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Identification of best practices for promoting food literacy and sustainable diets in higher education institutions

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Abstract

Food represents the one of the most powerful levers for positively impacting people's health and global sustainability. However, the major diets that characterize current societies worldwide fail to represent nutritionally balanced and environmentally friendly eating patterns and are threatening both individuals and the planet. What is needed is a shift in diet that includes a reduction in unhealthy foods and animal products through a gradual transition to eating patterns based on fresh, local, seasonal, and minimally processed foods, prioritizing plant-based products such as fruits, vegetables, whole grains, legumes and nuts, and less impactful animal products such as eggs, milk and fermented products, poultry, and sustainable fish. Given the complexity of factors influencing people's eating habits, contemporary lifestyles, and the increasingly obesogenic environment we live in, multi-strategic actions are needed to trigger lasting change toward sustainable behaviors. In this context, creating an enabling food environment that supports people in this transition and facilitates the adoption of healthy food choices is paramount. Among various living contexts, educational institutions play a key role in shaping the dietary behaviors of the younger generation. In particular, the provision of good-quality, healthy food through on-campus dining services encourages healthy dietary behaviors and fosters the general well-being of diners.

Based on these considerations, the purpose of this Doctoral Thesis was to identify best practices for implementing effective strategies to improve food literacy and promote sustainable diets through higher education institutions, particularly leveraging the key role of food services. To address this goal, two lines of research were pursued in parallel, and a workshop was organized to provide a position paper based on the latest evidence from the literature and the experiences of the leading experts in the field.

As primary research activity, a systematic review was conducted to assess the adherence to dietary guidelines in young populations (2-35 years) living in Europe. Overall, the results showed little compliance with national dietary guidelines and nutritional recommendations, confirming the current shift toward Western-style diets, characterized mainly by a low consumption of plant-based foods, and an excessive consumption of meat and meat products, sweets, and sugary drinks. However, due to the limited number of studies conducted on nationally representative samples over the past decade, drawing solid conclusions about the current dietary habits of younger European generations is difficult, especially for young adults.

Subsequently, an online survey addressed to two representative cohorts of Italian and American students was carried out to explore their adherence to the Mediterranean Diet (MD)

and the sustainability of their dietary behaviors, providing new evidence on the main drivers of dietary habits in this specific target population, considering different living contexts such as a Mediterranean and non-Mediterranean area. The results highlighted an active lifestyle, sustainable eating behavior, extensive consumption of plant-based foods, willingness to buy and eat healthy and sustainable meals, and regular university cafeteria attendance as the main predictors of high MD adherence. In this context, it is crucial to make university dining services an enabling environment for promoting healthy and sustainable food choices among students and the academic community.

Given this, a pilot study tested the effect of reordering menu items as a "light touch" nudging strategy to encourage low-carbon food choices. A significant effect of item placement on users' decisions was found. In particular, eco-friendly options were preferred if placed at the beginning of the menu, however the choice of beef options was not decreased. These outcomes confirmed the effectiveness of an easy-to-implement nudging approach, but also emphasize the need for a multi-strategy approach that includes outreach and education of students about the environmental impact of their food choices.

Raising awareness about nutrition and food sustainability issues among food service users is as important as increasing knowledge and skills of restaurant staff, especially chefs, on the same topics. In this connection, the second part of this thesis aimed to assess the impact of an intervention to raise knowledge on nutrition and food sustainability aspects in a control and intervention sample of culinary students registered at the International School of Italian Cuisine (ALMA) in Parma (Italy). The effectiveness of the educational project was confirmed by the increased level of knowledge in the intervention group and the adequate nutritional profile of the menus prepared by the chefs during a work project, a task organized as part of the educational intervention. However, the environmental impact of the menus, assessed as carbon footprint and water footprint, highlighted trade-offs within the environmental sustainability dimension, pointing out the need for a multi-factorial approach when addressing the concept of food sustainability.

The need for a holistic vision represents the key concept that emerged from the discussion among leading experts on the central role of university dining services in improving the eating habits and overall well-being of students and academic communities. Notably, creating an enabling environment and engaging the academic community have emerged as key strategies on which to build sustainable university food services, supported over time by connecting different academic departments, students, and other university and private stakeholders.

Chapter 1 - Introduction

1.1 Current global challenges and opportunities ahead

According to OECD-FAO Agricultural Outlook projections, the population is expected to grow annually by 0.9% reaching 8.5 billion people in 2030 [1]. Demographic development entails several changes besides population size, including income growth and distribution as well as food commodity prices, directly impacting food demand [1]. On the other hand, the processes of globalization, modernization and urbanization in recent decades have caused socio-cultural and lifestyle changes leading to a "nutritional transition" characterized mainly by a shift toward Western-style diets [2,3].

Regardless of nationality, the world's population seems to be adopting dietary patterns that are increasingly based on ultra-processed foods high in energy, saturated fat, salt, sugar, and refined carbohydrates, and low in fiber and essential nutrients [4,5]. These changes in eating habits, often combined with increasingly sedentary lifestyles, are reflected in a higher prevalence of overweight and obesity and increased risk of non-communicable diseases (NCDs) [6]. According to the World Health Organization (WHO), currently 74% of all deaths in the world are caused by NCDs, such as heart disease, stroke, cancer, diabetes, and chronic lung disease. NCDs impact the health of individuals, families, and communities in devastating ways and, due to their epidemic spread, are reflected in extremely high socioeconomic costs jeopardizing the healthcare system. In this regard, effective policy actions by governments are needed to control and prevent NCDs by taking action on the four main risk factors outlined by WHO, i.e., tobacco use, physical inactivity, the harmful use of alcohol, and unhealthy diets [7]. It is worth noting that overnutrition and diet related NCDs are only one side of the double burden of malnutrition [8]. Worldwide, according to the most recent estimates available, over 2.28 billion children and adults are overweight [9] and more than 700 million individuals are undernourished [10].

Given this framework, tackling hunger, food insecurity and malnutrition in all its forms is one of the main current challenges [7,10], particularly in the aftermath of the COVID-19 pandemic, which increased social disparities and brought out weaknesses in the agri-food system. Current estimates suggest that healthy food is not affordable for about 3.1 billion people, reflecting the higher commodities prices due to the health crisis as well as the current war in Ukraine that is shutting down supply chains and further influencing grain, fertilizer, and energy prices [10].

In parallel, the large environmental impact of the global food system is widely recognized [11–14]. Food systems are one of the main contributors to human-related

greenhouse gas (GHG) emissions (~30% of the total) and climate change [13,15], and are responsible for the overexploitation of freshwater reserves [11], land use and biodiversity loss [12,16], contamination of both terrestrial and aquatic ecosystems due to the efflux of nitrogen and phosphorus during the application of fertilizers and animal manures [17–19]. The environmental impact of food differs depending on the type of product and food demand. In general, animal products are more impactful than plant-based food, especially when considering GHG emissions. On the contrary, cropland use, bluewater use, phosphorus application and nitrogen application are mainly related to staple crops [14].

The future environmental pressure will be determined by expected growth in population and income. In general, feeding a larger population will result in an increase in the environmental footprint of each food group. At the same time, due to the projected growth in wealth, a transition toward higher consumption of animal products and lower consumption of staple crops is expected [14].

As suggested by the Lancet Commission, obesity, malnutrition, and climate change should not be considered individually, but as a "Global Syndemic" (or synergy of pandemics) and, because of their common drivers and effects, tackled with a holistic approach to achieve global targets of human and ecosystem health and well-being, economic flourishing, and social equity [20], in line with the UN 2030 Agenda for Sustainable Development Goals [21]. Along with transportation, urban design and land use, food and agriculture are leading drivers of this damaging synergy [20], and as stated by the Intergovernmental Panel on Climate Change (IPCC) “Consumption of healthy and sustainable diets presents major opportunities for reducing GHG emissions from food systems and improving health outcomes” [22].

1.2 Food as transformation

Food-based dietary guidelines provide the basis for orienting food and nutrition policies and public health interventions to counter all forms of malnutrition. National recommendations should also incorporate sustainability dimensions and, generally, encourage larger consumption of plant-based foods among populations [20,23]. Nonetheless, in several countries, the inclusion of environmental sustainability aspects in national dietary guidelines is hampered by large food companies in the beef, dairy, sugar, beverage, and ultra-processed food sectors [20].

In 2019, Food and Agriculture Organization of the United Nations (FAO) and WHO gathered in an international expert consultation to establish guiding principles for Sustainable Heathy Diets. This landmark paper approached the task by combining all dimensions of

sustainability, giving equal importance to international nutritional recommendations and the environmental impact of producing and consuming food, by taking into account feasibility and applicability according to different economic, cultural, and social circumstances. In this direction, Sustainable Healthy Diets aim to ensure optimal growth and development for all people, as well as sustain their lifelong physical, mental, and social health for current and next generations; help prevent all forms of malnutrition; decrease the risk of food related NCDs; and uphold biodiversity conservation and global health [24].

Concretely, Sustainable Healthy Diets: begin from birth with exclusive breastfeeding for up to 6 months; are combined with complementary food until at least two years of age; are based on a plentiful and various consumption of plant-based foods (such as fruits and non-starchy vegetables, whole grains, legumes, and nuts), while also including dairy products, eggs, poultry, and fish to a moderate extent, and a reduced intake of red meat, by preferring fresh or low-processed products, and drinking water as a source of hydration. In addition, energy and nutrient content, as well as contaminants, must be in line with nutritional recommendations and food safety guidelines, respectively, in order to prevent NCDs and foodborne diseases. Adopting diets with these features, along with reducing the use of hormones and antibiotics in food production, lowering the use of plastics and by-products in food packages, and minimizing food losses and waste, contributes to keep the impacts of food systems (e.g., GHG emissions, water, and land use, nitrogen and phosphorus application) within planetary boundaries and preserving terrestrial and marine biodiversity. Lastly, to embrace all dimensions of sustainability, healthy and sustainable diets must reflect the gastronomic heritage, preferences, and resources of the territory, enhancing local products and providing nutritious food that is accessible to all [24].

Simultaneously, the transition to a more resilient agri-food system must encompass sustainable agricultural strategies to satisfy the needs of the world's growing population without overexploiting the planet's resources [25]. To this end, the shift towards new lower-emission technologies and digital innovations is essential to boost productivity, monitor and manage risks, and achieve environmental, social, and economic sustainability goals [26].

In this context, the latest State of World Food Security and Nutrition report [10] emphasized that repurposing assets to promote sustainable food production, sourcing, and eating will contribute to making healthy diets less expensive and more accessible to all. Choosing the most suitable food and agricultural policies to implement is crucial and must take into account possible implications and trade-offs. Notably, although increasing the accessibility and affordability of healthy foods is imperative, it is not enough for people to select, favor, and

consume healthy and sustainable diets. Therefore, combining complementing policies that encourage a healthy diet is key to achieving the goal [10].

1.3 Actions for the implementation of sustainable healthy diets

Besides the comprehensive definition of a healthy and sustainable diet and the outlining of its guiding principles, the FAO and WHO expert consultation provided a set of actions to follow for their implementation (Figure 1).

By focusing on the actions not still discussed in previous chapters, the promotion of healthy and sustainable dietary habits requires a preliminary assessment of both the existing food system and current eating habits. A representative picture of the current situation is indeed useful for identifying which potential changes might be the most relevant for improving both communities' and the planet's health. Subsequently, it is important to recognize what might be the most suitable strategy to educate consumers and trigger a behavioral change supported over time by an enabling environment that makes the healthy choice the easy choice [24]. Because people's eating behaviors are strongly influenced by the living context, countering an increasingly obesogenic environment [27,28] is a key strategy to reduce both food insecurity and environmental pressure related to the food system.

In this transition process, people's engagement is central. Regardless of their role in society, everyone can be a promoter of change and, based on their preferences, shape the social norms and impact institutional policies of worksites, education institutions, and food distribution, by generating collective influence that encourages the health, economic well-being, equality, and sustainability of human communities [20].

Government actions should prioritize the creation of a supportive food environment that facilitates consumer choice and promotes population-wide healthy and sustainable eating. Recommended policies may include regulations to increase the quality of processed products, the establishment of food marketing laws, the improvement of nutrition labels, and the implementation of specific criteria for food procurement in public institutions to guarantee that the food offered in public entities contributes to healthy and sustainable diets [10]. In this connection, the transition towards a more sustainable and resilient food system takes alliances and the efforts of various actors beyond the stakeholders in the agri-food system [25].

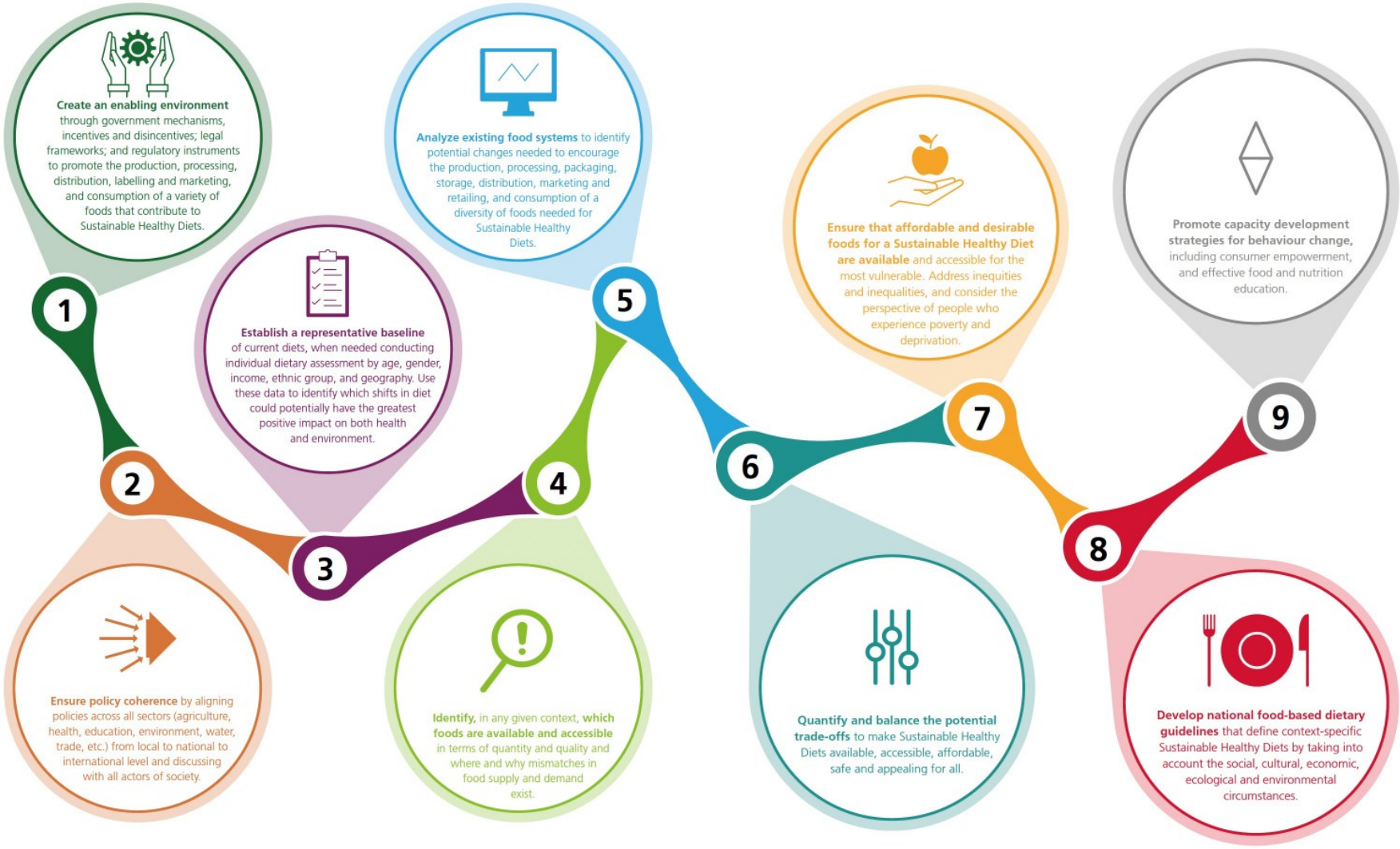

Figure 1. Actions for the implementation of sustainable healthy diets [24]

1.4 Making healthy food environments for young adults: universities as an ideal setting

Eating habits are related to multiple factors that can be classified in four levels: individual, social environment, physical environment, and macro-level environment. The framework presented in the Figure 2 shows the high complexity of the reality and how individuals and the environment are tightly intertwined.

Given these multilevel linkages, improvement of people eating behaviors should consider the living context such as homes, districts, as well as institutional environments [28]. In particular, educational institutions, from early childhood to higher education, play a crucial role in shaping the eating habits of the young generations [29–34], especially in view of the alarming trend of increasing obesity in school-age children, adolescents and adults [9,35].

