = 47) % (n)
Gender:				
Men	60.4 (87)	59.1 (26)	67.9 (36)	53.2 (25)
Women	28.5 (41)	18.2 (8)	28.3 (15)	38.3 (18)
Not answered	11.1 (16)	22.7 (10)	3.8 (2)	8.5 (4)
Education degree:				
Uneducated	1.4 (2)	0.0 (0)	1.9 (1)	2.1 (1)
First grade studies	21.5 (31)	25.0 (11)	18.9 (10)	21.3 (10)
Second grade studies	57.6 (83)	52.3 (23)	60.4 (32)	59.6 (28)
Third grade studies	16.7 (24)	18.2 (8)	18.9 (10)	12.8 (6)
Not answered	2.8 (4)	4.5 (2)	0.0 (0)	4.3 (2)
Experience of the restaurant owners in the catering sector [3]:				
Years		18.0 ± 10.6		

[1]: Total population is referred to the sum of restaurant owners (n = 44), cooks and kitchen staff (n = 53) and waiters (n = 47); [2]: Bonferroni tests were conducted for differences among restaurant owners, cooks and waiters (significance: $p < 0.05$); [3]: Data are expressed in Mean ± SD.

3.3. AMed Criteria

As shown in Table 3, the 44 included restaurants had fulfilled an average (mean ± SD) of 5.1 ± 1.6 out of 9 AMed compulsory criteria. In particular, 93.2% (n = 41) had culinary preparations that did not require the addition of large amounts of fats, and 75.0% (n = 33) used olive oil in dressings and olive oil or high oleic sunflower oil for cooking. However, only 34.1% (n = 15) of the restaurants offered whole-grain products, and only 2.3% (n = 1) of the restaurants had 50% of dessert offerings based on fresh fruits.

Regarding the AMed optional criteria, the included restaurants fulfilled an average of 6.5 ± 0.9 out of 8 AMed criteria (Table 3). In particular, (a) all the restaurants (n = 44) prioritized fresh seasonal and local foods, (b) 95.5% (n = 42) offered traditional and local cuisine on their menus and (c) 93.2% (n = 41) offered virgin olive oil at tables. Consequently, the 44 included restaurants fulfilled an average of 11.5 ± 2.1 of the 17 total AMed compulsory and optional criteria (Table 3).

Table 3. Compulsory and optional AMed criteria fulfilled by the included restaurants.

	N = 44 % (n)
AMed Compulsory criteria:	
(1) olive oil for dressing, and olive oil or high oleic sunflower for cooking	75.0 (33)
(2) 25% of the first course offerings are vegetables and/or legumes	70.5 (31)
(3) presence of whole-grain products	34.1 (15)
(4) 50% of the second course offerings based on fish, seafood and lean meat	59.1 (26)
(5) 50% of the dessert offerings based on fresh fruit (whole or prepared)	2.3 (1)
(6) offer of dairy desserts without added sugar	43.2 (19)
(7) offer of free nonpackaged drinking water	31.8 (14)
(8) wine, beer and cava are measured in glasses or individual units	100 (44)
(9) have culinary preparations that do not require the addition of large amounts of fat, and culinary techniques that use little or no fat are used	93.2 (41)
Number of total AMed compulsory criteria fulfilled per restaurant (mean ± SD) [1]:	5.1 ± 1.6
AMed Optional criteria:	
(1) prioritize fresh seasonal and local foods	100 (44)
(2) include proposals of the traditional and local cuisine	95.5 (42)
(3) offer virgin olive oil at tables	93.2 (41)
(4) prioritize side dishes of vegetables and legumes	84.1 (37)
(5) offer the most symbolic recipes of the restaurant that accomplish the AMed criteria to their customers	11.4 (5)

Table 3. *Cont.*

	N = 44 % (*n*)
(6) offer the option of unique dishes or medium portions	79.5 (35)
(7) offer options with no added salt	88.6 (39)
(8) disseminate information about leisure activities in the nearby environment	95.5 (42)
Number of total optional criteria fulfilled per restaurant (mean ±SD) [2]:	6.5 ± 0.9
Number of 17 total AMed criteria fulfilled per restaurant (mean ±SD) [3]:	11.5 ± 2.1

SD: Standard Deviation; AMed: Mediterranean Diet offer. [1]: 9 compulsory AMed criteria; [2]: 8 optional AMed criteria; [3]: 17 total AMed criteria.

3.4. SMAP Criteria

The 44 included restaurants fulfilled an average of 12.9 ± 2.8 of the 18 total SMAP criteria (Table 4), demonstrating that there are still six pending criteria to improve for avoiding gluten cross-contamination. The most fulfilled criteria were related to the use of different tools or non-cross-contaminated kitchen tools for gluten food preparation (95.5%; *n* = 42), and to the attention of the staff in cleaning the kitchen area and their hands before the preparation of gluten-free food (97.7%; *n* = 43); however, only 38.6% (*n* = 17) had exclusive equipment (fryers, ovens, microwaves, etc.) for gluten-free food preparation, and only 45.5% (*n* = 20) used closed salt shakers and spice boxes which are recommended to avoid cross-contamination. Furthermore, very few restaurants (29.5%; *n* = 13) avoided the use of kitchen cloths and wooden tools, which are materials that can retain traces of gluten, or offered seasonings for exclusive use or in single-dose portions, that are very useful tools to preserve consumers' safety (18.2%; *n* = 8) (Table 4).

Table 4. SMAP criteria fulfilled by the included restaurants.

	N = 44 %(*n*)
(1) working with suppliers who guarantee their products do not contain gluten, on labels or data sheets	75.0 (33)
(2) store gluten-free products separately from products containing gluten in closets, freezers or refrigerators	77.3 (34)
(3) transfer to hermetically closed containers after opening, and identify the content	86.4 (38)
(4) keep flours and breadcrumbs containing gluten tightly closed and store them away from other food products	70.5 (31)
(5) use different or non-cross-contaminated kitchen tools for gluten-free food preparation	95.5 (42)
(6) be provided of equipment for the exclusive use of gluten-free food preparation (fryers, ovens, microwaves, toasters, sandwich makers, pasta makers)	38.6 (17)
(7) preparation of gluten-free plates before the other food preparation	81.8 (36)
(8) have a differentiated area within the kitchen for the preparation of gluten-free food, or a good working protocol	68.2 (30)
(9) cleaning of the food preparation area before starting to work	97.7 (43)
(10) cleaning of the hands before starting the preparation of all the necessary ingredients	97.7 (43)
(11) be provided of a clean apron, if you work with flours or products that may leave gluten traces on the clothes	54.5 (24)
(12) dispose of closed salt shakers and spice boxes, or use a teaspoon to pick up the salt as long as hands will be not placed inside	45.5 (20)
(13) do not use kitchen cloths and wooden tools, which are materials that can retain traces of gluten	29.5 (13)
(14) do not reuse oil, cooking water or broths when gluten products have been cooked, and do not share spreads foods	86.4 (38)
(15) serve gluten-free food in dishes of different colours or easy to identify (e.g., flags), and cover up until the moment of service	72.7 (32)
(16) re-prepare gluten-free dishes if a potential contamination occurs with a gluten-containing product	95.5 (42)
(17) place on the tables bottles of oil and vinegar, sauces and baskets for exclusive use, or single-dose portions	18.2 (8)
(18) cleaning of the waiter's hands before the serving of the gluten-free dishes, to be taken	97.7 (43)
Number of total criteria fulfilled per restaurant (mean ± SD) [1]:	12.9 ± 2.8

[1]: 18 SMAP criteria in total.

3.5. Traffic Light and Nutritional Content Assessment of the Restaurants' Offered Dishes

Nutritional content assessment was performed for 297 dishes, whose nutrient content was measured according to the three-colour traffic light system as an easy tool to assess the nutritional quality of dishes. A green-light evaluation good indicates nutritional quality in line with the GDAs recommendation for a single portion. Of the 297 assessed dishes, n = 119 were starters, n = 138 were main dishes and n = 40 were desserts. Based on the traffic light nutritional assessment, the 119 starter dishes were mainly rated green for carbohydrates (55.5%; n = 66), whereas few dishes were rated green for fibre (27.7%; n = 33), sodium (13.4%; n = 16), energy (10.1%; n = 12) or fat (5.9%; n = 7) (Table 5). Regarding the 138 main dishes, only 9.4% (n = 13) were rated green for saturated fat, 5.8% (n = 8) were rated green for sodium and 1.4% (n = 2) were rated green for total fat (Table 5). Regarding the 40 desserts, few were rated green for fibre (20.0%; n = 8) or sugar (2.5%; n = 1) (Table 5).

Table 5. Traffic light and nutritional content assessment of the restaurants' offered dishes.

	Number of Green-Light Dishes per Nutrient and Type of Plate [1]:			
	Total (n = 297) % (n)	**Starters (n = 119) % (n)**	**Main dishes (n = 138) % (n)**	**Desserts (n = 40) % (n)**
Energy	7.7 (23)	10.1 (12)	3.6 (5)	15.0 (6)
Carbohydrates	47.1 (140)	55.5 (66)	45.7 (63)	27.5 (11)
Sugar	59.9 (178)	63.0 (75)	73.9 (102)	2.5 (1)
Protein	10.1 (30)	14.3 (17)	1.4 (2)	27.5 (11)
Total fat	6.1 (18)	5.9 (7)	1.4 (2)	22.5 (9)
Saturated fat	14.8 (44)	19.3 (23)	9.4 (13)	20.0 (8)
Sodium	18.2 (54)	13.4 (16)	5.8 (8)	75.0 (30)
Fibre	25.9 (77)	27.7 (33)	26.1 (36)	20.0 (8)
	Nutrient content of the restaurant dishes [2]:			
	Total (n = 297) Mean ± SD	**Starters (n = 119) Mean ± SD**	**Main dishes (n = 138) Mean ± SD**	**Desserts (n = 40) Mean ± SD**
Energy (Kcal)	490.3 ± 310.2	442.5 ± 290.8	566.3 ± 319.3	368.9 ± 271.4
Carbohydrates (g)	27.7 ± 26.5	26.6 ± 28.7	25.5 ± 23.8	38.7 ± 26.4
Sugar (g)	10.0 ± 13.2	6.8 ± 6.8	6.6 ± 7.4	31.3 ± 21.4
Protein (g)	25.5 ± 21.1	19.7 ± 17.3	35.5 ± 21.5	8.5 ± 10.1
Total fat (g)	30.2 ± 24.3	27.5 ± 21.6	35.7 ± 26.8	19.4 ± 17.6
Saturated fat (g)	8.5 ± 8.3	7.7 ± 8.8	8.8 ± 7.6	10.2 ± 9.4
Sodium (mg)	950.4 ± 814.4	1030.5 ± 836.8	1107.7 ± 778.0	169.6 ± 237.9
Fibre (g)	3.8 ± 4.0	4.0 ± 3.5	4.0 ± 4.4	2.2 ± 3.1

[1]: % (n); [2]: Data are expressed in Mean ± SD, and values are referred to a single portion.

Comparing green- and red-light dishes (data not shown), no significant difference was observed for starters, main dishes and desserts ($p > 0.05$). Correlation analysis of the total number of AMed criteria fulfilled and green-light dishes showed a significant positive, weak correlation between AMed criteria and sugar ($\varrho = 0.32$; p-value = 0.04), as well as a significant moderate correlation between AMed criteria and total fat ($\varrho = 0.57$; p-value = 0.03), indicating that a greater number of AMed criteria are fulfilled when sugar and fat nutrients are rated green in the traffic light system (Table S2). However, a significant weak negative correlation was detected between AMed criteria and fibre ($\varrho = -0.32$; p-value = 0.03). A greater number of fulfilled AMed criteria were correlated with a non-green traffic light rating for fibre. No other significant correlations were observed ($p > 0.05$) (Table S2).

As shown in Table 5, nutrient content was assessed for the type of plate. According to the recommended GDAs for a single portion [41], starters had high contents of energy, protein, fat, saturated fat and sodium; main dishes had high contents of energy, protein, fat, saturated fat and sodium; desserts had high contents of sugar, fat and saturated fat [40].

3.6. Allergen Content Assessment and Vegetarian and Vegan Dish Adequacy

The 14 most common allergens were identified by type of plate for the 297 analysed dishes. With respect to the allergen content (Table 6), few dishes were completely allergen-free (9.8%; $n = 29$), with the majority being starters (12.6%; $n = 15$) and main dishes (8.0%; $n = 11$) ($p = 0.02$). In particular, 142 of the total 297 analysed dishes (47.8%) were gluten-free, especially starters (53.8%; $n = 64$) and main dishes (44.2%; $n = 61$) ($p < 0.001$). Differences for type of plate (starter, main dishes and desserts) between allergen-free and gluten-free dishes were also statistically significant ($p < 0.001$).

Table 6. Allergen content assessment and vegetarian and vegan dish adequacy.

	Total [1] ($n = 297$) % (n)	**Starters [1,2] ($n = 119$) % (n)**	**Main dishes [1,2] ($n = 138$) % (n)**	**Desserts [1,2] ($n = 40$) % (n)**
Allergen-free [3]	9.8 (29)	12.6 (15)	8.0 (11)	7.5 (3)
Gluten-free [3]	47.8 (142)	53.8 (64)	44.2 (61)	42.5 (17)
Vegetarian [4]	26.9 (80)	36.1 (43) *	2.2 (3) *	85.0 (34) *
Vegan [4]	9.8 (29)	19.3 (23) *	0.7 (1) *	12.5 (5)

[1]: % (n); [2]: Bonferroni tests were conducted for differences among type of dishes: starters, main dishes and desserts; [3]: data refer to the dishes not containing the food allergen; [4]: data refer to vegetarian and vegan-adapted dishes; *: p-value ≤ 0.05.

According to the adequacy of vegetarian and vegan dishes (Table 6), 36.1% of the starters ($n = 43$) were suitable for vegetarians, and 19.3% were suitable for vegans ($n = 23$). On the other hand, only 2.2% of the main dishes ($n = 3$) were adapted for vegetarians, and 0.7% were adapted for vegans ($n = 1$). Finally, 85.0% of the desserts were appropriate for a vegetarian diet ($n = 34$), and 12.5% were appropriate for a vegan diet ($n = 5$). The main dishes are the type of dishes that contain fewer vegetarian options, compared among them, starters and desserts ($p < 0.01$). Moreover, main dishes contain fewer vegan options compared to starters ($p < 0.01$). Contrarily, the highest vegetarian options are present on desserts, and the highest vegan options on starters, compared to other dishes ($p < 0.01$). (Table 6).

3.7. Knowledge of Restaurant Staff about the Mediterranean Diet and Food Allergens

The restaurant waiters' and cooks' knowledge of the principles of the Mediterranean diet and food allergens was evaluated (Table 7). Regarding the Mediterranean diet, waiters received 7.9 ± 1.7 points and cooks received 6.9 ± 1.7 points of a total of 10 points, with a significant difference between the two groups ($p = 0.003$). On the other hand, regarding food allergen knowledge, waiters scored 5.8 ± 1.7 points and cooks scored 5.5 ± 1.5 points of a total of 10 points, with no significant difference ($p = 0.36$). Finally, general knowledge assessed out of a total of 10 points (5 points for the Mediterranean diet and 5 points for food allergens) amounted to 6.7 ± 1.5 points for waiters and 6.0 ± 1.7 points for cooks, with a significant difference between the two groups ($p = 0.03$) (Table 7).

Moreover, there was no significant correlation between the AMed criteria score and restaurant staff knowledge about the Mediterranean diet (cooks $\varrho = -0.05$, p-value > 0.05; waiters $\varrho = -0.05$, p-value > 0.05) or between the SMAP criteria score and restaurant staff knowledge about food allergens (cooks $\varrho = -0.18$, p-value > 0.05; waiters $\varrho = -0.14$, p-value > 0.05).

Table 7. Knowledge of restaurant staff about the Mediterranean diet and food allergens.

Mediterranean Diet Knowledge [1]:	Total Staff [2] (Mean ± SD)	Waiters (Mean ± SD)	Cooks (Mean ± SD)	*p*-Value [3]
1. Identification of foods adhering to the Mediterranean diet		7.9 ± 1.7	8.0 ± 1.4	0.94
2. Identification of healthy food			6.8 ± 1.2	
3. Identification of the AMed compulsory criteria			7.7 ± 1.7	
Total score about Mediterranean diet [1]	7.4 ± 1.8	7.9 ± 1.7	6.9 ± 1.7	0.003 *
Food allergens knowledge [1]:				
1. Identification of food allergens in traditional meals		3.2 ± 1.8		
2. Identification of the critical points of food allergen management		8.2 ± 1.7	3.6 ± 1.3	0.29
3. Identification of food allergy and intolerance reactions		8.0 ± 1.5	8.4 ± 1.4	0.55
Total score about food allergens [1]	5.6 ± 1.6	5.8 ± 1.7	5.5 ± 1.5	0.36
Total score of staff knowledge [1]	6.3 ± 1.7	6.7 ± 1.5	6.0 ± 1.7	0.03 *

AMed: Mediterranean Diet offer; SD: Standard Deviation. [1]: Scores are calculated on a total of a maximum of 10 points; [2]: Total staff includes restaurant waiters and cooks; [3]: *t*-test; *: *p*-value ≤ 0.05.

3.8. Additional Data

Restaurants' Purchased Foods

Preferred stores for food shopping by cooks and restaurateurs were wholesalers for fish (78.8%; *n* = 52/66), meat (78.8%; *n* = 52/66), fruit (66.7%; *n* = 44/66) and vegetables (63.6%; *n* = 42/66) (Table S3). Furthermore, 36.4% of the restaurants bought farm eggs (*n* = 24/66), and 27.3% bought pasteurized eggs (*n* = 18/66). Regarding oil, most of the restaurants bought extra virgin olive oil (84.8%; *n* = 56/66) or sunflower oil (57.6%; *n* = 38/66), while 22.7% also used other types of oils (*n* = 15/66), and 22.7% used virgin olive oil (*n* = 15/66) (Table S3). Extra virgin olive oil was used mainly for raw seasonings and sauces (90.9%; *n* = 60/66), grilled and roasted foods (46.9%; *n* = 31/66) and candied foods (39.4%; *n* = 26/66), while sunflower oil was the most used for frying (39.2%; *n* = 26/66) (Table S3).

4. Discussion

The present cross-sectional study provides data about Mediterranean diet-adherent, healthy and allergen-free offerings by 44 full-service restaurants located in the province of Tarragona and 297 dishes. Regarding Mediterranean diet offerings, the included restaurants fulfilled an average of 5.1 ± 1.6 out of 9 compulsory AMed criteria, demonstrating that further efforts by restaurants are needed to ensure that their gastronomic offerings adhere to the Mediterranean diet recommendations [33]. Regarding the traffic light assessment, the dishes analysed were mainly rated green for sugar but not for energy or total fat content.

Unsurprisingly, other previous studies have demonstrated that restaurants should improve the healthiness of their meals, as observed in the present cross-sectional analysis. For instance, an observational study in 2017 found that US restaurant meals exceeded the American Heart Association's (AHA) criteria, which indicate good nutritional content in terms of calories, total fat, saturated fat, cholesterol and sodium [45]. Similarly, another study reported that 25 of 32 restaurants analysed did not meet the criteria of the Nutrition Environment Measures Survey for Restaurants (NEMS-R); the study assessed the factors that contribute to increasing healthy food choices in restaurants, such as the availability of, promotion of and signage about healthy meals on the menu [46].

Although eating outside of the home is a pleasurable event for consumers, especially in Spain, where restaurants serve as a context for social and familiar interaction [47], eating pleasure should not be considered an enemy of health; in this sense, restaurants should offer healthier meals to customers without sacrificing taste [48] and should recognize the role of "food as wellbeing" [49]. Specifically, the present cross-sectional analysis showed that many restaurants do not include whole foods and desserts with no added sugar or based on fresh fruit on their menus. The importance of whole grain consumption is based on the recommended daily consumption of 2–3 servings per day of whole grains (±45 g/day) [50], as well as of fruit and vegetables (≥400 g/day) [51], which has been associated with a lower risk for developing noncommunicable diseases (NCDs), including cardiovascular diseases, diabetes type 2 and metabolic and gastrointestinal disorders [50,51]. However, the consumption of whole grains, fruit and vegetables worldwide still does not meet the recommended guidelines (38.4 g/day, 81.3 g/day and 208.8 g/day are actually consumed, respectively), thus constituting a global public health goal to be reached [52]. For instance, to help customers improve their daily consumption of whole grains and fresh fruits, restaurants should increase the availability of these healthy foods on their menus by directly substituting refined-grain foods with whole-grain foods [53] and serving fruit and vegetables as attractive side dishes or entrees [54]. Actually, a recent study about the changes that occurred in dietary habits of the Spanish population during the COVID-19 confinement revealed an increase in the consumption of Mediterranean diet-related foods such as olive oil, fruits, vegetables and legumes [55], reflecting that people desire to approach healthier dietary behaviours that restaurateurs should take into account. For instance, the closing of restaurant establishments could have improved people's consumption, pointing out the lack of healthier offerings offered by restaurants.

According to the traffic light nutritional content assessment, the starters were mainly rated green for carbohydrates but did not meet the recommended GDAs for fibre, sodium, energy or total fat. These results confirm the observation regarding unfulfilled AMed criteria, pointing out that restaurants should provide more fruit, vegetables and whole-grain ingredients in first courses. Similarly, the main dishes were high in total fat, saturated fat and sodium, with only 59.1% of the restaurants providing fish, seafoods and lean meat as second courses; the latter strategy would result in lower fat content, as demonstrated by the significant correlation between fulfilment of the AMed criteria and green ratings for fat according to the traffic light system. Finally, few desserts were rated green for fibre and sugar since the restaurants did not include fresh fruits or pastries with no added sugars, as observed based on the unfulfilled AMed criteria. Furthermore, the average nutrient content was higher than the recommended GDA values per single portion. Similarly, a Canadian cross-sectional analysis found that sit-down restaurant meals were high in calories, saturated fat and sodium with respect to the recommended daily values and that these contents were even significantly higher than those of fast-food restaurant meals [20]. To decrease caloric content, an effective strategy could be substituting fat and caloric foods with greater portions of vegetables, which improves the healthiness and sustainability of the diet [56].

Furthermore, none of the included restaurants presented nutritional information on the menu, such as GDAs and healthy choice indicators or symbols, and the majority of the restaurateurs (79.5%) considered their menus already to offer healthy meals. Previous studies have demonstrated that there is a growing demand for nutritional labels on restaurant menus, especially by consumers between 35 and 65 years of age with healthy lifestyles who frequently eat outside of the home. In this sense, restaurants should be proactive and responsive to the request of an important part of the customer population through the design of menus with nutritional information to encourage healthier choices [57].

In relation to the food allergen content, the restaurants included in the present cross-sectional analysis offered different allergen-free options on their menus and considered the availability of appropriate meals for people with food allergies as a point to be improved, but they did not recognize the lack of allergen-free options as a weakness (81.8%). The prevalence of food allergies in Europe relates to cow's milk, egg, wheat, soy, peanut, tree nuts, fish and shellfish [58]. In particular, although wheat is the main source of food in the world, providing up to 50% of the daily caloric intake in developed and developing countries [59], it is also the main source of gluten, whose disorders already affect the 1.4% of the global population [60]. For people who cannot consume foods containing gluten, the possibility to choose gluten-free meals when eating outside the home represents an important factor for their quality of life [61]; thus, restaurateurs should come across to these needs, improving menu offerings' options and communication [61]. However, as observed from the present cross-sectional analysis, only 29.5% of the restaurants identified food allergens on their menus, and only 9.8% of the offered dishes were allergen-free, despite European Union legislation recommending the disclosure of the 14 most common allergens [16]. On the other hand, 47.8% of the offerings are gluten-free, pointing out that restaurants are starting to take more account of this emerging consumers' need regarding food allergies.

The assessment of staff knowledge indicated that the waiters scored significantly higher than cooks for knowledge of the Mediterranean diet and total knowledge. On the other hand, concerning food allergen knowledge, both waiters and cooks received a barely passing score (5.8 ± 1.7 and 5.5 ± 1.5, respectively, out of 10 total points), and only 43.1% of the restaurateurs reported attending more than one training course on allergen management. Based on the described experience, although proper training on food safety is provided to restaurant staff, these courses are not always effective and have little impact on overall allergen management since theoretical courses are not combined with appropriate practical demonstrations [62]. However, it is essential to provide efficient training to restaurant staff about food allergy prevention and response, in case of adverse reactions [63], and about celiac disease and gluten-free diet management [64], as cooks still have many knowledge gaps in this area [65]. In the management of food allergens, the restaurants included in the present analysis fulfilled an average of 12.9 ± 2.8 SMAP criteria out of the 18 total recommendations defined by the Catalan Celiac Association [34], highlighting that restaurants were generally careful to avoid cross-contamination in the kitchen and dining room. However, few restaurants were equipped with tools for exclusive gluten-free preparations (ovens, fryers, etc.) or took special precautions such as providing single-serving dressings for allergic customers and closed containers for salt and spices. Although different studies have demonstrated that shared ovens for the cooking of gluten-free and gluten-containing pizza [66], as well as of kitchen utensils as spoons and knives [67], do not pose a relevant risk when specific requirements are complied, these tools could undergo cumulative contamination throughout the day and involve a higher risk during dinner service [68]. Thus, further precautions should be taken by restaurants for the preparation of allergen-free food to avoid adverse reactions and the endangerment of consumers' lives [69].

Additionally, few restaurants indicated meals suitable for vegetarian and vegan diets (29.5%) on their menus, and the offerings were very limited (26.9 and 9.8%, respectively). Although restaurants still have limited plant-based meal options, in 2019, 1.5% and 0.5% of the Spanish population reported following a vegetarian or a vegan diet, respectively [70], while in 2020, the sales volume of vegetarian and vegan food products in Spanish supermarkets increased by 20% [71]. Thus, as demonstrated by a recent study, the increase in vegetarian and vegan meal options could have a positive impact both on meal sales and on the improvement of consumers' sustainable food choices and satisfaction [72].

Finally, few of the included restaurants in this cross-sectional analysis offered child menus (29.5%), but the majority of them would prepare half-portion meals (88.6%). However, as suggested by previous studies, regarding the offering of half portions or smaller serving sizes of adult dishes to children, restaurants should include healthier options to accustom children to selecting and consuming healthy meals [73,74]. Similarly, as reported by Mueller et al., the improvement of healthy child menus seems to encourage the selection of healthier meals by adults [75].

Based on the present cross-sectional analysis, several recommendations could be proposed to restaurants to increase Mediterranean menu offerings and improve food allergen management (Table S4). In particular, when limited resources can be invested in the development of new offerings, as is the case for most independent restaurants that operate with narrower profit margins [13], restaurants should improve the promotion of existing healthy options and encourage consumers to select such offerings through symbols and indicators on menus.

Similarly, regarding food allergen management, according to the present analysis, restaurants should provide more training courses to their staff and provide more information to customers about the presence of food allergens on the menu (Table S4). On the other hand, several positive practices were observed at the included restaurants: the use of extra virgin olive oil for dressing and cooking, which has been associated with many health positive effects due to the high content of oleic acid and bioactive compounds (e.g., polyphenols) [76], as well as the preference of fresh seasonable and traditional fruit and vegetables, which contribute to a sustainable diet [77,78] (Table S4).

Several notable limitations were encountered in the present cross-sectional analysis. First, there were difficulties experienced during data collection since many restaurants did not respond or withdrew from the study before the beginning of data collection. Second, the present cross-sectional study occurred in the midst of the SARS-CoV-2 pandemic, limiting the participation and inclusion of restaurants in the study, many of which closed during the pandemic. Third, due to the pandemic, the restaurant industry has adapted its offerings according to national dispositions, so the current data could differ from the presented analysis. Fourth, since the majority of the included restaurants in the present study were urban, the inclusion of more rural and coastal restaurants in the same proportion would homogenize the results more, making them more representative of the province of Tarragona. Fifth, data collection methods are validated in our local area, being designed and developed by Catalan entities for local realities. However, the use of these data collection methods limited the comparison among international studies. Finally, some restaurant information was lost due restaurants not completing the questionnaires or not providing all the information requested.

5. Conclusions

In conclusion, the restaurants did not meet all of the AMed and SMAP criteria. An increase in fibre and a decrease in saturated fat content are needed to improve the nutritional quality of dishes and the consumers' adherence to healthy diets. Additionally, for restaurant staff, training courses on food allergens should be considered to improve the allergen management in restaurants. Furthermore, more information should be provided to customers on menus about the presence of food allergens, healthier food choices and vegetarian and vegan options.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13072464/s1. Table S1: STROBE checklist for observational cross-sectional studies; Table S2: Correlation analysis between total number of AMed criteria fulfilled and green-light dishes; Table S3: Restaurants' purchased foods; Table S4: Recommendations for restaurants to increase Mediterranean menu offerings and improve food allergen management.

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Abbreviations

RCT: Randomized Controlled Trial; GDA: Guideline Daily Amounts; AMed: Mediterranean Diet; SD: Standard Deviation.

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STUDY 2:

Interventions to Promote Healthy Meals in Full-Service Restaurants and Canteens: A Systematic Review and Meta-Analysis.

nutrients MDPI

Review

Interventions to Promote Healthy Meals in Full-Service Restaurants and Canteens: A Systematic Review and Meta-Analysis

Floriana Mandracchia [1,†], Lucia Tarro [1,2,†], Elisabet Llauradó [1,*], Rosa Maria Valls [1] and Rosa Solà [1,2,3]

[1] Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Healthy Environment Chair, Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili, 43201 Reus, Spain; floriana.mandracchia1@urv.cat (F.M.); lucia.tarro@urv.cat (L.T.); rosamaria.valls@urv.cat (R.M.V.); rosa.sola@urv.cat (R.S.)
[2] Institut d'Investigació Sanitaria Pere Virgili, 43204 Reus, Spain
[3] Hospital Universitari Sant Joan de Reus, 43204 Reus, Spain
* Correspondence: elisabet.llaurado@urv.cat; Tel.: +34-977758920
† These authors contributed equally to this work.