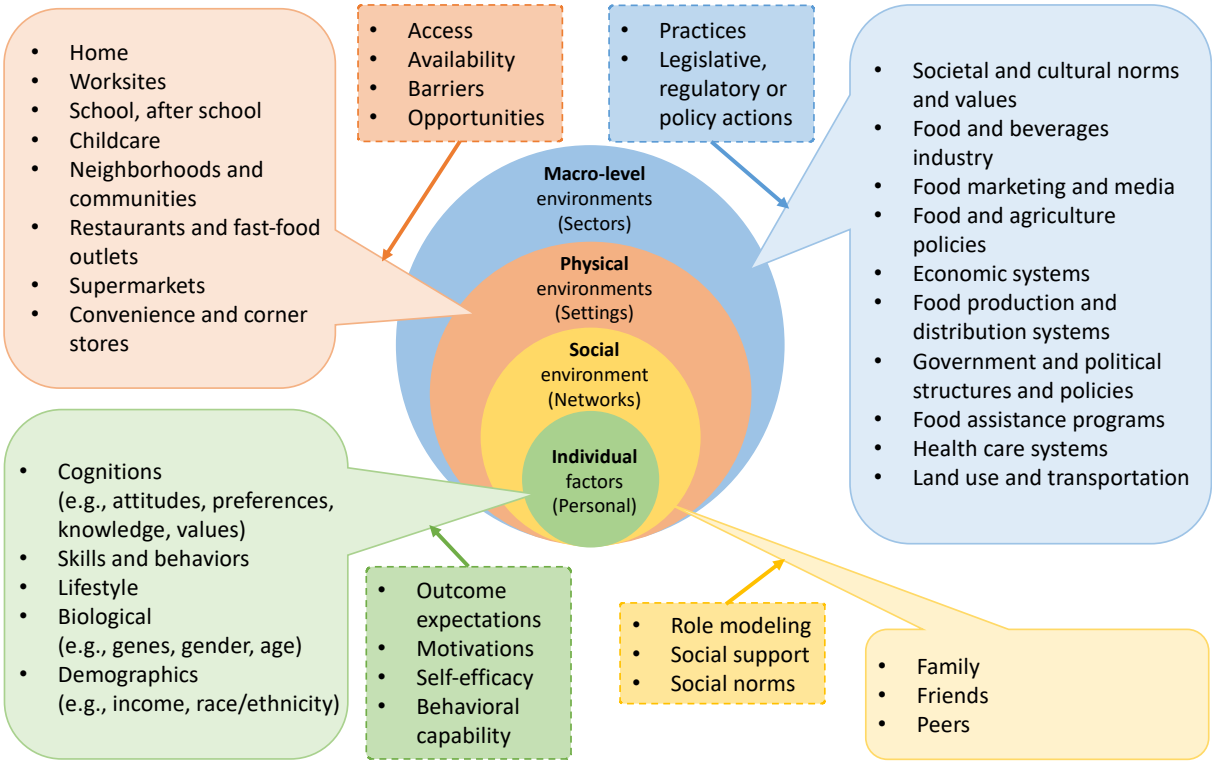

Figure 2. Ecological framework depicting the multiple influences on what people eat adapted from the model provided by *Story and colleagues* [28].

Promoting health through the adoption of lasting healthy foodways and lifestyles should be a priority for everyone, but it becomes even more important for children, adolescents, and young adults, particularly young women and males of childbearing age as they prepare for future pregnancies [36]. To date, school-based food and nutrition education is widely recognized as a crucial approach to advance nutritional status and overall well-being of children

and adolescents [37]. At the same time, a recent study published in Lancet Diabetes & Endocrinology [38] pointed out that young adults aged 18 to 24 years are the population group with the highest risk factor of becoming overweight or obese in the next ten years of life, regardless of gender, ethnicity, geographic or socioeconomic area. This finding suggests the urgent need for actions targeting such age group to prevent obesity and its long-term health implications [38].

In this context, higher education institutions, such as universities, provide an optimal setting for promoting healthy habits among young adults for several reasons. First, given the growing number of students enrolled in universities around the world [39], implementing interventions through the academia system makes it possible to reach a large number of individuals. Second, for many students, the transition from school to university means their first experience of living away from home and increased responsibility for managing their own eating habits [40–42]. Therefore, universities may play a key role in raising students' awareness of adopting healthy and sustainable diets by promoting virtuous behavior patterns on campuses [36]. Third, as centers of research and scientific excellence, universities have the crucial responsibility to identify and implement best practices to improve the well-being of students and university staff while also being a benchmark for the entire society and extending benefits beyond the university community [43,44].

1.5 Acting on food literacy as a remarkable strategy for healthy and responsible eating behaviors in universities

The university years bring several changes in the lives of young people, often associated with the adoption of unhealthy behavioral patterns [45,46]. Existing evidence identifies college life as a time of increased independence, and stress related to the study load, social expectations, economic restrictions, and inaccessibility of quality food [47–49]. Furthermore, contemporary life and the current food system increase the risk of consuming energy-dense and low-nutrient foods, such as ultra-processed products, convenience foods, and home-delivered meals [50,51]. In addition, individuals are constantly exposed to unreliable dietary information provided by the mass media [52], and advertising of unhealthy foods and beverages through social media, especially addressed to the youth generation [53]. All these factors expose university students to numerous health risks [47–49], including an increased likelihood of establishing unhealthy eating habits [54,55] and developing excess weight conditions and related diseases [56,57].

In this regard, the promotion of healthy eating behaviors is paramount for fostering individuals' well-being and preventing diet related NCDs [58]. As mentioned in section 1.4, given the complexity of factors influencing eating behaviors, nutrition education interventions in isolation are not sufficient [59]. Contrarily, increasing literature emphasizes the concept of "food literacy" as a possible solution to deal with the present industrialized food system, promote healthy and sustainable diets, and achieve lasting behavioral changes at both the individual and community levels [59–63]. Despite still lacking agreement on its standard definition [64], a recent publication [65] described food literacy as an interconnection between several factors: food and nutrition knowledge; proper skills to cook (e.g., preparing meals), self-efficacy and confidence (i.e., being able to find and recognize reliable information, having practical cooking skills for oneself and others while respecting culinary traditions, and showing a positive food attitude); external factors (i.e., various stages of food supply chain and social determinants of health, including wages, rent, educational environments, food safety, and cooking facilities); and food decisions (i.e., dietary behaviors). All these aspects should be considered when designing and implementing public health interventions aimed at promoting healthy and responsible eating behaviors [65].

Given the positive impacts reported in previous studies [66], it is very important to support food literacy among the younger generation, including university students. In this context, a recent study [67] investigated the challenges, opportunities, and motivators for college students to develop and implement food literacy within the university environment. The main findings were summed up by the authors as shown in Figure 3.

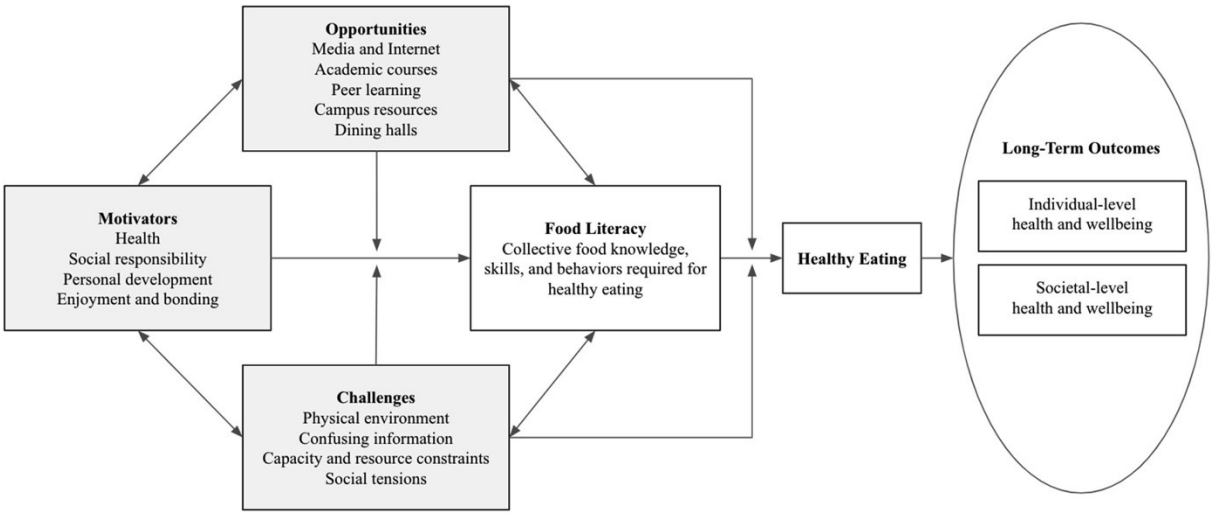

Figure 3. Conceptual model of emergent challenges, opportunities, and motivators for developing and applying food literacy in a university setting, generated form 11 focus groups with 82 students at a large public university [67].

In each of the three domains, themes that emerged from students' perspectives can be referred to as personal or external factors [67], confirming the deep interconnection between individuals and their life context on which the concept of food literacy is based [68]. Briefly, challenges include external factors such as the availability of food on campus or in grocery stores and supermarkets nearby, mistrust of food-related information provided by social media, and the stress associated with a new living environment characterized by new eating paces. On this basis, the opportunities identified involve several approaches to be leveraged, including media and the Internet as a source of information for their wide use, academic courses as an occasion to obtain reliable information upon which students can improve their behaviors, peers as the main social influence during the college years, and the enjoyment and exploitation of campus resources beyond the curricular programs, e.g., additional courses, events, campus food pantry, etc. Notably, students recognized on-campus dining halls as an appropriate environment for developing and implementing food literacy. Although students reported discomfort in approaching new foods, they appreciated the possibility of consulting energy content and nutrient composition of menus options and the logos next to dishes with reference to ingredients or type of food source, emphasizing the mealtime in the cafeteria as an opportunity to taste new foods, learn new food terminology, and encourage themselves to eat healthier. Indeed, health accounts one of the 4 motivators that, along with personal development, enjoyment and bonding, and social and environmental responsibility, should drive students to lasting behavioral change. These results indicated that students also see the college period as a favorable time to promote food literacy and the university as an appropriate and reliable context for triggering and leading change [67]. As pointed out by the authors, due to the design of the study, a general conclusion about higher education settings is prevented. However, this study provides a baseline for developing future research on the promotion of food literacy in academia, taking into account the differences related to the country and political context.

1.6 Promotion of healthy and sustainable foodways through food services

Considering the global importance of food in social and cultural practices, food provision necessarily has a significant impact on people's lives. On-campus food services, as well as in other workplaces, have been found to positively influence users' overall well-being by promoting social interactions and facilitating the adoption of proper food habits through the provision of good quality, healthy food [69]. In a broader perspective, as described by the 2017

Information Resources, Inc. (IRI) report, eating out is an increasingly common practice in today's society. Specifically, in Europe, 18% of all meals are eaten away from home [70].

A recent literature review [71] investigated out-of-home food consumption and its nutritional contribution, mainly related to energy and nutrient intake, food and beverage typology, and diet quality score. Eating away from home frequently has been associated with lower diet quality, excessive intake of calories, fat, saturated fatty acids, sugar, and sodium, suboptimal intake of fiber, vitamins, and minerals, and poor consumption of dairy products, fruits, and vegetables. Conversely, sugar-sweetened beverages and alcoholic beverages were prevalent during eating-out occasions [71].

Within this framework, food services provide a strategic context in which implementing public health interventions to support citizens in this urgent dietary shift toward healthy and sustainable foodways [72]. Given the importance of connecting different stakeholders in the food system and combining diverse expertise and assets to drive the urgent food system transformations, FAO has recognized chefs as one of the main agents of change. Indeed, with the growing interest in cuisine, chefs are playing an increasingly important role in shaping people's food preferences, raising public awareness, and building a new food culture [73]. However, chefs are often not sufficiently trained in nutritional or environmental food dimensions, prioritizing other characteristics of food such as taste, convenience, and cost [74]. On this note, food sustainability issues should be included in the curriculum of culinary students and deepened by chefs throughout their careers.

A virtuous example of closing this gap is an ongoing European Life project, funded by the European Commission and led by the Barilla Foundation [75], which seeks to raise awareness and empower chefs by providing them with knowledge and practical tools for enabling the creation of healthy and sustainable menus to be implemented in their daily activities in order to promote public health and mitigate the environmental impact of food systems [76].

In this context, catering services, including the university dining halls, play a crucial role in providing a balanced and accessible meal and increasing the food literacy and empowerment among kitchen staff and diners, such as students and academic employees. The ultimate goal is intended to be the pursuit of strategies that engage both the people who prepare the food and those who consume it toward a common change [36].

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Chapter 2 – Aim of the Doctoral Thesis

Food represents the one of the most powerful levers for positively impacting people's health and global sustainability. However, the major diets that characterize current societies worldwide fail to represent nutritionally balanced and environmentally friendly eating patterns and are threatening both individuals and the planet. What is needed is a shift in diet that includes a reduction in unhealthy foods and animal products through a gradual transition to eating patterns based on fresh, local, seasonal, and minimally processed foods, prioritizing plant-based products such as fruits, vegetables, whole grains, legumes and nuts, and lower-impact animal products such as eggs, milk and fermented products, poultry, and sustainable fish. Establishing national dietary guidelines that include the principles of environmental sustainability is critical and increasing compliance by populations is a very effective strategy to ensure food security and counteract current climate change, erosion of natural resources, and loss of biodiversity. Given the complexity of factors influencing people's eating habits, contemporary lifestyles, and the increasingly obesogenic environment we live in, multi-strategic actions are needed to trigger lasting change toward sustainable behaviors. In this context, creating an enabling food environment that supports people in this transition and facilitates the adoption of healthy food choices is paramount. Among various living contexts, educational institutions play a key role in shaping the dietary behaviors of the younger generation. After the school years, higher education institutions such as universities provide an appropriate setting for promoting food literacy among young adults and improving their eating habits and overall health. In particular, the provision of good-quality, healthy food through on-campus dining services encourages healthy dietary behaviors and fosters the general well-being of diners.

Based on these considerations, the purpose of this Doctoral Thesis is to identify best practices for implementing effective strategies to improve food literacy and promote sustainable diets through higher education institutions, particularly leveraging the key role of food services.

Three complementary tasks on two different target populations have been set to address this goal.

1. Assessing the current eating habits of the young populations, with a special focus on university students from Mediterranean and non-Mediterranean area, to identify peculiarities in dietary behaviors, critical issues and priorities that need to be addressed.
2. Making eating out of home a teaching and awareness-raising moment through the creation of sustainable food services, starting from the training of chefs and kitchen staff to enable them to provide nutritionally balanced and eco-friendly menus to users, in university dining halls and general catering.

3. Discussing current policies and initiatives applied at national and international level, as well as tracking future directions to follow to promote and support behavioral change within the university community toward healthy eating that is sustainable over time.

Based on these specific purposes, the activities of this Doctoral Thesis were carried out following two parallel lines of research.

On the one hand, a systematic review explored the eating habits of young European populations by considering nationally representative studies and attempting to provide a picture of current diets by distinguishing children, adolescents, and young adults (Study 1. *Adherence to Dietary Guidelines among Young Populations Living in Europe: A Systematic Review)*. The results of this literature review confirmed previous evidence showing the progressive shift away from healthy diets and the increasing adoption of Western-style dietary patterns in young generations. Given this and considering the low number of studies aimed at investigating the eating habits of nationally representative populations of young adult, an online survey of two representative cohorts of Italian and American university students was conducted. This cross-sectional study aims to provide insight into the current eating habits of young adults living in the Mediterranean and Western area by investigating their adherence to the MD and the sustainability of their food-related behaviors. More specifically the study is aimed to point out the main predictors and possible drivers to facilitate the adoption of a sustainable diet and behaviors (Study 2. *Adherence to the Mediterranean Diet and Its Association with Sustainable Dietary Behaviors, Sociodemographic Factors, and Lifestyle: An Online Survey in Italian and US University Students*). In this context, as part of visiting period abroad, an intervention study was conducted in a dining hall at the University of California, Los Angeles. This pilot study aims to test the effects of menu items reordering as a light nudging strategy to shape diners' food choices and encourage the selection of climate-friendly options (Study 3. *The Effect of Menu Re-ordering on the Carbon Footprint of Dietary Choices in University Dining*).

In parallel, this Doctoral Thesis includes a research activity that focuses on the role of food services in promoting healthy and sustainable diets among people, leveraging the importance of training chefs on the nutritional and environmental aspects of food. Specifically, owing to a partnership between the University of Parma and the International School of Italian Cuisine (ALMA), an intervention study was conducted on a sample of culinary students. This project entailed the assessment of students' nutritional and food sustainability knowledge before and after a nutrition course provided by the school. During the nutrition classes, aspects of food sustainability were also addressed, and practical skills were taught to enable students to develop

healthy and sustainable menus as part of the intervention (Study 4. *Promoting Nutrition and Food Sustainability Knowledge in Apprentice Chefs: An Intervention Study at the School of Italian Culinary Arts – ALMA*). The questionnaire used to assess students' food sustainability knowledge was specifically developed for this study and the assessment of its reliability and validity was performed on the same population (Study 5. *Validation of a Sustainability Knowledge Questionnaire in Italian Apprentice Chefs).*

In conclusion, to integrate the above-mentioned lines of research, as part of my Doctoral Program, I was involved in the organization of a workshop entitled "Multi-strategic intervention to promote the implementation of a healthy and sustainable university canteen policy," held in Parma, Italy, last September 29. The event brought together leading experts from different countries to discuss the importance of university food service as a leverage to improve food literacy and promote sustainable diets through academia. The speakers' talks and the panel discussion that followed provided food for thought on which the last article included in this thesis was rooted (Study 6. *Best Practices for Making the University Campus a Supportive Environment for Healthy and Sustainable Diets*).

Chapter 3 - Selected Studies

Study 1

Adherence to Dietary Guidelines among Young Populations Living in Europe: A Systematic Review

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Abstract

Background Dietary guidelines and nutrition recommendations represent science-based references for developing actions to promote healthy lifestyle, reducing the risk of malnutrition and diet-related disease among population.

Purpose This systematic review primarily aimed to investigate the current compliance with dietary guidelines and/or nutrition recommendations among nationally representative cohorts of European young populations.

Methods Literature search through PubMed, Scopus, and Web of Science databases was made according to the PRISMA guidelines. Only English-language articles that reported the participants' overall eating habits referred to a data collection carried out from 2010 onwards were included.

Results Twenty-nine papers were included for data extraction. Even if several documents reported data for different age groups, only results for 2–35-year-old participants have been included. Most of the studies focused on the dietary habits of children (n=12) and adolescents (n=17), whereas fewer data were found for the populations of young adults (n=7). Overall, the food intake was characterized by a low consumption of vegetables, fruit, grains, legumes, and nuts, and an excessive consumption of meat and meat products, sweets and sugar-sweetened beverages. In addition, findings pointed out an overall excessive intake of protein, fat, saturated fats and sugars, an insufficient fiber consumption, while mixed results were obtained for carbohydrates. Even when considering the principles of the MD, overall, European children, adolescents, and young adults showed only a low to medium level of adherence.

Conclusion This review shows that young populations living in Europe have eating habits that are poorly aligned with national dietary guidelines and nutritional recommendations. However, because a limited number of studies has been addressed to nationally representative samples in the last decade, it is challenging to draw robust conclusions on current eating habits for that geographical area.

Keywords

Children; adolescents; young adults; dietary habits; dietary guidelines; European countries

3.1.1 Introduction

The worldwide prevalence of obesity has rapidly increased in the last 50 years, reaching epidemic proportions, and representing a global health emergency [77]. Obesity condition increases the risk of several diseases such as cardiovascular disease, diabetes, dyslipidemia, cancer, mental illness, leading to a poor life quality of people [78–82] and, at the same time, by affecting total healthcare expenditure and increasing loss of money due to increased sick leave, disability, mortality, and low productivity [83,84]. Despite obesity have a multifactorial etiology, the main reason of this condition is an excessive energy intake not compensated by an adequate energy expenditure over time [85]. However, other than energy intake, the quality of entire diet should be evaluated, considering not only nutrients and calories but also food variety [86]. In this regard, over the years the elaboration and implementation of food-based dietary guidelines (FBDGs) across the European regions became necessary to support experts in the nutrition field as well to promote healthy eating behaviors in an easily comprehensible way among populations [87]. Given that nutritional recommendations, typology of available food, and culinary traditions vary from country to another, the definition of overarching FBDGs suitable for all European populations is not achievable [88].

In addition, based on current science-based nutritional recommendations, several dietary quality indices or indicators have been defined to assess healthiness of people's eating habits. Such indexes can be divided into three main typologies on the basis of: i) nutrients content (compared with requitements); ii) intake of food or food groups (compared to recommended portion sizes or servings); iii) nutrient content combined with food or food groups. In general, the Mediterranean Diet Score (MDS), the Healthy Eating Index (HEI), the Healthy Diet Indicator (HDI) and the Diet Quality Index (DQI) are among the most widely validated and reported in the literature, often applied in adult population using adapted and updated versions from the original based on the latest dietary recommendations [89].

Recent results from systematic reviews and meta-analyses show that high scores on these indices are inversely associated with all-causes mortality, pointing out and confirming the impact of lifestyle, and food habits in this case, on people's health and life quality [90–92].

In the last decades, the growing accessibility of foods, economic availability, technological innovation, and urban development have led to a nutrition transition towards dietary patterns characterized by a high consumption of processed and ultra-processed products, animal-based foods, and refined commodities, resulting in an excessive intake of saturated fatty acids (SFAs) and sugars, and a low intake of dietary fiber [93–96]. All these unhealthy eating

behaviors serve as well-recognized risk factors for human health [97]. In this context, a diet optimization towards food patterns based on large consumption of plant-based foods such as fruit, vegetables, nuts, legumes, whole grains, not tropical vegetal oils, as well as fish, can reduce both malnutrition and non-communicable diseases risk, by promoting at the same time human and environment health [98].

Indeed, a healthy and balanced nutrition is fundamental during all stages of life, especially during the period of growth when dietary choices and food behaviors consolidated, by influencing eating habits also during adulthood [99]. Personal development continues even after adolescence when several transformations occur, such as change of living place and social relationships, as well as self-maintenance [24–26]. This increased autonomy characterizing emerging adulthood seems to negatively influence the young adult's dietary habits towards unhealthy food behaviors, putting them at risk for malnutrition and weight gain [27–30].

Considering the current nutrition transition toward unhealthy eating habits [17–20], encouraging nutrition literacy among populations through educational projects is increasingly necessary and should be a public health priority [31]. In this regard, dietary guidelines and nutrition recommendations represent science-based references for developing actions to promote healthy lifestyle, reducing the risk of malnutrition and diet-related disease among population.

Despite the adherence to these guidelines and recommendations is strongly recommended by the World Health Organization (WHO), the poor quality of citizens' diet is still an issue worldwide [32]. For this reason, national dietary surveys continue to cover a key role in providing concrete information to the scientific community and to policy makers, with the aim of shedding light on current food intake at population level and taking actions by applying evidence-based strategies to face related-issues [33].

In this context, the present systematic review primarily aimed to investigate the current compliance with dietary guidelines and/or nutrition recommendations, at national or international level, among nationally representative cohorts of European young populations (i.e., children, adolescents, and young adults). Specifically, the adherence of eating habits to national or international dietary guidelines/recommendations has been evaluated in terms of food groups and/or energy and macronutrient intakes. As secondary aim, micronutrient intakes, lifestyle-related habits, and other possible factors (e.g., gender, age, nutritional status) favoring or limiting the compliance with dietary guidelines/recommendations have been explored.

3.1.2 Methods

The present systematic review, previously registered on international prospective register for systematic reviews PROSPERO (CRD42020190657), was lead and described according to PRISMA guidelines [33].

3.1.2.1 Search strategy

Literature search was made from their inception to February 2022 through three different electronic databases: PubMed, Scopus, and Web of Science. A combination of keywords and terms was used to form queries considering different domains (Table 1): i) target population, ii) nationality, iii) exposure, iv) outcome. In addition, only articles written in English and for which data collection was carried out from 2010 onwards were included. The latter criterion was set up to obtain un updated picture of the current and actual dietary habits of young European populations.

Table 1 Keywords and terms employed

	Search strategy
1.	adolescen* OR boy* OR girl* OR puberty OR teenager* OR youth* OR teen* OR young OR juvenil* OR pubescen* OR minor* OR child* OR adult*
2.	Europe
3.	(eat* OR consum* OR intake OR choice OR habit OR pattern OR prefer OR frequenc* OR practice) AND (food OR diet* OR drink OR beverage OR nutri* OR snack* OR energy OR vitamin OR mineral)
4.	guideline OR polic* OR recommend* OR reference OR "recommended daily allowance*" OR "recommended dietary allowance*" OR requirement

3.1.2.2 Study selection and data extraction

Study selection was performed based on title, abstract and full text which were screened by two independent researchers. Any discrepancies were discussed between the two independent researchers or solved by a third researcher.

All studies were included or excluded according to specific eligibility criteria pertaining the studied sample and the outcome measures. Specifically, only studies of a representative sample of apparently healthy children, adolescents, or young adults living in Europe were included. The age ranges were established in accordance with the international definitions of childhood (under 18 years of age) [34], including the majority of adolescents (10-19 years of age) [35], and young adulthood (18-35 years of age) [36]. Considering the WHO recommendation to

breastfeed children until 2 years of age [37], and taking into account the difficulty of determining the amount of breast milk intake and its nutritional content, studies performed only on children up to 2 years of age were excluded. Studies focused specifically on obese population and women of childbearing age were not included as they have not been representative of the general national population. Furthermore, only the studies which evaluated the participants' overall eating habits and their dietary intakes from food and beverage, excluding food supplements, were included. Consequently, studies analyzing exclusively a single nutrient or nutrient category (e.g., fatty acids, iodine, calcium, iron) or a single food or food group (e.g., fish, fruit and vegetable) or a single meal (e.g., breakfast) were not eligible for inclusion. These criteria were defined to restrict the inclusion to studies evaluating the overall adherence of food consumption to dietary guidelines or nutrition recommendations. Finally, studies involving subjects receiving parenteral or enteral nutrition were excluded.

For the included studies data extraction was made recording the following data: authors, year of publication, study population data (i.e., country, period of data collection, sample size, gender distribution, age), study design, tools used to assess dietary consumption adequacy, main outcomes (i.e., food or food group consumption and/or energy and macronutrient intake compared to dietary guidelines/recommendations; dietary quality index), and secondary outcomes (e.g., micronutrients intake, anthropometric measurements, lifestyle data, socioeconomic profile of the studied sample).

3.1.3 Results

A total of 8693 documents were collected from PubMed (n = 4431), Scopus (n = 2448) and Web of Science (n = 1814). After the removal of duplicates (n = 2086), records published before 2010 (n = 1707), articles not in English (n = 151), literature reviews and not original peer-reviewed works (n = 502), 4247 papers were screened for eligibility. During the title/abstract screening 3735 articles were excluded, whereas others 490 papers were excluded after the full-text analysis. In addition, 7 eligible records were identified through snowball searching (Figure 1). Finally, 29 papers were selected and included for data extraction.

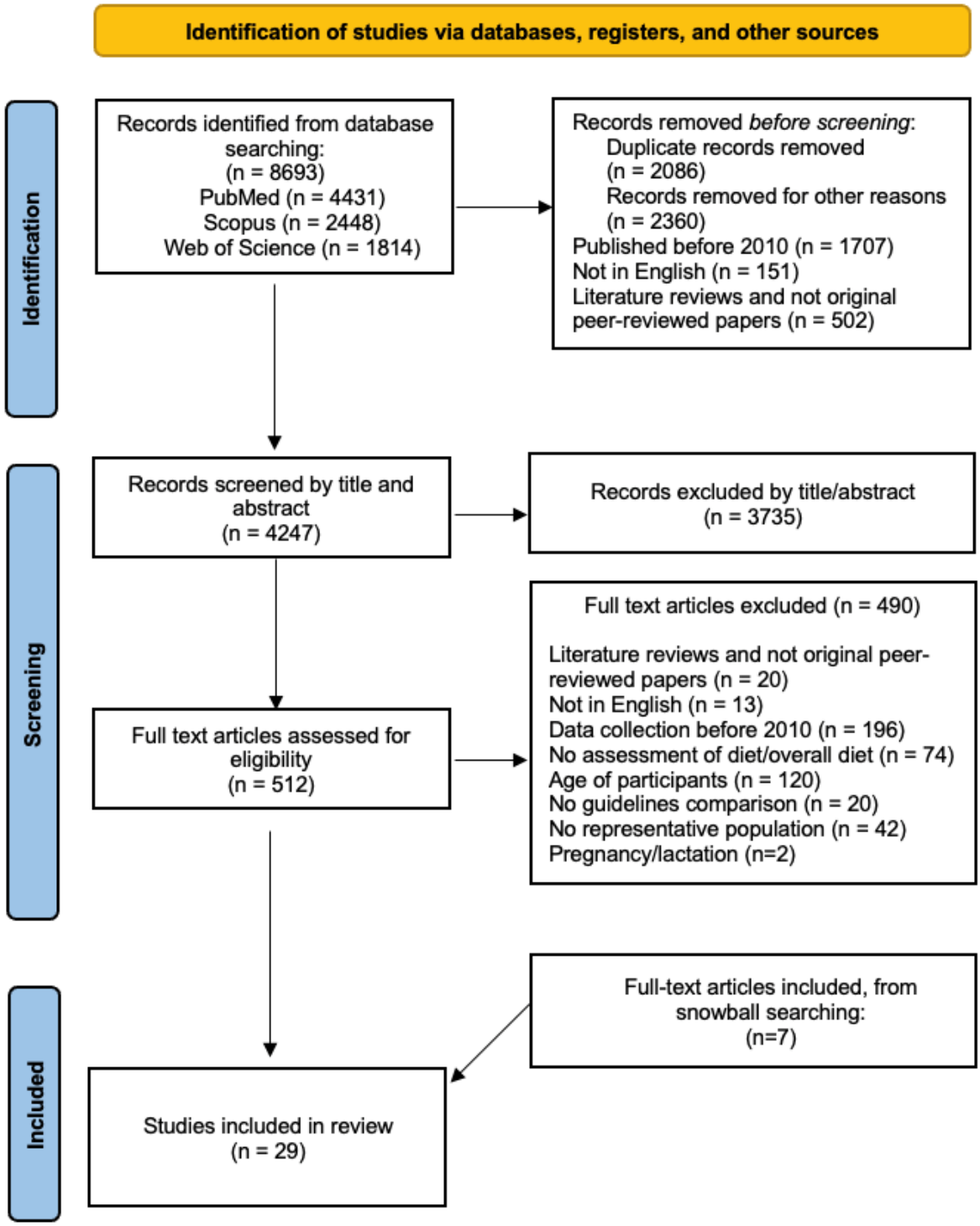

Figure 1 PRISMA flow diagram.

3.1.3.1 Characteristics of included studies

Country, year of data collection, and population description of the 29 records included in the systematic review (26 cross-sectional, 4 prospective and 1 intervention study) were reported in Table 2. The included publications referred to 26 different populations. Multiple articles reporting data for the same population were

included in the analysis; however, population information was reported only once. The included studied were conducted across 14 countries: Spain (n = 8), United Kingdom (n = 5), Netherlands (n = 3), Poland (n = 2), Cyprus (n = 2), Sweden (n = 2), Ireland (n = 1), France (n = 1), Greece (n = 1), Serbia (n = 1), Norway (n = 1), Germany (n = 1), Denmark (n = 1x), and Croatia (n = 1). Several documents reported data for different age groups; in these cases, only results for 2–35-year-old participants have been included. The diet of children, adolescents, and young adults was assessed in 12, 17 and 7 studies, respectively.

Among the included studies, the participant's dietary intakes were compared with national (n = 6), international (n = 9), both national and international (n = 3) dietary guidelines or nutrition recommendations, and Mediterranean Diet (MD) model (n = 4). The description of dietary guidelines and nutritional recommendations referred to the included studies is provided in Table 1S of the supplementary information.

Although only nationally representative populations were included, the sample size of the studies widely varied and ranged from 162 to 19582 participants.

Table 2 Main characteristics of included studies.

Sample	Country	Data collection (y)	Study design	Sample size (n)	Females (%)	Age [a]
Children						
Walton *et al.* (2017)[38]	Ireland	2010-11	Cross-sectional	374	50	2-4
Madrigal *et al.* (2020) [39] Samaniego-Vaesken *et al.* (2020) [40]	Spain	2018-19	Cross-sectional	992	50	3-10
Chouraqui *et al.* (2020) [41]	France	2013	Cross-sectional	206	n.a.	2-4
Children and adolescents						
Ruiz *et al.* (2016) [42] Olza *et al.* (2016) [43]	Spain	2013	Cross-sectional	424	38	9-17
Tornaritis *et al.* (2014) [43, 44]	Cyprus	2009-10	Prospective	1414	61	6-19
López-Sobaler *et al.* (2019) [45]	Spain	2012-14	Cross-sectional	1163	48	4-17
Tambalis *et al.* (2020) [46]	Greece	2015	Cross-sectional	177091	49	8-17
NDNS survey (2008-2010) [47, 48]	United Kingdom	2008-10	Cross-sectional	1376	50	4-18
NDNS survey (2010-2012) [47, 48]	United Kingdom	2010-12	Cross-sectional	1398	49	4-18
NDNS survey (2012-2014) [47, 48]	United Kingdom	2012-14	Cross-sectional	1043	50	4-18
NDNS survey (2014-2016) [47, 48]	United Kingdom	2014-16	Cross-sectional	1056	48	4-18
NDNS survey (2016-2019) [47, 48]	United Kingdom	2016-19	Cross-sectional	1408	50	4-18
Adolescents						
Dordic *et al.* (2019) [49]	Serbia	2016-17	Prospective	3278	50	10-19
Myszkowska-Ryciak *et al.* (2019) [50] Myszkowska-Ryciak *et al.* (2020)[51]	Poland	2013-15	Intervention	14044	54	13-19
Bottolfs *et al.* (2020) [52]	Norway	2017	Cross-sectional	611	49	13.2 (0.0)
Brettschneider *et al.* (2021) [53]	Germany	2015-17	Cross-sectional	1353	54	12-17
Roura *et al.* (2016) [54]	Spain	2013	Cross-sectional	2214	56	13-14

Sample	Country	Data collection (y)	Study design	Sample size (n)	Females (%)	Age [a]
Moraeus *et al.* (2020) [55]	Sweden	2016-17	Cross-sectional	2885	56	11-18
Bjerregaard *et al.* (2019) [56]	Denmark	2012-15	Prospective	19582	53	14.0 (0.0)
Adolescents and young adults						
Salas *et al*. (2013) [57]	Spain	2009-10	Cross-sectional	563	50	16-25
Young adults						
van de Rossum *et al.* (2020) [58]	Netherlands	2012-17	Cross-sectional	516	50	19-30
Kyprianidou *et al.* (2020) [59]	Cyprus	2018-19	Cross-sectional	162	n.a.	18-24
van de Kamp *et al.* (2018) [60]	Netherlands	2007-10	Cross-sectional	712	49	19-30
Ferreira-Pêgo *et al.* (2017) [61]	Spain	2012	Cross-sectional	431	n.a.	18-35
Children, adolescents, and young adults						
van de Rossum *et al.* (2011) [62]	Netherlands	2007-10	Cross-sectional	2416	50	7-30
Matana *et al.* (2022) [63]	Croatia	2021	Cross-sectional	2722	49	2-24

Data are reported as range and/or average (standard deviation). n.a.: not available.