Abstract: Out-of-home eating is increasing, but evidence about its healthiness is limited. The present systematic review and meta-analysis aimed to elucidate the effectiveness of full-service restaurant and canteen-based interventions in increasing the dietary intake, food availability, and food purchase of healthy meals. Studies from 2000–2020 were searched in Medline, Scopus, and Cochrane Library using the PRISMA checklist. A total of 35 randomized controlled trials (RCTs) and 6 non-RCTs were included in the systematic review and analyzed by outcome, intervention strategies, and settings (school, community, workplace). The meta-analysis included 16 RCTs (excluding non-RCTs for higher quality). For dietary intake, the included RCTs increased healthy foods (+0.20 servings/day; 0.12 to 0.29; $p < 0.001$) and decreased fat intake (−9.90 g/day; −12.61 to −7.19; $p < 0.001$), favoring the intervention group. For food availability, intervention schools reduced the risk of offering unhealthy menu items by 47% (RR 0.53; 0.34 to 0.85; $p = 0.008$). For food purchases, a systematic review showed that interventions could be partially effective in improving healthy foods. Lastly, restaurant- and canteen-based interventions improved the dietary intake of healthy foods, reduced fat intake, and increased the availability of healthy menus, mainly in schools. Higher-quality RCTs are needed to strengthen the results. Moreover, from our results, intervention strategy recommendations are provided.

Keywords: out-of-home eating; menu choice; restaurant-based interventions; family; restaurant; food-service; food behavior

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1. Introduction

The change in modern living due to urbanization and globalization [1] and the lack of sufficient free time to dedicate to home cooking have increased families' consumption of daily meals out of the home [2]. Restaurants, schools, workplace canteens and food stores providing prepared meals are the preferred food services by both children and adult populations [3,4].

Consequently, eating out of home is associated with a unhealthy diet [5] due to the lower consumption of fruits and vegetables [6]. Furthermore, comparisons of the nutritional profile of foods have shown that meals prepared out of the home are higher in energy density, fat and sodium and lower in calcium and fiber than foods prepared at home [7]. Thus, consumers of out-of-home meals may report important long-term health implications, such as obesity [8] and related chronic diseases [9]. In this regard, people are paying more attention to the healthiness of food when eating out of home [10], demanding higher-quality meals from food businesses that have the responsibility to provide them according to consumers' necessities [11].

For instance, potential strategies for the promotion of healthier meals could be the improvement of the nutritional quality of food in terms of energy, fat and sodium [12], the reduction of portion sizes in meals [13] and the provision of nutritional labels [14]. The lack of nutritional information on menus, known as the consumer "nutritional knowledge gap", could hinder people's healthy eating intentions when they are eating out of home [15].

However, the literature on the most effective interventions to improve consumers' diet when they are eating out of home is still scarce. Moreover, most nutrition interventions are set in fast-food and chain restaurants mainly placed in urban areas [16], leaving little evidence about independent restaurants and potential intervention strategies [17,18].

Another aspect is identifying suitable solutions for different population targets [19], such as children, adolescents and adults, and in different environments, such as restaurants [18], schools [20] and workplace canteens [21].

Thus, the aim of the present systematic review and meta-analysis is to elucidate the effectiveness of full-service restaurant- and canteen-based interventions targeting children, adolescents and adults in increasing the availability, purchase and intake of healthy meals.

2. Materials and Methods

This systematic review has been registered in the International Prospective Register of Systematic Reviews (PROSPERO) with the registration number CRD42019117411. The results of the included articles are reported according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines [22]. The PRISMA 2009 checklist is presented in Table S1.

2.1. Search Strategy

Three electronic databases were searched: Medline, Scopus, and Cochrane Library. Search filters were used in all three databases to limit the results to the "2000–2020" publication time range and English, Spanish, and Italian language articles. For the abstract and full-text screening of the articles, the Rayyan QCRI web-based software platform [23] was used to better manage the high volume of retrieved articles. Searches were conducted using the following keywords: "intervention" AND "controlled" AND "restaurant" OR "canteen" OR "food-service" AND "meal" OR "dietary intake" OR "food availability" OR "food purchase" OR "menu".

The Population, Intervention, Comparison and Outcomes (PICOS) criteria (Table 1) were used to define the research question of the present systematic review [24].

Table 1. PICOS criteria used to define the research question.

Criteria	Description
Population	Restaurant and canteen consumers (children and adults) and their staff.
Intervention	Restaurant- and canteen-based interventions concerning the promotion of healthy meals.
Comparison group	Comparison Group as a CG receiving any intervention.
Outcomes	Improvement in the promotion of healthy foods offered in restaurants and canteens; increase in the offer and the demand for healthy meals.
Setting	Restaurants and canteens.

2.2. Screening

Initial screening of the title, abstract, keywords and publication type was conducted by two reviewers independently (F.M.; L.T.). Full-text screening of potentially relevant studies was independently performed by the same two reviewers (F.M.; L.T.) based on the inclusion and exclusion criteria, and disagreements were resolved by a third reviewer (E.L.). Final doubts about the eligibility of a particular study were resolved through discussion between the three reviewers for further confirmation and consensus.

2.3. Inclusion and Exclusion Criteria

The inclusion criteria used for the selection of eligible articles in this review were (a) controlled trials, with or without random assignment, published from 2000 to 2020 to focus the search on healthy eating interventions in full-service restaurants and canteens, conducted in contemporary circumstances; (b) English, Spanish or Italian language articles; (c) articles describing full-service restaurant and canteen-based interventions aimed at improving menu offerings and increasing the offerings and demand for healthier meals as the primary or secondary outcome; (d) trials that included a control group (CG) that did not receive the intervention; and (e) trials that presented both pre- and postintervention measurements of the intervention group (IG) and the CG and the *p*-values of the difference between groups.

Articles were excluded when (1) they did not fulfill the abovementioned criteria; (2) they used the pretest condition as the CG; or (3) the authors of the article were not able to give further details about the intervention results when personally asked by the authors of the present paper.

2.4. Data Extraction and Management

The following data were extracted from the included intervention studies: (1) study design and type of intervention; (2) setting; (3) country; (4) population; (5) population age; (6) duration of the intervention; (7) outcome; (8) measurement tool; (9) results; and (10) intervention strategies.

If necessary, further information about the results was collected by emailing the corresponding authors [25–29], especially when it was not possible to deduce the information directly from tables and figures.

The extracted results included mean changes from baseline to postintervention or follow-up and significant differences between groups in changes from pre- to postintervention. For each variable examined in between-group comparisons, differences were considered significant at *p*-values ≤ 0.05.

2.5. Data Synthesis

For a better evaluation of intervention effectiveness, the included interventions were divided according to the following: (1) outcome category (dietary intake, food availability and food purchase); (2) strategies applied (consumer- and/or establishment-based); and (3) intervention setting (school, community, and workplace) reflecting the age of the target population, i.e., children and/or adults.

Moreover, the included interventions were classified similarly to previous studies as follows [30,31]: (1) effective, when all the measured variables indicated a statistically significant change from baseline to post assessment in favor of the IG compared to the CG; (2) partially effective, when some variables included in the study changed significantly favoring the IG and any variable changed favoring the CG; and (3) not effective, when any significant changes occurred or when a change favoring the CG occurred. For the interpretation of the final effectiveness of the systematic review, an intervention was considered effective when the corresponding study reported it to be totally and/or partially effective.

2.6. Outcomes

The included studies focused on different outcomes, which were grouped into three major categories, as described previously. Specifically, (1) the dietary intake outcome category referred to the increase in the study population's consumption of healthier meals, which, according to the World Health Organization (WHO) recommendations, requires the consumption of more fruits and vegetables, the limitation of the consumption of saturated and trans fats and sugar and salt, and a balanced energy intake [32]; (2) the food availability outcome category referred to the change in the offerings of healthy and/or unhealthy food items (in terms of quality and quantity) in restaurants and canteens, which represents one of the highest-impact interventions for changing the population's dietary behavior [33]; and

(3) the food purchase outcome category referred to the change in consumers' food selection towards the selection of healthier food options offered in restaurants and canteens, which is directly related to the increase in the availability of such options to satisfy consumers' demands [34].

2.7. Data Analysis

The meta-analysis was performed with Review Manager 5.4.1 and STATA 16.1 (StataCorp. 2019. Stata Statistical Software: Release 16. StataCorp LLC, College Station, TX, USA) when at least three of the included intervention studies presented similar outcome variables and units of measure. Meta-analysis was performed including both RCTs and non-RCTs, and then it was repeated by excluding non-RCTs to assure higher quality results. Studies were analyzed with a random effect model when the heterogeneity of the studies was evaluated over 75% by the I^2 statistic, with the results expressed as odds ratios (ORs). When the heterogeneity was <75%, the fixed effects model was used, and the results were expressed as the risk ratio (RR) [35]. Intervention studies that presented the same measurement units and outcomes were analyzed in subgroups of studies. If the SD, SE or 95% CI values were not available in the original articles, the intervention studies were not included in the meta-analysis. A p-value of ≤ 0.05 was considered statistically significant.

2.8. Risk of Bias and Quality Criteria

The risk of bias and quality assessment of the included intervention studies was performed using the standardized framework of the Quality Assessment Tool for Quantitative Studies Dictionary developed for the Effective Public Health Practice Project [36]. Each included intervention study was evaluated as weak, moderate or strong for six of the eight specific categories: selection bias, study design, confounders, blinding, data collection methods, and withdrawals and dropouts. Then, the overall quality of the studies was appraised based on a 3-point rating scale including strong (no weak ratings), moderate (one weak rating) or weak (two or more weak ratings).

3. Results

3.1. Results of the Search

A total of 8537 articles were retrieved from the search of the Medline, Cochrane Library and Scopus databases (Figure 1). A total of 731 duplicates were removed, resulting in 7806 articles for title and abstract screening. Of these, 7653 were excluded because they were irrelevant for the present review by title and abstract screening. The remaining 153 articles were selected for further full-text screening according to the inclusion criteria. Following the screening, an additional 114 articles were excluded for not fulfilling the inclusion criteria. A total of 39 English-language articles were evaluated as eligible for inclusion, together with 2 articles resulting from cross-reference searching, for a total of 41 articles finally included in the present systematic review. The detailed general characteristics of the included studies are shown in Table 2, and the results on the mean pre–post intervention changes in the IG and CG are shown in Table S2.

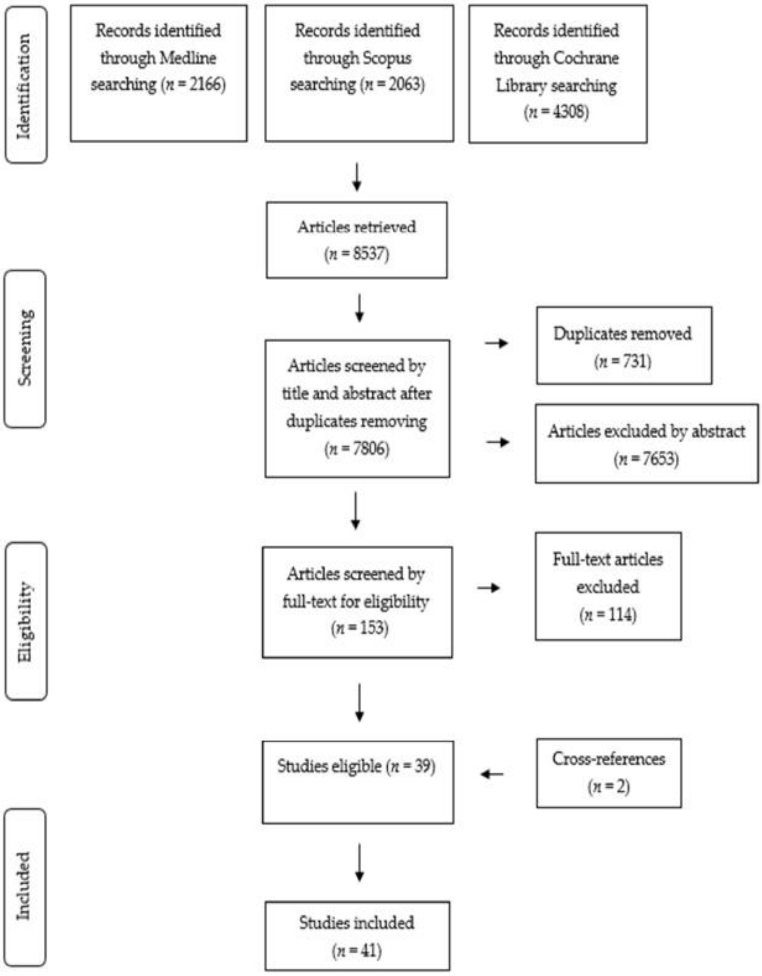

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 flow diagram for the systematic review of the article selection process.

Table 2. Characteristics of the included intervention studies in restaurants and food service establishments.

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Ayala et al.; 2017.	Cluster RCT; 3-arm restaurant-based intervention.	Community (restaurants)	USA	8 restaurants (Menu-plus IG $n = 4$; Menu-only CG $n = 4$) and weekend dinner customers (n = N/A).	≥12 y	2 m	Food purchase x	–	Weekly sales of new child menus ($/week).
Anderson et al.; 2005.	RCT; school-based nutrition education intervention.	School	Scotland	4 schools (IG $n = 2$; CG $n = 2$) and 129 students (IG $n = 64$; CG $n = 65$).	6–7 y and 10–11 y	9 m	Dietary intake ✓x	↑ Fruit (g).	Vegetables (g), total F&V (g), energy (kJ), % energy as fat/carbohydrate/protein, starch (g), sucrose (g).
Beets et al.; 2016.	RCT; multistep adaptive intervention.	Community (after-school program)	USA	9 schools (IG $n = 3$; CG $n = 6$), 4 churches (IG $n = 3$; CG $n = 1$), 7 communities (IG $n = 4$; CG $n = 3$) and 1765 students (IG $n = 895$; CG $n = 870$).	6–12 y	12 m	Food availability x	↑ F&V (days), ↑ dips (days); ↓ desserts (days), ↓ salty unflavored snacks (days), ↓total sweetened beverages (days), ↓ 100% fruit juice (days).	Dairy unsweetened snacks (days), dairy sweetened snacks (days), salty flavored snacks (days), unsweetened cereals (days), sugar-sweetened cereals (days), water, unflavored milk (days).
Bogart et al.; 2014.	RCT; multicomponent intervention.	School	USA	10 schools (IG $n = 5$; CG $n = 5$) and 3039 students (IG $n = 1515$; CG $n = 1524$).	±12–13 y	5 w	Food purchase ✓x	↑ All lunches (servings), ↑ free/reduced lunch (servings), ↑ full-price lunches (servings); ↑fruit servings during intervention; ↓ snack sales.	Fruit and vegetable servings postintervention.
Cohen et al.; 2014.	RCT; single-component intervention.	School	USA	8 schools (IG $n = 4$; CG $n = 4$) and 2746 students (IG $n = 1550$; CG $n = 1196$).	6–12 y	1 w	Food availability ✓x	↑ % of days offering WG (lunch).	WG and RG (options/breakfast and lunch), % of days offering WG (breakfast), % of days offering RG (breakfast and lunch).
Cohen et al.; 2015	RCT; 4-arm chef and choice architecture school-based intervention.	School	USA	14 schools (Chef IG-A $n = 2$; Smart Café IG-B $n = 4$; Chef plus Smart Café IG-C $n = 2$; CG $n = 6$) and 2638 students (Chef IG-A $n = 379$; Smart Café IG-B $n = 651$; Chef plus Smart Café IG-C $n = 672$; CG $n = 936$).	8–16 y	7 m (long-term intervention)	Dietary intake ✓x(IG-A, IG-C);x (IG-B).	↑ cups of fruits (IG-A), ↑ cups of vegetables (IG-A, IG-C), ↑ % of vegetables (IG-A, IG-C).	% Entrée, % cups of fruit (IG-B, IG-C), Cups of vegetable (IG-B), % of fruit (IG-A, IG-B, IG-C), % of vegetables (IG-B).
							Food purchase ✓x (IG-A, IG-B, IG-C)	↑ % of students selecting fruit and vegetables (IG-A, IG-B, IG-C).	% of students selecting entrée (p = N/A).

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Delaney et al.; 2017.	Cluster RCT; consumer behavior intervention.	School	Australia	10 schools (IG $n = 5$; CG $n = 5$) and 2714 students (IG $n = 1144$; CG $n = 1570$).	5–12 y	2 m (+2 m follow-up)	Food purchase ✓x	↑ Green menu items (%); ↓ energy (kJ), ↓ sodium (mg), ↓ saturated fat (g), ↓ red menu items (%).	Sugar (g).
Giles et al.; 2012.	RCT; environmental and policy change intervention.	Community (after-school programs)	USA	20 after-school programs (IG $n = 10$; CG $n = 10$) and 145 students (IG $n = 62$; CG $n = 83$).	±8 y	6 m	Food purchase ✓x	↑ water (ounces), ↑ frequency of water served/day; ↓ kcal from beverages served/day.	100% juice (ounces and frequency of service), milk (ounces and frequency of service).
Grady et al.; 2020.	RCT; web-based menu-planning intervention.	School (childcare centers)	Australia	54 childcare centers (IG $n = 27$; CG $n = 27$) and 54 menu planners (IG $n = 27$; CG $n = 27$).	3–6 y	12 m	Food availability ✓x	↑ Fruit (servings), ↑ meat and alternatives (servings); ↓ discretionary foods (unhealthy) (times/day).	Servings of: vegetables, cereals and breads, dairy and alternatives.
Habib-Mourad et al.; 2014.	Pilot cluster RCT; multicomponent intervention.	School	Lebanon	8 schools (IG $n = 4$; CG $n = 4$) and 374 students (IG $n = 193$; CG $n = 181$).	9–11 y	3 m	Food purchase ✓x	↓ Chips (%, n), ↓ chocolate (%, n), ↓ soft drinks (%, n).	Sweetened beverages (p = N/A), croissant (%, n), manoushe (%, n).
							Dietary intake ✓x	↓ Chips (%, n), ↓ soft drinks (%, n).	Chocolate (%, n), sweetened drinks (%, n), fruit (%, n), sandwich (%, n).
Haerens et al.; 2006.	RCT; 3-arm environmental and computer-tailored intervention.	School	Belgium	15 schools (parental involvement IG-A $n = 5$; intervention alone IG-B $n = 5$; CG $n = 5$) and 2840 students (IG-A $n = 1226$; IG-B/CG n = N/A).	±13 y	2 y	Dietary intake ✓x (girls); x (boys).	↓ Fat (g) (girls), ↓ %E from fat (girls).	Fat (g) (boys), %E from fat (boys), pieces of fruit (boys and girls), soft drinks (glass) (boys and girls), water (glass) (boys and girls).
Kenney et al.; 2015.	Cluster RCT; school cafeteria-based intervention.	School	USA	10 schools (IG $n = 5$; CG $n = 5$) and 1599 students (IG $n = 725$; CG $n = 874$).	6–18 y	3 w	Dietary intake ✓x	↑ Water (ounces), ↑ % students consuming free water; ↓ % students consuming 100%juice, ↓ % students consuming sugar-sweetened beverages.	% students consuming milk, % students consuming other beverages.

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Lassen et al.; 2010.	Cluster RCT; participatory and empowerment-based intervention.	Workplace	Denmark	8 workplaces (IG n = 5; CG n= 3) and 168 employees (IG n = 102; CG n = 66).	±42 y	6 m	Dietary intake ✓x	↑ Fiber (g/10 MJ), %E in carbohydrate; ↓ fat (g/day), ↓ saturated fat (g/day), ↓ fat (%E/day), ↓ cake and sweets (g/day and g/10 MJ).	Energy (kJ), protein (%E/day), added sugar (g/day and g/10 MJ), fiber (g/day), F&V (g/day and g/10 MJ), potatoes (g/day and g/10 MJ).
Lee et al.; 2018.	Cluster RCT; multilevel intervention.	Community (after-school programs)	USA	20 after-school programs (IG n = 10; CG n = 10) and 400 students (IG n = 188; CG n = 212).	≥5 y	9 m	Dietary intake ✓ (for on-site food services)	↑ whole grains (servings), ↑ F&V (servings); ↓ ounces 100% juice, ↓ foods with trans fats (servings), ↓ food and beverage calories (servings).	-
Martínez-Donate et al.; 2015.	Pilot RCT; food environment restaurant and food store-based intervention.	Community (food stores and restaurants)	USA	14 restaurants (IG n = 7; CG n = 7), 4 food stores (IG n = 2; CG n = 2), 721 restaurant customers (IG n = 319; CG n = 402) and 601 food store customers (IG n = 299; CG n = 302).	N/A	10 m	Food purchase x	-	% of restaurant orders, % of food store. purchases.
							Food availability x	-	Restaurant and food store nutrition environment (NEMS-R NEMS-S).
Morshed et al.; 2016.	Cluster RCT; multilevel obesity-prevention intervention.	School (childcare centers)	Mexico	16 childcare centers (IG n = 8; CG n = 8) and children (n = N/A).	3 y	2 y	Food availability ✓x	↓ Daily grams of fat from milk.	Fruit (servings), vegetables (servings), whole grains (servings), discretionary fat (grams), added sugar (teaspoons).
Muzaffar et al.; 2019.	Cluster RCT; peer education intervention.	Community (after-school programs)	USA	7 school groups (peer-led IG n = 4; adult-led CG n = 3) and 101 children (IG n = 49; CG n = 52).	11–14 y	3 m	Dietary intake ✓x	↑ Whole grains (servings).	Total kcal/day, fruits (servings), vegetables (servings), total fat/sugar/fiber/salt (g).
Nathan et al.; 2016.	RCT; multicomponent intervention.	School	Australia	53 schools (IG n = 28; CG n = 25) and 499 students (IG mean n = 232; CG mean n = 267).	5–12 y	9 m	Food availability ✓	↑ Menu with no red/banned items, ↑ menu with >50% of green items.	-
Ochoa-Avilés et al.; 2017.	Cluster RCT; curriculum and environment-based intervention.	School	Ecuador	20 schools (IG n = 10; CG n = 10) and 1430 students (IG n = 702; CG n = 728).	12–14 y	28 m	Dietary intake ✓x	↑ F&V (g); ↓ added sugar (g), ↓ unhealthy snacking (g).	Unhealthy snacking at school (proportion difference), breakfast intake (proportion difference), fat (%E/day).

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Rosmawati et al.; 2017.	Cluster RCT; school-canteen intervention.	School	Malaysia	16 schools (IG $n = 8$; CG $n = 8$) and 110 food handlers (IG $n = 52$; CG $n = 58$).	18–55 y	6 w (+12 w follow-up)	Food availability ✓x	↑ Milk and milk products (% served food).	% served food: carbohydrate, protein, fat, added sugar, vegetable, fruits, forbidden and not recommended foods, fast foods.
Seward et al.; 2017.	RCT; multistrategy intervention.	School (childcare centers)	Australia	45 childcare centers (IG $n = 25$; CG $n = 20$), canteen cooks (IG $n = 25$; CG $n = 20$), and 243 students (IG $n = 129$; CG $n = 114$).	N/A	6 m	Food availability ✓	Servings of: ↑ vegetables, ↑ fruit, ↑ breads and cereals, ↑ meat and alternatives, ↑ dairy; ↓ discretionary foods (unhealthy).	-
							Dietary intake ✓x	↑ Vegetables (servings), ↑ fruit (servings).	Servings of: breads and cereals, meat, dairy, discretionary.
Siega-Riz et al.; 2011.	Cluster RCT; school-based intervention.	School	USA	42 schools (IG $n = 21$; CG $n = 21$) and 3908 students (IG $n = 1964$; CG $n = 1944$).	10–14 y	30 m (five school semesters)	Dietary intake ✓x	↑ Fruit (g), ↑ water (g).	Energy (kcal), carbohydrates (g), protein (g), fat (g), fiber (g), grains (g), vegetables (g), legumes (g), sweets (g), sweetened beverages (g), fruit juice (g), fat and whole milk (g), 1% fat milk (g).
Souza et al.; 2013.	Cluster RCT; nutrition educational intervention.	School	Brazil	20 schools (IG $n = 10$; CG $n = 10$), 95 school lunch chefs (IG $n = 47$; CG $n = 48$) aged ±46 years, and students (n = N/A).	N/A	7 m	Food availability x	–	kg/child of: sugar, donuts, milky coffee, banana cereals, chocolate cereals, chocolate milk, powdered milk, cake mix.
							Dietary intake x	–	Energy (kcal), carbohydrates (%), lipid (%), protein (%), % energy derived from sugar/sweets/sugary drinks, portions/day of added sugar/sugary drinks/sweets.

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Story et al.; 2003.	RCT; multicomponent multicenter intervention.	School	USA	41 schools (IG $n = 21$; CG $n = 20$) and 1700 students (IG/CG n = N/A).	7–9 y	3 y	Food availability ✓x	↑ % energy from carbohydrates; ↓ % energy from total fat and saturated fat.	Total calories (kcal), total fat (g), saturated fat (g), protein (g), % energy from protein, carbohydrates (g), total sugars (g), sucrose (g), dietary fiber (g), sodium (mg).
Taylor et al.; 2017.	Pilot RCT; multicomponent intervention.	School	USA	2 schools (IG $n = 1$; CG $n = 1$) and 294 students (IG $n = 161$; CG $n = 133$).	9–10 y	9 m	Dietary intake ✓x	↑ Vegetable (cups).	Fruit (cups).
							Food purchase x	-	Vegetable (cups), fruit (cups).
Thorndike et al.; 2016.	RCT; 3-arm social norm intervention.	Workplace (hospital cafeteria)	USA	1 hospital and 2672 employees (feedback-only IG-A $n = 877$; feedback-incentive IG-B $n = 925$; CG $n = 870$).	≥18 y	3 m	Food purchase ✓(IG-B); x (IG-A)	↑ Green menu items (%) (IG-B).	Green menu items (IG-A) (%).
Trude et al.; 2018.	Cluster RCT; multilevel and multicomponent intervention.	Community (recreation centers including wholesalers, corner stores and carryout restaurants)	USA	30 recreation center zones (IG $n = 14$; CG $n = 16$) and 401 child–caregiver dyads (IG $n = 209$; CG $n = 192$).	9–15 y	14 m	Dietary intake ✓x	↓ % kcal from sweets (13-15y).	Total daily caloric intake, sugary beverages (kcal), fruit punch (ounces), dietary total sugar (g), dietary sodium (mg), fruit (total cups), vegetable (total cups), fat (servings) (9–15y); % kcal from sweets (9–12y).
							Food purchase ✓x	↑ healthier foods and beverages items per week (9–12y); ↑ unhealthy foods and beverages items per week (9–12y).	Healthy and unhealthy foods and beverages items per week (13–15y).
Warren et al.; 2003.	Pilot RCT; 4-arm school and family-based intervention.	School	UK	3 schools and 218 students (Eat Smart IG-A $n = 56$; Play Smart IG-B $n = 54$; Eat/Play Smart IG-C $n = 54$; Be Smart CG $n = 54$).	5–7 y	5 m	Dietary intake x (IG-A, IG-B, IG-C)	–	Weekly portion frequency of: vegetables, salads, fresh fruit, other fruit, confectionery, crisps (IG-A, IG-B, IG-C).

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Webb et al.; 2011.	Pilot RCT; menu labeling intervention.	Workplace (hospital cafeteria)	USA	6 cafeterias (menu board plus poster labeling IG $n = 2$; CG $n = 2$) and 554 customers (IG $n = 334$; CG $n = 220$).	>18 y	2 m	Food purchase ✓x	↑ % target side dishes (healthy), ↑ % target snacks (healthy).	% target entrées (healthy) (data N/A).
Wolfenden et al.; 2015.	Cluster RCT; multicomponent intervention.	Community (sporting clubs)	Australia	85 sporting clubs (IG $n = 42$; CG $n = 43$) and 1394 club members (IG $n = 689$; CG $n = 705$).	±34 y	2.5 y	Food availability ✓x	↑ F&V availability and promotion (%, n).	Non sugar-sweetened beverages (%, n).
							Food purchase ✓	↑ F&V (%, n items purchased), ↑ no sugar-sweetened beverages (%, n items purchased).	-
Wolfenden et al.; 2017.	RCT; multistrategic intervention.	School	Australia	70 schools (IG $n = 35$; CG $n = 35$) and 509 students (IG mean $n = 256$; CG mean $n = 253$).	5–12 y	12/14 m	Food availability ✓	↑ Menu with no red/banned items, ↑ menu with >50% of green items.	-
							Food purchase ✓x	↓ Total fat (g).	Energy (kJ), sodium (mg).
Wyse et al.; 2019.	Cluster RCT; online menu choice architecture intervention.	School	Australia	6 schools (IG $n = 3$; CG $n = 3$) and 1938 students (IG $n = 1203$; CG $n = 735$).	4–12 y	4 w	Food purchase x	-	% lunch orders containing target items (Fruit & Vegetable), % lunch order items that are target items (Fruit & Vegetable).
Yoong et al.; 2016.	RCT; multicomponent intervention.	School	Australia	72 schools (IG $n = 36$; CG $n = 36$) and 426 students (IG mean $n = 216$; CG mean $n = 210$).	5–12 y	12 m	Food availability ✓x	↓ % of red items in the menu.	Menus with no red or banned foods and beverages, menus with >50% of green items, % of amber, and green items.
Yoong et al.; 2019.	Cluster RCT; food service multistrategy intervention.	School (childcare centers)	Australia	28 childcare centers (IG $n = 15$; CG $n = 13$), 395 students (IG $n = 220$; CG $n = 175$) and 28 cooks (IG $n = 15$; CG $n = 13$).	2–5 y	6 m	Dietary intake ✓x	↑ Vegetables (servings), ↑ whole grain cereals (servings), ↑ meat/meat alternatives (servings).	Fruit (servings), dairy/dairy alternatives (servings).