3.1.3.2 Dietary intakes of young population living in Europe

Only in 5 populations the diet quality was assessed considering both food groups and nutrient intake. A diet quality score was also considered for one of these. In four samples dietary intakes were reported as food groups only, while in 11 populations only the analysis of the dietary nutritional values were reported. One study also applied a dietary quality index by simultaneously evaluating the consumption of multiple food groups. Finally, 5 publications assessed diet only through a diet quality index score, most of these (n = 4) using MDSs. Instruments used for data collection, detailed information about food group consumption, nutrient intake, dietary quality score, and secondary outcomes, such as micronutrients intake, anthropometric data, lifestyle and socio-demographic variables, are provided in Table 2S of the supplementary information. In addition, Tables 3, 4, 5, 6, and 7 were created to present information in an easier and more structured way.

3.1.3.2.1 Food groups

As shown in Table 3, dietary intakes were assessed as food group consumption in different target populations: children (n = 1), adolescents (n = 7), adolescents and young adults (n = 1), and young adults (n = 3). Food groups intakes were collected using semi-quantitative questionnaires (n = 1), food frequency questionnaires (FFQ) (n = 4), dietary history (n = 1), a 7-day food diary (n = 1), and a 24 h recall (24h-R) used twice (n = 3). Consumption of different

food groups were reported in two different ways: as, on average, low, adequate, or high intake (n = 4) compared to recommendations, and as percentage of the sample meeting the recommendations (n = 6). Both average intake and percentage of adherence to guidelines were reported in 1 study.

Regardless sample typology, in most of the studies less than 1/3 of the sample met the recommendation for vegetables [49, 52–54, 56, 57, 62], fruit [52–54, 56, 57, 62], starchy foods [49, 52, 53, 57, 60, 62], milk and dairy products [53, 54, 58, 60, 62], meat and meat products [49, 53, 54, 56, 57, 60, 62], fish [49, 52, 53, 56, 57, 60, 62], eggs [49, 53, 57, 62], legumes [49, 57, 58, 60], nuts [49, 57, 58, 60] and cooking fats [53, 57, 60, 62]. In addition, the results shown a low adherence to the recommendations for occasional intake of certain foods, such as sweets [49–54], sugar-sweetened beverages (SSBs) [50–54, 62], fast food [60, 62], and alcoholic drinks [60]. Apart few exceptions, these results generally underline a poor consumption of plant-based products such as vegetables, fruit, grains, legumes, and nuts, and an excessive consumption of meat and meat products, sweets and SSBs. More adequate consumptions, according which more than 2/3 of the sample was aligned with the dietary recommendations, were reported for: SSBs in Danish adolescents [56]; fruit and cheese intake in Serbian adolescents [49]; fruit, vegetables, starchy food, fish, eggs, milk and dairy products, fast foods, sweets and SSBs in Polish adolescents [50, 51]; fish, legumes and alcoholic drinks in Spanish adolescents [54]; alcoholic drinks, milk and dairy products in Spanish adolescents and young adults for which dietary consumption are reported in aggregated form [57]. Few studies assessed breakfast and non-alcoholic drinks consumptions. Among these, the average consumption of non-alcoholic drinks was adequate in German and Dutch adolescents [53, 60, 62] and Dutch young adults [62], but was low in Dutch children [62]. Considering Spanish [54] and Serbian [49] adolescents, more than 2/3 of the sample having breakfast every day. Most healthy behaviors, namely more than 2/3 of the sample, were reported for the intake of meat, meat products, fish and eggs in Dutch children and adolescents, and only cheese in Dutch children [62].

Finally, it should be considered that the typology of the assessed food groups was different among the included studies. In most of the studies the consumption of fruit and vegetables, starchy foods, milk and yogurts, meat and meat products, fish, eggs, sweets and SSBs was included in the eating habits analysis. On the contrary, only a few studies have also evaluated the consumption of cheese, legumes, nuts, cooking fat, fast food, alcoholic and non-alcoholic drinks. [41]

3.1.3.1.2 Nutritional values

As reported in Table 4, nutritional analysis of dietary consumptions was performed in a single or in a combination of target populations: children (n = 6), children and adolescents (n= 4), adolescents (n = 5), young adults (n = 1) children, adolescents, and young adults (n=1). For these populations data were collected using a FFQ (n = 2), 1-day food diary (n=1) recorded in two occasions 2 weeks a part , a 3-day food diary (n=2), a 4-day food diary (n =2), a 7-day food diary (n =1), a 24h-R (n = 3) filled twice 2 weeks a part, and a 24h-R used in combination with a 3-day food diary (n=1). Nutrient values were reported in three different ways: average intake (n = 7) considering it low, adequate, or high compared with recommendations; percentage of the sample meeting the recommendation (n = 9), and both the outcomes (n=2).

Few studies reported data about adequacy of energy intake. The energy content of the diet was adequate in Spanish children [39] and Dutch young adults [62], and moderately adequate in French children [41]. In many populations less than 1/3 of the sample met the recommendation for protein [38, 39, 41, 42, 44, 54, 62], SFAs [38, 42–44, 47, 48, 54, 60, 62, 64], sugars [38, 42, 43, 47, 48, 54], all characterized by a higher intake, and fiber [38, 41–44, 47, 48, 60] being sub-optimally consumed. The exceptions are represented by Spanish children, adolescents, and young adults [45], and Dutch young adults [60], who had an adequate protein intake. Moreover, Danish adolescents had an adequate consumption of SFAs, sugars and fiber [56]. About carbohydrate and fat intake, adherence varied widely across study populations. For carbohydrates more than 2/3 of Cypriot children [44], Spanish adolescent [45] and Dutch children, adolescents, and young adults [62] met the recommendation. Only Irish children [38] had a low carbohydrates intake. As for carbohydrates, a great variance was recorded for fat intake. In French [41] and Irish children [38] the consumption of fat was low; in Spain the number of children and adolescents who met the recommendation ranges from less than 1/3 of the sample [42, 54] to less than 2/3 [39, 45], whereas in Cyprus [44] 2/3 of children and 1/3 of adolescents showed adequate fat intake. On the contrary, more than 2/3 of Dutch children, adolescents, and young adults [62] were in line with fats recommendations. In the prospective study (2008-2019) carried out on five different samples of children and adolescents in United Kingdom [47, 48] fat intake resulted always excessive except during the period from 2010 to 2012, when it was adequate. With regard to the fatty-acids intake, even if considered in a few studies, an excessive intake of monounsaturated fatty acids (MUFA) was found in Spanish adolescents [54], while a low intake of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) was found in Irish children [38] and Dutch children, adolescents, and young adults [62].

An adequate intake of trans-fatty acids characterized instead English [47, 48] and Dutch children, adolescents, and young adults [62]. For polyunsaturated fatty acids (PUFA) intake data ranged from a poor (less than 1/3 of the sample) to moderate (more than 1/3 but less than 2/3 of the sample) adherence in Cypriot children [44] to good adherence (more than 2/3 of the sample) in Spanish children and adolescents [42, 43]. Only one study referred to Cypriot population [44] assessed cholesterol intake, by underlining a greater adherence to recommendation in females compared to males, except for 9-14 y age group where both females and males had a moderate adherence.

3.1.3.1.3 Adherence to the Mediterranean Diet

Diet quality was defined according to MD pillars in 4 studies investigating children and adolescents (n = 1), young adults (n=2), children, adolescent, and young adults (n =1). Food consumptions were collected by using validated questionnaires specifically developed to assess the adherence score to the MD. The used scores are the following: the KIDMED score [65] (n=2), the score proposed by Martínez-González and colleagues [66] (n=1), and that one proposed by Panagiotakos and colleagues [67] (n=1). The KIDMED score ranges from a 0 to 12 points and it is based on 16 questions requiring a dichotomous answer (i.e., yes/no), 12 of which referred to MD-related behaviors and 4 to non-MD-related behaviors. For negative answers no score is assigned, while for positive answers the assigned score is 1 or -1 for MD-related and non-MD-related behaviors, respectively. The MedDiet adherence score ranges from 0 to 14 points and it is calculated through a questionnaire based on 14 questions requiring a yes/no answer specifically addressed to assess MD representative eating behaviors. Both the scores allow to characterize the adherence of the sample as low (<5 points), medium (6-7 points), and high (>8 points). The MedDiet score is calculated on a 0–55-point range by applying a scoring system to the dietary consumptions collected through a FFQ and assigning higher scores to the frequency of consumption of food or food groups closer to the MD principles. In contrast to the previous two scores, the level of adherence in this case is not defined *a priori*, but it allows to divide the sample in tertiles of low, medium, and high adherence, according to the distribution of study population. Results have been reported as average score (n=1), as percentage distribution according to three adherence levels (low, medium, high) (n = 1), and as both the outcome variables (n=2). The KIDMED score in Greek children and adolescents [46], and Croatian children, adolescents, and young adults [63] falls in the medium level (Greece 6.7 (2.4) *vs* Croatia 6 (3)), highlighting that their dietary habits

resulted relatively adequate. By comparing the different levels of adherence to the MD among Cypriot [59] and Spanish [61] young adults, and Croatian children, adolescents, and young adults [63], high adherence ranged from 20% (Croatia) to 27% (Cyprus), medium adherence between 35% (Spain) and 61% (Croatia), and low adherence ranged between 19% (Croatia) and 52% (Spain). For Cypriot young adults also median score was reported, confirming the low-medium adherence of the population.

3.1.3.1.4 Other Diet Quality Score

Besides MD scores other 3 dietary quality indices were used: the Recommended Dietary Intake index, the Swedish Healthy Eating Index for Adolescents 2015 (SHEIA15), and the Healthy Eating Index (HEI).

The Recommended Dietary Intake index (0–10-point range) has been obtained through a short-FFQ (12 questions with 9 answer options) according to Norwegian dietary recommendations [68] for whole grain cereals, fish, sweets/bakery goods/sugary soda, fruits/berries, and vegetables. This index highlighted a poor adherence to fruits/berries, vegetables, whole grain cereals, fish, sweets and SSBs recommendation in Norwegian adolescents [52]. The SHEIA15 (0-9 point range) has been calculated based on the Nordic Nutrition Recommendation [69], by starting from the intake assessed through two 24h-R and assigned a score of 0 or 1 to each of the nine components (vegetables and fruit, whole meal, fish and shellfish, red and processed meat, fiber, PUFA, MUFA, SFAs, and added sugar) and according to the sample distribution the participants are classified into low (1^{st} quartile), medium (2^{nd} and 3^{rd} quartile) and high (4^{th} quartile) adherence groups. Among Swedish adolescents only 19% of males and 30% of females had a high quality of diet, characterized by an adequate intake of vegetables, wholegrains, fish, and fruit, and a low intake of red and processed meat and sweets, rich in n-3 fatty acids, PUFA, and low in SFAs, and added sugars [55]. The HEI (0–80-point range) has been computed based on food consumption collected through a FFQ and by scoring diet quality considering the Danish Dietary Guidelines [70] for fruits and vegetables, fish, red meat, SSBs, and the Nordic Nutrition Recommendation [71] for fiber, SFAs, sodium, and add sugars, by assigning a score between 0 to 10 to each food group. This index has been used to evaluate the dietary habits of Danish adolescents [56], which resulted low in fruit, vegetable, and fish consumption and high for red meat and sodium. At the same time, an adequate consumption of fiber, and a limited intake of SFAs, added sugars and SSBs were reported.

3.1.3.3 Secondary outcomes

3.1.3.3.1 Micronutrients intakes

Out of the 13 publications reporting nutritional values of participants' dietary intakes, 7 also analyzed micronutrient intakes [38, 43, 44, 56, 60, 62, 72] in 10 different populations from Ireland (children n=1), Denmark (adolescents n=1), Spain (children n=1 and adolescents n=1), Cyprus (children, n=1, children and adolescents, n=1, adolescents, n=1), and Netherlands (young adults n=2, children, adolescents and young adults, n=1). Regardless of the target population, the intakes of vitamins and minerals were mostly adequate, except for vitamin D in Irish children [38]. Of note, sodium intake exceeded the recommendation in Danish adolescents [56], Cypriot children and adolescent [44], and Dutch young adult [58, 60].

3.1.3.3.2 Lifestyle outcomes

Among the included studies, 6 publications assessed physical activity using different evaluation criteria. In Spanish children [40], data were reported as physical activity level (PAL) and emphasized sedentary behavior among participants. Greek children and adolescents [46] spent 9.4 hours per week in physical activity. Among Serbian adolescents [49], about half of the sample reported following a physical activity program and/or performing vigorous physical activity (VPA) for 20 or more minutes at least three times per week, about one-third of the participants engage in light to moderate physical activity and/or participate in recreational physical activities and/or perform stretching exercises at least 3 times per week, and most of the sample exercised during normal daily activities. Norwegian adolescents [52] spent an average of 54 minutes in moderate to vigorous physical activity (MVPA) per day and only 36% of participants met the physical activity recommendation [73]. In Spanish young adults [61] the physical activity varied widely and most of the sample exercised no more than 2 times per week. In the Dutch population [62], most children practiced at least 7 hours of physical activity per week, young adults also showed good adherence to physical activity recommendations [62], in contrast less than one third of adolescents met the recommendations [62]. Two of the above-mentioned studies [46, 52] also assessed the sleep behavior, by reporting respectively for Greek [46] and Norwegian [52] samples 8.6 (1.6) hours per day during weekdays and a sleep index (6-30) of 10.9 (3.5). In addition, both in Greek [46] and Polish [51] children and adolescents the screen time was assessed, showing that Greek spent on average 8.6 (8.5) hour per week in

front of a screen, while, for the Polish population, 60% of girls and 40% of boys complied with the recommendation of no more than 2 hours per day.

3.1.3.4 Factors associated with adherence to dietary recommendations

3.1.3.4.1 Gender

Among adolescent populations, Polish females [50] showed a higher adherence to recommendations for fruit, vegetables, whole grains, and fast food. On the contrary males had a more adequate consumption of fish, sugared drinks, and sweets. German females [53] consumed more fruits and vegetable, and fewer soft drinks than males; in Spain [54] difference was reported only for meat intake, which was higher in males. The difference among genders in young adults was observed in two Dutch cohorts [60, 62] by reporting mixed results. In one of them [62], females showed a more adequate intake of fish, chicken, eggs, or other meat replacement products, in contrast cheese intake was more adequate in males, in the other cohort [60], males showed a better intake of fish, cheese, milk and dairy products. Considering the nutritional profile of the diet, among Cypriot children and adolescents [44], males showed higher intakes of protein, fat, SFAs, MUFA, PUFA and fiber and lower intakes of carbohydrates. In addition, Spanish adolescents [54] showed the same differences for fat, SFAs, MUFA and carbohydrate intake, in contrast protein intake was higher in females. Regarding diet quality scores in Greek children and adolescents [46] adherence to MD was higher in females. A better score was also found in Norwegian adolescent females [52] who were more adherent to recommendations for whole grains, fish, fruits and vegetables, sweets, and sugary drinks. Swedish adolescent females [55] also showed higher adherence to national recommendations than males. Lastly, among both Cypriot children and adolescents [44], and Dutch young adult [58, 60] males showed a higher intake of sodium.

3.1.3.4.2 Age

Age-related trend in adherence to dietary guidelines has also been reported in some studies. The study of Polish adolescents [50] showed a significant reduction ($p < 0.001$) in the intake of vegetables, fresh fruit, milk or milk beverages, and regular breakfast consumption with growth; in contrast, the intake of sugary soft drinks and fast food increased significantly with age. At the same time, among Croatian children, adolescents, and young adults [63] adherence to MD decreased with age as well as the intake of fruit, vegetables, fish, nuts, pasta

or rice, consumption of olive oil, consumption of dairy products at breakfast, and yogurt or cheese in general. In Spanish children [39], and Dutch children, adolescents, and young adults [62] adequacy of fiber intake lowered by decreasing with age. Regarding carbohydrate and fat intake, the adherence was moderate (more than 1/3 but less than 2/3 of the sample) in Spanish children [39, 45] and Cypriot adolescents [44] and good (more than 2/3 of the sample) in Cypriot children [44] and Spanish adolescent [45], by pointing out a positive and negative effect of the growth in Spanish and Cypriot populations, respectively. In the Spanish population [43], younger subjects showed higher adherence to the recommendation for vitamin A, folate, calcium, and zinc, whereas vitamin C and iron were quite adequate and comparable between age groups. Cypriot children and adolescents [44] showed similar micronutrient intakes, except for magnesium intake, which was very low in adolescents, at the same time vit A, vit B, calcium and potassium intake was lower in male adolescents. In addition, in the Dutch population [62, 63], the distribution of micronutrient intakes was homogeneous among children, adolescents, and young adults, except for vit A, D, B1, folate, calcium, and iron, the adequacy of which decreased with age, especially in females.

3.1.3.4.3 Anthropometric variables

Nutritional status of participants was assessed in 15 populations by using different anthropometric measurements: average BMI only (n=5), BMI category only (n=8) of which two reported only the overweight/obese category), average BMI combined with overweigh/obese percentage (n=1), average BMI combined with waist circumference (WC) and waist to height ratio (WHR) (n=1). Despite this, only five studies evaluated possible association between nutritional status and dietary habits. In Cyprus [44], the children and adolescent in overweight or obesity condition showed a higher protein intake. In Poland, underweight and normal weight adolescents [50] were more likely to have breakfast every day. On the contrary, obese adolescents were more likely to consume fruit, and overweight adolescents to consume milk or milk beverages. At the same time, whole-grain bread and fish consumption increased with BMI category, whereas the consumption of sweet beverages, sweets and fast foods decreased according to BMI category. In Spain [54], compared to normal weight peers, overweight or obese adolescents consumed more energy, sugars, fat, SFAs and less protein, carbohydrates, MUFA and PUFA. Regards the adherence to the MD, poor adherence was more prevalent in overweight and obese Croatian children, adolescents, and young adults [63].

3.1.3.4.4 Socio-demographic, lifestyle, and food behavior variables

Among European adolescents, other factors associated to the adherence to dietary recommendations were found. For example, among Polish [51], adherence to healthy eating behaviors was inversely associated with screen time, showing that participants who spent no more than 2 hours per day in front of a screen were more likely to have breakfast every day, consume fish, fresh fruit, vegetables, whole-grain bread and milk or milk beverages, and had a low likelihood of eating unhealthy foods and drinks such as fast food, sweets, and sweet drinks. Among Norwegians [52], physical well-being and a good school environment improved the probability of having a higher quality of diet. At the same time, in Swedish [55] and Danish [56] adolescents the parental educational level and mothers' diet during pregnancy, respectively, were favorable predictors of offspring's eating habits. Considering physical activity, in Spanish children, adolescents, and young adults [63] a good level of physical activity was positively associated with both adherence to the MD and recommended dietary behaviors. Also, in a cohort of Spanish adolescents [54] a poor level of physical activity was associated with a low intake of fruit, vegetables, legumes, dairy products meat, fish, and an unbalanced carbohydrates intake characterized by and excessive sugar consumption. In addition, the results of one included study revealed that in Spanish children and adolescents [56] exclusive consumption of olive oil was positively correlated with recommended eating habits such as intake of vegetables, pulses, and milk and derivates, and with a reduced risk of overweight/obesity or central obesity.

Table 3 Level of adherence to dietary guidelines among young European populations.

	Vegetables	Fruit	Starchy foods	Milk and yogurt	Cheese	Meat and meat products	Fish	Eggs	Legumes	Nuts	Sweets	Sugar-sweetened beverages	Cooking fats	Fast food	Alcoholic drinks	Non-alcoholic drinks
Children (7-8 y)																
van de Rossum *et al.* (2011) [62] Netherlands	L	L	L	L	A	A	A	A	n.a.	n.a.	n.a.	n.a.	L	n.a.	n.a.	L
Children and adolescents (9-13 y)																
van de Rossum *et al.* (2011) [62] Netherlands	L	L	L	L	L	A	A	A	n.a.	n.a.	n.a.	n.a.	L	n.a.	n.a.	A
Adolescents (10-19 y)																
Brettschneider *et al.* (2021) [53] Germany	L	L	L	L	n.a.	H	L	L	n.a.	n.a.	H	H	L	n.a.	n.a.	A
Bjerregaard *et al.* (2019) [56] Denmark	L	L	n.a.	n.a.	n.a.	H	L	n.a.	n.a.	n.a.	n.a.	A	n.a.	n.a.	n.a.	n.a.
van de Rossum *et al.* (2011) [62] Netherlands	L	L	L	L	A	A	A	A	n.a.	n.a.	n.a.	n.a.	L	n.a.	n.a.	A
Young adults (19-30 y)																
van de Rossum *et al.* (2020) [58] Netherlands	L	L	◊ L	L	n.a.	H	n.a.	n.a.	L	L	n.a.	H	n.a.	n.a.	n.a.	L
van de Kamp *et al.* (2018) [60] Netherlands	L	L	L	♂A ♀L	♂A ♀L	A ∇ H	♂A ♀L	n.a.	L	L	n.a.	n.a.	L	H	H	n.a.
van de Rossum *et al.* (2011) [62] Netherlands	L	L	L	L	♂A ♀L	♂H ♀A	♂H ♀A	♂H ♀A	n.a.	n.a.	n.a.	n.a.	L	n.a.	n.a.	A

∇ red meat only; ◊ whole grains. Data are reported as level of adherence to recommendation considering the average food intake (low; adequate; high). Different colors highlight different adequacy of the food consumption: yellow for low average intake; green adequate average intake; red for high average intake. L: low; A: adequate; H: high; ♂: males; ♀: females; n.a.: not available.

Table 4 Percentage of the sample who met dietary guidelines among young European populations.

	Vegetables	Fruit	Starchy foods	Milk and yogurt	Cheese	Meat and meat products	Fish	Eggs	Legumes	Nuts	Sweets	Sugar-sweetened beverages	Cooking fats	Olive oil	Fast food	Alcoholic drinks	Breakfast
Adolescents (10-19 y)																	
Dordic *et al.* (2019) [49] Serbia	20	35	10	34			27				17	n.a.	n.a.	n.a.	n.a.	n.a.	78
Myszkowska-Ryciak *et al.* (2019) [50] Poland	♂ 48 ♀ 47 (♂*)	♂ 55 ♀60 (♀**)	◊ ♂ 40 ♀ 44 (♀**)	♂ 66 ♀ 55	n.a.	n.a.	♂56 ♀45 (♂**)	n.a.	n.a.	n.a.	♂58 ♀55 (♂**)	♂65 ♀50 (♂**)	n.a.	n.a.	♂76 ♀82 (♀**)	n.a.	♂65 ♀55 (♀**)
Bottolfs *et al.* (2020) [52] Norway	♂6 ♀14		◊ ♂17 ♀18	n.a.	n.a.	n.a.	♂24 ♀25	n.a.	n.a.	n.a.	♂32 ♀33		n.a.	n.a.	n.a.	n.a.	n.a.
Roura *et al.* (2016) [54] Spain	1	2	n.a.	21		23 (♂*)	39	26	41	n.a.	47	47	n.a.	n.a.	61	90	77
Adolescent and young adults (16-25 y)																	
Salas *et al.* (2013) [57] Balearic Islands (Spain)	♂ 7 ♀ 12	♂ 18 ♀ 16	♂ 29 ♀ 24	♂ 52 ♀ 53			32		♂ 8 ♀ 6	♂ 14 ♀ 13	♂ 76 ♀ 79	♂ 82 ♀ 84	♂ 8 ♀ 12	♂ 22 ♀ 29	n.a.	♂ 93 ♀ 97	n.a.
Young adults (19-30 y)																	
van de Rossum *et al.* (2020) [58] Netherlands	8	♂ 6 ♀ 10	◊ ♂52 ◊ ♀32	♂ 33 ♀ 24	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.

◊ whole grains. Data are reported as percentage (%) of the sample who met recommendation. Different colors highlight different adequacy of the food consumption: very light green: less than 1/3 of the sample of the sample met the recommendation; light green: more than 1/3 and less than 2/3 of the sample met the recommendation; bright green: more than 2/3 of the sample met the recommendation. If different guidelines were used for comparison, a range of the percentages has been reported. c: children; a: adolescents; ♂: males; ♀: females; n.a.: not available. *$p < 0.05$, **$p < 0.001$ significative higher in comparison the other gender of the same age-group.

Table 5 Level of adherence to nutritional recommendations among young European populations.

	Energy	Protein	Fat	SFAs	MUFA	PUFA	Trans fatty acids	EPA and DHA	ALA	Carbohydrates	Sugars	Fiber
Children (2-10 y)												
Walton *et al.* (2017)[38] Ireland	n.a.	H	A	H	n.a.	n.a.	n.a.	L	A	L	H	L
Chouraqui *et al.* (2020) [41] France	n.a.	H	L	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	L
Children and adolescents (4-19 y)												
§Ruiz *et al.* (2016) [42] Spain	n.a.	H	H	H	n.a.	A	n.a.	n.a.	n.a.	L	H	n.a.
NDNS survey (2008-2010) [47, 48] United Kingdom	n.a.	n.a.	H	H	n.a.	n.a.	A	n.a.	n.a.	n.a.	H	L
NDNS survey (2010-2012) [47, 48] United Kingdom	n.a.	n.a.	A	H	n.a.	n.a.	A	n.a.	n.a.	n.a.	H	L
NDNS survey (2012-2014) [47, 48] United Kingdom	n.a.	n.a.	H	H	n.a.	n.a.	A	n.a.	n.a.	n.a.	H	L
NDNS survey (2014-2016) [47, 48] United Kingdom	n.a.	n.a.	H	H	n.a.	n.a.	A	n.a.	n.a.	n.a.	H	L
NDNS survey (2016-2019) [47, 48] United Kingdom	n.a.	n.a.	H	H	n.a.	n.a.	A	n.a.	n.a.	n.a.	H	L
Adolescents (10-19 y)												
Roura *et al.* (2016) [54] Spain	n.a.	H (♀**)	H (♂**)	H (♂**)	H (♂**)	n.a.	n.a.	n.a.	n.a.	n.a.	H (♀**)	n.a.
Bjerregaard *et al.* (2019) [56] Denmark	n.a.	n.a.	n.a.	A	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	A	A
Young adults (18-35 y)												
van de Kamp *et al.* (2018) [60] Netherlands	A	A	n.a.	H	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	L
Children, adolescents, and young adults (2-30 y)												
van de Rossum *et al.* (2011) [62] Netherlands	n.a.	H	A	H	n.a.	n.a.	A	L	A	A	n.a.	7-18 y A 19-30 y L

Data are reported as level of adherence to recommendation considering the average food intake (low; adequate; high). Different colors highlight different adequacy of the food consumption: light yellow for low average intake; light green adequate average intake; light red for high average intake. L: low; A: adequate; H: high; ♂: males; ♀: females; n.a.: not available; SFAs: saturated fatty acids; PUFA: poly unsaturated fatty acids; y: years; MUFA: monounsaturated fatty acids; ALA: a-linolenic acid; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid. *$p < 0.05$, **$p < 0.001$ significative higher in comparison the other gender of the same age-group.

Table 6 Percentage of the sample who met nutrition recommendation among young European populations.

	Energy	Protein	Fat	SFAs	Cholesterol	PUFA	Carbohydrates	Sugars	Fiber
Children (2-10 y)									
Madrigal *et al.* (2020) [39] Samaniego-Vaesken *et al.* (2020) [40] Spain	3-<6 y 76-117 6-<10 y 68-95	3-<6 y 369-414 6-<10 y 278-312	3-<6 y 37-48 a** 6-<10 y 36-63 b**	n.a.	n.a.	n.a.	3-<6 y 47-57 a** 6-<10 y 51-52 b**	n.a.	4-6 y 20-45 7-10 y 0-18
Chouraqui *et al.* (2020) [41] France	24-29 months 49 24-35 months 58	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
§Olza *et al.* (2016) [43] Spain	n.a.	n.a.	n.a.	♂ 16 ♀27	n.a.	♂ 76 ♀ 78	n.a.	♂ 10 ♀ 6	♂ 15 ♀14
Tornaritis *et al.* (2014) [43, 44] Cyprus	n.a.	♂ 32 ♀ 27	♂ 54 ♀ 56	♂ 7 ♀ 9	♂43 ♀72	♂ 17 ♀ 13	♂ 74 ♀ 82	n.a.	♂ 0 ♀ 2
López-Sobaler *et al.* (2019) [45] Spain	n.a.	100	54	n.a.	n.a.	n.a.	♂ 52 ♀ 42	n.a.	n.a.
Children and adolescents (4-19 y)									
Tornaritis *et al.* (2014) [43, 44] Cyprus	n.a.	♂ 22 ♀ 31 (♂**)	♂ 38 ♀ 36	♂ 7 ♀ 7	♂39 ♀33	♂ 29 ♀ 25	♂ 59 ♀ 62	n.a.	♂ 1 ♀ 2
Ruiz *et al.* (2016) [42] Spain	n.a.	n.a.	n.a.	♂16 (c) 25 (a) ♀27 (c) 23 (a)	n.a.	♂76 (c) 70 (a) ♀78 (c) 81 (a)	n.a.	♂10 (c) 14 (a) ♀6 (c) 9 (a)	♂15 (c) 6 (a) ♀14 (c) 2 (a)
López-Sobaler *et al.* (2019) [45] Spain	n.a.	100	♂ 54 ♀ 56	n.a.	n.a.	n.a.	♂ 71 ♀ 70	n.a.	n.a.
Adolescents (10-19 y)									
Olza *et al.* (2016) [43] Spain	n.a.	n.a.	n.a.	♂ 25 ♀ 23	n.a.	♂ 70 ♀ 81	n.a.	♂ 14 ♀ 9	♂ 6 ♀ 2
Tornaritis *et al.* (2014) [43, 44] Cyprus	n.a.	♂ 17 ♀ 33 (♂**)	♂ 16 ♀ 3 (♂**)	♂ 3 ♀ 9 (♂**)	♂ 41 ♀ 68 (♂**)	♂ 39 ♀ 30 (♂*)	♂ 34 ♀ 56 (♀*)	n.a.	♂ 2 ♀ 5 (♂*)
López-Sobaler *et al.* (2019) [45] Spain	n.a.	100	♂65 ♀61	n.a.	n.a.	n.a.	♂69 ♀65	n.a.	n.a.

Data are reported as percentage (%) of the sample who met recommendation. Different colors highlight different adequacy of the food consumption: very light green: less than 1/3 of the sample of the sample met the recommendation; light green: more than 1/3 and less than 2/3 of the sample met the recommendation; bright green: more than 2/3 of the sample met the recommendation. If different guidelines were used for comparison, a range of the percentages has been reported. c: children; a: adolescents; ♂: males; ♀: females; n.a.: not available; SFAs: saturated fatty acids; PUFA: poly unsaturated fatty acids; y: years; MUFA: monounsaturated fatty acids; ALA: a-linolenic acid; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid. $*p < 0.05$, $**p < 0.001$ significative higher in comparison the other gender of the same age-group. $^{a/b}*p < 0.05$, $^{a/b}**p < 0.001$ significative higher in comparison the other age-group.

Table 7 Adherence to dietary guidelines and/or nutritional recommendation among young European populations expressed through dietary quality scores.

	Score	Results
Children and adolescents (8-17 y)		
Tambalis *et al.* (2020) [46] Greece	KIDMED score (0-12)	♂ 6.7 (2.4) ♀ 6.8 (2.4) (♀**)
Children, adolescents, and young adults (2-24 y)		
Matana *et al.* (2022) [63] Croatia	KIDMED score (0-12)	6 (3) Poor 19 Medium 61 Good 20
Adolescents (11-18 y)		
Moraeus *et al.* (2020) [55] Sweden	SHEIA15 score (0-9)	11.5 (0.4) y: ♂ 5.7 (0.7); ♀ 5.9 (0.7) 14.5 (0.4) y: ♂ 5.7 (0.8); ♀ 6.0 (0.8) 17.7 (0.6) y: ♂ 5.5 (0.9); ♀ 6.0 (0.9) Low ♂ 31 ♀ 19 Medium ♂ 50 ♀ 51 High ♂19 ♀ 30
Bjerregaard *et al.* (2019) [56] Denmark	HEI score (0-80)	24 (9) Q1: 14 (3) Q2: 20 (2) Q3: 26 (2) Q4: 35 (5)
Bottolfs *et al.* (2020) [52] Norway	Recommended dietary intake (0-10)	♂ 5.8 (1.7) ♀ 6.4 (1.8) (♀**)
Young adults (18-35 y)		
Kyprianidou *et al.* (2020) [59] Cyprus	MedDiet score (0-55)	16 (13, 18) Low 32 Medium 40 High 27
Ferreira-Pêgo *et al.* (2017) [61] Spain	MedDiet adherence score (0-14)	Low 52 Medium 35 High 21

Data are reported as percentage (%) for different level of adherence to recommendation or as mean (SD) or as median (Q1, Q3) score. Different colors highlight different adequacy of the food consumption: yellow when the majority of the sample has a medium/fair level of adherence or if the average score is the half of total score; red when the majority of the sample has a poor/low level of adherence or if the average score is lower than 1/3 of total score. Q: quartile; ♂: males; ♀: females. *$p < 0.05$, **$p < 0.001$ significative higher in comparison the other gender of the same age-group. KIDMED: MD Quality Index for children and adolescent (≤ 3: insufficient dietary habits, 4-7: relatively sufficient dietary habits, ≥ 8: sufficient dietary habits); MedDiet Score: Mediterranean Diet Score (0-55); MedDiet adherence score: Mediterranean Diet adherence score (<5 low; 6-7 medium; >8 high) ; SHEIA15: Swedish Healthy Eating Index for Adolescents 2015; HEI: Healthy Eating Index.