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Yoong et al., 2020.	Cluster RCT; web-based menu-planning intervention.	School (childcare centers)	Australia	35 childcare centers (IG/CG n = N/A) and 220 children for baseline dietary data observation (IG n = 112; CG n = 108).	2–6 y	12 m	Dietary intake ✓x	↑ Fruit (servings), ↑ dairy and alternatives (servings); ↓ cereals and bread (servings), ↓ discretionary foods (unhealthy) (times consumed).	Vegetables (servings), meat and alternatives (servings).
Bell et al.; 2014.	Non-RCT; implementation intervention.	School (childcare centers)	Australia	431 childcare centers (IG n = 240; CG n = 191) and 153 children (IG n = 79; CG n = 74).	3–6 y	20 m (+ 5-m follow-up)	Food availability x	↑ Vegetable (servings); ↓ high-fat/salt/sugar food (items), ↓sweetened beverages (items); ↓ fruit (servings).	-
Bogart et al.; 2011.	Pilot non-RCT; obesity-prevention and peer leader advocacy intervention.	School	USA	2 middle schools (IG n = 1; CG n = 1) and 399 students (IG/CG n = N/A).	±13 y	5 w	Food purchase ✓	↑ Fruits (% students served); ↑ healthy entrées (% students served).	-
							Dietary intake x	-	Soda (%students drink), sports/fruit drinks (% students drink).
Burgess-Champoux et al.; 2008.	Pilot non-RCT; multicomponent school-based intervention.	School	USA	2 schools (IG n = 1; CG n = 1) and 150 parent/child pairs (IG n = 67; CG n = 83).	±10 y	3 m	Dietary intake ✓x	↑ WG (servings), ↑ fiber (g); ↓ RG (servings).	Energy (kcal).
Geaney et al.; 2016.	Cluster non-RCT; 4-arm workplace-based intervention.	Workplace	Ireland	4 workplaces (Education IG-A n = 1; Environment IG-B n = 1; Combined IG-C n = 1; CG n = 1) and 517 employees (Education IG-A n = 107; Environment IG-B n = 71; Combined IG-C n = 272; CG n = 67).	18–64 y	±7 9 months (intervention+ follow-up)	Dietary intake ✓x	↓ Salt (g) (IG-C), ↓ saturated fat (g/day for IG-A, IG-C, and %E for IG-B, IG-C), ↓ total sugars (g) (IG-B).	Salt intake (g) (IG-A, IG-B), total energy (kcal), total fat (g/day and %E), saturated fat (g) (IG-B), %E saturated fat (IG-A), total sugars (g) (IG-A, IG-C), fiber (g) (IG-A, IG-B, IG-C).

Table 2. *Cont.*

Study	Study Design and Type of Intervention	Setting	Country	Study Samples	Age	Duration [1]	Effectiveness	Between Groups Significance	Between Groups No Significant Changes
Quinn et al.; 2018.	Non-RCT; behavioral economics-based choice architecture intervention.	School	USA	11 schools (IG $n = 6$; CG $n = 5$) and 2245 students (IG $n = 1026$; CG $n = 1219$).	11–18 y	7 m	Dietary intake x (among students who selected)	↑ proportion students consuming fruit (including juice), ↑ fruit items consumed (excluding juice), ↑ vegetables items consumed (including potatoes) in favor of the CG.	Proportion students consuming: fruit (including/excluding juice), vegetables (including/excluding potatoes), low-fat milk; mean number of: fruit (including/excluding juice), vegetables (including/excluding potatoes), low-fat milk.
							Food purchase ✓x	↑ proportion students selecting fruit (including/excluding juice); ↑ fruit items (including/excluding juice).	Proportion students selecting: vegetables (including/excluding potatoes), low-fat milk; mean number of: vegetables (including/excluding potatoes), low-fat milk.
Williams et al.; 2002.	Cluster non-RCT; 3-arm nutrition education and food service intervention.	School (childcare centers)	USA	9 childcare centers (nutrition education IG-A $n = 3$; safety education IG-B $n = 3$; CG $n = 3$) and 1296 students (IG/CG n = N/A).	2–5 y	20 m	Dietary intake ✓x (results of IG-A and IG-B are presented together)	↓ Saturated fat (g), ↓ fat and saturated fat (% kcal), ↑ iron (mg), ↑ magnesium (mg).	Fat (g), kcal, cholesterol (mg), protein (g), fiber (g), calcium (mg), zinc (mg), Vitamin A and Folic Acid and Vitamin B12 (microgram), Vitamin E and C (mg), riboflavin (mg).

The included studies in the present systematic review are sorted in the following table by RCTs and non-RCTs and by alphabetical order. N/A: not available; F&V: fruit and vegetable; WG: whole grain; RG: refined grain. ✓: effective; x: not effective; ✓x: partially effective. [1]: duration in weeks (-w), months (-m) or years (-y).

3.2. General Characteristics of the Included Intervention Studies

The 41 included interventions (Table 2) were based on different study designs: 35 were RCTs [25–29,37–61], and 6 were non-RCTs [62–67]. A total of 3 studies consisted of 4-arm parallel-group conditions [27,57,64] and 4 studies had a 3-arm parallel-group intervention [26,28,49,67].

The included interventions were set in 12 different countries. Most of them were performed in the United States (n = 20) [26–28,37,38,40,48,51,52,55,56,60,61,63,65–70] and Australia (n = 11) [25,39,41,43,45–47,58,59,62,71], while the other studies were conducted in Lebanon [29], Brazil [44], Denmark [50], Malaysia [42], Scotland [53], Belgium [49], Mexico [72], Ecuador [54], Ireland [64], and the UK [57].

3.3. Settings of the Included Studies

The included studies took place in different settings. Twenty-four RCT and 5 non-RCT studies were applied in school settings, specifically in primary and secondary schools [25,27,29,38,41,42,44,46–49,53–55,57,60,63,65,66,68,69,71] or in a childcare service center [39,43,58,59,62,67,72]. Then, 8 RCTs were conducted in community settings, including 1 intervention in sporting clubs [45]; 2 interventions in restaurants [26] and/or food stores [40]; 4 interventions in after-school programs in churches, communities and schools [37,51,52,70]; and 1 intervention in recreation centers, including corner stores, wholesalers and carry-out restaurants [56]. Four interventions, including 3 RCTs and 1 non-RCT, were conducted in workplace settings [28,50,61,64] (Table 2).

3.4. Samples of the Included Studies

The total sample size of the 41 included studies was 35,638 participants (IG: 18,988; CG: 16,650) (Table 2). In particular, there were 16,824 participants in dietary intake interventions (children, school chefs and employees), 9361 participants in food availability interventions (children, school chefs, customers and club members), and 20,019 participants in food purchase interventions (children, employees, club members and customers). The study samples were varied and stratified in terms of sample size (from 28 to 3908 people) and age (children and adults, as reflected by the different settings).

3.5. Intervention Duration

The applied interventions lasted from 1 week to 3 years (Table 2). In particular, in the dietary intake outcome category, 16 interventions lasted less than one year [27,29,43,44,50–53,57,58,63–66,68,69] and 6 interventions lasted up to one year [49,54–56,59,67]. In the food availability outcome category, 6 interventions lasted less than one year [38,40–44] and 8 interventions lasted up to one year [37,39,45–48,62,72]. In the food purchase outcome category, 13 interventions lasted less than one year [25–29,40,60,61,65,66,69–71] and 3 interventions lasted up to one year [45,46,56].

3.6. Intervention Type

The intervention type was based on the strategies used. Each intervention applied different consumer-based and establishment-based strategies to achieve the evaluated outcome (Table 3). In particular, 3 consumer-based strategies were used to provide support, information and education (defined as a, b, and c) to consumers to improve their healthy food choices. Nine establishment-based strategies (defined as d to l) were applied for the improvement of the nutrition environment, including implementing menus offering healthier options and increasing the knowledge of restaurants and food service staff about healthy nutrition. Based on the strategies used in effective interventions, strategy recommendations were derived according to the outcome and setting applied (Table 4).

Table 3. Effectiveness of the strategies used in the included intervention studies.

Setting	Studies	Outcome Categories					
		Food Availability		Dietary Intake		Food Purchase	
		Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies
School	Anderson et al.; 2005.			✓x a, b, c	✓x d		
	Bogart et al.; 2014.					✓x a, b, c	✓x d, h, i, k
	Cohen et al.; 2014.		✓x e, f, g				
	Cohen et al., 2015.				✓x (IG-A, C) x (IG-B) IG-A: d, f, g; IG-B and IG-C: d, f, g, i		✓x (IG-A, B, C) d, f, g, i
	Delaney et al.; 2017.						✓x d, i, h, k
	Grady et al., 2020		✓x e				
	Habib-Mourad et al.; 2014.			✓x a, b, c	✓x d	✓x a, b, c	✓x d
	Haerens et al.; 2006			✓x (girls), x (boys) IG-A, B: a, b IG-A: c	✓x (girls), x (boys) IG-A, B: d, e, f, g, h		
	Kenney et al.; 2015.			✓x a	✓x d		
	Morshed et al.; 2016.	✓x a, b, c	✓x d, e, f, g, k				
	Nathan et al.; 2016.	✓ c	✓ d, e, f, g, h, j				
	Ochoa-Avilés et al.; 2017.			✓x a, b, c	✓x e, f		
	Rosmawati et al.; 2017.		✓x e, f, g				
	Seward et al.; 2017.		✓ d, f, g, h		✓x d, f, g, h		

Table 3. *Cont.*

Setting	Studies	Outcome Categories					
		Food Availability		Dietary Intake		Food Purchase	
		Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies
	Siega-Riz et al.; 2011.			✓x a, b, c	✓x d		
	Souza et al.; 2013.		x e, f		x e, f		
	Story et al.; 2003.		✓x e, f, g, j				
	Taylor et al.; 2017.			✓x a, b, c	✓x d, e, j	x a, b, c	x d, e, j
	Warren et al.; 2003.			x IG-A and C: a, b, c; IG-B: b, c	x IG-A, B, C: j		
	Wolfenden et al.; 2017.	✓ c	✓ d, e, f, g, h, j			✓x c	✓x d, e, f, g, h, j
	Wyse et al.; 2019.						x g, i
	Yoong et al.; 2016.		✓x d, e, g, h				
	Yoong et al.; 2019.				✓x e, f, g, h		
	Yoong et al., 2020.				✓x e, f, g, h		
	Bell et al.; 2014.	x a, c	x e, f, g, h, j				
	Bogart et al.; 2011.			x a, b	x d, f, i, j	✓ a, b	✓ d, f, i, j
	Burgess-Champoux et al.; 2008.			✓x a, b, c	✓x d, f, g, h		
	Quinn et al.; 2018.				x d, e, f, g, i, j		✓x d, e, f, g, i, j
	Williams et al.; 2002.				✓x IG-A, B: d, f		

Table 3. *Cont.*

Setting	Studies	Outcome Categories					
		Food Availability		Dietary Intake		Food Purchase	
		Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies	Consumer-Based Strategies	Establishment-Based Strategies
Community	Ayala et al.; 2017.					x a	x d, f, g, h, i
	Beets et al.; 2016.		x d, f, g				
	Giles et al.; 2012					✓x c	✓x d, e, f, g, h, j
	Lee et al.; 2018.			✓ a, b, c	✓ d, e, f, g, h, j		
	Martínez-Donate et al.; 2015.	x a, b	x d, g, i			x a, b	x d, g, i
	Muzaffar et al.; 2019.			✓x a, b	✓x e, j		
	Trude et al.; 2018.			✓x a, b, c	✓x f, i, j	✓x a, b, c	✓x f, i, j
	Wolfenden et al.; 2015.	✓x a	✓x d, e, f, g, h, i, j, l			✓ a	✓ d, e, f, g, h, i, j, l
Workplace	Lassen et al.; 2010.			✓x a, b	✓x d, e, f		
	Thorndike et al.; 2016.					x(IG-A), ✓(IG-B) IG-A and B: a	✓(IG-B) IG-B: l
	Webb et al.; 2011.					✓x a	✓x i, k
	Geaney et al.; 2016.			✓x (IG-A, B, C) IG-A and C: a, b	✓x (IG-A, B, C) IG-A: g, k; IG-B: d, g, i, l; IG-C: d, g, i, k, l		

The included studies in the present systematic review are sorted in the following table by RCTs and non-RCTs and by alphabetical order. ✓: Effective; x: Not effective; ✓x: Partially effective. Consumer-based strategies: (a) provision of promotional/educational materials in the form of leaflets, posters, manuals, emails and messages directed to consumers; (b) organization of workshops/lessons/meetings/activities for customers; and (c) participants' family involvement through letters, meetings, and activities in school canteen-based interventions. Establishment-based strategies: (d) implementation of a menu with healthier options and limitation of the unhealthier ones, including meal portion-size control and nutrient-content limitations; (e) provision of promotional/educational materials in the form of leaflets, posters, manuals, emails and messages directed to the restaurant and canteen staff; (f) training of the restaurant and canteen managers and chefs; (g) professional on-site and remote support; (h) performance monitoring and feedback reports for the restaurants and canteens; (i) point-of-purchase strategic food positioning, attractive packaging, prompts, menu inserts, and symbols; (j) monetary incentives/rewards/recognition for the participating restaurants and canteens; (k) food labeling information (i.e., traffic light system), and (l) price discounts for customers. The strategies shown in this table are derived from the recommendations in Table 4.

Table 4. Strategy recommendations derived from effective interventions included in the systematic review.

Setting	Outcome Categories		
	Food Availability	**Dietary Intake**	**Food Purchase**
School	The involvement of the students' families, as a consumer-based strategy, together with the application of multiple establishment-based strategies, seemed to be effective in improving food availability in the school setting.	The application of consumer-based strategies together with the implementation of a menu with healthier options and limitation of the unhealthier ones, applied alone or in combination with other establishment-based strategies, seemed to be effective in improving dietary intake in the school setting. On the other hand, the provision of monetary incentives/rewards/recognition for the participating school canteen was not effective.	The application of consumer-based strategies together with the implementation of a menu with healthier options and limitation of the unhealthier ones, applied alone or in combination with other establishment-based strategies, seemed to be effective in improving food purchases in the school setting.
Community	No recommendation can be provided about both consumer- and establishment-based strategies.	The application of consumer-based strategies, together with establishment-based strategies such as the provision of monetary incentives/rewards/recognition for the participating restaurant or canteen, seemed to be effective in improving dietary intake in the community setting.	The application of multiple establishment-based strategies, including monetary incentives/rewards/recognition for the participating restaurant or canteen, seemed to be effective in improving food purchases in the community setting.
Workplace	Outcome not evaluated.	The application of consumer-based strategies together with the implementation of a menu with healthier options and limitation of the unhealthier ones, as an establishment-based strategy, seemed to be effective in improving dietary intake in the workplace setting; however more evidence is needed.	No recommendation can be provided about both consumer- and establishment-based strategies.

These recommendations are based on the interventions included in the present systematic review, as shown in Table 3.

3.7. Outcomes

The 41 included interventions were analyzed for one or more of the three outcomes identified and mentioned above: (1) 22 interventions (17 RCTs and 5 non-RCTs) aimed to improve customers' dietary intake regarding the consumed food and beverage items and the nutritional composition of food in terms of micro- and macronutrients [27,29,43,44,49–59,63–69]; (2) 14 interventions (13 RCTs and 1 non-RCT) aimed to increase healthy food offerings on menus [37–48,62,72]; and (3) 16 interventions (14 RCTs and 2 non-RCTs) aimed to increase the population's healthy food purchases [25–29,40,45,46,56,60,61,65,66,69–71] (Table 2).

3.8. Dietary Intake Outcome Category

A total of 11 of the 22 interventions targeting dietary intake outcome [27,29,43,52,57–59,65,66,68,69] presented results on the population's food and beverage intake. On the other hand, 2 interventions [64,67] presented results on the population's nutrient intake, and 9 interventions assessed both food and beverage intake and nutrient intake [44,49–51,53–56,63] (Table S2).

Among these 22 interventions focused on dietary intake, (a) 1 intervention effectively improved children's dietary intake for all the measured variables by increasing healthy food items and decreasing unhealthy ones [52]; (b) 17 interventions were partially effective in changing the population's dietary intake of some of the evaluated healthy or unhealthy menu items and nutrients (sugar, fat, saturated fat, energy and sodium) [27,29,43,49–51,53,56,58,59,63,64,67–69], of which 2 studies were partially effective only in some of the evaluated IGs [27,49]; and (c) 4 interventions reported no effectiveness for any of the evaluated variables [44,57,65,66] (Table 2).

One effective intervention was set in a community setting as an after-school program and lasted 9 months [52]. Among the 17 partially effective interventions, 2 were implemented in workplace settings, 2 in community settings and 13 were implemented in school settings, and they lasted from 3 weeks to 30 months [27,29,43,49–51,53,56,58,59,63,64,67–69].

3.9. Food Availability Outcome Category

A total of 3 RCTs of the 14 interventions that targeted food availability outcome [41,46,47] presented results of the analysis of menu offerings in school canteens (no "red" or banned food items and >50% "green" food items). The other 11 interventions (10 RCTs and 1 non-RCT) [37–40,42–45,48,62,72] presented food availability results in relation to the increase or decrease in healthy items (fruits and vegetables, unsweetened beverages, water, whole grains, etc.) or unhealthy items (high-fat, high-energy, high-sugar and high-sodium foods) on the menus of restaurants and canteens, and 3 of these studies also evaluated changes in the availability of nutrients [42,44,48] (Table S2).

Among these 14 interventions focused on food availability, 3 interventions effectively improved food availability for all the measured variables by increasing menu offerings of healthy food and beverage items and decreasing the offerings of unhealthy ones in the IG compared to the CG [41,43,46].

On the other hand, 7 interventions were partially effective by significantly changing the availability of only some of the evaluated variables, which were healthy/unhealthy food items offered on the menu, in favor of the IG [38,39,42,45,47,48,72]. Furthermore, 4 intervention studies reported no positive changes for any of the evaluated variables or reported negative changes for some variables in favor of the IG [37,40,44,62] (Table 2).

The 3 food availability interventions that were totally effective [41,43,46] were conducted in school settings, namely primary and secondary schools, and lasted from 6 to 14 months. On the other hand, among the 7 partially effective interventions, 1 was implemented in the community and 6 were implemented in schools, and they lasted from 1 week to 3 years [38,39,42,45,47,48,72].

3.10. Food Purchase Outcome Category

Among the 16 interventions targeting food purchase outcomes [25–29,40,45,46,56,60,61,65,66,69–71], (a) 13 presented results on food and beverage items purchased in restaurants and food service establishments by customers [26–29,40,45,56,60,61,65,66,69,71], (b) 1 intervention [46] presented results on healthy purchases in terms of food nutrient content, and (c) 2 interventions presented results on both food items and nutrient content [25,70] (Table S2).

Among these 16 interventions focused on food purchases, 3 were totally effective: 2 interventions effectively improved the population's purchase of healthy food items and beverages [45,66], and the other 3-arm intervention reported an increase in "green" food items purchased in only one of the IGs [28]. Another 9 interventions were partially effective in changing the population's food purchase of some of the evaluated healthy or unhealthy menu items, also according to their nutrient content (sodium, sugar, energy) [25,27,29,46,56,60,61,65,70], and the other 4 interventions reported no effectiveness for any of the evaluated variables [26,40,69,71] (Table 2).

Between the 3 totally effective interventions, 1 was implemented in a workplace setting, namely, hospital canteens [28], 1 in the school [66] and 1 a community setting, namely, sporting club canteens [45]; they lasted from 5 weeks to 2.5 years.

On the other hand, of the 9 partially effective interventions, 6 were conducted in school settings, 2 in community settings and 1 in a workplace setting, and they lasted from 5 weeks to 14 months [25,27,29,46,56,60,61,65,70].

3.11. Results of the Meta-Analysis

A total of 16 RCTs [27,41,43,44,46,47,49–53,55,56,58,59,69] and 3 non-RCTs [63,64,67] comprising 20,897 participants in total were included in the meta-analysis for the evaluation of dietary intake and food availability outcomes. For dietary intake outcome, 9 studies (8 RCTs and 1 non-RCT) were included to analyze the increase in servings/day of healthy food items [27,43,51,52,56,58,59,63,69], 5 studies (3 RCTs and 2 non-RCTs) for the increase in the intake of fiber g/day [50,51,55,64,67], 5 studies (3 RCTs and 2 non-RCTs) for the decrease of nutrients g/day [49–51,64,67], 5 studies (3 RCTs and 2 non-RCTs) for the decrease in energy percentage (%E) deriving from fat [49,50,53,64,67], and 7 studies (4 RCTs and 3 non-RCTs) for the decrease of daily caloric intake [44,51,55,56,63,64,67]. For food availability outcomes, 3 RCT studies were included to evaluate the proportion of school canteen menus offering healthier food items by reducing unhealthy items (red or banned items) [41,46,47]. Any intervention study for the food purchase outcome could be included in the present meta-analysis because of the lack of data to be compared. With the exception of food availability, where the studies included presented similar interventions (I^2 statistic = 43%), the forest plots of dietary intake outcome presented high heterogeneity (I^2 statistic $\geq$ 90%). Thus, for dietary intake outcome, the analysis was conducted with randomized and nonfixed effect models, and the results are expressed as weighted mean differences with 95% CIs between the pre- and postintervention values of both the IG and CG. For food availability outcomes, meta-analysis was performed by pooling risk ratios (RRs) using the Mantel–Haenszel method.

3.11.1. Dietary Intake Meta-Analysis

For the dietary intake outcome, the included intervention studies (RCTs and non-RCTs) were effective in increasing +0.24 servings/day of healthy food groups in favor of the IG (95% CI, 0.16 to 0.32; $p < 0.001$; Figure 2), including fruit, vegetables, whole grains, lean meat, and alternatives (poultry, fish, eggs, tofu, seeds, and legumes), dairy food items and alternatives (milk, yogurt, cheese). Specifically, +0.60 servings/day of whole grain (95% CI, 0.30 to 0.90; $p < 0.001$; Figure 2) and +0.21 servings/day of dairy food items and alternatives (95% CI, 0.01 to 0.40; $p = 0.04$; Figure 2) significantly increased in favor of the IG. Moreover, when non-RCTs were excluded from the meta-analysis, the effectiveness was also confirmed (Figure S1). An increase of +0.50 g/day of fiber was also observed in favor of the IG for the analyzed intervention studies (95% CI, 0.08 to 0.92; $p = 0.02$; Figure S1). However, when non-RCTs were excluded from the meta-analysis, the effectiveness was not confirmed (Figure S1). Furthermore, a positive decrease of −4.17 g/day of nutrients such as saturated fat, fat and added sugar (95% CI, −5.43 to −2.92; $p < 0.001$; Figure 3) occurred, favoring the IG. Specifically, −4.64 g/day saturated fat (95% CI, −7.21 to −2.08; $p < 0.001$; Figure 3) and −8.95 g/day fat (95% CI, −14.56 to −3.34; $p = 0.002$; Figure 3) significantly decreased in favor of the IG. However, when non-RCTs were excluded from the meta-analysis, only fat intake could be assessed since at least 3 studies were included and the effectiveness was confirmed (Figure S1).

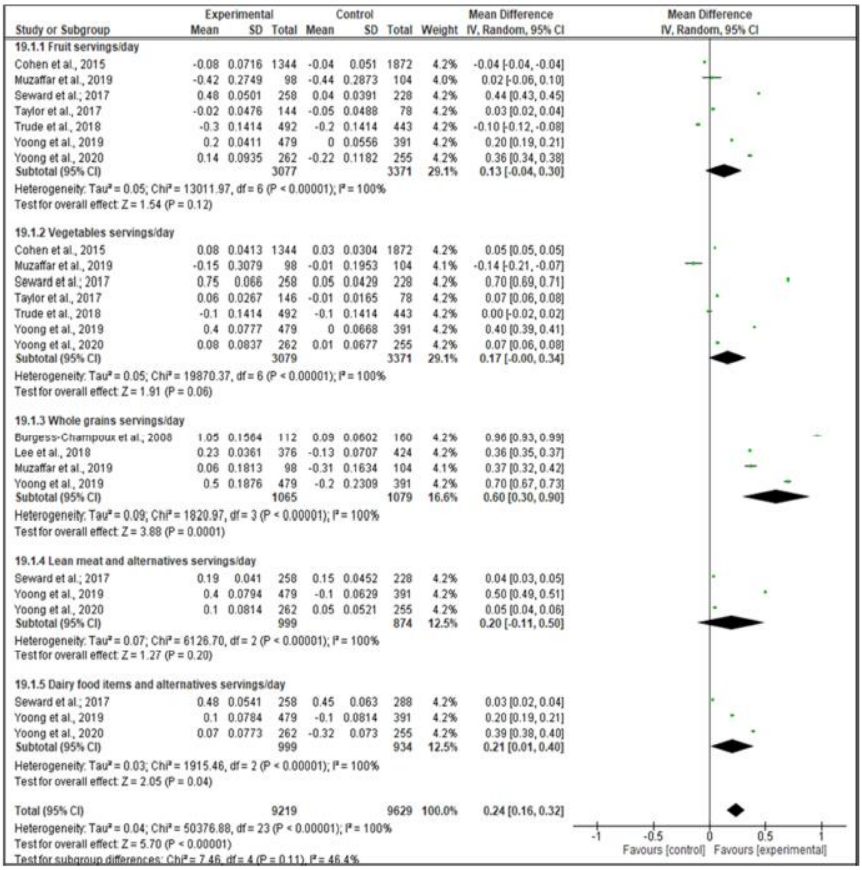

Figure 2. Forest plot of the effectiveness of increasing the dietary intake of healthy food items (servings/day), according to the included intervention studies (RCTs and non-RCTs).

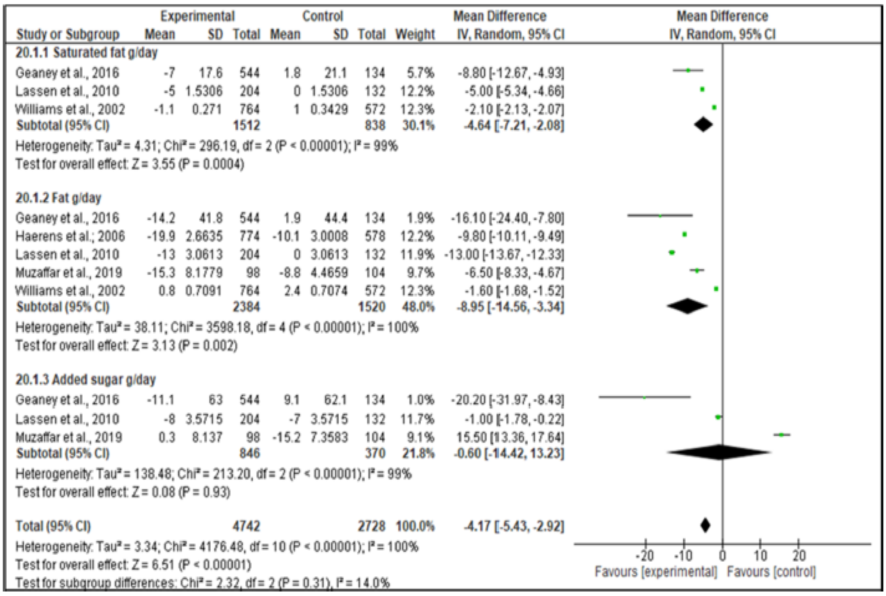

Figure 3. Forest plot of the effectiveness of decreasing the dietary intake of saturated fat, fat and added sugar nutrients (g/day) according to the included intervention studies (RCTs and non-RCTs).

On the other hand, no effectiveness was observed in the overall effect size for the intervention studies aimed at reducing the percentage of caloric intake derived from fat (%E/day) (dietary intake, −3.50; 95% CI, −7.24 to 0.24; $p = 0.07$; Figure S1). Moreover, these results were confirmed when excluding non-RCTs from the meta-analysis (Figure S1).

Furthermore, a significant increase in the daily total caloric intake of +25.59 kcal/day (95% CI, 10.80 to 40.37; $p < 0.001$; Figure S1) was observed in favor of the CG and remained significant in the CG when non-RCTs were excluded from the analysis (Figure S1).

3.11.2. Food Availability Meta-Analysis

Regarding the food availability outcome, the included interventions effectively reduced the risk of intervention schools offering unhealthy items on canteen menus by 47%, labeled red or banned food items and beverages (RR 0.53; 95% CI, 0.34 to 0.85; $p = 0.008$; $I^2 = 43\%$; Figure 4).

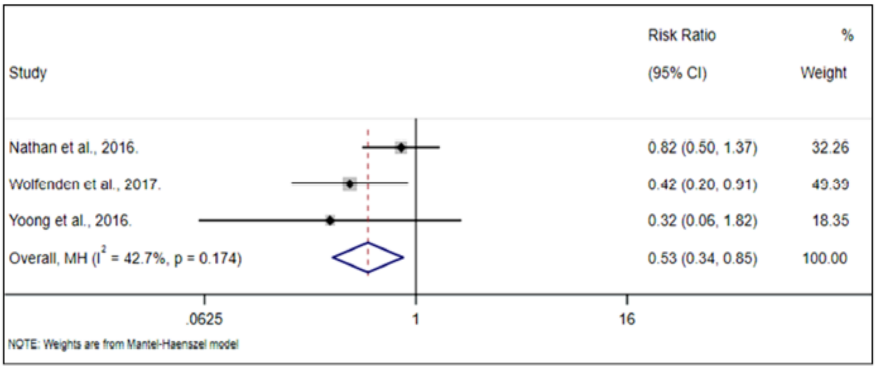

Figure 4. Forest plot of the relationship between the effectiveness of the included interventions (RCTs) and the risk for schools to offer unhealthy items on canteen menus.

3.12. *Quality Assessment Results*

Based on the risk of bias and quality assessment of the included studies, all of the studies were of weak quality, and blinding was not used in any study due to the nature of the intervention (Table S3). Although all 41 studies presented a strong study design, the majority of them had weak selection bias [25–28,37,40–42,45,48,49,51,53,54,56,61,63,66,67,69,71,72], weak confounders [25–29,38–43,45,48,51,53,57–61,63,64,66–69,71], and weak data collection methods [25–29,37–40,42,44–48,50–56,59–62,66–72]. Additionally, regarding withdrawals and dropouts, studies presented mixed results with 16 weak [26,27,37,38,40,42,48,50,51,53,55,61,62,65,67,72], 12 moderate [43,47,49,52,54,56,58–60,64,66,69], and 13 strong [25,28,29,39,41,44–46,57,63,68,70,71] (Table S3).