3.1.4 General discussion

This systematic review summarizes the results of recent studies aimed at assessing the overall dietary habits of young European populations and evaluating their adherence to national/international dietary guidelines, nutritional recommendations, or healthy dietary patterns (e.g., MD). The included studies (n=29) were conducted in Northern, Eastern, Central European, and Mediterranean areas for a total of 14 countries, providing a partial view of the current situation that does not include: Austria, Belgium, Bulgaria, Czechia, Estonia, Finland, Hungary, Italy, Latvia, Lithuania, Luxemburg, Malta, Portugal, Romania, Slovakia, and Slovenia. Most of the studies focused on the dietary habits of children and adolescents, whereas fewer data were found for the populations of young adults.

All studies conducted in the child population reported only the nutritional values of the participants' diets, except for one Dutch publication that also analyzed food group intake. Children diets resulted in excessive intakes of protein, SFAs, and sugars in almost all populations. At the same time, carbohydrate and fat intake varied between low and high adherence to recommendations; in contrast, reported fiber intake was nearly always insufficient. Lipid profile of children diet was analyzed in a limited number of studies, which reported a low intake of EPA and DHA, adequate intakes of trans fatty acids and ALA, and conflicting data on cholesterol and PUFA intakes. The only study investigating food consumption showed low consumptions of fruit and vegetables, starchy foods, milk and dairy products, cooking fats and non-alcoholic drinks, on the contrary intakes of cheese, meat and meat products, fish and eggs were in line with the recommendations. In addition, two studies showed a medium adherence to the MD in Greek and Croatian children. Regarding macronutrient distribution, similar to the findings of this review, excessive protein consumption and some variability in carbohydrate and fat intake have been found previously by Börnhrst and colleagues [74]. The study analyzed the diet quality of European children aged 2-9 years, finding that the average protein intake exceeded the recommended intake in all children and that one-third of the sample had a diet low in carbohydrates and excessively high in fat. Also, the findings on poor fruit and vegetable consumption and insufficient intake fiber are consistent with the most recent report of the WHO's European Childhood Obesity Surveillance Initiative (COSI), which found that only 43% of children aged 6 to 9 years eat fresh fruit every day, while the percentage drops to 34% for daily vegetable intake [75]. On the contrary, in line with results of this review, children’s sugar intake across Europe exceeded the recommended daily energy intake (i.e., 10%) and is

mainly related to the consumption of sugar-sweetened beverages [76], in fact, about 1 out of 4 European children used to consume soft drinks more than 3 days per week [75].

Adolescents were the age group for which more findings were available. Eating habits were reported both as food group and nutrition values. Similar to the child population, most of the adolescents had a diet with a content of protein, SFAs, and sugars that exceeded recommendations, an average adequate amount of carbohydrate, and almost always insufficient fiber consumption. Fat intake was less adequate than in children. Even in adolescents, the lipid profile was poorly investigated reporting medium to high and low to high adherence to recommendations for cholesterol and PUFA, respectively, and excessive MUFA intake. Regarding the consumed foods, adherence to recommendations for fruits and vegetables, starchy foods, milk and dairy products, meat and meat products, fish, eggs, legumes, nuts, and cooking fats was poor in almost all countries considered and inversely associated with age. In general, adolescents' dietary habits were characterized by low intakes of fruits and vegetables, starchy foods, milk and dairy products, cheese, fish, eggs, legumes, nuts, and cooking fats, and excessive intakes of meat and meat products, sweets, and SSBs. Intakes of fast food, alcoholic and non-alcoholic beverages were reported in a few studies and were mostly in line with recommendations. The habit of having breakfast was only investigated in Spanish, Serbian and Polish cohorts, showing medium to high adherence to this recommendation. In addition, a medium adherence to the MD was reported among Greek and Croatian adolescents, and two other diet quality scores were also used in Norwegian and Swedish adolescents showing medium adherence to dietary guidelines and nutritional recommendations. The results of this review are generally concordant with an earlier European cross-sectional study [77], which described suboptimal adherence to nutrition recommendations and dietary guidelines among adolescents. Regarding the nutritional profile of the diet, adolescents showed excessive protein intake, nearly twice higher than the recommended, and SFAs intake about 40% higher compared to reference intake. Also, about cholesterol and PUFA intake, our results were aligned with those of this European cohort according to cholesterol intake was approximately in line and PUFA intake was lower than recommended. Lastly, adequate intakes of carbohydrates and fiber were reported. These results are consistent with the studies included in our revision, for carbohydrates but not for fiber. In fact, we found that fiber intake was low or most of the sample did not reach the recommendations. Taking into consideration food groups, no more than half of the sample met the food-based dietary guidelines on fruits, vegetables, bread and cereals, and about two-thirds had adequate intake of milk products and eggs. In addition, excessive consumption of meat, fats, sweets, and soft drinks was found compared with

recommendations [78, 79]. In contrast to our findings, Diethelm *et al.* [79] reported an average fish intake above recommendations among European adolescents. Although a low number of studies have investigated breakfast habit, this review showed a higher percentage of breakfast consumers than adolescents enrolled in previous European studies [80, 81].

Dietary habits of young adults have been reported in few studies. Food groups intake was reported only for Dutch and Spanish populations, showing poor consumption of fruit and vegetables, starchy foods, legumes, nuts, cooking fats, milk, and dairy products in almost all young adults. Spanish young adults also had inadequate intake of fish, eggs and olive oil, excessive intakes of meat and meat products and good adherence to recommendations for sweets, SSBs, and alcoholic beverages. On the other hand, Dutch had excessive intakes of SSBs, fast food, and alcoholic beverages, whereas the intakes of cheese, meat and meat products, fish, and eggs were different between genders, with females showing on average better intakes. In addition, for non-alcoholic drinks the results were in contrast in the Dutch populations. Considering the nutritional profile of the young adult diet, results are limited and referred only to Dutch subjects, who showed adequate intake of carbohydrates, fat, ALA, and trans fatty acids, low intake of fiber, and EPA and DHA, excessive intake of SFAs, and mixed results for protein. Finally, adherence to MD was analyzed in for Spanish and Croatian young adults, who showed on average a poor and medium level of adherence, respectively. But it is important to underline that Croatian study results were reported as average value of the sample which also included children and adolescents. Furthermore, authors reported a significant higher adherence in the youngest participants compared to the others. Due to the small number of nationally representative surveys specifically addressing the young adult population, discussion of the results is difficult; however, in a review aimed at investigating the nutrient intakes of adults living in WHO European countries, results for the 18-35 age group were reported in some countries [82]. Specifically, carbohydrate and fiber intakes were found to be insufficient in several European regions, such as Estonia, Turkey, Iceland, Sweden, Austria, Ireland, Netherlands, and Spain, while gender differences were observed for Hungarian, Norwegian, and German young adults, with only males achieving the recommended fiber intake. These results are in line with the low consumption of plant-based foods such as vegetables and fruits, cereals, legumes, and nuts recorded in Dutch and Spanish populations [57, 58, 60, 62]. However, in one of the three Dutch cohorts, young adults showed adequate intake of carbohydrates [62]. Average fat and SFAs intake exceeded recommendations in all European populations considered [82], regardless of geographic area and gender. Only the results on SFAs are consistent with dietary habits of Dutch young adults. Lastly, information

on sugar intake was available for a limited number of countries, including Estonia, Hungary, Finland, Sweden, Norway, and Austria, showing an intake between the recommended and maximum intake, except for Estonian and Finnish young adults, among whom females surpassed the maximum recommended intake [82]. No information on young adults' sugars intake was found in our review, however, sweets and soft drink intake was excessive and adequate in the Dutch and Spanish populations, respectively.

With regard to the different factors predicting adherence, females showed a better adherence to dietary guidelines on food groups intake and to the MD compared to their male peers, whereas for nutrient intakes the influence of gender was not clear. This difference is consistent with evidence previously reported in the literature that girls have healthier eating habits and better adherence to MD [79, 83]. However, mixed results were found in a more recent systematic review of MD adherence in European adolescents [84]. The few studies that evaluated a possible age-related trend pointed out a negative association between age and adherence to food group intake recommendations and to the MD. Similarly, in the European IDEFICS/I.Family cohort, compared to school-age children, preschoolers showed lower consumption of energy-dense foods and higher assumption of fruits, vegetables, and dairy products, as well as lower fat and sugar intake and higher total carbohydrate and protein intake [85, 86]. The same negative trend was observed when comparing children with the adolescent population, which showed lower adherence to FBDG and a high intake of ultra-processed foods [87], as well as low adherence to MD [83].

Concerning anthropometric measurements, the relationship between nutritional status and adherence to recommendations widely varied, but generally a better diet quality in the normal weight population has been reported, regardless age-group. Finally, despite the few available data, the exclusive consumption of olive oil, proper screen time, parents' education level, quality of mother's diet, and a good level of physical activity is associated with a higher adherence to dietary guidelines.

To summarize, this review shows that young populations living in Europe have eating habits that are poorly aligned with dietary guidelines and nutritional recommendations. Even when considering the principles of the MD, overall, European children, adolescents, and young adults showed only a low to medium level of adherence. However, because of the small number of studies it is difficult to draw robust conclusions. Understanding the adherence to dietary guidelines and nutrition recommendation among young populations and investigating how it changes during growth is fundamental to develop effective nutrition education projects able to

improve eating behaviors in young populations and promote overall well-being of European populations.

3.1.5 Strengths and limitations

The assessment of adherence to dietary guidelines was carried out by underling differences between different age group population and geographical areas, to provide a general overview of eating behaviors of young populations living in Europe. The inclusion of only nationally representative cohorts and the definition of a limited time frame allowed to reduce possible bias related to the low sample size and the nutritional transition taking place in the last decades as a result of exponential globalization [17–20], by allowing to provide an overview of the actual and current diets of young European populations. Considering data collection, for both food groups and nutritional values, several assessment tools were used, characterized by different accuracy levels to the gold standard (i.e., food diary) that was applied in a few studies. In addition, the included studies evaluated food consumption habits considering a different food group categorization or different nutrients, making difficult the comparison between different populations. Furthermore, the use of the assessment criteria applied to determine the quality of diet changed according to the dietary guidelines or nutrition recommendations used as reference in the different European countries made challenging the data aggregation. Assessment of adherence to the MD was also estimated using different validated questionnaires, except for the KIDMED questionnaire, which was applied in two different populations allowing for more comparable data.

3.1.6 Conclusion

Bearing in mind all these remarks, to the best of our knowledge this is the first systematic review that has synthetized the diet quality of young European populations, both considered food groups intake and nutrition values, and not only considering childhood period but also including the transition period from adolescent to adulthood. These findings shed light on several issues of interest for the scientific community and policy makers as well. First, a limited number of studies has been addressed to nationally representative samples in the last decade in Europe, therefore an accurate and reliable information on current eating habits for that geographical area is prevented. At the same time, the heterogeneity of data collection tools and dietary guidelines considered as reference criteria underline the importance of standardizing study methodologies across Europe to ensure data comparability. Finally, the

limited number of studies specifically conducted on young adult populations highlights the knowledge gap related to this period of life characterized by greater independence and central to root healthy dietary habits that can persist into adulthood.

Supplementary information

Table 1S. Recommendations used as reference in the systematic review.

Target population	Food groups [a]	Recommendations [b]	Reference
Children			
National and international dietary reference values (EFSA[88, 89],SACN[90])		Carbohydrates (% En): 45-60 Fat (% En): 20-40 (2 y) 20-35% (3-4 y) SFAs (% En): <10 ALA (% En): 4 EPA + DHA (mg): 250 Protein (g kg^{-1} body wt): 0.79 (2 y) 0.73 (3 y); 0.69 (4 y) Fiber (g): > 15 Sugars (% En): ≤ 5 Vit A (µg): 205 (2-3 y) 245 (4 y) Vit D (µg): 7.5 Vit B1 (mg/1000 kcal): 0.3 Vit B2 (mg): 0.5 (2-3 y) 0.6 (4 y) Vit B3 (mg/1000 kcal): 5.5 Vit B6 (µg g^{-1} protein): 13 Vit B12 (µg): 0.4 (2-3 y) 0.7 (4 y) Folate equivalents (µg): 90 (2-3 y) 120 (4 y) Vit C (mg): 15 (2-3 y) 25 (4 y) Ca (mg): 390 (2-3 y) 680 (4 y) Fe (mg): 5 Mg (mg): 65 (2-3 y) 90 (4 y) Z (mg): 3.6 (2-3 y) 4.6 (4 y) Copper (mg): 260 (2-3 y) 340 (4 y) I (µg): 65	Walton *et al.* (2017) [38]
International dietary recommendation (EFSA, 2019[91], IOM, 2005[92])		EFSA Carbohydrates (% En): 45-60 Fat (% En): 20-35% Protein (g/kg bw). 0.73-0.72 (3-6 y) 0.74-0.75 (7-10 y) Fiber (g): 14 (4-6 y) 16 (7-10 y) IOM Carbohydrates (% En): 45-65 Fat (% En): 20-35% Protein (g/kg bw) 0.86-0.77/0.87-0.76 (M/F 3-6 y) 0.77-0.74/0.76-0.77 (M/F 7-10 y)	Madrigal *et al.* (2020) [39] Samaniego-Vaesken *et al*. (2020) [40]

Dietary reference values (EFSA, 2013) [93]	Energy (kcal): 1028/946 (M/F 24 months) 1174/1096 (M/F 36 months) Carbohydrates (% En): 45-60 Fat (% En): 35-40 Protein (g/kg bw): 0.97 (24 months) 0.90 (36 months) Fiber (g): > 10	Chouraqui *et al.* (2020)[41]
Children and adolescents		
International dietary reference values for nutrients (EFSA, 2017[94], FAO 2010[95], WHO 2015[96])	Carbohydrates (% En): 45-60 Fat (% En): 20-35 SFAs (% En): ≤10 PUFA (% En): 6-11 Protein (g/kg bw): 0.75 (9 y) 0.70/0.67 (M/F 17 y) Sugar (% En): ≤ 10 Fiber (g): 18 (9-12 y) 20 (13-17 y) Ca (mg): 820 Fe (mg): 8 (9-12 y) 20 (13-17 y) Z (mg): 8 (9-12 y) 11/10 (M/F 13-17 y) Folate (µg): 185 (9-12 y) 234 (M/F 13-17 y) Vit C (mg): 50 (9-12 y) 75/69 (M/F 13-17 y) Vit A (µg): 400 (9-12 y) 540/486 (M/F 13-17 y)	Ruiz *et al.* (2016) [42] Olza *et al.* (2016) [43]
International dietary reference intakes and nutritional guidelines (IOM 2006[97]. WHO/FAO, 2003[98], FAO, 2010[95])	Carbohydrates (% En): 45-65 Fat (% En): 25-35 SFAs (% En): ≤10 PUFA (% En): 6-10 Protein (% En): 10-15 Fiber (g): > 14 Cholesterol (mg): ≤300 Vit A (µg): 275 (6-8 y) 445/420 (M/F 9-13 y) 630/485 (M/F 14-19 y) Vit C (mg): 22 (6-8 y) 39 (9-13 y) 63/56 (M/F 14-19 y) Vit B1 (mg): 0.5 (6-8 y) 0.7 (9-13 y) 1.0/0.9 (M/F 14-19 y) Vit B2 (mg): 0.5 (6-8 y) 0.8 (9-13 y) 1.1/0.9 (M/F 14-19 y) Vit B6 (mg): 0.5 (6-8 y) 0.8 (9-13 y) 1.1/1.0 (M/F 14-19 y) Ca (mg): 800 (6-8 y) 1300 (9-19 y) P (mg): 405 (6-8 y) 1055 (9-19 y) Mg (mg): 8 (9-12 y) 11/10 (M/F 13-17 y) K (g): 3.8 (6-8 y) 4.5 (9-13 y) 4.7 (14-19 y) Na (mg): 1.2/1.9 (M/F 6-8 y) 1.5/2.2 (M/F 9-13 y) 1.5/2.3 (M/F 14-19 y)	Tornaritis *et al.* (2014) [44]

American dietary recommendation (2005) [92]		Carbohydrates (% En): 45-65 Fat (% En): 25-35 Protein (% En): 10-30	López-Sobaler *et al.* (2019) [45]
Dietary reference values for the United Kingdom (COMA, 1991[99], SACN 2011[100], SACN 2019[101], SACN 2015[102])		Fat (% En): ≤33 SFAs (% En): ≤10 Trans fatty acids (% En): ≤2 Sugar (% En): ≤5 Fiber (g): 15 (2-5 y) 20 (5-11 y) 25 (11-16 y) 30 (16-18 y)	*NDNS survey* (2008-2019) [47, 48]
Adolescents			
American dietary guidelines (2015) [103]	(per day) Milk, yogurt, or cheese: 2-3 Fruit: 2-4 Vegetables: 3-5 Protein-based foods: 2-3 Bread, cereal, rice, and pasta: 6-11		Dordic *et al.* (2019) [49]
Dietary guidelines for the Spanish population (2001) [104]	(per day) Vegetable: ≥ 2 Fruits: ≥ 3 Dairy products: 2-4 Fish, eggs, legumes, meat: 2: Fried foods, baked products, and soft drinks: occasionally		Roura *et al.* (2016)[54]
HEI score based on Danish national food-based dietary guidelines (2017) [70] and Nordic Nutrition Recommendations (2016) [71]	Fruits and vegetables (g/day): ≥ 600 of where at minimum half is vegetables Fish (g/week): ≥ 350 Red meat (g/week): ≤500 SSBs (ml/week): 500	(per day) Fiber (g): ≥30 SFA (% En): <10 Added sugar (% En): <10 Sodium (g): ≤2.4	Bjerregaard *et al.* (2019) [56]
Healthy nutrition behaviors for Polish	Have breakfast Fresh fruit (day): ≥ 1 Vegetables (day): ≥ 2 Milk or milk beverages (yoghurt/kefir/butter milk, etc.): every day		Myszkowska-Ryciak *et al.* (2019) [51]

adolescents[105] [106]	Whole grain bread: every day Fish (week): ≥ 1 Sugared soft drinks (week): few times Sweets (week): no more than 1 Fast food (week): no more than 2		Myszkowska-Ryciak *et al.* (2020) [51]
Recommended dietary intake index based on Norwegian dietary recommendations (2014) [68]	Whole grain cereals: daily Fish (week): ≥3 times Sweets/bakery goods/sugary soda (week): ≤ 1 time Fruits/berries, and vegetables (day): several times On the base of the previous indicators a average score was assigned to score diet quality		Bottolfs *et al.* (2020) [52]
	Amounts referred to 12 y, F 13-14 y, M 13-14 y, F 15-17 y, M 15-17 y. *Foods to be consumed plenty:* Beverages (ml/d) 950, 1000, 1200, 1100, 1400 Vegetables (g/d) 300, 320, 390, 340, 440 Fruits (g/d) 280, 300, 360, 310, 410 Bread/(breakfast) cereals (g/d) 180, 190, 230, 200, 260 Potatoes/rice/pasta (g/d) 160, 170, 200, 180, 230 Foods to be consumed moderately: Milk/dairy products (g/d) 470, 490 600, 520, 680 Meat/meat products (g/d) 50, 50, 60, 50, 70 Eggs (pieces/week) 2–3, 3, 3, 3, 3–4 Fish (g/week) 90, 100, 110, 100, 130 *Foods to be consumed sparingly:* Oil/margarine/butter (g/d) 30, 30, 35, 30, 40 Unfavorable foods (max. kcal/d) 180, 200, 230, 190, 260		Brettschneider *et al.* (2021) [53]
SHEIA15 score based on Nordic Nutrition Recommendation (2014) [69]	Vegetables and fruit (g/day): ≥ 500 g (potatoes not included) Whole meal (g/10MJ): 75 Fish and shellfish (g/day) 45(frequency of 2–3 per week and portion size 125 g) Red and processed meat (g/week) <500	Fibre (g/MJ): 2.5 PUFA (% En): ≥ 7.5 MUFA (% En): ≥ 15 SFA (% En): ≤10 Added sugar (% En): ≤10	Moraeus *et al.* (2020) [55]
Adolescents and young adults			
Dietary guidelines for the Spanish population. (2001) [104]	(per day) Meat (g): 100-125 Fish (g): 125-150 g Eggs (g): 55 Milk (mL) 200-250 Dairy products (g): Yogurt (200-250), cheese (40-60) Olive oil (mL) 10 Other oils and fats (g or mL) 10 g Vegetables (g): 150 Fruit (g): 136		Salas *et al*. (2013) [57]

	Nuts (g): 30 Pulses (g): 150-200 (cooked weight) Potatoes (g): 200 Cereals (g): 120 Bread (g): 35 Sugar and cakes (g): 10 (sugar), 30-50 (cakes) Soft drinks (mL) 300 Alcoholic drinks (mL) 200 (fermented), 60 (distilled)		
Young adults			
Netherlands guidelines (2016[107]) and dietary reference intakes (2014) [108]	(per day) Vegetable (g): 250 Fruit (g): 200 Potatoes (g):158 Bread (g): 245 Grain products (g): 113 Pulses (g): 19 Nuts and seeds (g): 25 White meat and meat replacement (g): 29 Red meat (g): 43 Fish (g):14 Eggs (g): 18 Milk and milk products (g): 375 Cheese (g): 40 Fats and oils (g): 65 Non-alcoholic drinks (mL): 1500 Alcoholic drinks, other soups, sweet and savoury snacks, sauces, sweet and savory sandwich filling, ready to eat meals: not consume	Energy (kcal): 2790 (M) 2020 (F) Protein (g): 63-174 (M) 45-126 (F) SFAs (g): ≤ 31 (M) ≤ 22 (F) Fibre (g): ≥ 40 (M) ≥29 (F) Ca (mg): 1000-2500 Fe (mg): ≥ 9 (M) ≥15 (F) Na (mg): ≤ 2400 Z (mg): 9-25 (M) 7-25 (F) Vit B1 (mg): ≥ 1.1 Vit B2 (mg): ≥ 1.1 (M) ≥ 1.5 (F) Vit B12 (µg): ≥ 2.8 Vit D (µg): 3-5-100 Vit C (mg): ≥ 75 Vit A (µg): 900-3000 (M) 700-3000 (F)	van de Kamp *et al.* (2018) [60]
Mediterranean Diet based on MedDiet adherence score [109]	Using olive oil as the principal source of fat for cooking Preferring white meat over red meat Olive oil: 4 or more tablespoons (1tablespoon = 13.5 g) Vegetables (day) ≥2 servings Fruit (day) ≥3 pieces Red meat or sausages (day) <1 serving Animal fat (day) <1 serving SSBs (day) <1 cup (1 cu 100 mL) Red wine (week) ≥7 servings Pulses (week) ≥3 servings Fish (week) ≥3 servings Commercial pastries (week) <2 Nuts(week) ≥3 servings	.	Ferreira-Pêgo *et al.* (2017) [61]

	Dish with a traditional sauce of tomatoes, garlic, onion or leeks sauted in olive oil (week) ≥2 servings	
Dutch food-based dietary guidelines (2016) [110]	Whole grain products (g/day): ≥90 Alcohol (glass/day): ≤ 1 Fish (day/week): ≥ 1 Unsalted nuts (g/day): ≥15 Fruit (g/day): ≥200 Vegetables (g/day): ≥200 Tea (cups/day): ≥3 Salt (g/day): <6 Legumes (day/week): ≥ 1 Dairy products daily, including milk or yoghurt (g/day): ≥ 300 Limit the consumption of red meat and particularly processed meat Minimize the consumption of sugar-containing beverages	van de Rossum *et al.* (2020) [58]

Mediterranean Diet based on MedDiet score[111]	*Frequency of consumption (score): never/rarely (0), 1–3 times/month (1), 1–2 times/week (2), 3–6 times/week (3), 1 time/d (4) and more than 2 times/d (5),* *Positive food or food groups (high intake - high score)* Non-refined cereals (whole grain bread, pasta, rice, etc.) Potatoes Fruits Vegetables Legumes Fish Use of olive oil in cooking *Negative food or food groups (less intake - high score)* Red meat and products Poultry Full fat dairy products (cheese, yoghurt, and milk) Alcoholic beverages		Kyprianidou *et al.* (2020) [59]
Mediterranean Diet based on KIDMED score[65]	*Recommended behaviors (yes:1; no 0)* Takes a fruit or fruit juice every day Has a second fruit every day Has fresh or cooked vegetables regularly once a day Has fresh or cooked vegetables more than once a day Consumes fish regularly (≥ 2 – 3 times per week) Likes pulses and eats them more than once a week Consumes pasta or rice almost every day (5 or more times per week) Has cereals or grains (bread, etc.) for breakfast Consumes nuts regularly (≥ 2 – 3 times per week) Uses olive oil at home Has a dairy product for breakfast (yoghurt, milk, etc.) Takes two yoghurts and/or some cheese (40 g): daily *Not recommended behaviors (yes:-1; no 0)* Skips breakfast Has commercially baked goods or pastries for breakfast Takes sweets and candy several times every day Goes more than once a week to a fast-food (hamburger) restaurant		Tambalis *et al.* (2020) * [46] Matana *et al.* (2022) [63]
Children, adolescents, and young adults			
Dutch food-based dietary guidelines (2011) [112] and dietary reference values (Gezondheidsraad, 2001[113],	Vegetables (g/day): 150 (7-13 y) 200 (14-30 y) Fruit (g/day): 150 (7-8 y) 200 (9-30 y) Fish (times/week): ≥ 2 Bread (g/day): 140 (7-8 y), 150-200 (9-13 y), 245/210 (M/F 14-30 y) Potatoes (or rice, pasta or legumes) (g/day): 150 (7-8 y), 140-175 (9-13 y), 250/225 (M/F 14-30 y M), 200 (19-30 y) Dairy products (g/day): 400 (7-8 y), 600 (9-18 y), 450 (19-30 y)	Carbohydrate (% En): 45–60 Fiber (g): 16 (7-13 y), 19 (14-18 y), 25 (19-30 y) Protein (g): 17/16 (M/F 7-8 y), 28 (9-13 y), 43/38 (M/F 14-18 y), 47/40 (M/F19-30y) Fat (% En): 20–35/40 SFAs (% En): ≤10 Trans fatty acids (g): ≤1	van de Rossum *et al.* (2011) [62]

EFSA, 2010[88, 89])	Cheese (g/day): 10 (7-8 y), 20 (9-18 y), 30 (19-30 y) Meat (products) fish, chicken, egg or other meat replacement products (g/day): 80 (7-8 y), 80-100 (9-13 y), 100-125 (14-30 y) Spread (g/day): 20 (7-8 y), 20-250 (9-13 y), 35/30 (M/F 14-30) Cooking fat (g/day): 15 Drinks (g/day): 1,000 (7-8 y), 1,000-1,500 (9-13 y), 1,500-2,000 (14-30 y)	EPA and DHA (mg): 250 ALA (% En): 0.5 Vit A (μg): 300 (7-8 y), 440 (9-13 y), 600/510 (M/F 14-18 y), 620/530 (M/F 19-30 y) B1 (mg): 0.5 (7-8 y), 0.8 (9-13 y, 19-30 y), 1.1 (14-18 y) B2 (mg): 0.7 (7-8 y) 1 (9-13 y) 1.5/1.1 (M/F14-18 y), 1.1/0.8 (M/F 19-30 y) Vit B6 (mg): 0.7 (7-8 y), 1.1 (9-13 y, 19-30 y), 1.5 (14-18 y) Folate (μg): 150 (7-8 y), 225 (9-13 y) 300 (14-18 y) 200 (19-30 y), Vit B12 (μg): 1.3 (7-8 y), 2 (9-13 y, 19-30 y), 2.8 (14-18 y) Vit C (mg): 50 (7-13 y), 65 (14-18 y), 70 (19-30 y) Vit D (μg): 2.5 Vit E (mg): 9.1/8.3 (M/F 7-8 y and 9-13 y), 11.8/10.6 (M/F 14-18 y), 13.0/9.9 (M/F 19-30 y) Ca (mg): 700 (7-13 y), 1,200 (M 14-18 y) 1,000 (F 14-18 y, 19-30 y) Copper (mg): 0.34 (7-8 y), 0.54 (9-13 y) 0.685 (14-18 y) 0.7 (19-30 y) Fe (mg): 8 (7-13 y), 15/12 (M/F 14-18 y), 11/16 (M/F 19-30 y) Mg (mg): 120 (7-13 y), 220/210 (M/F 14-18 y), 300/250 (M/F 19-30 y) P (mg): 600 (7-13 y), 700 (14-30 y) K (mg): 3,800 (7-8 y), 4,500 (9-13 y), 4,700 (14-30 y) Se (μg): 20 (7-13 y), 40 (14-18 y), 50 (19-30 y) Z (mg): 4 (7-8 y), 7 (9-13 y), 8.5/7.3 (M/F 14-18 y), 9.4 (M/F 19-30 y)

% En: percentage of total dietary energy; [a] Recommendations reported as daily or weekly amount/serving. [b] Recommendations reported as daily intake. SFAs: saturated fatty acids; M: males; F: females; PUFA: poly unsaturated fatty acids; y: years; MUFA: mono unsaturated fatty acids; ALA: a-linolenic acid; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid; SSBs: sugar-sweetened beverages; P: pregnancy; PC: preconception; L: lactation; MedDiet adherence score (0-14, <5 low; 6-7 medium; >8 high) ;HEI: Healthy Eating Index (0-80); KIDMED: Mediterranean Diet Quality Index for children and adolescent (0-12, ≤ 3: insufficient dietary habits, 4-7: relatively sufficient dietary habits, ≥ 8: sufficient dietary habits); MedDiet adherence score; Mediterranean Diet adherence score MedDiet Score: Mediterranean Diet Score (0-55); Recommended dietary intake index (0-10); SHEIA15: Swedish Healthy Eating Index for Adolescents 2015 (0-9). * Children and adolescent.

Table 2S Instruments used for data collection, adherence to dietary guidelines and nutrient recommendations, dietary quality scores and secondary outcomes such as micronutrients intake, anthropometric data, lifestyle, socio-demographic, and other variables.

Sample	Instrument	Food groups	Nutritional values	Diet quality score	Secondary outcomes
Children					
Walton *et al.* (2017)[38] Ireland	Diary: 4-day record		*Mean intake was* *low*: DHA and EPA, carbohydrates, and fiber *adequate*: fat, ALA *high*: protein, SFAs, sugars differences among genders were not reported		*Proportion of children (2-3-4 y) meeting micronutrient recommendation:* Vit A 99% Vit D 8% 7% 7% Vit B1 100% Vit B2 100% Vit B3 100% Vit B6 100% Vit B12 100% Folate equivalents 99% 99% 95% Vit C 100% 99% 99% Ca 99% 97% 66% Fe 93% 88% 95% Mg 100% Z 97% 94% 78% Cu 100% I 96% 93% 92%
Madrigal *et al.* (2020) [39] § Spain	2 x 24h-R*		The results are reported by groups based on the kind of milk consumed, milk-reference (SRS) sample and adapted and fortified milk formulas- adapted milk (AMS) sample. *Proportions of children (3-<6) meeting EFSA recommendations:* energy SRS 115% AMS117% protein SRS 414% AMS 411% carbohydrates SRS 47% AMS 57% fat SRS 39% AMS 37% *Proportions of children (3-<6 y) meeting IOM recommendations:* energy SRS 76% 78% AMS protein SRS 385% 369% AMS carbohydrates SRS 49% AMS 57% fats SRS 48% AMS 48%		

		Proportions of children (6-<10 y) meeting EFSA recommendations: energy SRS 97% 95% AMS protein SRS 278% 278% AMS carbohydrates SRS 51% AMS 51% fat SRS 40% AMS 63% *Proportions of children (6-<10 y) meeting IOM recommendations:* energy SRS 68% AMS 68% protein SRS 312% 305% AMS carbohydrates SRS 51% AMS 52% fats SRS 39% AMS 36% Adherence to IOM recommendation for protein and fat were significative different between children of SRS and AMS groups (p<0.001). Within AMS group adherence to EFSA recommendation for carbohydrates was significative different between 3-<6 y and 6-<10 y children (p<0.001) Adherence to IOM recommendation for fat was significative different between 3-<6 y and 6-<10 y girls (p<0.001).	
Samaniego-Vaesken *et al.* (2020) [40] § Spain		*Fiber recommendation was met by*: *Children (3-<6 y)* of SRS M 45%, F 35% *Children (3-<6 y)* of AMS M 38%, F 20% *Children (6-<10 y)* of SRS M 18%, F 11% *Children (6-<10 y)* of AMS M 0%, F 7%	PA level Median (IR) *Children (3-<6 y)* SRS 1.6 (1.4- 1.7) AMS 1.5 (1.4–1.7) *Children (6≤y<10)* SRS 1.6 (1.4–1.7) AMS 1.6 (1.5–1.7)
Chouraqui *et al.* (2020) [41] France	3-day food diary	*Median intake was:* *low*: fat and fiber *adequate*: carbohydrates *high*: protein	OW/OB 24-29 months: 8% 30-35 months: 5%