Since all the studies included in the systematic review had weak quality, the meta-analysis was performed considering RCT and non-RCT intervention studies together, and it was repeated by excluding non-RCTs to assure results with higher quality.

4. Discussion

The present systematic review included 41 interventions, 35 RCTs and 6 non-RCTs, and of these, 16 RCTs and 3 non-RCTs were included in the meta-analysis. Eligible interventions were full-service restaurants and canteen-based interventions aimed at increasing dietary intake, food availability, and food purchases in different settings, such as schools, workplaces, and communities. The results from the present systematic review showed that restaurant- and canteen-based interventions are effective in improving healthy dietary intake and food availability, mainly in the school setting, with a beneficial impact on children. However, there is partial evidence for the improvement of food purchases, and more evidence is needed about workplaces and community settings as full-service restaurants. Moreover, when the meta-analysis was performed without considering non-RCT studies, the results were confirmed in dietary intake for increasing healthy food intake and in the reduction of fat intake.

The results are discussed considering systematic review and meta-analysis outcomes because meta-analysis contributes to evaluating the effectiveness of this type of intervention, and systematic review allows us to review the characteristics of interventions with effective results.

The included interventions in the meta-analysis demonstrated effectiveness in increasing the intake of healthy food items (whole grains, dairy products and alternatives) and nutrients such as fiber [27,43,50–52,55,56,58,59,63,64,67,69] mainly in children, demonstrating that schools are a favorable environment for the promotion of healthy dietary intake. Furthermore, an increase in daily caloric intake occurred in favor of the

CG [44,51,55,56,63,64,67], and effectiveness was observed for decreasing the consumption of other nutrients such as saturated fat and fat in the IG [49–51,64,67]. For food availability outcome, the intervention studies included in the meta-analysis were also demonstrated to be effective in reducing the risk, for the intervention schools, of offering unhealthy foods and beverages on canteen menus [41,46,47].

For interventions in the dietary intake outcome category, the present results showed effectiveness mainly in school settings, which was the preferred setting for interventions targeting these outcomes. When targeting children, an important factor to be considered in nutrition interventions is food presentation in terms of color and smell, which should be appetized to trigger food selection and consumption. Thus, repeated exposure to healthier foods presented in attractive ways could help children become more accustomed to and consume it [73]. Focusing on adults, changing dietary habits to achieve a healthier lifestyle is made more difficult by the perceived barriers, such as: lack of cooking skills and willpower; time scarcity; the need to give up one's favorite foods [74]; and social, cultural and economic conditions [75]. However, although the evidence about workplace settings is very limited in the present review, workplace interventions have the potential to change consumers' dietary behavior through the working lifespan [76]. Long-term workplace interventions for approximately one year evidenced an improvement in dietary change among the participants [77], while the included studies in this systematic review lasted less than one year. However, it is important to highlight that published evidence and its quality in workplace programs are suboptimal; thus, this conclusion needs to be verified with high-quality interventions [77].

From the present results, regarding the intervention strategies applied to improve dietary intake, the implementation of establishment-based interventions is different in the three evaluated settings. Specifically, the strategies that showed higher effectiveness in schools were the addition of healthier menu options combined with on-site support, training for the school canteen staff, performance monitoring and feedback reports (Table 4). However, in the community setting, including after school programs and recreation centers, the provision of monetary incentives, rewards, and recognition for the participating food service are effective, while these methodologies are ineffective in schools.

According to the interventions in the food availability outcome category, none of them were set in workplaces, and little evidence resulted in the community setting [45], whereas effectiveness was reported in the school setting [38,39,41–43,45–48,72]. In schools, regarding the intervention strategies applied for food availability outcomes, the involvement of the participants' families, namely students and their parents in school-based interventions, through invitations to meetings, activities and the distribution of information letters, was the most effective consumer-based strategy [41,46,72]. Similarly, in a recent review focusing on family-based interventions to improve children's diets, the family involvement strategy through the provision of information, advice and monitoring was also reported to be effective in improving the food environment of school canteens, demonstrating that parents are an important component when children are targeted [78].

Children's improvements in food availability are important because their adherence persists in adulthood, whereas unhealthy food availability reinforces children's preference for nutrient-poor and ultra-processed foods [79]. The increase in healthy food availability in school settings is directly correlated with healthy food purchases, with the final aim of changing children's dietary intake [80].

On the other hand, the implementation of healthier food availability in the community setting is more difficult due to the barriers stakeholders encounter, such as the lack of demand by customers and the increased cost associated with healthy fresh foods with a short shelf life [81–83], but financial support and resources such as guidelines and training from established associations could help achieve such improvements [81]. Thus, future interventions aimed at increasing the availability of healthier food options in community settings should also target an increase in consumers' demands for healthy meals, as well as assure food services of the low risk of changes in their profits [84].

For the interventions in the food purchase outcome category, partial effectiveness was reported mainly in schools through the implementation of multiple consumer- and establishment-based strategies, including the involvement of participants' families [25,27,29,46,60,65,66]; thus, family certainly has a good influence on children's food selection [85].

On the other hand, little evidence about effective strategies in community and workplace settings was apparent in the present systematic review; however, in community settings such as restaurants and food stores, the provision of information and communication to consumers may not be enough to achieve behavior changes such as the selection of healthier food options [26,40], whereas multiple strategies targeting changes in the food environment could be fundamental for improving customers' food purchases [45].

Moreover, effective consumer- and establishment-based strategies were derived from the included interventions to develop methodological recommendations, by outcome and setting, for the implementation of future restaurant and canteen-based interventions (Table 4). There were some limitations in the present systematic review and meta-analysis. First, the lack of randomized controlled studies in workplace and community settings, such as full-service restaurants, limited the evidence about the adult population and the evaluation of the interventions' effectiveness. Second, the exclusion of fast-foods and chain restaurants in this systematic review and meta-analysis limited the generalizability of the results to other out-of-home settings, but it allowed us to provide specific recommendations for full-service restaurants and canteens. Third, the lack of enough evidence for the different community settings included, such as after-school programs, restaurants, sporting clubs, and recreation centers, made it difficult to detect differences in intervention strategies. Fourth, none of the included studies were set in low-income countries because of the intervention gap in the literature about middle- and low-income countries [86], limiting the inclusivity of a wider target population. Fifth, in the meta-analysis, the wide heterogeneity of the included studies in terms of outcomes and units of measure, and the huge quantity of different outcomes included, as well as the lack of specific numerical data in the articles, made it difficult to compare interventions and reduced the interventions included. Finally, the quality of most of the included studies was assessed to be of weak quality since the majority had no blinding, poor data collection methods, selection bias or confounders.

5. Conclusions

In conclusion, restaurant- and canteen-based interventions demonstrated effectiveness in the improvement of healthy food intake and in the reduction of fat intake and in increasing healthy menu availability, mainly in school settings. For food purchases, a systematic review showed that interventions could be partially effective in improving healthy foods. However, higher-quality RCTs are needed to strengthen the results. Moreover, intervention strategy recommendations were provided for each outcome assessed to increase the effectiveness of restaurant-based interventions implemented.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13041350/s1, Table S1: PRISMA 2009 Checklist; Table S2: Included intervention study results; Table S3: Quality of the included intervention studies; Figure S1: Forest plots of the included intervention meta-analysis.

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Abbreviations

CG: Control Group; F&V: Fruit and Vegetable; IG: Intervention Group; N/A: Not Available; RCT: Randomized Controlled Trials; RG: Refined Grain; WG: Whole Grain.

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STUDY 3:

Potential use of mobile phone applications for self-monitoring and increasing daily fruit and vegetable consumption: A systematized review.

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MDPI

Review

Potential Use of Mobile Phone Applications for Self-Monitoring and Increasing Daily Fruit and Vegetable Consumption: A Systematized Review

Floriana Mandracchia [1,†], Elisabet Llauradó [1,†], Lucia Tarro [1,2,*], Josep Maria del Bas [2], Rosa Maria Valls [1], Anna Pedret [1,2], Petia Radeva [3,4], Lluís Arola [2,5], Rosa Solà [1,2,6,*] and Noemi Boqué [2]

1. Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili, 43201 Reus, Spain; floriana.mandracchia1@urv.cat (F.M.); elisabet.llaurado@urv.cat (E.L.); rosamaria.valls@urv.cat (R.M.V.); anna.pedret@urv.cat (A.P.)
2. Unitat de Nutrició i Salut, Centre Tecnològic de Catalunya, Eurecat, 43204 Reus, Spain; josep.delbas@eurecat.org (J.M.d.B.); lluis.arola@urv.cat (L.A.); noemi.boque@eurecat.org (N.B.)
3. Facultat de Matemàtiques i Informàtica, Universitat de Barcelona, 08007 Barcelona, Spain; petia.ivanova@ub.edu
4. Centre de Visió per Computador, 08193 Bellaterra (Barcelona), Spain
5. Nutrigenomics Research Group, Department of Biochemistry and Biotechnology, Universitat Rovira i Virgili, 43007 Tarragona, Spain
6. Hospital Universitari Sant Joan de Reus, 43204 Reus, Spain

* Correspondence: lucia.tarro@urv.cat (L.T.); rosa.sola@urv.cat (R.S.); Tel.: +34-977-758-920

† F.M. and E.L. contributed equally to this work.

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Abstract: A wide range of chronic diseases could be prevented through healthy lifestyle choices, such as consuming five portions of fruits and vegetables daily, although the majority of the adult population does not meet this recommendation. The use of mobile phone applications for health purposes has greatly increased; these applications guide users in real time through various phases of behavioural change. This review aimed to assess the potential of self-monitoring mobile phone health (mHealth) applications to increase fruit and vegetable intake. PubMed and Web of Science were used to conduct this systematized review, and the inclusion criteria were: randomized controlled trials evaluating mobile phone applications focused on increasing fruit and/or vegetable intake as a primary or secondary outcome performed from 2008 to 2018. Eight studies were included in the final assessment. The interventions described in six of these studies were effective in increasing fruit and/or vegetable intake. Targeting stratified populations and using long-lasting interventions were identified as key aspects that could influence the effectiveness of these interventions. In conclusion, evidence shows the effectiveness of mHealth application interventions to increase fruit and vegetable consumption. Further research is needed to design effective interventions and to determine their efficacy over the long term.

Keywords: mobile app; mHealth; fruits; vegetables; self-monitoring; healthy diet

1. Introduction

The health benefits of consuming fruits and vegetables have been extensively demonstrated. These beneficial effects are attributed to their high contents of fibre, vitamins, minerals and phytochemicals (mainly antioxidants) together with negligible amounts of fat. Increased consumption of fruits and vegetables has been associated with reduced risks of many chronic diseases, such as obesity, cardiovascular diseases, type II diabetes, osteoporosis and certain cancers, as well as all-cause mortality [1,2]. In fact, it was estimated that in 2013, 7.8 million premature deaths worldwide could be attributed to low fruit and vegetable intake [1]. Moreover, adequate intake of fruits and vegetables could avoid approximately 31% of ischaemic heart disease, 19% of stroke, 20% of oesophageal cancer and 19% of gastric cancer cases [3].

Health authorities, such as the World Health Organization (WHO), recommend a daily intake of at least 400 g of fruits and vegetables, which corresponds to 5 servings of 80 g per day [4]. For the purpose of encouraging fruit and vegetable consumption in all women, children and men so they meet the recommended intake, the WHO launched an international programme termed "5 a day", which has been adopted by most national governments, including Spain, France, Germany and the United Kingdom. Similarly, the Dietary Guidelines for Americans advise that one-half of the plate should be fruits and vegetables [5], and Canada's Food Guide recommends including plenty of vegetables and fruits in daily meals and snacks to prevent the risk of heart diseases [6].

International organizations and national governments have set increasing fruit and vegetable intake as a priority. Despite the numerous and diverse public health campaigns implemented in recent decades to promote increased consumption of fruits and vegetables in Western countries, the average intake remains far from these recommendations, reflecting the modest impact of these kinds of interventions. Data from a European Food Safety Authority (EFSA) analysis based on national dietary surveys revealed that only 4 of the European Union (EU) member states reported adequate consumption of fruits and vegetables [7]. The success of the last major campaigns conducted worldwide that intended to increase fruit and vegetable consumption has been reviewed by Rekhy et al. [8], who concluded that these interventions were quite effective in the short term but generally failed over the long term despite the enormous cost and effort they require. Importantly, it is inferred from the same work that the effectiveness of these health programmes is greater when factors such as behavioural changes, goal setting, clear messages and interactive approaches are included.

In recent years, strategies for promoting long-term adherence to different interventions have focused on multidisciplinary approaches. For example, management of weight loss depends on multiple factors, such as behaviour, a cognitive component, personality traits and even the patient-therapist interaction [9]. This multifaceted approach has been proven successful for weight loss maintenance over the long term (up to 42 months) by means of coaching strategies [10]. Integrative health coaching conducted by telephone calls has been used as a tool for enhancing treatment outcomes in type 2 diabetic patients, who are able to improve their adherence to medication and glycated haemoglobin, a marker of long-term blood glucose levels [11]. Johnson et al. showed that health coaching delivered by videoconference was an effective strategy for reducing weight and ameliorating insulin-resistance markers in obese individuals [12]. Overall, health coaching and behavioural changes have arisen as key elements for achieving substantial and long-term adherence to healthy habits. Therefore, such approaches represent a promising strategy for increasing the consumption of fruits and vegetables.

In this scenario, current advances in information and communication technologies (ICTs), also known as eHealth [13], might provide a wide array of supportive tools, allowing a wide deployment of coaching and behavioural change strategies to the general population. Importantly, it is inferred from the same work that the effectiveness of these health programmes is greater when factors such as self-monitoring, goal setting, clear messages and interactive approaches are included. MHealth applications, which are used on mobile phones and wireless devices, such as tablets, personal digital assistance (PDA) devices, and so on, could be a better method to improve people's lifestyles [13] than traditional face-to-face education methods [14]. The mHealth App Developer Economics study showed an increase of 25% year-to-year from 2015 to 2017 of the number of mHealth applications [15]. Moreover, from the mHealth Economics report, an increase from 2.1 billion smartphone users in 2016 to 2.5 billion in 2019 [16] is expected. Mobile technologies allow interactions with users in real-time and the delivery of health interventions at any time [17] and can act in different environmental and behavioural contexts [17]. Mobile technologies have been demonstrated to be a valid tool for dietary self-monitoring [18]. Toro-Ramos et al. showed that using a mobile phone application that provides nutritional and behavioural education together with coaching promoted clinically significant long-term weight loss, reduced blood glucose levels and improved different lipid markers in overweight and obese individuals [19]. There are several basic mobile and web journaling applications that allow users to set weight-loss goals, collect daily calorie target chart data to reflect trends over time, and record food consumption and exercise levels. The indicative paradigms of journaling applications are weight management applications, such as Weightbot© (2017 Meeco Labs, Linz, Austria), LoseIt© (2008–2019 FitNow, Inc, Saint Honoré, Paris), InsideTracker© (2009–2019 Segterra, Inc, Cambridge, MA, U.S.A.), FoodLog© (2013 foo.log, Inc, Tokyo, Japan), Cronometer© (2011–2019, Cronometer.com, Revelstoke, BC, Canada), MyFitnessPal© (2009–2019 MyFitnessPal, Inc, San Francisco, CA, U.S.A.), MyPlate© (2017 LIVESTRONG.COM, Santa Monica, CA, U.S.A.), EasyFit© (2016 Cellularline, Reggio Emilia, Italy), FatSecret© (2019, FatSecret, Victoria, Australia), MyNetDiary© (2018 MyNetDiary Inc, Marlton, NJ, U.S.A.), and so on, which enable the user to enter weight and body composition measurements, visualize curves, superimpose trends and track progress. Following standard paper-based analogues to obtain information on nutrition habits, mobile applications provide electronic forms and efficient interfaces to assist in logging food intake and beverages in terms of types, meal courses, total meal calories, recipes, photos, and so on. These applications calculate energy intake and balance, report additional parameters and visualize summaries [20]. Three systematic reviews demonstrated the efficacy of mHealth applications to prevent obesity in young people [21–23], but there is a lack of scientific evidence of the effects on fruit and vegetable consumption, while the majority of published studies focus on weight management and physical activity improvement [24]. Thus, new technologies represent a promising opportunity in fields such as nutrition and health monitoring [25–27].

Increasing and improving the consumption of fruits and vegetables in the general population represents a challenge for public health that has not yet been resolved. ICTs might represent an opportunity to achieve this objective. Therefore, we conducted a systematized review of the last 10 years to assess whether interventions based on mobile phone applications result in positive outcomes and to identify the main weaknesses of the different approaches used to date.

2. Materials and Methods

The present paper is a systematized review and has some characteristics of a narrative review and some of a systematic review [28].

2.1. Search Strategy

Article searches were limited to a recent time range of 10 years, considering that the use and availbility of mobile phone applications, which are the key tools evaluated in the present review, increased only a few years ago, starting from 2007, when they appeared on the market. In this sense, there is a lack of published trials on the use of mobile phone applications for health interventions before 2010 [29–31]. This systematized review was based on two electronic databases: PubMed and Web of Science. The search strategy involved peer-reviewed and English-language articles. For the search strategy, the following keywords were used separately or in combination: 'Self-monitoring' AND 'Fruit and Vegetables' OR 'Healthy meals', 'Fruit and vegetables' AND 'Mobile health applications' OR 'eHealth' OR 'mHealth' OR 'Mobile technology', and 'Mobile phone applications' AND 'Fruit and Vegetables'.

2.2. Selection Criteria and Data Collection

The PubMed and Web of Science databases were searched, resulting in a total of 1208 articles, as shown in the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram for systematic reviews and meta-analysis (Figure 1); of these articles, 228 were found in

MEDLINE (PubMed) and 980 in Web of Science. During the screening of possible articles, the reference lists of the full-text articles were assessed for eligibility and cross-checked; it was decided to evaluate articles from these lists when they focused on the same outcome, resulting in the identification of 14 articles for further screening. The titles and abstracts of the 1222 total articles were screened by two researchers (F.M. and E.L.) to determine if they fulfilled the eligibility criteria. The articles had to include clinical trials and other experimental studies designed to develop, test or validate a mobile phone application for dietary self-monitoring in which fruit and/or vegetable intake was one of the principal outcomes (primary and/or secondary). Studies including other health concerns (physical activity, weight control, sugar-sweetened beverage intake, takeout meals, dietary habits, etc.) were included, and no limitations were made in terms of the type of population (gender, age, race, health status). Studies using web-based self-monitoring technologies were excluded, which focused the search on mobile phone applications only. This selection process was performed by two reviewers (F.M. and E.L.). In cases of discrepancy, a third reviewer (L.T.) was consulted.

Following the screening, 1196 articles were excluded on the basis of their title or abstract. The remaining 26 articles were subjected to a detailed examination of the abstract to determine their eligibility on the basis of the inclusion criteria. Of these, 18 were excluded due to the type of technology tool used or lack of results, leaving 8 peer-reviewed papers included in the current review.

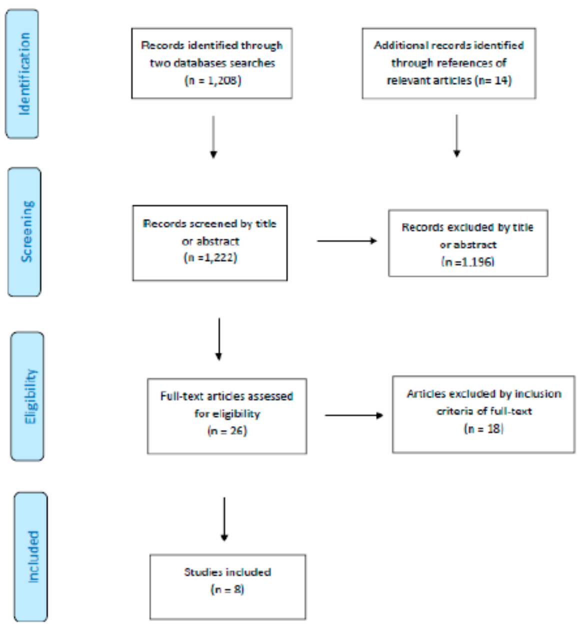

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2009 flow diagram for the systematic review and meta-analysis of the article selection process.

2.3. Data Extraction

Data extraction from the included studies was performed by two reviewers working simultaneously (F.M. and E.L.) and revised by all others. The data extraction tables include the following study variables: name of the article, authors, year of publication, name of the intervention or mobile phone application, country, type of intervention, objective, intervention duration, number of participants, population, description of the mobile phone application (name and measurement of the outcome), brief description of the intervention, results of fruit and vegetable consumption variables, and conclusions of the study.

2.4. Quality of Studies Included

The quality of the included studies was assessed using the standardized framework of the Quality Assessment Tool for Quantitative Studies, developed by the Effective Public Health Practice Project. This tool consists of 8 items: selection bias, study design, confounders, blinding, data collection methods, withdrawals and dropouts, intervention integrity and analysis. This tool allows the categorization of each study's methodological quality as weak (≥2 weak category ratings), moderate (1–3 strong category ratings and 1 weak category rating) or strong (≥4 strong category ratings and no weak category ratings) (Table S1).

3. Results

The systematized search identified 1222 articles, of which eight studies were found to meet the inclusion criteria to be considered in the review (Table S2).

The most relevant characteristics of the data extracted from the included studies are presented in Table 1 and Table S2: Relevant information regarding the data extracted from the included studies.

The eight studies included were randomized controlled trials (RCTs) [32–39], one of which was a pilot study [32], and included a total of 1524 participants at baseline. Additionally, the participants covered a large age range, from 16 to 71 years, and one of the interventions was conducted through parents, although the target population was children. In the vast majority of cases, the participants did not present any disease. Most of the studies were conducted in the United States (n = 4), followed by Australia (n = 2), the Netherlands (n = 1) and Sweden (n = 1).

From the selected studies, two studies aimed to evaluate the effectiveness of mobile phone applications in stimulating both fruit and vegetable intake [34,38], two targeted only vegetable consumption [32,33], three tested whether a multicomponent intervention integrating a mHealth application could improve dietary habits (including the increase of fruit and/or vegetable intake) and physical activity [35,37,39], and only one assessed the effectiveness of a mobile phone application to achieve a healthy weight and healthy body fat percentage by changing daily servings of fruits and vegetables [36].

Moreover, different methodologies were used to improve fruit and/or vegetable intake: (a) three of the studies used personalized informative and motivational messages (text and/or audio) [34,38,39]; (b) seven added personal dietary feedback at a regular frequency [32–38]; (c) three sent push notifications to remind users about their goals [32,33,36]; (d) two provided rewards as incentives [35,37]; (e) three provided remote coaching support through mobile phone calls, emails and in-person meetings [35,37,39]; (f) one offered the possibility of receiving support from a dietitian or a psychologist [36]; and (g) two provided access to further informative material and information through a diet booklet [39] and a mobile phone application [36,39].

Fruit and/or vegetable intake was assessed by the Food Frequency Questionnaire (FFQ) in three RCTs [32–34], by a dietary record in one study [35], by self-monitoring through a mobile phone application in two studies [36,38], and by categorical questions in the other two studies [37,39]. Moreover, the results were expressed as servings, pieces/day or pieces/week of fruits and/or vegetables in six RCTs [32–35,37,38]; grams of fruits and/or vegetables in one RCT [36]; and percentage of participants who consumed ≥2 servings or pieces of fruits and/or vegetables per day in one RCT [39].

Six of the eight studies included were effective in increasing fruit and/or vegetable intake. Of these, five studies [32,33,35,37,39] demonstrated that the interventions were effective for increasing vegetable consumption, and interestingly, all of them included a self-monitoring component implemented by a mobile phone application. Some of the included studies used other methodologies apart from self-monitoring: four used dietary feedback [32,33,35,37] and three provided remote coaching support [35,37,39]. Furthermore, three studies [34,35,37] reported that the interventions were effective for increasing daily fruit consumption. All three mHealth interventions included a self-monitoring component by mobile phone application and personal dietary feedback, while two of them [35,37] provided a financial incentive as a reward and remote coaching support. The increase in intake ranged from +2.4 servings/day to +10.6 servings/day.

Moreover, from the effective interventions identified in the present review, two focused on overweight adults [32,33], three focused on adults with unhealthy lifestyles [34,35,37], and one focused on young adults characterized by unhealthy lifestyles [39].

Half of the included studies considered the improvement of fruit and/or vegetable intake [32–34,38] as the primary outcome, and the other half considered it to be a secondary outcome [35–37,39].

Of the four RCTs that designated increasing fruit and/or vegetable intake as the primary outcome [32–34,38], two were only effective in increasing vegetable intake [32,33], one showed was only effective in increasing fruit intake [34], and the last one presented no improvement [38]. These four RCTs lasted from 2 to 6 months and were population stratified by common characteristics.

Mummah et al. have iteratively developed a theory-driven mobile phone application called Vegethon to increase vegetable consumption through self-monitoring, goal setting, feedback, and social comparison [40]. Vegethon has been tested in two studies: A RCT pilot study [32] and a RCT [33]. The target population of the Vegethon pilot study comprised 17 overweight adults aged 18–50 years [31,32] who were randomized for the use of the Vegethon mobile phone application as the intervention group or to a wait-listed control condition. The intervention group was instructed to use the Vegethon application and encouraged to self-monitor and increase their vegetable intake. At 12 weeks, the results showed that vegetable intake was significantly increased in the intervention group by +7.5 servings/day (from 6.0 $\pm$ 2.7 to 13.5 $\pm$ 8.1) compared with the decrease in the control group of -3.1 servings/day (from 7.0 $\pm$ 5.9 to 3.9 $\pm$ 2.0), resulting in a significant difference of +10.6 servings/day between both groups (p = 0.02). Moreover, as mentioned, the effectiveness of Vegethon in increasing vegetable consumption was also verified in an RCT among 135 overweight adults aged 18–50 years [20]. The intervention was the same as in the pilot study. The intervention group reported an increase of +0.7 servings/day of vegetables (from 6.7 $\pm$ 5.2 to 7.4 $\pm$ 5.4), while the control group reported decreased vegetable consumption of -1.7 servings/day (from 8.1 $\pm$ 8.2 to 6.4 $\pm$ 4.3), resulting in a significant difference of +2.4 servings/day between both groups (p = 0.04). As a result, the Vegethon mobile phone application was effective in improving vegetable consumption.

Table 1. Description of the studies included in the present review.

Reference	Study Design	Duration	Type of Intervention and Target Population	Outcome	Effectiveness	Change in Fruit Consumption	Change in Vegetable Consumption
[32]	Randomized Controlled Pilot Study	3 months	Self-monitored by mobile-phone application. Directed to overweight adults aged 18–50. Total: 17 participants (intervention: n = 8; control: n = 9).	Primary	✔For vegetables	Fruit consumption not measured	**Intervention group:** +7.5 servings/day; **Control group:** −3.1 servings/day; **Difference between groups:** 10.6 servings/day
[33]	Randomized Controlled Trial	2 months	Self-monitored by mobile-phone application. Directed to overweight adults aged 18–50. Total: 135 participants (intervention: n = 68; control: n = 67).	Primary	✔For vegetables	Fruit consumption not measured	**Intervention group:** +0.7 servings/day; **Control group:** −1.7 servings/day; **Difference between groups:** 2.4 servings/day
[34]	Randomized Controlled Trial	6 months	Self-monitored by mobile-phone application, text-based or audio-based health messages. Directed to adults aged 16–71 who had not yet succeeded in consuming the daily recommended fruit and vegetable consumption. Total: 146 participants (intervention: n = 88; control: n = 58).	Primary	✔For fruits x For vegetables	**Textual feedback condition:** −0.6 pieces/ week; **Auditory feedback condition:** +3.3 pieces/week; **Control group:** +0.4 pieces/week; **Differences between Textual-Control:** −0.2; **Differences between Auditory-Control:** 3.7	Non-significant difference
[35]	Randomized Controlled Trial (4-arm parallel groups)	6 months (3 weeks of treatment and 20 weeks of follow-up)	Self-monitored by a PDA, remote coach support and financial incentives. Directed to adults aged 21-60 who eat <5 servings of fruits and vegetables a day, consume ≥8% daily calories from saturated fat; do <150 min/ week of Physical Activity and watch >120 min/ week of leisure screen time. Total: 204 participants (group A: n = 47; group B: n = 48; group C: n = 56; group D: n = 53).	Secondary	✔For fruits and vegetables (only significant improvements in Behaviour C intervention)	**Baseline vs. 3 weeks** **Behaviour A (targeted saturated fat and physical activity):** +0.6 servings/day; **Behaviour B (targeted fruit/vegetable intake and physical activity):** +4.3 servings/day; **Behaviour C (targeted fruit/vegetable intake and sedentary behaviours):** +4.3 servings/day; **Behaviour D (targeted saturated fat and sedentary behaviour):** +0.5 servings/day	

Table 1. *Cont.*

Reference	Study Design	Duration	Type of Intervention and Target Population	Outcome	Effectiveness	Change in Fruit Consumption	Change in Vegetable Consumption
[36]	Randomized Controlled Trial	6 months	Self-monitored, informed and supported by a mobile-phone application, weekly graphic feedback and facultative dietitian contact for further support. Directed to parents of children aged 4.5. Total: 315 participants (intervention: $n = 156$; control: $n = 159$).	Secondary	x For fruits x For vegetables	**Intervention group:** +2.9 ± 78.9 g/day; **Control group:** −12.1 ± 87.9 g/day	**Intervention group:** −6.7 ± 42.1 g/day; **Control group:** −3.6 ± 39.7 g/day
[37]	Randomized Controlled Trial (3-arm parallel groups)	9 months (6 months of treatment and 3 months of post-intervention follow-up)	Self-monitored by a mobile-phone application and an accelerometer, remote coaching by telephone and rewarding financial incentives. Directed to adults aged 18–65 characterized by those who eat <5 servings of fruits and vegetables a day, consume ≥8% daily calories from saturated fat; do <150 min/week of Physical Activity and watch >120 min/week of leisure screen time. Total: 212 participants (intervention A: $n = 84$; intervention B: $n = 84$; control: $n = 44$).	Secondary	✔For fruits and vegetables	**Baseline vs. 6 months** **Group A (Simultaneous):** +6.6 servings/day; **Group B (Sequential):** +7.4 servings/day; **Control group:** +0.5 servings/day.	
[38]	Randomized Controlled Trial (3-arm parallel groups)	6 months	Self-monitored by a mobile-phone application, dietary feedback messages and text messages via mobile-phone. Directed to young adults aged 18–30. Total: 212 participants (intervention A: $n = 84$; intervention B: $n = 84$; control: $n = 44$).	Primary	x For fruits x For vegetables	**Group A:** −0.2 ± 0.1 servings/day; **Group B:** −0.1 ± 0.1 servings/day; **Control Group:** −0.2 ± 0.1 servings/day; **Between group difference in Mean change ($p > 0.05$)**	**Group A:** +0.2 ± 0.1 servings/day; **Group B:** +0.4 ± 0.1 servings/day **Control Group:** +0.4 ± 0.1 servings/day; **Between group difference in Mean change ($p > 0.05$)**
[39]	Randomized Controlled Trial	3 months	Self-monitored and trained by a mobile-phone application, text messages, e-mails, coach calls, diet booklet and access to resources. Directed to young adults aged 18–35 characterized by fruit intake <2 servings/day and vegetable intake <5 servings/day. Total: 248 participants (intervention: $n = 123$; control: $n = 125$).	Secondary	✔For vegetables x For fruits	Non-significant difference	Intervention group: from 34.1% (baseline) to 64.3% (12 weeks) of people consuming ≥2 servings/day; **Control group:** from 36% (baseline) to 48% (12 weeks) of people consuming ≥2 servings/day

✔ Effective in increasing fruit or vegetable consumption (mentioned in the table). x No effective in increasing fruit or vegetable consumption (mentioned in the table).

3.1. Increasing Daily Fruit and/or Vegetable Consumption as the Primary Outcome

The study by Elbert et al. [34] provides evidence-based insight into the effects of a mobile health application in changing fruit and vegetable intake in a 6-month intervention. This study was a 3-arm RCT that included a population of 146 adults aged 16–71 years. The intervention groups (A and B) were exposed monthly to tailored health information and feedback in the form of either (A) an audio-based intervention or (B) a text-based intervention via mobile phone application over a 6-month period. Participants in the control group only completed the baseline and post-intervention measures. After 6 months, the average fruit intake, measured by a food frequency questionnaire, increased by +3.3 pieces/week (from 14.2 ± 10.6 to 17.5 ± 11.1) in intervention group A, whereas in intervention group B, the average fruit intake decreased by −0.6 pieces/week (from 14.8 ± 11.1 to 14.2 ± 6.9), and in the control group, the average fruit intake increased by +0.4 pieces/week (from 13.4 ± 10.4 to 13.8 ± 9.4). However, the intake of vegetables was not improved by these interventions.

In another 3-arm RCT, the Connecting Health and Technology study [38], Kerr et al. aimed to evaluate the effectiveness of tailored dietary feedback and weekly text messaging to improve the dietary intake of fruits and vegetables among other dietary improvements over a 6-month period in a population-based sample of men and women aged 18–30 years. Participants were randomized into three groups: (A) a group that received dietary feedback and weekly text messages, (B) a group that received dietary feedback only and (C) a control group (that received any intervention). Dietary intake was assessed using a mobile food record application in which participants captured images of the foods and beverages they consumed over 4 days at baseline and at 6 months post-intervention. After 6 months of intervention, participants in group B and the control group demonstrated a significantly increased daily intake of vegetable servings (+0.4 ± 0.1, $p = 0.002$ and +0.4 ± 0.1, $p = 0.02$, respectively), while group A demonstrated a significantly decreased daily intake of fruit servings (−0.2 ± 0.1; $p = 0.03$). However, no significant differences between groups in terms of fruit and vegetable intake were observed ($p < 0.05$).

3.2. Increasing Daily Fruit and/or Vegetable Consumption as a Secondary Outcome

Of the four RCTs that designated increasing fruit and/or vegetable intake as the secondary outcome [35–37,39], one revealed that the intervention was effective in both targets [37], two were partially effective [35,39], and the last one was not effective for either of the two targets [36]. These four RCTs lasted from 3 to 9 months, and all of the RCTs were population stratified.

The Make Better Choices (MBC) study [35] was a comparative 4-arm RCT designed to discern the optimal approach to simultaneously target diet and physical activity. The MBC study [35] consisted of a 6-month intervention (3-week intervention and 5-month follow-up) with 204 adults aged 21–60 years who were randomized into one of four behavioural change prescriptions. The MBC study compared four different behaviours: (1) 5 fruit/vegetable servings; (2) saturated fat consumption of less than 8% of total calories; (3) physical activity of at least 60 min/day; and (4) sedentary leisure of less than 90 min/day. The intervention consisted of present and remote coaches accessed by a mobile personal digital assistant (PDA) that tailored the behavioural strategies based on the baseline data of the participants. Moreover, participants received financial incentives when they reached the goals. The two groups targeted to increase fruit and vegetable intake (Group B and Group C) seemed more successful than the other two groups targeted to change other behaviours: Group B increased from 1.3 ± 1.1 servings/day at baseline to 5.6 ± 1.1 servings/day at the end of the intervention, and Group C increased from 1.2 ± 0.9 servings/day at baseline to 5.5 ± 1.0 servings/day at the end of the intervention. The two groups that were not targeted to improve fruit and vegetable intake (Group A and Group D) seemed less successful than the other two groups: Group A increased from 1.1 ± 0.9 servings/day at baseline to 1.7 ± 1.1 servings/day at the end of intervention; Group D increased from 1.4 ± 1.1 servings/day at baseline to 1.9 ± 1.6 at the end of intervention. However, the differences between baseline and the end of intervention regarding fruit and vegetable intake in each group and among groups were not reported by the researchers.

Another study related to the MBC study was the MBC 2 trial [37], a 3-arm RCT that tested whether a multicomponent intervention of 9 months (6-month intervention and 3-month follow-up) integrating a mHealth application, modest incentives and remote coaching could sustainably improve dietary habits and physical activity. Participants were randomly assigned to one of two interventions. Intervention group (A) targeted performing moderate to vigorous physical activity (MVPA) simultaneously with other diet and activity targets, and intervention group (B) targeted the same goals but sequentially. The control intervention group only addressed improving stress and sleep. After 6 months, fruit and vegetable intake increased by +6.6 servings/day in group A (simultaneous), by +7.4 servings/day in group B (sequential) and by +0.5 servings/day in the control group.

In the third study, Partridge et al. [39] performed a 2-arm RCT from a larger mHealth lifestyle program called "TXT2BFiT" to improve dietary and physical activity behaviours among 248 young adults aged 18–35 years who were at high risk for the development of obesity. The intervention group comprised 8 weekly motivational text messages, 5 personalized coaching calls, 1 weekly email, a diet booklet and a mobile phone application that provided education, self-monitoring, access to a community blog and support resource, over 3 months. Control group participants only received 4 text messages and dietary and physical activity guidelines. Intervention participants were more likely to consume greater quantities of vegetables after 3 months compared to control participants ($p = 0.009$). Additionally, at 3 months, the proportion of participants with a vegetable intake of $\geq$2 servings/day increased from 34.1% to 64.3% in the intervention group and from 36% to 48% in the control group.

The Mobile-Based Intervention to Stop Obesity in Pre-schoolers (MINISTOP) [36] aimed to help, through intervention by their parents, 315 children aged 4.5 years to improve their body status, nutritional habits and physical activity via a smartphone application during a 6-month intervention. Participants were randomly assigned to the intervention or control group: the intervention group received a 6-month mHealth application to register information about their child's food consumption and physical activity; and the control group received a pamphlet on healthy eating and physical activity. The differences between baseline and the follow-up for the intervention group resulted in an increase of 2.9 ± 78.9 g/day of fruits and -6.7 ± 42.1 g/day of vegetables consumed, while for the control group, decreases of -12.1 ± 87.9 g/day of fruits and -3.6 ± 39.7 g/day of vegetables were observed. However, no significant differences between groups were observed in fruit or vegetable intake.

3.3. *Quality Appraisal and Risk of Bias in the Included Studies*

Analysis of the quality of the included studies showed that all of the studies were of weak quality ($\geq$2 weak category ratings). The best good quality items were the study design and dropouts, whereas the other items were of poor quality.

4. Discussion

The present review aimed to investigate the current literature on the potential use of mobile phone applications to self-monitor and increase the intake of fruits and/or vegetables. From a search of the literature, eight studies were included in the final screening for evaluation. The present review proposes that mobile phone applications that include a self-monitoring component have great potential in improving fruit and vegetable intake, supporting the important health benefits associated with technology-based interventions. Six of the eight studies included in the review were effective. These studies focused on overweight adults and adults or young adults with unhealthy lifestyles. Thus, it could be inferred from the current review that the interventions delivered through mobile phone applications that successfully improved the intake of fruits and/or vegetables had something in common: stratification of a specific population that has common interests and motivations. Focusing on the age of the participants, it was observed that 5 studies targeting the adult population (18–60 years) were effective, 2 studies targeting young adults (18–35 years) were not effective or partially effective, and 1 study targeting children through their parents was not effective. Age seems to be an irrelevant factor in determining the effectiveness of the intervention, while other factors, such as participants' common interests, play a key role in achieving an increase in fruit and vegetable intake. Indeed, population selection is one of the characteristics considered in social marketing principles to enable healthy choices [41]. Moreover, two [32,33] of the six effective studies focused on increasing fruit and/or vegetable intake in targeted overweight adults, suggesting that the effectiveness of these types of interventions could be influenced by specific motivations, such as overweight-associated health risks. Pre-existing health problems in the study population were related to increased effectiveness of the intervention compared with the effectiveness observed in the population without diseases, as demonstrated in a previous review [23].

Furthermore, it seems that both outcomes, increased fruit and vegetable daily intake, were better achieved when self-monitoring and dietary feedback were used in the intervention. However, two of the analysed RCTs that failed to increase fruit and vegetable consumption [36,38] also included these methodologies together with push notifications or motivational text messages. These contradictory results could be explained because in one of these studies, parents were responsible for improving the fruit and vegetable consumption of their children [36]; thus, it seems that monitoring the dietary intake of children via their parents is not effective in improving dietary habits.

On the other hand, increasing fruit and/or vegetable intake was not the primary outcome for all of the eight included studies. Four studies had decreasing body weight or body fat or improving diet and activity behaviours as their primary outcome, while increasing fruit and/or vegetable intake was set as a secondary outcome [35–37,39]. In these trials, the effects on fruit and/or vegetable intake evaluated as a secondary outcome were unclear. Thus, our results suggested that when the increase of fruit and/or vegetable intake was defined as the primary outcome, the intervention was more effective than when it was defined as a secondary outcome.

All of the eight studies included in this review implemented a self-monitoring and self-reporting component through a mobile phone application to set and control users' daily fruit and/or vegetable intake goals. Considering the other parts of the methodologies of the studies included in the review, all the studies were randomized controlled studies ranging from two to nine months of intervention and reported the need for further investigations to observe the effects over time. From the results presented in this systematized review, it was observed that an increase of fruit and/or vegetable intake could be observed from two to nine months, and an early rise in vegetable intake compared to that in fruit intake was found, which required more time to achieve an effective improvement.

The increased amount of fruit and/or vegetable intake is an important point to be discussed. Considering that one serving is equal to a minimum of 80 g [42], the minimum increase achieved in the eight studies included in the present review of +2.4 servings/day is an approximately 200 g increase in fruit and/or vegetable intake. Accordingly, an increase of 200 g/day of fruit and/or vegetable intake is associated with an 8%–16% reduction in the relative risk of coronary heart disease, 13%–18% reduction in the risk of stroke, 8%–13% reduction in the risk of cardiovascular diseases, 3%–4% reduction in the risk of cancer, and 10%–15% reduction in the risk of all-cause mortality [1].

The use of mHealth applications has increased, but the question of whether these applications are better than traditional methods is still open. Users have demonstrated general acceptability and adherence to mobile phone tools [43,44] in comparison with the traditional methods of dietary self-monitoring [45,46] because of their personal tailoring, low cost, and interactivity [47]. Furthermore, self-monitoring though mobile phone applications seems to provide easier and real-time dietary assessments [48] and is also associated with better quality dietary data compared with traditional methods, which could be affected by users' memory [44]. However, more evidence is needed for mHealth applications because the majority of these applications are developed with minimum feedback users and little support [49]. Although self-monitoring via mobile phone applications seems to have positive effects on fruit and/or vegetable intake, its relationship with an effective improvement of dietary habits has not yet been confirmed. Although mobile phone applications have been widely tested in weight-loss trials [24,50], their utilization for the improvement of specific target food group intake is still scarce.

Comparing different methodologies used to increase the consumption of fruits and/or vegetables, a systematic review from 2005 that considered 44 studies using diverse approaches, but not mobile phone applications, observed increases in fruit and vegetable intake from 0.1 to 1.4 servings/day in heathy adults [23]. Computer-tailored information and interventions using telephone contacts were found to represent an adequate alternative to face-to-face education and counselling-based interventions [23]. Notably, the improvements in fruit and/or vegetable intake observed in the studies included in the present review (range: +0.2 to +7.5 servings/day of fruit and vegetable), which used mobile phone applications, seem to be greater than those obtained from interventions employing more traditional methodologies.

Finally, although the use of different mobile phone applications in several studies [9,11,19,51] shows a positive outcome in increasing the awareness of the quality of food intake, improving dietary habits and educating individuals, it is clear that the implementation of mHealth applications for fruit and/or vegetable intake promotion can deeply affect the final outcome. Moreover, it seems that only monitoring fruit and/or vegetable intake may not be sufficiently engaging; thus, implementing smart techniques for individual engagement, such as expert feedback [9,10,12,19] or positive rewards, could affect the final success of the mobile phone application [12,19]. In other words, it is well known that the effectiveness of mHealth applications depends on the usability their interface, feedback, rewards, and so on. A complete comparison would require using different mobile phone applications and studying their usability and effectiveness in the same population group. Unfortunately, most of the mobile phone applications used are built in-house and thus are not publicly available for direct comparison. Moreover, implementation of an extensive usability study is beyond the scope of this paper.

Additionally, assessment of food intake through web and mobile app tools requires the collaboration of individuals and thus can be subjective, retrospectively biased, and suffer from low compliance. It is tedious for people to continuously annotate their food intake over long periods of time. In addition to the fact that having to annotate all meals is embarrassing and subjective, people generally do not remember all the food they have eaten. Another important drawback of manual annotation is food underreporting [20]. Moreover, many health applications are not created by nutritional professionals. Additionally, we cannot assume that food diaries based on personal annotations of a few days are representative of an individual's complete diet [20]. Recently, some web-based and mobile applications have included automatic food recognition that is based on smartphone pictures. Some applications have very recently claimed to introduce this option: LoseIt!© (2008–2019 FitNow, Inc., Saint Honoré, Paris), MyFitnessPal© (2009–2019 MyFitnessPal, Inc., San Francisco, CA, U.S.A.), CalorieMama© (2017, Azumio, Inc., Redwood city, CA, U.S.A) and FatSecret© (2019, FatSecret, Victoria, Australia). This ability makes the process of food intake reporting easier, faster and more pleasant, but it currently suffers from not being able to recognize a large amount of foods in the diet, demonstrating sub-optimal performance and limited recognition of different types of dishes.

In general, the majority of the articles included in the present systematized review discussed future interventions, such as larger-scale and longer trials, rather than technical improvements of mHealth applications. Regardless, some design elements could be taken into account for the future development of mHealth applications to improve vegetable and fruit intake, such as (a) inclusion of a validated tool to register food intake and to improve dietary assessments [38]; (b) weekly messages to reinforce the health recommendations about vegetable and fruit intake [39]; (c) remote connected coaching [37]; (d) remainders to buy fruits and vegetables when people are in the supermarket (e) interactive information between users and coaches [34,35]; and (f) tracking and sensor technologies as an interactive information system [34].

There are several limitations in this review. First, the majority of the trials included in this review presented the following limitations: the population sample was not representative of the community setting because of the small size, level of education, gender and origin [32–36,38,39] and low reliance of the data, which were self-reported by participants [32,33,35–39]. Second, the reviewed studies expressed results on the primary outcome (fruit and/or vegetable intake) using different units of measure, such as g/day, servings/day, pieces/week and percentage of people consuming ≥2 servings/day. Third, a description of the amount of grams considered to be a serving of fruit and/or vegetable intake was not provided. Fourth, the self-monitoring tool type was not the same for all the studies, which influenced the presentation of the final results (servings/day or week, g/day, percentage, etc.), and could be better expressed in future studies as servings/day or g/day. Fifth, only two databases were used to search for results: PubMed and Web of Science. Although these databases are the most commonly used, the inclusion of other databases could have increased and influenced the final results of the review. Sixth, the present paper is a systematized review, i.e., the review process is shorter than that of a systematic review, may or may not include comprehensive searching, may or may not include quality assessment, and describes the uncertainty around the findings and the limitations of the methodology [28]. Finally, although the study quality was not an inclusion criterion, the weakness of the majority of the included studies presents problems for the generalizability of the results of this systematized review.

5. Conclusions

The present review demonstrates that effective interventions to increase fruit and vegetable consumption using mobile phone applications last from two to nine months and are characterized by a stratified population that shares the same motivation to achieve better dietary habits. Furthermore, the inclusion of behavioural change techniques, such as dietary feedback together with self-monitoring and remote coaching support, has been identified as a key element that can definitively facilitate the adoption of new dietary habits. This issue strongly suggests that behavioural theory-based strategies must be considered when designing dietary mHealth application interventions. Further research on mHealth applications is needed to design more effective interventions and to determine their efficacy over the long term. Although evidence shows a promising future for mHealth applications to promote healthy nutrition, it is an open question as to how to ensure that the maturity and popularity of these applications is similar to those of other tools for the promotion of healthy habits, such as activity trackers.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/11/3/686/s1, Table S1: Quality of the studies included in the systematized review; Table S2: Relevant information regarding the data extracted from the included studies.

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STUDY 4:

Mobile phone apps for food allergies or intolerances in app stores: Systematic search and quality assessment using the mobile app rating scale (MARS).

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Original Paper

Mobile Phone Apps for Food Allergies or Intolerances in App Stores: Systematic Search and Quality Assessment Using the Mobile App Rating Scale (MARS)

Floriana Mandracchia[1*], MS; Elisabet Llauradó[1*], PhD; Lucia Tarro[1,2], PhD; Rosa Maria Valls[1], PhD; Rosa Solà[1,2,3], MD, PhD

[1]Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Healthy Environment Chair, Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili, Reus, Spain

[2]Unit of Nutrition and Health, EURECAT-Technology Centre of Catalonia, Reus, Spain

[3]Hospital Universitari Sant Joan de Reus, Reus, Spain

[*]these authors contributed equally

Corresponding Author:
Lucia Tarro, PhD
Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Healthy Environment Chair
Facultat de Medicina i Ciències de la Salut
Universitat Rovira i Virgili
C/Sant Llorenç, 21
Reus
Spain
Phone: 34 977758920
Email: lucia.tarro@urv.cat

Abstract

Background: Food allergies and intolerances are increasing worldwide, and mobile phone apps could be a promising tool for self-management of these issues.

Objective: This study aimed to systemically search and assess food allergy or intolerance apps in app stores using the multidimensional Mobile App Rating Scale (MARS) to rate the objective and subjective quality and to identify critical points for future improvements.

Methods: This systematic search identified apps through the keywords "food allergy," "food intolerance," and "allergens" in English, Spanish, and Italian in the Apple App Store (iOS) and Google Play Store (Android). The inclusion criteria were a user star rating of ≥3 (of 5 stars) to limit the selection to the most highly rated apps; ≥1000 reviews as an indicator of reliability; and the most recent update performed up to 2017. Then, the apps were divided according to their purpose (searching for allergen-free "food products," "restaurants," or recipes in "meal planners") and evaluated on a scale of 1 to 5 points using the MARS in terms of (1) app classification category with a descriptive aim; (2) app subjective and objective quality categories comprised of engagement, functionality, esthetics, and information sections (Medline was searched for eligible apps to check whether they had been tested in trials); and (3) an optional app-specific section. Furthermore, the output and input features were evaluated. Differences between MARS sections and between app purposes and correlations among MARS sections, star ratings, and numbers of reviews were evaluated.

Results: Of the 1376 apps identified, 14 were included: 12 related to food allergies and intolerances that detect 2-16 food allergens and 2 related only to gluten intolerance. The mean (SD) MARS scores (maximum 5 points) were 3.8 (SD 0.4) for objective quality, highlighting whether any app had been tested in trials; 3.5 (SD 0.6) for subjective quality; and 3.6 (SD 0.7) for the app-specific section. Therefore, a rating ≥3 points indicated overall acceptable quality. From the between-section comparison, engagement (mean 3.5, SD 0.6) obtained significantly lower scores than functionality (mean 4.1, SD 0.6), esthetics (mean 4, SD 0.5), and information (mean 3.8, SD 0.4). However, when the apps were compared by purpose, critical points were identified: meal planner apps showed significantly higher engagement (mean 4.1, SD 0.4) than food product (mean 3.0, SD 0.6; P=.05) and restaurant (mean 3.2, SD 0.3; P=.02) apps.

Conclusions: In this systematic search of food allergy or intolerance apps, acceptable MARS quality was identified, although the engagement section for food product and restaurant purpose apps should be improved and the included apps should be tested in trials. The critical points identified in this systematic search can help improve the innovativeness and applicability of future food allergy and intolerance apps.

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KEYWORDS

food allergy; food hypersensitivity; food intolerance; allergens; mobile applications; mobile health; mHealth; eHealth.

Introduction

Food allergies and intolerances are adverse reactions to the ingestion of, contact with, or inhalation of a specific food, derivative, or additive [1]. The prevalence of such adverse food allergy and intolerance reactions is increasing worldwide, especially in developed countries [2].

On the one hand, food allergies involve an immune-mediated reaction that occurs between a few minutes and 1 hour after exposure to the allergen, with symptoms ranging from moderate to severe [3]. The prevalence of food allergies is higher in children (<10%) than in adults (approximately 1%-2%) [3]. On the other hand, food intolerances are nonimmunological hypersensitivity responses due to a nontolerated dose of a food or a component of a food, with symptoms or signs occurring several hours after food consumption and lasting from hours until several days afterward [4]. Food intolerances are more common worldwide than food allergies, affecting up to 15%-20% of the general population [5].

Although new approaches to food allergies have recently been under clinical investigation [6], one strategy is to correctly identify food allergens to avoid the consumption of even small amounts of an allergen that causes a reaction [7]. To help consumers easily identify food allergens in food products, prepackaged or not, European legislation from 2014 (EU Food Information for Consumer Regulation No. 1169/2011) requires food businesses to clearly provide consumers, through labels or other verbal or written communications, with information about nutritional values and the presence of any of 14 specified food allergens (cereals containing gluten, crustaceans, eggs, fish, peanuts, soya, milk, nuts, celery, mustard, sesame, sulfur dioxide, lupin, and mollusks) [8]. Despite the European legislation, a 2019 study showed gaps in compliance with the regulation, finding that only 83 of the 295 evaluated restaurants (28.1%) labeled food allergens on the menus and that the restaurant staff had deficiencies in their food allergen knowledge and management [9]. In addition to relying on the information provided by food businesses and their employees, consumers must fundamentally self-monitor and self-manage their health [10].

In this context, there is increasing interest in mobile technology, such as apps, that focuses on helping consumers supervise what they are eating [11] by detecting allergens [12] not derived from cross-contamination and delivering specific health information [13,14] in relation to preparing daily meals, purchasing suitable food products, or searching for restaurants with allergen-free menus.

In recent years, mobile health (mHealth) technologies, including software, sensors, and mobile phones [15], have improved the management of health care services [16] and interventions such as the achievement of weight loss and smoking cessation as well as the management of several chronic and mental diseases [17]. Currently, the potential of apps for food-related conditions [18] such as food allergies and intolerances, whose incidence is growing worldwide [19], is also being studied. The convenience of apps in health management is favored by approximately 59% of the world population, corresponding to 4.57 billion people, mostly in northern Europe and the United States, who were active internet users in 2020 [20]. Apps enabling consumers to identify food allergens in foods and products, find allergen-free restaurants, and report and evaluate symptoms related to food allergies are already available, but most of them offer irrelevant and poor content [21].

Since plenty of apps currently exist, their reliability must be verified [22], as the traditional systems used to test app quality, such as users' star ratings (evaluating apps on a scale of 1 to 5 stars) and reviews, could allow fake or subjective reviews, giving wrong indications to users [23]. Furthermore, app descriptions in app stores are often incomplete or incorrect and are not a valid tool for assessing the quality of an app [24], especially when dealing with sensitive topics such as food allergies.

The necessity of regulating the quality and safety of mHealth technologies, defined by the World Health Organization as medical and public health practices supported by mobile phones, patient monitoring devices, personal digital assistants, and other wireless devices [25], is particularly important for apps intended to be used for the diagnosis, cure, mitigation, treatment, and prevention of a disease or other conditions by aiding clinical decision-making [26]. These kinds of apps are classified and regulated as medical devices by the US Food and Drug Administration to ensure the safety of apps that are recommended by health professionals to their patients [26]. For instance, in 2015, the government of Catalonia (Spain) introduced a public platform for apps with quality accreditation from health professionals (mConnecta platform), thus establishing a safe and reliable environment for people to use these mHealth apps to self-monitor their health practices [27]. However, nonmedical apps intended to provide information and education to users, such as apps for food allergies and intolerances, also need to be regulated since incomplete information is often provided [28]. In this way, apps will provide better information to help users make health-related choices [29], mHealth will have more value, and fewer ineffective and unsafe apps will be available [30].

Owing to the necessity of ensuring better app quality for users, a Mobile App Rating Scale (MARS) was developed by a multidisciplinary team of experts as a simple, objective, and reliable tool for researchers, developers, and health professionals to assess app quality and provide suggestions for future designs [31]. The MARS tool provides a multidimensional evaluation of app quality, whereas other existing tools mostly use one-dimensional measures. For example, the Intercontinental Medical Statistics Institute for Healthcare Informatics tool [32] assesses only app functionality, and the criteria of the Health Care Information and Management Systems Society tool [33] evaluate only app usability. The MARS tool has already been used for the quality assessment of different apps related to nutrition [34-36], sleep management [37], food provision [38], calorie counting [39], smoking cessation [40], physical activity [41], and weight management [42] but has not previously been used for food allergy or intolerance apps.

The aim of this paper was to systemically search app stores for apps about food allergies or intolerances, to assess the apps using the multidimensional MARS ratings of objective and subjective quality, and to identify the critical points for future improvements of these apps.

Methods

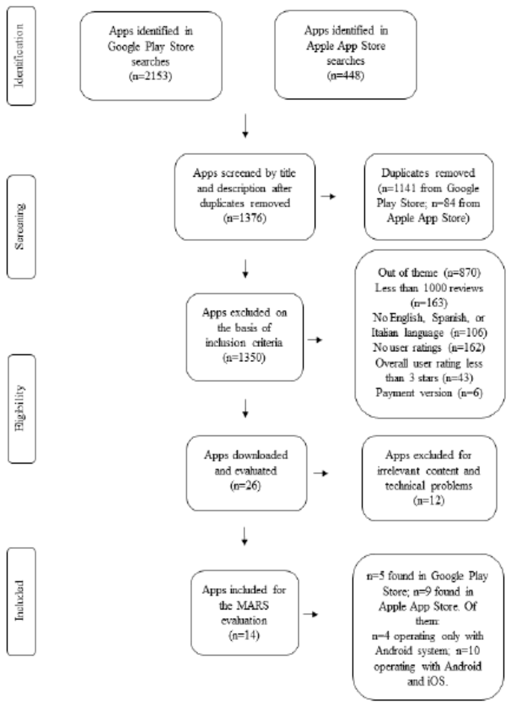
Search Strategy

The present study featured a systematic search and content analysis of apps about food allergies or intolerances available in the Apple App Store (iOS) and Google Play Store (Android). The apps were searched by the two authors between May 2019 and June 2019. The searches were conducted anonymously by logging out of the user accounts for the stores. Specific keywords such as "food allergy," "food intolerance," and "allergens" in English, Spanish, and Italian were used to search for the available apps in any of these 3 languages.

App Selection

The app selection process is described in Figure 1. Specific inclusion and exclusion criteria were applied to limit the search to the most relevant and reliable apps, in line with previous studies [35,38,41,42]. In particular, only apps that offered a free version were included in the search, as they are most commonly used by the general population. Apps in English, Spanish, and Italian were considered if they had (1) a minimum user star rating ≥3 (of 5 stars) to limit the search to the apps most highly rated by users, (2) ≥1000 reviews to identify the apps that were most commonly used and experienced, and (3) a last update up to 2017 to evaluate the most recently produced and revised apps. Finally, apps were included if their aim was to help allergic or intolerant users select suitable food products to buy or consume, personalize their daily nutrition on the basis of their needs and food restrictions, detect allergens in recipes and food product labels, search for specific restaurants or supermarkets according to their needs, and obtain information and advice about allergen self-management. Duplicates and apps that did not fulfill the aforementioned inclusion criteria or did not work were excluded from the study.

Figure 1. Flow diagram for the selection process of the apps included in the study.



Data Extraction

All the identified apps were registered in an initial list to count the total number of apps and the number of duplicates. The general characteristics of the included apps were extracted from the information in the app stores, while the main app features were verified by the authors by using the app. Furthermore, the features were categorized as input and output features on the basis of whether the app content was created by the users or automatically generated.

After data extraction, the authors divided the apps according to 3 purpose types (considering that the apps included presented different purposes): (1) searching for allergen-free food products, (2) searching for restaurants offering menus adapted to different food allergies and intolerances, and (3) functioning as meal planners for suitable daily meals according to users' food allergies or intolerances. This division of the included apps allowed us to compare the MARS quality ratings among apps with a similar purpose and to provide suggestions for future app designs in line with this purpose.

Moreover, web-based searches on the Medline database were conducted by app name (Eat This Much, Fitberry, Mealime, Recetas Vegetarianas y Veganas, SideChef, Tasty, Mercadona, Mi Intolerancia Alimentaria, Open Food Facts, ¿Qué Puedo Comer?, Club VIPS, Find Me Gluten Free, Foster's Hollywood, and Happy Cow) and by "apps for food allergies and/or intolerances" to determine whether they had already been evaluated in scientific trials.

MARS App Quality Assessment

App quality was assessed using the MARS rating scale, a reliable tool with a high internal consistency (α=0.90) and an interrater reliability interclass correlation coefficient of 0.79 [31]. The following steps were taken. First, before assessing the app quality, the authors followed specific web-based training organized by the MARS developers [43], such as an exercise to better understand how to classify the apps. Then, to experience and test the functionality of the included apps, the two authors independently used each of the 14 apps for 1 month. Finally, the quality assessment was conducted in agreement between the two authors, and disagreements were resolved through discussion with a third author.

The MARS rating scale consists of 2 categories. The first is the app classification category, with 6 items of descriptive and technical information for each app: (1) descriptive information (name, number, and type of ratings for all versions; developer; version; cost; platform; description; update), (2) focus, (3) theoretical background and strategies, (4) affiliations, (5) age group, and (6) technical aspects (login, password protection, web access, app community, social sharing, and reminder functions). The second category is the app quality category, which is divided into objective and subjective quality. Objective quality has 4 sections (engagement, functionality, esthetics, and information) with 19 items, while subjective quality is comprised of 4 items, for a total of 23 items.

In addition to these 2 categories, there is an optional app-specific section with 6 items to collect further information about the perceived impact of the app on the user (awareness, knowledge, attitudes, intention to change, help-seeking, behavior change).

The app classification category was not rated since its purpose was only descriptive. Instead, to evaluate the app quality category, each item was scored on a 5-point rating scale from 1 to 5 (1: inadequate; 2: poor; 3: acceptable; 4: good; 5: excellent). For each app, the total mean score was the sum of the score of each item divided by the number of total items. The mean score of the 4 objective quality sections (engagement + functionality + esthetics + information) was calculated separately from that of the subjective and app-specific sections to strengthen the impartiality of the measure.

For each objective quality section, the maximum score was 25 points for engagement, 20 points for functionality, 15 points for esthetics, and 35 points for information, for a total of 95 points for objective quality. Subjective quality could reach a maximum of 20 points, and the app-specific section could reach a maximum of 30 points.

In addition to the objective and subjective quality ratings, the app-specific section was evaluated on the 5-point rating scale.

Statistical Analysis

Continuous variables of the scores obtained for each section of the MARS quality assessment, with the exception of the app classification category, are presented as the mean and SD. Categorical variables for the included apps and their input and output features are presented as percentages. Multiple comparisons between the 3 purposes of the included apps (food products, restaurants, meal planners), MARS scores, and user star ratings were performed and adjusted using the generalized linear model of the Bonferroni test. Correlations among the MARS scores, user star ratings, and number of reviews were analyzed using Pearson correlation coefficients (for normally distributed variables) and Spearman correlation coefficients (for not normally distributed variables), which were interpreted as strong or moderate according to previously published cutoff points [44]. The analysis was performed with SPSS Statistics version 25. Statistical significance was considered at $P \leq .05$.

Results

App Selection

Figure 1 shows the flowchart of the app selection process. After the removal of duplicates found in both stores, 1376 apps about food allergies or intolerances were screened by title and description by the two authors, resulting in 1350 apps being excluded on the basis of the inclusion criteria. To further evaluate the eligibility of their content, 26 apps were downloaded, and 12 of these were excluded by common agreement because of irrelevant content (apps from the same developer with equivalent features and findings) and technical problems. As a result, 14 apps about food allergies or intolerances were finally included in the study for quality assessment using the MARS tool; 5 of the 14 (36%) were found in the Google Play Store, and 9 of the 14 (64%) were found in the Apple App Store. Moreover, 4 of the 14 apps (29%) operated only on the Android system, and 10 of the 14 apps (71%) operated on both the Android and iOS systems. None of the included apps had previously been evaluated in scientific trials.

Data Extraction: App General Characteristics

The general characteristics of the 14 included apps about food allergies or intolerances, shown in Multimedia Appendix 1, are described in the following sections.

App Purpose

First, the 14 included apps were divided according to their purpose.

Of the 14 apps, 6 (43%) were meal planners, helping users search for and plan meals adapted to allergies or intolerances. In particular, 4 apps (Tasty, Recetas Vegetarianas y Veganas, SideChef, and Fitberry) propose food recipes that can be filtered by the users' allergies or intolerances and on the basis of personal preferences, such as cooking difficulty and type of meal, diet, and cuisine. The other 2 apps (Mealime and Eat This Much) are meal planners that allow weekly meals to be organized on the basis of personal preferences, dietary goals, and food restrictions, such as food allergies and intolerances. In this way, users can create a personal profile indicating allergens to eliminate from their diet and organize their daily or weekly diet plan, choosing among the dishes proposed automatically by the apps and filtering them by the selected allergen.

Of the 14 apps, 4 (29%) function as food product search tools, helping users search for suitable food products according to their food allergies and/or intolerances. In particular, 3 apps (Open Food facts, ¿Qué Puedo Comer?, and Mercadona) help users search, through barcode scanning or database searches, for the most suitable food by showing the allergens declared on the food product label and indicating the nearest place to buy them, and 1 app (Mi Intolerancia Alimentaria) is a calculator of food compatibility. According to the presence of an allergen, the user's individual tolerance of the food or meal is calculated and shown using a 3-color code alert system (red, orange, and green) according to whether the compatibility of the food is low, medium, or high.

Restaurant searches represented the main purpose of 4 of the 14 apps (29%), helping users search for restaurants that offer menus adapted for allergic or intolerant consumers. In particular, 1 app (Happy Cow) searches for gluten-free, vegetarian, and vegan restaurants, hotels, supermarkets, and caterers; 1 app (Foster's Hollywood) belongs to a popular restaurant chain and offers the possibility of looking at the restaurant's allergen-free menu by checking the available meals in advance; 1 app (Club VIPS) searches for the nearest locations of different restaurant chains with allergen-free options; and 1 app (Find Me Gluten Free) searches for restaurants with gluten-free options.

Operating System

Of the 14 apps, 10 (72%) operate on both the Android and iOS systems, and 4 (28%) operate only on the Android system.

Number of Reviews

The number of reviews of the included apps varied from 1013 to 48,597 reviews.

Languages Available

Of the 14 apps, 4 (28%) are available only in Spanish, 5 (36%) are available only in English, and 5 (36%) are offered in 3-130 different languages.

Actions

The included apps enable users to benefit from different actions for the daily management of food allergies or intolerances.

Focus

Of the 14 apps, 12 (86%) are related to food allergies or intolerances, while 2 (14%) deal with gluten intolerance only.

Allergens Detected

The included apps differed in the number of allergens detected. Specifically, 10 of the 14 apps for food allergies identified milk and eggs; 9 identified crustaceans, peanuts, and nuts; 8 identified fish and soya; 6 identified sesame, mustard, and sulfur dioxide; 5 identified celery and lupin; and 1 identified wheat and grain. In addition, all 14 of the apps for food intolerances identified gluten, 4 identified lactose, and 2 identified fructose, sorbitol, histamine, and salicylic acid.

Thus, 5 of the 14 apps (36%) detected all 14 allergens that must be declared in the European Union (cereals containing gluten, crustaceans, eggs, fish, peanuts, soya, milk, nuts, celery, mustard, sesame, sulfur dioxide, lupin, and mollusks) above other food allergens present on the food product label, 2 of the 14 apps (14%) detected only gluten, and 7 of the 14 apps (50%) detected 2-10 food allergens.

Input and Output Features

The app features were distinguished as output features (Multimedia Appendix 2), where content is automatically generated by the app, and input features (Multimedia Appendix 3), where content is inserted and created by the user.

The lowest-rated app in the objective quality category, Mi Intolerancia Alimentaria (mean MARS score 3.2, SD 0.5), has fewer output features (4 of the 20 features) than the apps scoring >4 points, which offer 12-15 of the 20 output features and also had the highest scores in the engagement section. The same situation occurred for the input features, with apps scoring >4 points offering 8-9 of the 9 input features.

According to the app purposes, the most used features for the meal planner apps were allergen detection, search filters, sending of reminders and notifications, shopping list creation, suggestions and tips, rating and reviewing possibilities, personal profile, creation of a favorites list, and social sharing. For the food product apps, the most used features were allergen detection, listing of ingredients and additives, personal profile, and rating and reviewing possibilities. For the restaurant apps, the most used features were allergen detection, search filters, prompts and discounts, geolocation, rating and reviewing possibilities, personal profile, and social sharing.

MARS App Quality Assessment

The MARS app classification category is the part that collects descriptive and technical information about the included apps. Descriptive data include general information (app name, rating of all versions, developer, number of ratings of all versions, version, cost of basic and upgraded versions, platform, description and last update, focus, theoretical background and strategies, affiliations, age group) and technical aspects present in the app description in the app store. Of these data, only the relevant aspects were extracted (focus, theoretical strategies, affiliation, age group, and technical aspects); they are described in Multimedia Appendix 4.

According to the MARS evaluation, the quality of the 14 included apps assessed in terms of the 4 objectives (engagement, functionality, esthetics, and information) and the one subjective section are shown in Multimedia Appendix 4. Additionally, the results of the optional app-specific section are included.

The overall mean (SD) MARS objective quality score, which allows the evaluation of the general app quality (maximum of 5 points), was 3.8 points (SD 0.4 points); thus, the quality of the 14 included apps was considered acceptable. The score of the subjective quality section was 3.5 points (SD 0.6 points), and that of the app-specific section was 3.6 points (SD 0.7 points).

In particular, the mean scores of the 4 single objective quality sections, from the highest to the lowest score, were as follows: functionality section, 4.1 points (SD 0.6 points); esthetics section, 4 points (SD 0.5 points); information section, 3.8 points (SD 0.4 points); and engagement section, 3.5 points (SD 0.6 points).

When the scores of the 6 MARS sections (4 objective, 1 subjective, and 1 app-specific) were compared, the score of the esthetics section (mean 4, SD 0.5) was significantly higher than that of the engagement section (mean 3.5, SD 0.6; P=.007), and the score of the functionality section (mean 4.1, SD 0.6) was significantly higher than that of the subjective quality section (mean 3.5, SD 0.6; P<.001). Moreover, the score of the information section (mean 3.8, SD 0.4) was significantly higher than that of the subjective quality (mean 3.5, SD 0.6; P=.002) and app-specific (mean 3.6, SD 0.7; P=.001) sections. No further significance was found in the other between-section comparisons.

Among the 3 app purposes (food products, restaurants, and meal planners), comparisons between the MARS sections, as shown in Table 1, were evaluated. The score of the engagement section was significantly higher for meal planner apps (mean 4.1, SD 0.4) than for the food product (mean 3.0, SD 0.6; P=.05) and restaurant (mean 3.2, SD 0.3; P=.02) apps. Furthermore, it emerged that for meal planner apps, the scores of the engagement (mean 4.1, SD 0.4; P=.04) and functionality (mean 4.3, SD 0.7; P=.02) sections were significantly higher than those of the subjective quality section (mean 3.9, SD 0.5), and the score of the functionality section was significantly higher than that of the esthetics section (mean 4.3, SD 0.3; P=.04). No further significance was found in the other between-section comparisons among the 3 app purposes.

Table 1. Differences in the mean MARS scores between app purposes.

Mean MARS[a] scores	Meal planners	Food products	Restaurants	P value[b]	P value[c]	P value[d]
Engagement	4.10	3.00	3.20	.05	.02	1.0
Functionality	4.29	4.12	3.69	1.0	.43	.96
Esthetics	4.28	3.67	3.83	.17	.46	1.0
Information	3.97	3.79	3.62	1.0	.79	1.0
Subjective quality	3.87	3.31	3.19	.46	.26	1.0
App-specific	3.97	3.46	3.25	.75	.35	1.0

[a]MARS: Mobile App Rating Scale.
[b]Comparison between meal planners and food products.
[c]Comparison between meal planners and restaurants.
[d]Comparison between food products and restaurants.

Additional Analysis

The relationships between MARS score quality and user star rating and number of reviews were determined using correlations (described in Table 2) and showed that the star ratings were significantly and strongly positively correlated with the MARS engagement section (r=0.69; P=.007) and app-specific section (ρ=0.79; P=.001). A moderate correlation was also found between MARS subjective (r=0.63; P=.01) and total objective quality (r=0.60; P=.02). However, no significant correlations were found between MARS sections and number of reviews.

Table 2. Correlation coefficients between MARS scores, user star ratings, and number of reviews.

Mobile App Rating Scale (MARS)	Number of reviews	Star ratings	P value[a]	P value[b]
Functionality[c]	0.13	0.33	.65	.25
Esthetics[c]	0.11	0.43	.71	.12
App-specific[c]	0.05	0.79	.87	.001
Number of reviews[c]	1.00	0.30	N/A[d]	.30
Engagement[e]	0.20	0.69	.50	.007
Information[e]	–0.14	0.42	.62	.14
Total objective quality[e]	0.03	0.60	.92	.02
Subjective quality[e]	–0.03	0.63	.93	.01
Star ratings[e]	0.30	1.00	.29	N/A

[a]Correlation between MARS scores and number of reviews.
[b]Correlation between MARS scores and star ratings.
[c]Spearman (ρ).
[d]N/A: not applicable.
[e]Pearson (r).

In addition, to verify whether the star ratings assessed by users were similar to the MARS scores obtained in our study, the comparisons were analyzed. The star ratings were significantly higher (mean 4.2, SD 0.4) than the MARS subjective quality score (mean 3.5, SD 0.6; P=.04).

Discussion

The present systematic search and quality assessment study provides information about the objective (engagement, functionality, esthetics, and information) and subjective quality of the available apps for food allergies or intolerances in app stores. The quality assessment using the MARS tool indicated that the overall app quality of the 14 included apps was acceptable, according to MARS mean ratings of ≥3 from a maximum of 5 points.

By comparing the 6 MARS sections (4 objective quality, 1 subjective quality, and 1 app-specific), the most significant results were related to the apps' functionality, esthetics, and information, as they appeared visually pleasant, sufficiently descriptive, well arranged, and easy to use, whereas the engagement section of most of these apps needs to be improved. As observed in other studies, apps with simple functionality can motivate people who have no familiarity with technology to adopt mobile apps [45]. Moreover, esthetics, such as visual attractiveness, is another key element for increasing users' motivation to use the app [46].

Regarding the information section, the included 14 apps clearly presented their content through the support of images, graphics, and videos. Nevertheless, none of the apps has been tested in scientific trials, which is an important aspect of this section of the MARS tool. In addition, it is important to evaluate the apps' efficacy in helping consumers self-manage food allergies or intolerances, since previous studies have demonstrated that commercial apps do not always provide the expected results when they are evaluated in trials [47-49]. For meal planner apps, future trials could evaluate the improvement in user knowledge and awareness of food allergens, which are considered important targets for the management of food allergies [50].

Moreover, the efficiency of food product apps should be tested in clinical trials to increase users' confidence when food shopping and reading product labels. For the allergic and intolerant population, it is fundamental for the food labeling system to be available and comprehensive [51], and this kind of app could help consumers more quickly detect allergens in food products. Finally, for restaurant apps, customer satisfaction when eating away from home could be evaluated as a measure of food businesses' compliance with the European regulation and with the allergen-free menus published on the app. Positive experiences when eating away from home are correlated with the availability of food allergen information provided by the restaurants [52].

Moreover, none of the 14 included apps claims any validation of the content by health professionals or allows remote support. Actually, a critical assessment published in 2015 found that most apps about food allergies lack important health information and are not developed with the support of health professionals [21]. It is important for such apps to be evaluated by health professionals to provide better information to help users make health-related choices [53-55]. Furthermore, apps providing professionally oriented support and communication are more engaging and favored by users, especially adolescents [54].

The results obtained in the present study indicate that app engagement is the section with the lowest score with respect to functionality, esthetics, and information, in line with other MARS assessments of apps for food provision [38], checking for drug interactions [56], and drunk driving prevention [57], and the lack of interactive features influences the engagement quality of these apps. However, in a comparison of the 3 purposes of the included apps, the engagement section of the meal planner apps received higher quality scores than that of the food product and restaurant apps. In fact, food product and restaurant apps do not use interactive features that motivate users to use them repeatedly [58], but for these apps, which are designed for short and specific use such as finding restaurants or products, user engagement and daily use are not really as essential as in meal planner apps. However, including features such as tips and suggestions to support consumers' decisions or sending notifications [59] to notify users of new products or restaurants could improve the user app experience, growth of the app community, and app competitiveness. To increase user enjoyment and participation, meal planner, food product, and restaurant apps should perhaps include features such as rewards, goal-setting options, challenges, and leader boards, which have been recognized as effective tools in past studies [60-62], especially in adolescent populations, where game competition can motivate users to participate [63]. Finally, features such as feedback and self-monitoring, which have been demonstrated in previous studies to be effective in increasing users' motivation [32,58] and health behavior [64,65], should be available in apps focused on self-managing food allergies or intolerances; however, only 2 of the 14 apps included in the present systematic search offer these features.

The subjective quality and app-specific sections need to be improved in relation to the 3 purposes of the included apps (meal planners, food products, and restaurants). These sections refer to general users' impressions of the app, which, if positive, would lead them to recommend and use it. In this context, the lack of enough engagement could influence users' perceptions. Thus, it is important to increase users' subjective quality perception and impact of the apps (app-specific) by reinforcing, for example, the engagement profile, as discussed earlier, which mainly influences users' view of the app.

Based on the number of input and output features offered, among the meal planner apps, Eat This Much, Mealime, and SideChef were found to be the most practical for users, obtaining higher scores in the MARS assessment than other apps with the same purpose. Previous studies have shown that food allergies and intolerances impact people's quality of life and emotional status, increasing anxiety and depression [66,67]. The avoidance of food allergens requires constant attention because their presence in food is not always evident or is unknown [68]. This problem becomes even more complicated when consumers have to adapt food recipes or make appropriate ingredient substitutions according to their allergy or intolerance [69] without accurate recommendations or support. In this sense, these 3 apps could better help users while providing suggestions for self-managing food allergies or intolerances in terms of cooking and daily menus. Among the food product apps, the ¿Qué Puedo Comer? app was the most practical for users, offering more features and gaining higher scores in the MARS assessment. This app helps consumers understand food product labels, detect food allergens, and search for food products according to allergies, intolerances, or dietary requirements. Since food product ingredients change regularly and consumers may need to read packaging labels several times [69], these apps can provide instant information and support [70]. Among the restaurant apps, the Find Me Gluten Free and Happy Cow apps were the most practical for users compared to others with the same purpose. The provision of food allergen information on restaurant menus is very important for consumers, and these kinds of apps encourage the dissemination of such information by making it easier to search for restaurants with allergen-free menus [52].

The correlations of star ratings with the app-specific, engagement, and subjective sections suggest that when evaluating an app, users refer more to the subjective impression of the app given by the engaging features offered than to the quality and quantity of the information provided [71], as shown by the results obtained in the present study. As observed in previous studies, there is an evident difference between the quality evaluation obtained by a researcher using a more objective tool such as the MARS and a real-world user who tends to evaluate app quality through star ratings in a much more subjective way [72]. Nevertheless, app store user star ratings cannot be totally trusted since they are sometimes derived from piloted reviews or paid bots deployed by the developer [73].

Thus, according to the results obtained, we consider that MARS quality assessment is a valid tool for providing more accurate app quality information and suggestions for future apps.

Suggestions for Future App Development

Based on the present app assessment, several suggestions emerged for the future design of high-quality apps focused on improving the wellbeing of subjects with food allergies or intolerances:

1. Further features should be included, especially in meal planner apps, to improve the user app experience and increase participation.
2. Content should be validated by health professionals and scientists to provide users with more reliable information about food allergies or intolerances [36].
3. Remote support by health professionals would help users manage their food allergies or intolerances [54].
4. Testing in scientific trials would demonstrate the apps' reliability and effectiveness [74] in detecting food allergens and improving user knowledge.
5. Regulation of nonmedical apps should be considered in the future since it would avoid the development of unrealistic and ineffective apps, provide more correct information to users [29], and provide more value to mHealth technology [30].
6. App quality should be evaluated through innovative methods, including multiple dimension perspectives, as in the MARS tool. The MARS tool, compared to other scales [32,33], represents a multidimensional evaluation of app subjective quality as well as engagement, functionality, esthetics, and information as indicators of objective quality. However, although the MARS tool has been widely tested, it should be validated in the near future [75] to increase its value, and, depending on the area of interest of the app (eg, health care, nutrition, sports, psychology), the items in each section should be more specific and theme-based. Apps for food allergies or intolerances, for example, should include items asking whether food allergen information is effectively and appropriately provided to users.

Limitations

The present study also has several limitations. First, the majority of the apps about food allergies or intolerances found in the app stores had fewer than 1000 reviews and a user star rating <3, indicating low interest by users. Consequently, it was not possible to include most of the apps because we considered a rating of 3 stars as the minimum threshold for app quality. However, it was important for the inclusion criteria to limit the findings to the most reliable and popular apps, as the market includes plenty of dubious apps. Second, apps with only a paid version were excluded from the search. Third, several apps were excluded because of technical problems, such as being unable to open or use the app. Fourth, because this study is not a systematic review of the literature but is a systematic search of app stores, it was not possible to register it in PROSPERO [76]. Finally, despite the increasing attention to apps, the literature about the assessment of app quality is very scarce [77] and not oriented to food allergies and intolerances.

Conclusions

In this systematic search of food allergy or intolerance apps, acceptable MARS quality was identified, although the engagement of food product and restaurant apps should be improved and the included apps should be tested in trials. The critical points identified in this systematic search can help improve the innovativeness and applicability of future food allergy and intolerance apps.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

General characteristics of the mobile phone apps included in the review.
[PDF File (Adobe PDF File), 313 KB-Multimedia Appendix 1]

Multimedia Appendix 2

Output features of the included apps.
[PDF File (Adobe PDF File), 146 KB-Multimedia Appendix 2]

Multimedia Appendix 3

Input features of the included apps.
[PDF File (Adobe PDF File), 125 KB-Multimedia Appendix 3]

Multimedia Appendix 4

Mobile App Rating Scale (MARS) and user star ratings of the included apps in mean (SD).
[PDF File (Adobe PDF File), 217 KB-Multimedia Appendix 4]

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Abbreviations

IMS: Intercontinental Medical Statistics
MARS: Mobile App Rating Scale
mHealth: mobile health

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STUDY 5:

The "Healthy Meals" web app for the assessment of nutritional content and food allergens in restaurant meals: Development, evaluation and validation.

(Editor submitted)

Original paper

The "Healthy Meals" web app for the assessment of nutritional content and food allergens in restaurant meals: Development, evaluation and validation.

Floriana Mandracchia[1†], MS; Lucia Tarro[1,2†], PhD; Elisabet Llauradó[1*], PhD; Rosa Maria Valls[1], PhD; Rosa Solà[1,2,3], MD, PhD.

[1]Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut), Healthy Environment Chair, Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili, 43201 Reus, Spain; floriana.mandracchia1@urv.cat (F.M.); lucia.tarro@urv.cat (L.T.); rosamaria.valls@urv.cat (R.M.V.); rosa.sola@urv.cat (R.S.).

[2]Institut d'Investigació Sanitària Pere Virgili (IISPV), 43204 Reus, Spain.

[3]Hospital Universitari Sant Joan de Reus, 43204 Reus, Spain.

†These authors contributed equally to this work.

[*]**Corresponding Author:**

Elisabet Llauradó, PhD

Functional Nutrition, Oxidation, and Cardiovascular Diseases Group (NFOC-Salut)

Facultat de Medicina i Ciències de la Salut, Universitat Rovira i Virgili

Carrer de Sant Llorenç 21, Reus, 43201, Spain.

Phone: +34 977758920

Email: elisabet.llaurado@urv.cat

ABSTRACT

Background: The potential of web apps (eHealth) to improve the healthfulness and food allergen identification of meals in restaurants remains unknown.

Objectives: The present study aimed to describe the development of the Healthy Meals web app and evaluate its usability, quality, and validity according to a panel of restaurateurs and nutritionists.

Methods: The Healthy Meals web app was based on the nutritional content of restaurant meals assessed in the form of Multiple Traffic Light (MTL) labels and the detection of 14 recognized food allergens. App evaluation included the following: 1) usability evaluation, by 6 restaurateurs and 10 nutritionists who entered a recipe sheet into the web app, and then completed the Computer System Usability Questionnaire (CSUQ), which assessed four factors (system, interface, information, and overall usability) with a maximum score of 7 points; 2) quality evaluation, by the same 10 nutritionists who performed the usability evaluation, and then completed the Mobile App Rating Scale (MARS), with a maximum score of 5 points in the following domains: (a) objective app quality (engagement, functionality, aesthetics, and information), (b) subjective app quality, and (c) user's impacts on the app; 3) validation evaluation, according to the differences in nutrient contents between 2 different nutritionists who entered the same 10 recipe sheets into the web app. Reliability of the ratings was assessed by the Interclass Correlation Coefficient (ICC) to measure the replicability of ratings and was considered moderate (ICC 0.50 to 0.75), good (ICC 0.75 to 0.90) or excellent (ICC >0.90). Furthermore, nutritionists and restaurateurs were asked two open-ended questions to identify critical points to improve.

Results: Users agreed with the web app usability according to the CSUQ (mean 5.6/7 points, SD 0.9), with moderate reliability among ratings (ICC=0.57; 95% CI, 0.18 to 0.82). Factors with lower scores were interface and information usability (mean 5.6/7 points, SD 1.2; mean 5.5/7 points, SD 1.2, respectively). The web app showed good objective quality according to the MARS (mean 4.0/5 points, SD 0.4), with excellent reliability among nutritionists (ICC=0.91; 95% CI, 0.85 to 0.96). Sections with lower scores were engagement, information and subjective quality (mean 3.4/5 points, SD 0.7; mean 3.9/5 points, SD 0.6; mean 3.1/5, SD 0.4, respectively). For web app validation, no significant differences were observed between the two nutritionists' data, with excellent reliability (ICC=0.98; 95% CI, 0.97 to 0.99). Regarding the points for improvement identified, users proposed ameliorating app data entry by improving the availability of the food database.

Conclusions: The Healthy Meals web app was demonstrated to be usable, of good quality and a valid tool for the nutritional assessment and food allergen identification of dishes. Points to improve were identified, while the effectiveness of the app should be tested in scientific trials.

Word account: 449/450

Keywords: nutrition assessment; food allergy; food intolerance; allergens; mobile applications; mobile health; restaurants.

Introduction

The assessment of the nutritional contents of meals and the identification of food allergens is necessary to guarantee the availability of heathier meals and allergen-free dishes to consumers [1]. Nutritional information on the menus of food services and restaurants could help customers make healthier food choices while increasing their awareness about the nutritional composition of meals [2,3]. In particular, previous nutritional content assessments of restaurant and fast food offerings have pointed out the high energy content and poor nutritional quality of the offered dishes [4,5]. Thus, more support of restaurants is required for the establishment of healthier menus that are developed according to the recommended nutritional guidelines [6].

Nutritional content analysis and dietary intake assessment can be performed using different food composition databases [7,8], which are valid cost-effective alternatives to chemical analysis [9]. However, restaurateurs are demanding better digital tools that could provide more consistent nutritional data and related food information [10], including suitability for particular dietary patterns such as veganism/vegetarianism or the presence of food allergens. In Europe, the vegetarian and vegan population is growing, and in Spain, the prevalence of vegetarians and vegans reached 1.5% and 0.5%, respectively, in 2019 [11]. Similarly, food allergen detection by restaurants represents another important assessment to allow for correct allergen management and the avoidance of severe reactions by consumers with allergies [12], whose incidence is growing worldwide [13].

Apart from the European Union (EU) legislative regulation that requires food producers to declare the 14 groups of foods recognized as allergenic, reliable methods are needed to help restaurants identify these food allergens in their menu offerings [14]. From recent surveys, it was found that restaurant managers and staff still have important gaps in food allergy knowledge, such as believing that consuming small amounts of allergenic food is not harmful for allergic people [15] or that removing the allergen from a finished meal provides a safe meal [16]. To fill this allergy knowledge gap, aside from ensuring adequate training to the staff with the support of health professionals [17], the US Food and Drug Administration (FDA) recommends that restaurants implement computer technology for the identification of food allergens present in menu items, which could also help cooks in the preparation of allergen-free meals [18,19].

Thus, eHealth technology in the form of a web app represents a potential strategy for food composition analysis and allergen identification due to its feasibility, accessibility [20], customization and engagement [21]. However, existing diet- and nutrition-related eHealth systems for nonprofessional use still lack data on validity and reliability [22].

The present study describes the development of the Healthy Meals web app with the proposal of 1) assessing the nutritional content of dishes according to the Guideline Daily Amounts (GDA) for food servings, expressed in the form of a Multiple Traffic Light (MTL) system label, and 2) detecting the presence of the 14 recognized food allergens in restaurant meals.

In particular, the Healthy Meals web app could increase awareness of the nutritional composition of restaurant meals, encouraging the improvement of meal healthfulness and food allergen identification.

Thus, the present study aims to describe the following regarding the Healthy Meals web app: 1) its development and 2) its evaluation, including the assessment of usability, quality and validation.

Methods

The Healthy Meals web app was created in the framework of a European Union funded project, called PECT-TurisTIC in Family, for use in the Healthy Meals Randomized Controlled Trial (RCT), of which one of the aims was to improve the nutritional content and food allergen management of meals offered by full-service restaurants in the province of Tarragona (Catalonia, Spain).

2.1 Development of the Healthy Meals web app

The development of the Healthy Meals web app required 4 steps: 1) the analysis of the scientific evidence regarding food labeling systems providing nutritional information, 2) design of the web app interface and features, 3) development of the first prototype in the Spanish language, and 4) revision of the web app by researchers and developers to verify its functionalities and identify required adjustments.

2.1.1 Development step 1: Analysis of the scientific evidence regarding food labeling systems providing nutritional information

The first step of web app development consisted of a literature search to determine a more convenient and comprehensible labeling system to communicate the nutritional information of the assessed meals to restaurateurs. The MTL labeling system was identified as the most readable label for the interpretation of nutrient content [23]. Along with the need to facilitate the nutritional assessment of meals, restaurateurs need to facilitate the identification of food allergens [19], as well as suitable options for individuals with particular dietary patterns such as vegetarianism and veganism [24]. Thus, these features were then considered for the development of the web app.

2.1.2 Development step 2: Design of the web app

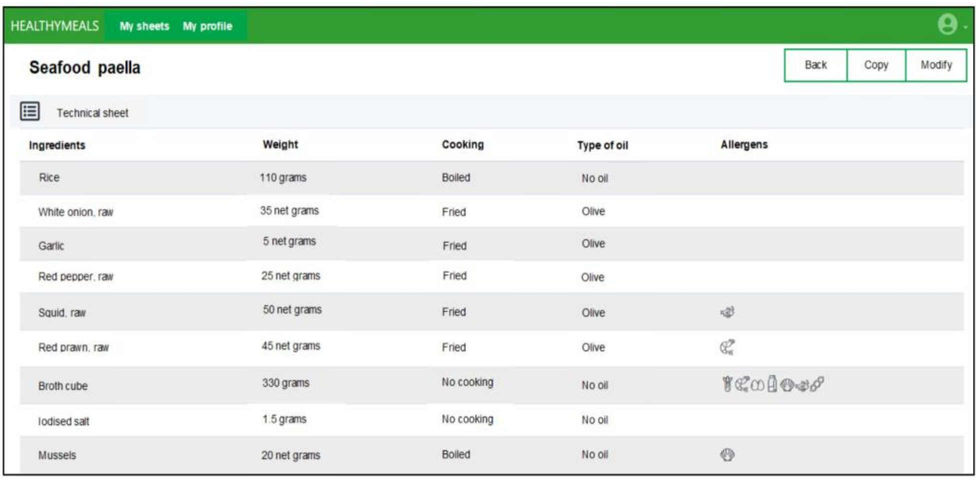
For a single plate portion, the Healthy Meals web app requested the entry of the following data:

1) name, description and photo (optional) of the plate, and

2) ingredients, selected from a food database together with their detailed information such as a) weight in kg/g/mg (net or brute); b) type of cooking (no cooking, fried, stir-fried, boiled, floured, battered), and according to the selected options, the web app calculates the percentage of oil/egg/flour absorbed during cooking based on the food net weight; and c) type of oil (olive, sunflower, palm) or flour (wheat, rice, oat, barley, rye, chickpeas, soy, corn) if required for cooking.

From these data entered in the web app, the nutritional composition of the dish is shown in the form of a technical sheet (*Figure 1*), which summarizes the ingredients, weights, cooking methods, oil used, and whether the plate is a vegetarian/vegan option.

Figure 1: Example of a technical sheet created by the Healthy Meals web app for a seafood paella recipe, per single portion serving.



Ingredients	Weight	Cooking	Type of oil	Allergens
Rice	110 grams	Boiled	No oil	
White onion, raw	35 net grams	Fried	Olive	
Garlic	5 net grams	Fried	Olive	
Red pepper, raw	25 net grams	Fried	Olive	
Squid, raw	50 net grams	Fried	Olive	
Red prawn, raw	45 net grams	Fried	Olive	
Broth cube	330 grams	No cooking	No oil	
Iodised salt	1.5 grams	No cooking	No oil	
Mussels	20 net grams	Boiled	No oil	

As shown in *Figure 1*, the web app generated a technical sheet for the seafood paella recipe (translated to English by researchers). Starting from the far-left column, the following information is provided: the list of ingredients, the ingredients' weight, the type of cooking, the type of oil used, and the allergens within the dish.

Furthermore, the web app identifies and indicates which of the 14 common allergens were certainly (red-marked) or potentially (orange-marked) present, according to the ingredients and the cooking method used (*Figure 1*). When appropriate measures have been taken to avoid allergen cross-contamination during meal preparation (for instance, if the cook has used a clean pan and oil for frying a food instead of using the common fryer), the user could also deselect the orange-marked allergens that the web app had automatically indicated for precaution.

From the nutrient content analysis, an MTL label including energy (Kcal), protein (g), carbohydrates (g), sugar (g), fat (g), saturated fat (g), sodium (mg) and fiber (g) content was created (*Figure 2*). In the MTL label, nutrient content is rated as one of three colors according to a) high (red-colored), b) medium (orange-colored) or c) low (green-colored) content, in agreement with the cutoff of the UK Food Standards Agency and the GDA for an adult's healthy diet of 2000 Kcal recommended by the EU [25,26].

Specifically, a single plate portion was marked in green if it contained <7.5% of the GDA, orange when it contained between 7.5 and 20% of the GDA, and red when it contained >20% of the GDA.

Figure 2: Example of the MTL label derived from the nutritional assessment of the seafood paella recipe generated by the Healthy Meals web app.

As shown in *Figure 2*, using the Healthy Meals web app, an MTL label was created after entering data from the seafood paella recipe (translated to English by researchers). This MLT shows the content of energy in Kcal, protein in grams, carbohydrates in grams, sugar in grams, total fat in grams, saturated fat in grams, salt as sodium in milligrams, fiber in grams and the GDA for each nutrient as a percentage. Nutrients are classified into three color codes according to their high (red), medium (orange) or low (green) content. In the seafood paella dish, energy, protein, carbohydrates, fat, saturated fat, and sodium are colored red, while sugar is green and fiber is yellow. Moreover, the Health Meals web app provided a summary of potential and certain allergens present in dishes in the box above the MTL.

2.1.3 Development step 3: Healthy Meals web app prototype

The Healthy Meals web app prototype was developed in cooperation with professional software developers. Data from different public food composition databases [27–31] and commercial food products were inserted into the Healthy Meals web app as a source of nutritional information for nutrient assessment and allergen identification.

Additionally, the possibility of further inclusion of nutritional data was included, allowing for the update and enrichment of the food database by nutrition professionals and for the consideration of users' requests, especially concerning food products not present yet in the database, such as specific commercial food brands.

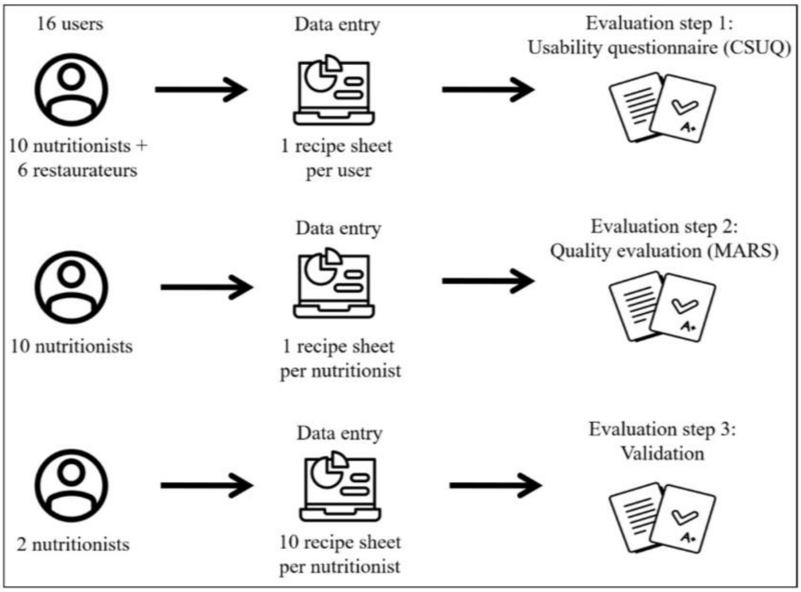
2.1.4 Development step 4: Revision of the Healthy Meals web app

The initial prototype of the Healthy Meals web app was reviewed step by step by developers under the supervision of researchers to verify functionalities and detect points to be adjusted. Examples of data entry and nutritional calculations were performed to test the functionality of the web app and evaluate its design.

2.2 Evaluation of the Healthy Meals web app

The evaluation of the final prototype of the Healthy Meals web app included the assessment of 1) web app usability to assess the usability, functionalities and features; 2) web app quality to assess its objective and subjective quality; and 3) web app validation to measure the accuracy of recipe data entry (*Figure* 3).

Figure 3: Description of the Healthy Meals web app evaluation process including usability, quality, and validation.



2.2.1 Evaluation of web app usability by restaurateurs and nutritionists

For the web app usability evaluation, a minimum number of 16 users comprising restaurateurs and nutritionists were recruited as an appropriate sample for identifying web app usability problems, in line with Alroobaea et al. [32]. Users were asked to enter a recipe sheet into the web app with detailed information about the cooking steps and the ingredients and their quantities for one serving. Following the data entry of the recipe sheet, web app usability was evaluated through the CSUQ (version 3), which was validated in the Spanish language [33] and administered online. The CSUQ was derived from the Post-Study System Usability Questionnaire (PPSUQ), and its reliability and validity have previously been demonstrated [34]. The CSUQ consists of 16 items rated on a 7-point Likert scale: 1: strongly disagree, 2: disagree, 3: somewhat disagree, 4: neither disagree nor agree, 5: somewhat agree, 6: agree, and 7: strongly agree.

The CSUQ evaluates four different factors: 1) the system's usability (questions 1–6), 2) information quality related to the web app usability (questions 7–12), 3) interface quality including the set of features provided by the web app to users (questions 13–15), and 4) overall usability (question 16).

Moreover, reliability among the 16 users evaluating web app usability was assessed to measure the replicability of their ratings and was considered a) moderate (Interclass

Correlation Coefficient (ICC) 0.50 to 0.75), b) good (ICC 0.75 to 0.90), or c) excellent (ICC >0.90) [35].

Moreover, to identify the web app's points for improvement, users were asked two further questions in Spanish by researchers, and these results were expressed as percentages:

1) *Have you encountered difficulties entering the recipe data? If so, at what point? Please, select from the following options using a cross:* a) Finding ingredients (the system does not work/lack of ingredient availability/lack of specific food brands/other problems), b) entering food weight (I do not know the exact weight/I know quantities in pieces or spoons or pinches/other problems), and c) selecting type of cooking (It is not available/there are more types of cooking/I use a different type of oil or flour or egg/other problems).

2) *Do you think the web app should be improved? If so, in which aspects? Please, select from the following options using a cross:* a) Design, b) Functionality, c) Comprehensibility, d) Data entry, e) Data analysis, f) Data presentation, and g) User support.

2.2.2 Evaluation of web app quality by nutritionists

Web app quality evaluation was performed using the MARS tool among the same panel of 10 nutritionists who also evaluated web app usability, since there is no evidence regarding the minimum sample size required for web app quality assessments. Nutritionists were recruited for the quality evaluation since they are confident and competent to verify app components such as the information content and functionalities [38]. Nutritionists were asked to enter a recipe sheet into the web app and to assess web app usability and web app quality through the MARS tool, which was provided online.

The MARS consists of objective and subjective quality assessments and has been recently validated [36]. The objective quality comprises 4 sections with 19 total items. Specifically, the sections are 1) engagement, 2) functionality, 3) aesthetics, and 4) information. On the other hand, the subjective quality assessment comprised 4 items, with a total of 23 questions about web app quality [37].

Furthermore, to collect information about the perceived impact of the web app on the user, 6 items belonging to the optional app-specific MARS section were asked [37].

Each MARS item was scored on a 5-point scale: 1: inadequate, 2: poor, 3: acceptable, 4: good, and 5: excellent. Total mean scores were calculated for each section. In particular, regarding the objective quality sections, for the engagement section, the maximum score was 25 points; for the functionality section, it was 20 points; for the aesthetics section, it was 15 points; and for the information section, it was 35 points, for a total of 95 points. For subjective quality, the maximum score was 20 points, and for app-specific section, it was 30 points.

Reliability among nutritionists evaluating the web app was assessed to measure the replicability of their ratings and was rated as moderate (ICC 0.50 to 0.75), good (ICC 0.75 to 0.90), or excellent (ICC >0.90) [35].

2.2.3 Evaluation of web app validation by nutritionists

Finally, the Healthy Meals web app was validated according to the accuracy of data entry by 2 different nutritionists who did not participate in the usability and quality assessment since there is no evidence about the minimum sample size required for web app validations. Furthermore, the Healthy Meals web app was validated by nutritionists because they are experts in the field of nutrition, which allows them to evaluate the appropriateness of the web app for providing nutritional content data [38]. Nutritionists were asked to enter the same 10 recipe sheets into the web app. From the resulting nutritional assessment, differences in nutrient contents expressed as the mean ± Standard Deviation (SD) were compared between the 2 nutritionists to evaluate web app validity.

Reliability between the two nutritionists validating the web app was assessed to measure the replicability of their ratings and was rated as moderate (ICC 0.50 to 0.75), good (ICC 0.75 to 0.90), or excellent (ICC >0.90) [35]. Furthermore, percent agreement was measured for the resulting MTL labels from nutritional composition analysis to evaluate the nutrient color rating agreement between nutritionists [39].

Statistical Analysis

Continuous variables are presented as the mean (SD), while categorical variables are presented as percentages.

Interrater reliability (IRR) among nutritionists and restaurateurs evaluating and validating the web app was measured as percent agreement for categorical variables [39] and according to the ICC for continuous variables, with 95% confidence intervals based on mean rating (k=2), consistency and a two-way random-effects model [35].

Bonferroni tests were conducted to assess the differences among MARS sections and CSUQ factor scores. Student's *t*-test or Mann-Whitney nonparametric test for independent samples was used for the assessment of data entry accuracy according to the difference among nutrient contents assessed by the two nutritionists in the validation phase. Statistical analysis was performed using SPSS software (version 25), and the significance level was fixed at $P \leq 0.05$.

Results

3.1 Evaluation of web app usability by nutritionists and restaurateurs

Web app usability was evaluated using the CSUQ by 16 users (n=10 nutritionists and n=6 restaurateurs). The mean total score (SD) for the four CSUQ factors assessed by the 16 users was 5.6/7 points (SD 0.9), meaning that users found the web app usable (*Table 1*).

However, reliability among users evaluating web app usability using the CSUQ was moderate (ICC=0.57; 95% CI, 0.18 to 0.82).

For each of the four CSUQ factors, scores obtained by the 16 users were as follows (*Table 1*):

1) For the system usability factor (questions 1–6), the web app obtained a total mean score of 5.7/7 points (SD 1.0), which means that users agreed that the web app system was usable. Regarding each question item of the system usability factor, lower agreement scores were obtained for the agreement of users on the speed with which they could complete the activity (mean 5.5/7 points, SD 1.4) and become comfortable with its use (mean 5.5/7 points, SD 1.3 points).

2) For the information quality factor, related to web app usability (questions 7–12), users gave a total mean score of 5.5/7 points (SD 1.2). Regarding the single question items of the information quality factor, lower agreement scores were found regarding the provision of clear error messages to solve problems in the web app (mean 5.2/7 points, SD 1.7), effective instructions to perform an activity (mean 5.2/7 points, SD 1.5), and the web app's simple and fast problem solving (mean 5.4/7 points, SD 1.7). Despite these lower results, users' responses were higher than half of the total points.

3) For the interface quality factor (questions 13–15), the web app obtained a total mean score of 5.6/7 points (SD 1.2). Regarding the single question items of the interface quality factor, the lowest agreement score was regarding the statement that the web app had all the expected tools (mean 5.0/7 points, SD 1.6).

4) Finally, regarding the overall usability factor in the context of the user's satisfaction with the web app (question 16), the web app received a total mean score of 5.7/7 points (SD 1.4), which indicates that users agreed that they were satisfied overall with the web app.

Regarding the differences in results between nutritionists and restaurateurs, nutritionists gave higher scores for the usability of the web app; however, the differences were not significant (*P*-value=.23) (*Table 1*).

On the other hand, differences among the four CSUQ factors for the 16 users were statistically significant (*Table 1*). Specifically, the system usability and the overall usability factors were significantly higher with respect to the information quality (*P*-value=.01; *P*-value=.02, respectively) and interface quality factors (*P*-value=.02; *P*-value=.00, respectively). Thus, the usability of the information provided by the web app, as well as the availability of the features accessible to the user, should be improved in the Healthy Meals web app to obtain higher CSUQ usability scores for information and interface factors.

Table 1: Healthy Meals web app usability evaluation using the CSUQ.

CSUQ factors	Total[a] Mean (SD)	Total nutritionists Mean (SD)	Total restaurateurs Mean (SD)
System usability[b, g]	5.7 (1.0)	5.8 (0.7)	5.4 (1.4)
Information quality[c, g]	5.5 (1.2)	5.9 (0.9)	5.0 (1.5)
Interface quality[d, g]	5.6 (1.2)	5.9 (0.7)	5.1 (1.8)
Overall usability[e, g] (User satisfaction)	5.7 (1.4)	6.1 (0.6)	5.2 (2.1)
Total CSUQ usability[f]	5.6 (0.9)	5.9 (0.1)	5.2 (0.2)

[a]: Total mean (SD) for the 16 users, on 7 maximum points; [b]: Including 6 items scored on 7 maximum points; [c]: Including 6 items scored on 7 maximum points; [d]: Including 3 items scored on 7 maximum points; [e]: Including 1 item scored on 7 maximum points; [f]: Total mean of CSUQ factors comprising system usability, information quality, interface quality and overall usability; [g]: Significant *P*-value <.05.

Regarding the web app points for improvement and suggestions, two further questions were asked to the 16 users (n=10 nutritionists and n=6 restaurateurs) during the usability evaluation step (*Table 2*).

In particular, most of the users (n=13/16, 81.3%) encountered difficulties entering the recipe data due to a) a lack of ingredient availability in the food database (n=10/12, 83.3%), b) a lack of specific food product brands (n=3/12, 25%) or c) other unspecified problems (n=5/12, 41.7%) (*Table 2*).

Furthermore, other participants encountered problems related to the entry of ingredients' weights (n=7/12, 58.3%) because a) they did not know the exact weight of the ingredients (n=3/12, 25%) as in the case of seasonings, spices or salt, for instance, or b) they could not convert in gram weights expressed in the recipe sheet into household measures such as pieces, spoons or pinches (n=3/12, 25%) (*Table 2*).

Difficulties were also experienced during the selection of the cooking methods due to a) the need to include more types of cooking for the same ingredient (n=6/9, 66.7%) or b) because a specific cooking method was not available (n=4/9, 44.4%) (*Table 2*).

Thus, all the responding users reported that the web app should be improved (n=14/14, 87.5%), especially regarding where data entry is concerned (n=14/16, 87.5%) (*Table 2*).

Table 2: Web app points for improvements identified by nutritionists and restaurateurs.

	N=16 % (n)
Have you encountered difficulties entering the recipe data?	
Yes	81.3 (13)
No	18.7 (3)
if so, at what point?	
a) Finding ingredients[a]	
The system does not work	0.0 (0)
Lack of ingredient availability	83.3 (10)
Lack of specific food brands	25 (3)
Other problems	41.7 (5)
Not answered	25 (4)
b) Entering food weight[a]	
I do not know the exact weight	25 (3)
I know quantities in pieces or spoons or pinches	25 (3)
Other problems	58.3 (7)
Not answered	25 (4)
c) Selecting type of cooking[a]	
It is not available	44.4 (4)
There are more types of cooking	66.7 (6)
I use a different type of oil or flour or egg	11.1 (1)
Other problems	33.3 (3)
Not answered	43.8 (7)
Do you think the web app should be	

improved?	
Yes	87.5 (14)
No	0.0 (0)
Not answered	12.5 (2)
if so, in which aspects?	
Design	6.3 (1)
Functionality	0.0 (0)
Comprehensibility	0.0 (0)
Data entry	87.5 (14)
Data analysis	0.0 (0)
Data presentation	0.0 (0)
User support	6.3 (1)

[a]: Total percentage of respondents is higher than 100% due to the multiple-option responses.

3.2 Evaluation of web app quality by nutritionists

Web app quality was assessed by the same 10 nutritionists who evaluated web app usability. Nutritionists' MARS evaluation of the web app objective quality resulted in a total mean score of 4.0/5 points (SD 0.4), which indicates a good evaluation of web app quality (*Table 3*).

Reliability among the ten nutritionists evaluating web app quality through the MARS was excellent (ICC=0.91; 95% CI, 0.85 to 0.96).

Specifically, regarding the four objective quality sections, good scores (≥4 points) were given to the web app's functionality (mean 4.5/5 points, SD 0.6), aesthetics (mean 4.2/5 points, SD 0.5), and information (mean 3.9/5 points, SD 0.6), while an acceptable evaluation (≥3 points) was given for engagement (mean 3.5/5 points, SD 0.7) (*Table 3*).

The subjective quality section scored 3.1/5 points (SD 0.4), which represents an acceptable evaluation. On the other hand, the app-specific section related to the web app impact on the user obtained a mean score of 4.3/5 points (SD 0.7), representing a good evaluation (*Table 3*).

Differences among the MARS sections showed that the total objective quality and the aesthetics sections were significantly higher with respect to the engagement (*P*-value=.04; *P*-value=.04, respectively) and information sections (*P*-value=.02; *P*-value=.02, respectively), meaning that the web app should be improved in regard to the provision of information and the entertainment of the user. Moreover, web app functionality was significantly higher than that in the app-specific section (*P*-value=.02), and the total objective quality was higher than that in the subjective quality sections (*P*-value=.048) (*Table 3*). Thus, although the overall quality of the web app is good, the positive impact the web app gives to the user, as well as the subjective quality, should be improved, perhaps by enhancing the web app's information and engagement sections.

Table 3: Results from the nutritionists' MARS evaluation of the Healthy Meals web app quality.

MARS sections	**Total[a]** Mean (SD)
Engagement[b]	3.4 (0.7)
Functionality[c, i]	4.5 (0.6)
Aesthetics[d, i]	4.2 (0.5)
Information[e, i]	3.9 (0.6)
Total objective quality[f, i]	4.0 (0.4)
Subjective quality[g, i]	3.1 (0.4)
App specific section[h]	4.3 (0.7)

[a]: Total mean (SD) score of the 10 nutritionists, on 5 maximum points; [b]: Including 5 items scored on 5 maximum points; [c]: Including 4 items scored on 5 maximum points; [d]: Including 3 items scored on 5 maximum points; [e]: Including 7 items scored on 5 maximum points; [f]: Sum of engagement +functionality +aesthetics +information sections, including 19 items scored on 5 maximum points; [g]: Including 4 items scored on 5 maximum points; [h]: Including 6 items scored on 5 maximum points; i: significant *P*-value <.05.

3.3 Evaluation of web app validation by nutritionists

Web app validity was assessed by two different nutritionists. After the entry of 10 recipe sheets by nutritionists, differences between nutritional contents were assessed according to nutrients' mean values (*Table 4*).

No statistically significant difference was observed between the two nutritionists' data (*P*>.05), indicating the validity of the nutritional content assessment of dishes (*Table 4*). Furthermore, the reliability between the 2 nutritionists was excellent (ICC=0.98; 95% CI, 0.97 to 0.99).

From the analysis of the MTL labels, the total percent agreement between the two nutritionists for the eight assessed nutrients was equal to 93.75%. A lower agreement in the MTL labels between the two nutritionists was found for fiber (80%), while for protein, sugar, and saturated fat, agreement reached 90%. MTL labels for energy, carbohydrates, total fat and sodium were equal between the two nutritionists.

Table 4: Results from the nutritionists' validation of the Healthy Meals web app.

Nutrients	**Nutritionist 1 Mean (SD)[a]**	**Nutritionist 2 Mean (SD)[a]**	***P*-valor**
Energy (kcal)	761.1 (564.9)	731.4 (570.7)	.74[b]
Proteins (g)	31.4 (22.1)	30.7 (23.8)	.68[b]
Carbohydrates (g)	50.9 (41.1)	52.7 (41.5)	.92[c]
Sugar (g)	9.5 (15.8)	10.2 (17.1)	.68[b]
Fats (g)	46.7 (56.6)	43.3 (57.0)	.63[b]
Saturated fats (g)	8.2 (6.2)	7.7 (6.0)	.85[c]
Sodium (mg)	706.8 (370.2)	955.1 (485.2)	.21[c]
Fiber (g)	6.1 (8.6)	5.7 (7.0)	1.00[b]

[a]: Nutrients content differences between the two nutritionists are expressed in mean (SD); [b]: Mann-Whitney test for not normally distributed values; [c]: Student's t-test for normally distributed values.

Discussion

The usability and quality of the Healthy Meals web app was evaluated by a panel of nutritionists and restaurateurs and then validated by two different nutritionists,

confirming it to be a usable, high-quality, valid tool for restaurants to improve dishes' nutritional content and identify food allergens in their menu.
Evaluating the usability of apps is an essential step to determine the ease by which the app could be used to achieve a specific goal [40]. In this regard, it is important to evaluate the usability of a web app before it is released to a wider population, and the evaluation should be performed through appropriate and validated usability criteria [41], such as the CSUQ, which is a highly reliable and valid tool [34].

Specifically, in the present usability evaluation, nutritionists and restaurateurs agreed about the usability of the Healthy Meals web app (mean 5.6/7 points, SD 0.9) according to the CSUQ, meaning that a positive evaluation concerning user satisfaction was given about the usability of the four assessed factors, which are the web app system, interface, information and overall usability. Therefore, the Healthy Meals web app was demonstrated to be a simple and user-friendly tool that requires minimal effort from the users to conduct the expected activity [42]. Furthermore, the good usability of the Healthy Meals web app also represents its acceptability to users, who are more encouraged to use a tool that is easy to understand and use [41].

The moderate reliability observed in the usability evaluation among restaurateurs and nutritionists was due to lower ratings given by restaurateurs, who do not have experience performing nutritional compositional analysis and may need more time than nutritionists to become confident with it. However, as observed by Condrasky et al., in a nutrition knowledge survey, chefs are willing to acquire more competences regarding food composition and recipe modification principles to cook healthier meals for consumers [43]. However, to achieve this, chefs need appropriate education through innovative tools that fit with their busy schedule, such as digital tools [43]. Thus, the Healthy Meals clearly represents an opportunity for restaurateurs to learn more about food composition and increase cooking competences over time through the easy-to-read MTL label provided by the web app after the food composition analysis. Furthermore, in the present study, the interface and information usability were the CSUQ factors with lower scores. For instance, the provision of clear, easy, and concise instructions and information in the web app interface to guide restaurateurs could increase the usability and confidence of restaurateurs with the Healthy Meals web app.

Regarding the web app points for improvement identified through two open-ended questions during the usability evaluation, 81.3% of nutritionists and restaurateurs encountered difficulties during recipe sheet data entry. Some of the problems faced were related to the lack of ingredient availability in the food database. Gaps in food composition databases are due to the constant production of new food products according to the needs of consumers, so a steady effort must be made to update these food composition databases [44]. However, as the Healthy Meals web app has an open food ingredient database, ingredients could be easily introduced when requested by restaurants. Other encountered difficulties were related to the entering of the ingredients' weights, with users not being able to estimate portions or convert household measures into grams. Accuracy in the estimation of portion sizes using hand or household measures is difficult and could be subjected to considerable errors [45]. A cross-sectional survey about adults' perceptions of household measuring utensils demonstrated that perceived sizes of household measurements could be under- or overestimated by participants, leading to an incorrect evaluation of the ingredient's weight [46]. In this regard, visual aids such as photographs or atlases for the identification of portion size ranges could be a valuable tool [47] to implement in the Healthy Meals web app.

The quality evaluation of web apps is another important step to assess to ensure high-quality content and functionalities for users, especially when these are related to health aspects, as in the case of the Healthy Meals web app. Actually, it is highly recommended to involve nutrition experts in the design and development of nutrition-based apps to safeguard users [49]. For this reason, the quality evaluation was assessed by a panel of nutrition professionals who were able to better verify the content and functionality of the web app and were more competent in regard to nutritional data.

Specifically, the MARS total objective quality received a mean score of 4.0 (SD 0.4) of 5 maximum points, which indicates a good quality evaluation of the Healthy Meals web app by nutritionists. Furthermore, excellent reliability was observed, reinforcing the reproducibility of the results.

In particular, the functionality and aesthetics MARS sections obtained the highest scores in the quality evaluation, meaning that the Healthy Meals web app appeared aesthetically pleasant and practical to nutritionists. This represents a favorable point for the Healthy Meals web app, since users generally tend to prefer apps that are enjoyable and have a positive visual impact [50] and good functionality to motivate use by people with little familiarity with technology [51].

Nonetheless, similar to what was observed in the usability evaluation, the engagement and information quality could be improved through the introduction of more ingredients in the food database, as well as through the provision of different cooking methods and aids in the entry of ingredient weights. Therefore, through the provision of more inputs, user engagement would also increase, resulting in long-term use and better experience of the web app [52].

Last, validation of eHealth app contents by health professionals is very important to ensure that the information generated by the app is valid and correct for use by end-users [53]. For instance, assessing the accuracy in data in the Healthy Meals web app by nutritionists, who are experts in food nutritional composition, helped us to demonstrate the appropriateness and relevance of the web app for wider population use, such as restaurateurs [38]. Furthermore, their participation throughout the entire process of the web app evaluation maximized the identification of the web app points for improvement by providing a more professional and qualified viewpoint [54].

Specifically, the results from the Healthy Meals web app validation showed that there were similar results between nutritionists entering the data, with 93.75% percent agreement in the MTL labels, meaning that the nutrient labels obtained from the two nutritionists were exactly the same for most of the assessed micro- and macronutrients. Excellent reliability values between nutritionists were observed, which further supports the replicability of their ratings.

Thus, the Healthy Meals web app represents a valid tool for restaurants to improve their offering of healthier meals, as well as for the identification of food allergens, for which restaurant staff still have many gaps [55,56].

Unlike the previous experimental apps and web apps for nutritional content assessment and food allergen identification, the Healthy Meals web app exhibits several differences, demonstrating it to be an innovative web app. For instance, the *Foodtracker app* was developed as a system for fast food recommendations to help consumers make their food choices by providing them with the caloric content of restaurant menu offerings in the form of an MTL label [57]. However, this system only focuses on nudging individual behavior dietary changes, not considering restaurateurs as the first step for enacting healthy changes, as does the Healthy Meals web app. On the other hand, leading nutrition-tracking apps aimed at assessing consumer nutritional intake underestimate nutrient contents, indicating that commercial apps still lack appropriate evaluation and validation [58].

Furthermore, the Healthy Meals web app represents an important food allergen database that could support restaurateurs in the preparation of allergen-adapted meals for allergic and intolerant consumers and in the identification of the 14 most common food allergens in menu offerings to communicate to customers. Thus, the Healthy Meals web app also presents several differences and advantages with respect to other existing technologies for food allergen detection. For instance, Lizuka et al.[59] developed a “Food Menu Selection Support” system, available from mobile and computer devices, to help users make safe food choices according to different dietary constraints (food allergies, dialysis, old age, recovery after hospital stay, etc.). This type of system considers individual personal information, which should be entered to create a user profile and generate a list of tailored food products and menus adapted for the user [59]. Similarly, the “Personal Mobile Restaurant” system was designed to approach the strict dietary needs of consumers, such as food allergies, health conditions, dislikes, diets, and religious or culture aspects, by identifying suitable restaurants and creating a personalized list of adapted meals to order [60]. However, these systems are centered only on consumers’ personal use and needs, rather than on both restaurateurs and consumers, and do not integrate food allergen identification with nutritional content assessment, as does the Healthy Meals web app. Furthermore, the Healthy Meals web app has been evaluated and validated by a panel of nutrition professionals.

Limitations

Several limitations arose during the development and validation of the Healthy Meals web app. First, because of the COVID-19 pandemic, the participation of restaurants in the evaluation was limited due to the difficult situation of the catering sector and the lack of restaurant personnel. Second, the lack of similar web apps prevented the comparison of our web app with other existing apps and limited the availability of information about evaluation methods for this kind of web app. Finally, recipe sheets contained rough amounts of ingredients (spoons, glasses, pinches, etc.), so the lack of knowledge of users regarding the exact amounts may have limited the data entry and affected the nutritional analysis.

Suggestions for future improvements

According to the two open-ended questions asked to nutritionists and restaurateurs during the usability evaluation and personal suggestions received by some restaurateurs after participation in the web app evaluation, considerable suggestions for future improvements are provided. These future improvements will increase both usability and quality aspects assessed in the present study by nutritionists and restaurateurs. In particular, the next advances should include the following:

1) Introduction of more cooking methods (i.e., grilled, roasted, preprocessed, precooked, etc.), with the possibility of inserting more cooking methods for the same ingredient.

2) Addition of more household units of measurement for the ingredients (i.e., mL, pieces, spoons, pinches, etc.), to help users enter data of ingredient weights. For instance, the implementation of visual aids such as food portion photographs could help restaurateurs enter the correct weights when corresponding grams are unknown.

3) Implementation of a food database with more product brands and varieties.

4) Improvement of the overall data entry by improving the ingredient search.

5) Creation of an observation field for additional comments about the recipe preparation or content.

6) Addition of new functionalities to help restaurateurs in the design of the menu, in the management of the warehouse, in the preparation of the food shopping list, etc.
7) Inclusion of alerts to remind restaurateurs to insert any after-preparation dressing.

Conclusion

The Healthy Meals web app was demonstrated to be usable, of good quality and a valid tool for the nutritional assessment and food allergen identification of dishes. Points to improve were identified, while the effectiveness of the app should be tested in scientific trials.

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Conflicts of Interest

The authors declare no conflicts of interest.

Abbreviations

CSUQ: Computer System Usability Questionnaire; GDA: Guideline Daily Amounts; ICC: Inter-class Correlation Coefficient; IRR: Inter-Rater Reliability; MARS: Mobile App Rating Scale; MTL: Multiple Traffic Light; SD: Standard Deviation.

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GENERAL DISCUSSION

GENERAL DISCUSSION

The hypothesis of the present thesis is verified and suggests how to encourage healthier meal choices in restaurants. In this regard, the present thesis provides some specific effective intervention strategies and evidence regarding the use of innovative technologies in restaurant-based interventions for the promotion of healthier meals when eating out and for better management of food allergens by restaurants.

At the outset of this thesis, there were no data on the nutritional content of local restaurants' meals or on the potential intervention strategies to improve healthy nutrition and good management of food allergens by restaurants.

Following the results obtained, the present thesis produced **five key findings** (*Figure 7*):

1. Provided tailored recommendations to restaurants to improve the nutritional content of their meals and food allergen management according to the assessed local restaurants' current situation;

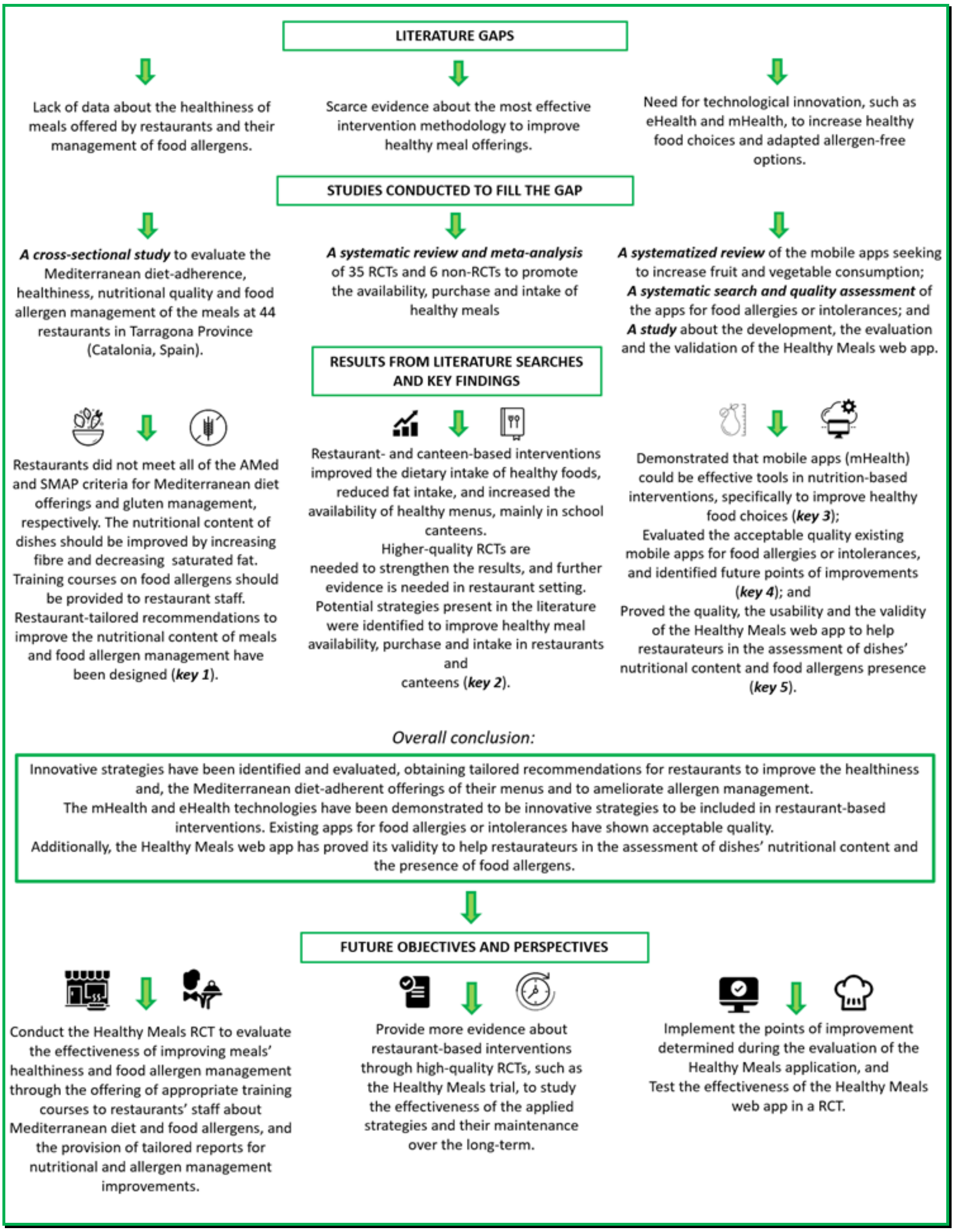
2. Identified potential strategies present in the literature that can be applied in future interventions to improve healthy meal availability, purchase and intake in restaurants and canteens;

3. Demonstrated that mobile apps (mHealth) could be effective tools in nutrition-based interventions, specifically to improve healthy food choices;

4. Evaluated acceptable quality of the existing mobile apps for food allergies or intolerances and identified future points of improvement; and

5. Proved the quality, usability and validity of the Healthy Meals web app designed for the project to help restaurateurs assess dishes' nutritional content and the presence of food allergens.

Figure 7: Key findings and future perspectives for the improvement of the healthy meal offerings and food allergen management in restaurant-based interventions: studies included to tackle thesis-specific aims.



Source: designed by the author.

One of the specific objectives of this thesis was to address the existing gap regarding the adherence to the Mediterranean diet, the healthiness of the gastronomic offerings provided by and the level of food allergen management of local independent restaurants in the province of Tarragona, in order to form restaurant-tailored recommendations for future improvements (***Study 1:*** Mandracchia et al., 2021).

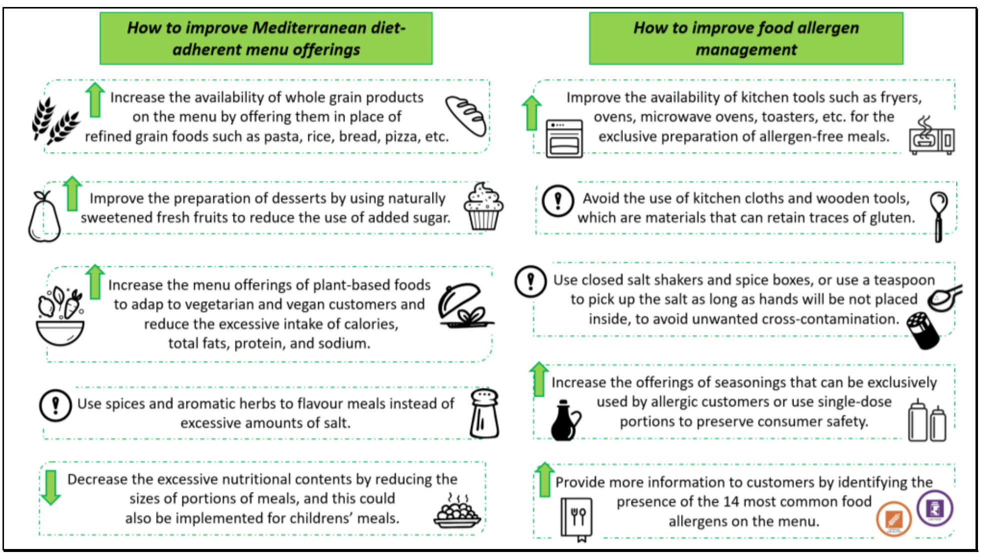
Regarding the nutritional assessment of their menus, it emerged that independent restaurants did not entirely adhere to the healthy Mediterranean dietary pattern according to the fulfilled AMed criteria designed by the Spanish Public Health Agency (Agencia de Salud Pública de Cataluña, 2007). Moreover, the nutrient contents of the offered dishes exceeded the European Union (EU)-recommended Guideline Dietary Amounts (GDA) for single portions (***Study 1:*** Mandracchia et al., 2021).

Specifically, according to the GDAs, for a single portion, restaurant meals exceeded the recommended cut-offs. In particular, starters were high in calories, protein, fat, saturated fat and sodium; main dishes had high contents of calories, protein, fat, saturated fat and sodium; and desserts were high in sugar, fat and saturated fat. Additionally, a significant correlation was observed between the unfulfilled AMed criteria and the nutritional gaps determined in the nutritional content assessment of the offered dishes, demonstrating that further efforts should be made by restaurants to ensure that they adhere to the Mediterranean diet recommendations. Thus, a greater compliance with the AMed criteria would result in an increase in dishes with green ratings in the traffic light system, corresponding to a healthier offer. In this regard, from the identified needs of the analysed restaurants in the Healthy Meals cross-sectional study, detailed recommendations have been developed, specifically for restaurants in Tarragona Province to improve their gastronomic offerings in line with the Mediterranean diet (***Study 1:*** Mandracchia et al., 2021) (*Figure 8*).

Furthermore, the identification of the 14 food allergens present in the offered dishes of the menus of restaurants is still lacking (Borchgrevink et al., 2009). As observed from this thesis conducting cross-sectional analysis of the gastronomic offerings in Tarragona Province restaurants (***Study 1:*** Mandracchia et al., 2021), only 29.5% of the restaurants identified food allergens on their menu, showing that further efforts should be made to conform to EU legislation (The European Parliment and the Council of the European Union, 2011).

Restaurants in the province of Tarragona offer different gluten-free options and fulfil several of the SMAP criteria defined by the Catalan Celiac Association (Associació Celíacs de Catalunya, 2014). The most fulfilled criteria were related to the use of different tools or non-cross-contaminated kitchen tools for the preparation of food without gluten and to the attention of the staff in cleaning the kitchen area and their hands before the preparation of gluten-free food. However, further efforts are necessary to improve the fulfilment of all 18 SMAP criteria; thus, specific recommendations were designed for restaurants on the basis of the cross-sectional analysis results (***Study 1:*** Mandracchia et al., 2021) (*Figure 8*).

Figure 8: Tailored recommendations to improve Mediterranean diet-adherent offerings and food allergen management in Tarragona Province restaurants.



Source: designed by the author, adapted on ***Study 1*** (Mandracchia et al., 2021)

Furthermore, the scarce knowledge of restaurant staff about food allergen management obtained from our cross-sectional analysis in Tarragona Province (***Study 1:*** Mandracchia et al., 2021) supports the need to provide more appropriate training courses to restaurant waiters, cooks, and kitchen helpers through both theoretical notions and practical training, which have been demonstrated to be effective strategies in previous interventions (Roberts et al., 2018).

Regarding the availability of meals suitable for vegetarian and vegan customers, restaurants still provide limited options, although the demand has increased in recent years and the vegetarian and vegan Spanish populations reached 1.5% and 0.5%, respectively, in 2019 (Medina, 2019).

Thus, our results are in line with previous studies, demonstrating that the frequent consumption of out-of-home meals could lead to an unbalanced, unhealthy, and poor diet (Jia et al., 2018; Suggs et al., 2018; Zang et al., 2018). In particular, Spanish restaurant meals were high in calories, total fat, and sodium content and very low in dietary fibre, similar to what has been observed worldwide (Bleich et al., 2020; Ho et al., 2020; Muc et al., 2019; Murphy et al., 2020).

In this sense, our results support recent evidence that indicates that Mediterranean countries differ from the Mediterranean dietary pattern due to modern lifestyles and socioeconomic conditions, although the Mediterranean diet has been associated with several health benefits (Cavaliere et al., 2018).

The present thesis also intended to provide more data regarding the effectiveness of previous strategies applied in independent restaurant- and canteen-based interventions to promote healthy food availability, dietary intake and food purchase (***Study 2***: Mandracchia et al., 2021). The systematic review conducted in the present thesis (*Figure 7*) showed that restaurant and canteen-based interventions could be effective in a) improving healthy food availability and b) increasing the consumption of whole grains, dairy products, and nutrients as fibre and decreasing the intake of fat and saturated fat, mainly in schools (***Study 2***: Mandracchia et al., 2021).

Although there is a positive outcome of increasing healthy food availability and purchases, the difficulty in implementing such interventions in restaurants lies in the barriers encountered by restaurateurs, identified in previous studies: a) the costs associated with the purchase of high-quality and healthy foods (Kim et al., 2017), b) the risk of a low profit margin (Boelsen-Robinson et al., 2019), and c) the lack of sufficient staff training and cooking skills to manipulate recipes (Obbagy et al., 2011).

Nonetheless, the demand for better offerings is increasing among consumers who are unsatisfied with the current menu options available. Specifically, customers would like meals to be prepared with healthier cooking methods instead of fried foods, with fresher ingredients in place of frozen ingredients, and with more vegetable-based dishes to be available on weekdays and special occasions. According to these actual consumers' needs, restaurants should try to overcome their barriers and meet the demand for heathier meals (Newson et al., 2015).

Furthermore, as observed in the systematic review included in this thesis, in community-based interventions (considering restaurant-based and canteen-based studies), the application of both consumer-based and establishment-based strategies seemed to improve customers' healthy dietary intake and food purchases. Specifically, the strategies that were identified to be the most effective for achieving such outcomes include a) the delivery of promotional and educational materials in the form of leaflets, posters, manuals, or messages, as well as the organization of activities directed to the consumers; and b) the provision of monetary incentives, rewards or recognition for participating establishments such as restaurant, recreation centres, sporting clubs and after-school programme canteens (***Study 2***: Mandracchia et al., 2021).

One of the potential strategies investigated during this thesis was the use of mobile and web apps in the context of restaurant-based interventions. Specifically, several research studies were conducted to deepen the understanding of the following: a) the effectiveness of mobile phone apps in dietary self-monitoring and in increasing the intake of fruits and/or vegetables (***Study 3:*** Mandracchia et al., 2019); b) the quality of existing mobile phone apps for food allergies and intolerances (***Study 4***: Mandracchia et al., 2020); and c) the quality, usability and validity of a web app designed and developed in the framework of the Healthy Meals RCT to help restaurateurs ameliorate nutritional content and identify the food allergens in offered dishes (***Study 5:*** Mandracchia et al., *editor submitted*).

The use of mobile apps has widely expanded in recent years, and those aimed at improving nutritional behaviours and nutrition-related health outcomes, have confirmed their promising positive outcomes in different studies (Paramastri et al., 2020; Villinger et al., 2019). Specifically, apps focused on improving users' motivation, attitude, knowledge, self-monitoring, and goal setting are particularly suited to promoting nutritional behaviour change (West et al., 2017). In particular, app features such as the sharing of the same motivation to achieve a healthier lifestyle by the targeted population, as well as the use of behavioural-based strategies such as personal feedback and remote support, are important drivers of the efficiency of the intervention and the acceptability of the app by the user (***Study 3:*** Mandracchia et al., 2019). However, agreement regarding the effectiveness of apps in promoting healthy nutritional behaviours should come from appropriate testing in RCTs, and there is still limited data on the topic (Coughlin et al., 2015; Schoeppe et al., 2016).

Likely, as observed from the systematic search and quality assessment of apps for food allergies or intolerances (***Study 4***: Mandracchia et al., 2020), few commercial apps have been tested in RCTs, although it would be appropriate to test their effectiveness before presenting them to users, especially when addressing users' health (Krebs & Duncan, 2015). Evidence from RCTs is considered a gold standard approach, although it requires the use of more time and resources, but allows us to assess the effectiveness of the app compared with other methods (Jake-Schoffman et al., 2017). Therefore, in the meantime these apps' efficacy would be tested in RCTs, their evaluation in terms of a) quality (Stoyanov et al., 2015), b) usability (Abrahão et al., 2008), and c) content validation from health professionals (Misra et al., 2013) represent fundamental steps to safeguard users' health.

To evaluate the quality of the app, the Mobile App Rating Scale (MARS) was used both in ***Study 4*** (Mandracchia et al., 2020) and in ***Study 5*** (Mandracchia et al., *editor submitted*). The MARS tool provides a multidimensional evaluation of app quality comprising engagement, functionality, aesthetics, and information features (Stoyanov et al., 2015) whereas other existing tools mostly use one-dimensional measure (Aitken et al., 2013). Furthermore, the MARS tool has recently demonstrated high reliability and validity (Terhorst et al., 2020); and as shown by this thesis analysis experience, the MARS tool helps to provide accurate suggestions for future app improvements.

According to the systematic search and quality assessment of existing mobile apps for food allergies or intolerances, acceptable quality by MARS was observed, although the engagement aspect should be ameliorated and testing in scientific trials is recommended to demonstrate the apps' reliability and effectiveness (***Study 4:*** Mandracchia et al., 2020).

Furthermore, in ***Study 5*** (Mandracchia et al., *editor submitted*) the MARS tool showed that the Healthy Meals web app possessed good quality on the basis of nutritionists' evaluation. In particular, the functionality and aesthetics of the app received higher scores than those of the engagement and information sections, which should be ameliorated.

Another necessary requisite to evaluate digital health apps is the usability of the app for users, which means simplifying the experience and requiring minimal effort to conduct the expected activity (Mathews et al., 2019).

The Computer System Usability Questionnaire (CSUQ), previously validated and used in similar evaluations (Farzandipour et al., 2021; García-Peñalvo et al., 2019; Ledesma et al., 2016), allowed us to assess different usability factors in ***Study 5*** (Mandracchia et al., *editor submitted*) including the following: a) the system usability, representing the general ease of use of the app; b) the quality of the information provided in terms of availability, clarity and appropriateness; c) the interface quality, representing the set of features that the app provides to the users; and d) the overall app usability, representing the general satisfaction of the user about the app (Sauro & Lewis, 2016).

From the usability evaluation performed in ***Study 5*** (Mandracchia et al., *editor submitted*) among nutritionists and restaurateurs, the Healthy Meals web app demonstrated to be usable. However, interface quality related to the type and number of features provided by the web app, and information quality related to the presence of clear instructions and messages for the user to realize the activity, are the CSUQ factors which should be improved.

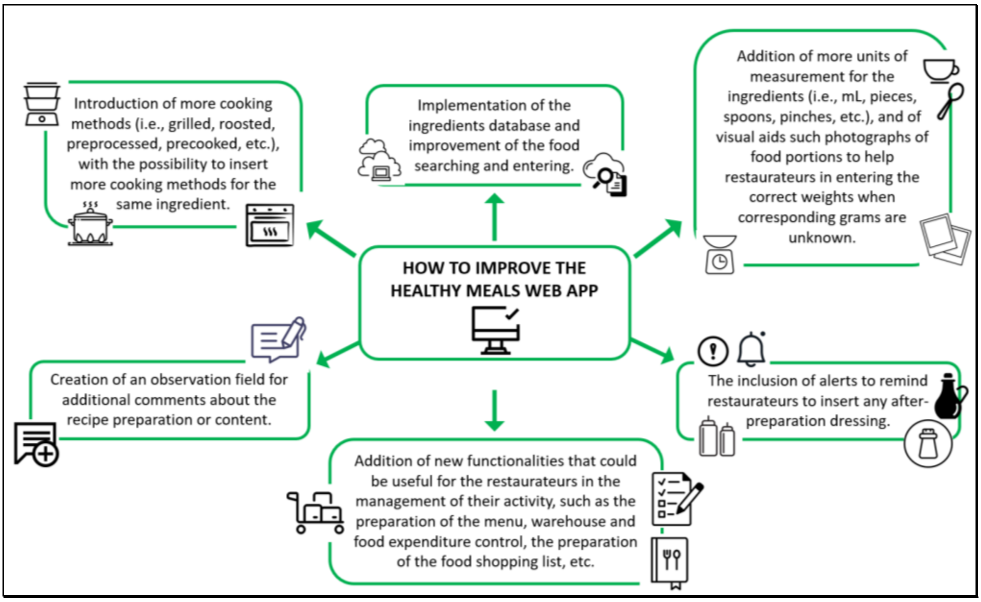
Furthermore, according to the web app points for improvements identified by nutritionists and restaurateurs through two more open questions provided during the usability evaluation, a lack of availability of nutritional information for some ingredients in the Healthy Meals database was reported (***Study 5:*** Mandracchia et al., *editor submitted*).

Gaps in food composition databases are due to the rapid introduction of new products in the market, based on emerging consumer needs; therefore, a constant effort must be made to update these food composition databases and make the different existing databases as homogeneous as possible (Ocké et al., 2021).

Other app aspects to ameliorate were the provision of more units of measurement representing those used in households to help users enter ingredient weights when exact grams were unknown (***Study 5:*** Mandracchia et al., *editor submitted*). As a result, the estimation of food quantities could be affected by under- or overestimation, leading to erroneous nutritional assessments (Gibson et al., 2016).

Thus, the assessment of the usability of the Healthy Meals web app allowed us to determine future points for improvements (***Study 5:*** Mandracchia et al., *editor submitted*) (*Figure 9*).

Figure 9: Points of future improvements to be implemented in the Healthy Meals web app (***Study 5:*** Mandracchia et al., *editor submitted*).



Source: designed by the author.

In addition to the evaluation of the quality of the app, the validation assessment measures the app's ability to report valid and reliable information. For instance, assessing the accuracy and precision of an app when the app is used by different users is very important to ensure the usability of the device among the general population and to prove that the app could be used with a basic level of training provided to users (Franko, 2012). The validation of the Healthy Meals web app did not show significant differences between the data entry of nutritionists (***Study 5:*** Mandracchia et al., *editor submitted*), with excellent reliability values among them, demonstrating that the web app could represent a valid tool. Specifically, this web app could help restaurants in the assessment of dishes' nutritional content and in the provision of food allergen information to customers on menus, and these demands are constantly increasing. Such information could drive consumers towards healthier menu choices and consequently guide them closer to a healthier lifestyle (Shah et al., 2014).

Thus, the next steps will be aimed at improving the Healthy Meals web app following the results of the evaluation (***Study 5:*** Mandracchia et al., *editor submitted*), in addition to its testing in the context of a high-quality RCT.

In conclusion, future research will rely on the performance of a full-service restaurant-based intervention, such as the Healthy Meals RCT, to evaluate the effectiveness of improving meals' healthiness and food allergen management through the application of a multiple intervention comprising different steps:

1. ***The analysis of the menu offerings*** in order to: a) evaluate the adherence to the healthy Mediterranean dietary pattern (Fundación Dieta Mediterránea, 2010), according to the fulfilment of the AMed criteria (Agencia de Salud Pública de Cataluña, 2007); b) assess meals' nutritional contents through the specifically created Healthy Meals web app; and c) evaluate the fulfilled SMAP criteria for food allergen management (Associació Celíacs de Catalunya, 2014).

The analysis of the menu offerings was effective in highlighting the healthiness, Mediterranean diet adherence and allergen management of the restaurants included in the cross-sectional study of the present thesis (***Study 1:*** Mandracchia et al., 2021), demonstrating this to be a good intervention strategy for future studies.

2. ***The provision of specific training courses to the restaurant staff*** comprising waiters and cooks on two important topics: a) the principles of the Mediterranean diet, since as observed by an earlier survey on the Spanish population, people still do not possess full knowledge regarding the composition of this diet and its benefits, and this may result in the poor adherence to this healthy dietary pattern (Posta, 2019); and b) food allergen management in kitchens and dining rooms, which personnel may report to have knowledge of but actually lack understanding and application (National Academies of Science Engineering and Medicine; Health and Medicine Division; et al., 2016). In this sense, the provision of appropriate training has been demonstrated in previous studies to improve restaurant staff knowledge and practice regarding food allergies, representing a promising strategy for future restaurant-based interventions (Bailey et al., 2014; Tarro et al., 2017).

3. ***The provision of tailored reports about Mediterranean diet adherence and food allergen management*** could help to increase restaurant awareness and encourage restaurant self-improvement (De Vries et al., 2008); furthermore, the identification of the allergens present in the offered dishes and suitable options for vegetarian and vegan dietary patterns could safeguard customers when making food choices outside the home (Young & Thaivalappil, 2018).

4. ***The provision of tailored recommendations for restaurants*** that need to be supported in their improved provision of healthier meals and options adapted for allergic and intolerant consumers on their menus (Obbagy et al., 2011), as well as the spreading of the intervention results for future evidence-based actions (Brunner et al., 2001).

CONCLUSIONS

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Study 1: Restaurants partially met the AMed and SMAP criteria, demonstrating that further efforts are needed to improve Mediterranean diet-adherent menu offerings and food allergen management. Increasing fibre and decreasing saturated fat are necessary to improve the nutritional content of restaurant meals and consequently consumers' adherence to a healthy diet. Additionally, for restaurant staff, training courses should be considered as a way to reinforce adequate food allergen management in restaurants.

Study 2: Restaurant- and canteen-based interventions improved the dietary intake of healthy foods, reduced fat intake, and increased the availability of healthy menus, mainly in schools. However, higher-quality RCTs are needed to strengthen these results. Moreover, from our results, intervention strategy recommendations are provided.

Study 3: The present review demonstrates that mHealth app-based interventions, lasting from two to nine months and characterized by a stratified population that shares the same motivation to achieve better dietary habits, are effective in increasing fruit and vegetable consumption. Furthermore, the inclusion of behavioural change techniques, such as dietary feedback together with self-monitoring and remote coaching support, has been identified as a key element that can definitively facilitate the adoption of new dietary habits. This issue strongly suggests that behavioural theory-based strategies must be considered when designing dietary mHealth interventions. Further research on mHealth apps is needed to design more effective interventions and to determine their efficacy over the long term.

Study 4: Food allergy or intolerance apps showed acceptable MARS quality (≥3 points of 5), although the engagement section for food product and restaurant purpose apps should be improved, and the effectiveness of the applications has yet to be tested in trials. The critical points identified can help improve the innovativeness and applicability of future food allergy and intolerance apps.

Study 5: The Healthy Meals web app was demonstrated to be usable, of good quality and a valid tool for the nutritional assessment and food allergen identification of dishes. Points to improve were identified, while the effectiveness of the app should be tested in scientific trials.

OVERALL CONCLUSION

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In conclusion, innovative strategies have been identified and evaluated, obtaining tailored recommendations for restaurants to improve the healthiness and the Mediterranean diet-adherent offering of their menus and to ameliorate allergen management.

Regarding the inclusion of digital technologies, mHealth and eHealth technologies have been demonstrated to be innovative strategies that can be included in restaurant-based interventions. Existing apps for food allergies or intolerances have shown acceptable quality. Additionally, the Healthy Meals web app has proven its usability, quality, and validity to help restaurateurs assess dish nutritional content and the presence of food allergens.

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