		Energy recommendation was met by: *Children (24-29 months)* 49% *Children (24-35 months)* 58% Differences between gender were not shown.	
Children and adolescents			
Ruiz *et al.* (2016) [42] § Spain	24h-R* + 3-day food diary	*Mean intake was:* *low*: total carbohydrates *adequate*: PUFA *high*: fat, SFAs, protein and sugar	
Olza *et al.* (2016) [43] § Spain		*Proportions of children and adolescents (9-12 y) meeting the recommendations:* PUFA M 76% F 78% SFAs M 16% F 27%, sugars M 10% F 6% fiber M 15% F 14% *Proportions of adolescents (13-17 y) meeting recommendations for:* PUFA M 70% F 81% SFAs M 25% F 23% sugars M 14% F 9% fiber M 6% F 2% Significative gender differences were not reported.	*Proportions of children (9-12 y) meeting micronutrient recommendations:* Ca 54% Fe 94% Z 69% folate 38% Vit C 64% Vit A 77% *Proportions of adolescents (13-17y) meeting micronutrient recommendations:* Ca 25% Fe 95% Z 23% folate 15% Vit C 64% Vit A 55%
Tornaritis *et al.* (2014) [44] Cyprus	3-day food diary	*Proportions of children (6-9 y) meeting recommendation for:* carbohydrate M 74% F 82% fat M 54% F 56% SFAs M 7% F 9% PUFA: M 17% F 13% cholesterol M 43% F 72% protein M 32% F 27% fiber M 0% F 2% *Proportions of children and adolescent (9-14 y) meeting recommendation for:*	*Proportions of children (6-9 y) meeting micronutrient recommendations:* Vit A M 54% F 46% Vit C M 96% F 97% Vit B1 100% Vit B2 M 99% F 100% Vit B6 99% Fe 98% P 100% Mg M 96% F 98% Na M 22% F 28%

		carbohydrates M 59% F 62% fat M 38% F 36% SFAs M 7% F 7% PUFA M 29% F 25% cholesterol M 39% F 33% protein M 22% F 31% fiber M 1% F 2% M shown a higher intake of protein ($p < 0.05$). M shown higher intake of protein, ($p < 0.001$) *Proportions of adolescent (14-19 y) met recommendation for:* carbohydrates: M 34% F 56% fat M 16% F 31% SFAs M 3% F 9% PUFA M 39% F 30% cholesterol M 41% F 68% protein M 17% F 33% fiber M 2% F 5% M shown higher intake of protein, fat, SFA, cholesterol ($p < 0.001$), PUFA, and fiber ($p < 0.05$), and a lower intake of carbohydrates ($p < 0.001$).	*Proportions of children and adolescents (9-14 y) met recommendation for:* Vit A M 80% F 82% Vit C M 84% F 83% Vit B1 M 95% F 93% Vit B2 M 98% F 97% Vit B6 M 94% F 91% Fe M 97% F 94% P M 82% F 72% ($p<0.05$) Mg M 67% F 55% ($p<0.05$) Na M 31% F 46% M shown higher intake of Na ($p < 0.001$) *Proportions of adolescents (14-19 y) met recommendation for:* Vit A M 64% F 67% ($p < 0.001$) Vit C M 64% F 67% Vit B1 M 90% F 85% Vit B2 M 91% F 92% Vit B6 M 87% F 79% Fe M 93% F 75% ($p < 0.001$) P 100% Mg M 15% F 10% Na M 24% F 52% M shown higher intake of Na ($p < 0.001$) Mean intake of Ca and K was below the recommendation but % was not shown. UW: 9%; NW: 63%; OW: 19%; O: 9% Overweight and obese participants shown a higher intake of protein
López-Sobaler *et al.* (2019) [45] Spain	2 x 1-day food diary (4-10 y) and 2x 24h-R* (11-17 y).	*Proportions of children (4-8 y) met the recommendation for:* carbohydrates 54% fat M 52% F 42% protein 100% *Proportions of children and adolescent (9-13 y) met the recommendation for:* carbohydrates M 71% F 70% fat M 54% F 56%	BMI: 18.1 (3.1)

		protein 100% *Proportions of adolescent (14-17 y) met the recommendation for:* carbohydrates M 69% F 65% fat M 65% F 61% protein 100% Statistical analysis to compare M and F was not reported.		
Tambalis *et al.* (2020) [46] Greece	KIDMED questionnaire*		*KIDMED score (0-12) expressed as m*ean (SD): TS 6.7 (2.4) M 6.7 (2.4) F 6.8 (2.4) Significant differences between gender were found ($p < 0.001$)	Mean (SD) *PA (h/wk)* TS 9.4. (5.5) M 10.4 (5.9) F 8.4 (5.2) *Screen time (h/wk)* TS 8.6 (8.5) M 9.3 (8.8) F 7.8 (7.8) *Sleeping time weekdays (h/d*) TS 8.6 (1.6) M 8.6 (1.6) F 8.7 (1.6) For all variables significative differences between genders were found $p<0.001$. BMI: TS 19.7 (3.8); M 19.8 (3.8); F 19.5 (3.7). WC: TS 70.4 (10.7); M 71.6 (11.1); F 69.2 (10.2). WHR: TS 0.30 (0.46); M 0.32 (0.47): F 0.28 (0.45). The exclusive olive oil consumption was a predictor of favorable eating behaviors regarding the intake of vegetables, pulses, and milk and derivates, and a lower risk of overweight/obesity or centrally obesity

NDNS survey (2008-2019) [47, 48] United Kingdom	4-day food diary	*Data collections* 2008-2010, 2012-2019 *Median intake was:* *low:* fiber *adequate*: trans fatty acid, *high*: fat, SFAs, free sugars *Data collections 2010-2012* *Median intake was:* *low:* fiber *adequate:* fat, trans fatty acid *high*: SFAs, free sugars		
Adolescents				
Dordic *et al.* (2019) [49] Serbia	Questionnaire*	*Proportions of adolescents met recommendation for*: breakfast 78% milk, yogurt, or cheese 34% fruit 35% vegetables 20% protein-based foods 27% bread, cereal, rice and pasta 10% limit use of sugars and food containing sugar 17%		8% choose a diet low in fat, SFAs, and cholesterol and 12% read labels to identify nutrients, fats, Na content in packaged food. 45% follow a planned exercise program 44% practice vigorous exercise for ≥ 20 min at least 3 times a week 39% take part in light to moderate physical 29% take part in leisure-time (recreational) physical activities 41% do stretching exercises at least 3 times per week 73% get exercise during usual daily activities

Myszkowska-Ryciak *et al.* (2019) [50] § Poland	Questionnaire*	*Proportions of adolescents met recommendation for:* Breakfast TS 60% M 65% F 55% (p<0.001) Fresh fruit TS 58% M 55% F 60% (p<0.001) Vegetables TS 48% M 47% F 48% (p=0.0241) Milk or milk beverages (yoghurt/kefir/butter milk, etc.) TS 60% M 66% F 55% Whole grain bread TS 43% M 40% F 44% (p<0.001) Fish TS 50% M 56% F 45% (p<0.001) Sugared soft drinks TS 57% M 65% F 50% (p<0.001) Sweets TS 56% M 58% F 55% (p<0.001) Fast food TS 79% M 76% F 82% (p<0.001)		Intake of vegetables, fresh fruit, milk or milk beverages and regular breakfast consumption significative decreased and sugared soft drinks and fast food significative increased with age (p<0.001). BMI: TS 21.3 ± 3.5; F 20.9 ± 3.33; M 21.7 ± 3.68 (p<0.001). According to BMI category significative trends were found. Normal and underweight adolescents were more likely to have breakfast every day. Compared to underweight participants obese subjects were more likely to consume fruit, while overweight people were more likely to consume milk or milk beverages. Whole-grain bread and fish consumption increased with BMI category. On the contrary, the consumption of sweet beverages, sweets and fast foods decreased according to BMI category.
Myszkowska-Ryciak *et al.* (2020) [51] § Poland				Adolescents who met daily screen time recommendation (≤ 2h) were more likely to follow healthy eating behaviors (i.e., breakfast every day, consume fish, fresh fruit, vegetables, whole-grained bread and milk or milk beverages), and low probability to eat unhealthy food and drinks such as fast food, sweet and sweet beverages.
Bottolfs *et al.* (2020) [52] Norway	FFQ°	*Proportions of adolescents met recommendation for*: Whole grain cereals M 17% F 18% Fish M 24% F 25% Sweets/bakery goods/sugary soda M 32% F 33% Fruits/berries, and vegetables M 6%, F 14%	*Recommended dietary intake index (0-10)* expressed as mean (SD): TS 6.2 (1.8) M 5.8 (1.7) F 6.4 (1.8) A significative difference between gender was found. (p<0.001)	Minute/day of MVPA Mean (SD) TS 54.1 (22.9) M 58.4 (24.8) F 50.3 (20.3) (p<0.001) Compliance with PA recommendations TS 36% M 41% F 31%

				Sleep index (6-30) Mean (SD) TS 10.86 (3.5) M 10.68 (3.49) F 11.04 (3.54) Recommended dietary intake index was positively correlated with physical well-being and school environment. BMI: TS 20.1 (3.4); M 19.6 (3.2); F 20.5 (3.6) ($p<0.001$). OW/O: TS 95%; M 41%; F 54%.
Brettschneider *et al.* (2021) [53] Germany	Dietary history*	*Median intake was:* *low*: fruits, vegetables, starchy food, milk and dairy products eggs, fish, and fats (oil/butter/margarine) *adequate*: beverage *high*: sweet, pastries and sugar-sweetened drinks, meat and meat products F showed a better diet quality, specifically for the higher intake of fruit and vegetables and the lower intake of soft drinks compared to M.		
Roura *et al.* (2016) [54] Spain	7-days food diary	*Proportions of adolescents met recommendation for*: vegetable 1% fruits 2% dairy products 21% white fish 23% blue fish 46% eggs 26% legumes 41% meat 23% fried foods 61% soft drinks 47% baked products 47%	*Mean intake was* *high*: proteins, fat, MUFA, SFAs and sugars Protein and carbohydrates intake was higher in F ($p < 0.001$). Intake of fat, SFAs and MUFA were higher in M ($p < 0.001$).	Males were more active than females ($p<0.05$). UW; 2%; NW: 78%; OW:12%; O: 8%. Compared to normal weight adolescents, overweight and obese participants shown a higher intake of energy, sugars, fat, SFAs but less intake of protein, carbohydrates, MUFA and PUFA ($p<0.05$). Low PA was associated with a low intake of fruit, vegetables, legumes, dairy products meat, white and blue fish

		90% had an adequate alcohol consumption and 77% had breakfast every day. Only for meat M had a higher intake compared to F (70% *vs.* 66%, p<0.05).			(p<0.05). In addition, an inadequate PA level was associated with a low intake of carbohydrates and higher sugars consumption (p<0.05).
Moraeus *et al.* (2020) [55] Sweden	2 x 24h-R†			*SHEIA15 score (0-9)* expressed as mean (SD): 11.5 (0.4) y: M 5.7 (0.7); F 5.9 (0.7) 14.5 (0.4) y: M 5.7 (0.8); F 6.0 (0.8) 17.7 (0.6) y: M 5.5 (0.9); F 6.0 (0.9) *Level of adherence:* *low* M 31% F 19% *medium* M 50% F 51% *high* M 19% F 30% Mean of SHEIA15 score was higher F, regardless from age group.	High SHEIA15 score was associated with high intake of vegetable, wholegrains, fish, and fruits, and low intake red and processed meat and sweets, high n-3 fatty acids, PUFA, wholegrains, and energy recalculated with fiber, and low intake of energy, SFAs, and added sugars. OW/O: 11.5 (0.4) y 22%; 14.5 (0.4) y 17%; 17.7 (0.6) y M 26% F 22%. High educated parents were a favorable predictor of adolescents' SHEIA15 score (p<0.001).
Bjerregaard *et al.* (2019) [56] Denmark	FFQ°	*Mean intake was:* *low*: fruit, vegetable, and fish *adequate*: SSBs *high*: red meat No correlations between diet quality and gender were found.	*Mean intake was:* *adequate*: fiber, SFAs, and added sugar (in the Q3 and Q4)	*HEI (0-80) expressed as* mean (SD): 24 (9). Q1: 14 (3) Q2: 20 (2) Q3: 26 (2) Q4: 35 (5).	*Mean intake was:* *high*: Na. HEI scores were associated with high intake of fruits and vegetables, dietary fiber, and fish, and low intake of red meat, SFAs, SSBs, and added sugars. On the contrary, for total energy and Na intake the trend was not linear among the HEI quartiles. UW: 15%; NW: 76%; OW/O: 9%. Mothers' eating habits during pregnancy were a favorable predictor of offspring's diet quality at age 14 years (p<0.001).
Adolescents and young adults					
Salas *et al*. (2013) [57] Spain	FFQ°	*Proportions of adolescents and young adults met recommendation for*: meat, fish, and eggs 32%	*Mean intake was*: *high*: salt		

		milk and dairy products M 52% F 53% olive oil M 22% F 29% other oils and fats M 8% F 12% vegetables M 7% F 12% fruits M 18% F 16% nuts M 14% F 13% pulses M 8% F 6% potatoes M 29% F 24% cereals and bread M 29% F 24% sugar and cakes M 76% F 79% soft drinks M 82% F 84% alcoholic drinks M 93% F 97%	*Proportions of children met recommendation for*: salt M 10% F 40%		
Young adults					
van de Rossum *et al.* (2020) [58] Netherlands	2 x 24h-R*	*Mean intake was*: *low*: fruit and vegetables, dairy products (including milk and yogurt), unsalted nuts, legumes, tea, wholegrain products *high*: red meat and processed meat, sugar-containing beverages *Proportions of young adults met recommendation for*: fruits M 6% F 10% vegetables 8% milk and yogurt M 33% F 24% nuts 2% wholegrain products M 52% F 32% Statistical analysis to compare gender difference was not reported.			*Mean intake was*: *high*: Na UW: M 5%, F 4%; NW: M 64%, F 58%; OW: M 25%, F 24%; O: M 7%, F 14%.
Kyprianidou *et al.* (2020) [59] Cyprus	FFQ*			*MedDietScore (0-55) expressed as m*edian (Q1, Q3) 16 (13, 18) *and level of adherence:* *low:* 32%, *medium:* 40%, *high:* 27%	
van de Kamp *et al.* (2018) [60] Netherlands	2 x 24h-R*	*Mean intake was*: *low*: vegetable, fruit, bread, grain products, pulses, nuts and seeds,	*Mean intake was:* *low*: fiber *adequate*: energy and protein		*Mean intake was*: *low*: in F, Ca, Fe, Vit B1, Vit D.

		fats, oils and eggs, milk and milk products (F), fish and cheese (F) *adequate*: white meat and meat replacement, milk and milk products (M), fish and cheese (M) *high*: red meat, alcoholic drinks, non-alcoholic drinks, other soup sweet and savoury snacks, sauces, sweet and savoury sandwich filling, and ready to eat meals	*high*: SFAs		*adequate*: in M Ca, Fe, Vit B1, Vit D, in in TS Z, Vit B2, Vit B12, Vit C, Vit A, in F Na *high*: in M Na Carbon footprint of the total diet (kg CO2-equivalents per day) M 5.9 F 4.3
Ferreira-Pêgo *et al.* (2017)[61] Spain	Questionnaire†			*MedDiet adherence*: *low*: 52% *medium*: 35% *high*: 21% Significative gender differences were not reported.	PA (times per week) *≤ 1-2* 32% *1-2* 39 % *≥ 2* 34 %
Children, adolescents, and young adults					
van de Rossum *et al.* (2011) [62] Netherlands	2 x 24h-R + fish consumption FFQ*	*Median intake was:* *Children (7-8y)* *low:* vegetables, fruit, bread, potatoes (or rice, pasta, or legumes), dairy products, spread, cooking fat, drinks *adequate*: cheese, meat (products) fish, chicken, eggs or other meat replacement product *Adolescents (9-13 y)* *low:* vegetables, fruit, bread, potatoes (or rice, pasta, or legumes), dairy products, cheese, spread, cooking fat *adequate*: meat (products) fish, chicken, eggs or other meat replacement product, drinks *Adolescents (14-18 y)* *low:* vegetables, fruit, bread, potatoes (or rice, pasta, or legumes), dairy products, spread, cooking fat	*Mean intake was:* *low*: EPA and DHA, fiber (19-30 y) *adequate*: fat, ALA, trans fatty acids, carbohydrates, fiber *high*: SFAs, protein		*Micronutrient recommendation not met for:* Vit A 7-8 y M 8% F 9%, 9-13 y M 20% F 30% 14-18 y M 35% F 40% 19-30 y M 30% F 38% Vit B1 7-13 y low 14-18 y M low F ns 19-30 y M 5% F 24% Vit B2: 7-18 y low 19-30 y M 8% F 7% Folate 7-8 y low 9-18 y ns 19-30 y M 17% F 41% Vit B12 7-18 y low, 19-30 y M 2% F 8% Vit C 7-30 y low Vit D

	adequate: cheese, meat (products) fish, chicken, eggs or other meat replacement product, drinks *Young adults (19-30 y)* *low:* vegetables, fruit, bread, potatoes (or rice, pasta, or legumes), dairy products, cheese (F), spread, cooking fat *adequate:* cheese (M), meat (products) fish, chicken, eggs or other meat replacement product (F), drinks *high*: fish, chicken, eggs or other meat replacement product (M) In addition, *recommendation for fish were met from*: 6% of children 7-8 y 7% of adolescent 9-13 y 8% of adolescent 14-18 y (M 9% F 7% 12% of young adults 19-30 y (M 13% F 11%)		7-8 y ns 9-18 y M low F ns 19-30 y M low F low/ns Vit E 7-30 y low Ca 7-13 y low 14-18 y ns 19-30 y M low F ns Cu 7-8 y 0% 9-13 y M 1% F 2% 14-18 y M 1% F 7% 19-30 y M 1% F 5% Fe 7-8 y M low/ns F ns 9-13 y M low/ns F ns 14-18 y M ns F ns 19-30 y M low/ns F ns Mg 7-30 y low P 7-30 y low K 7-30 y ns Se 7-8 y low 9-13 y M low F low/ns 14-30 y M low/ns F ns Z 7-8 y M 2% F 1% 9-13 y M 15% F 29% 14-18 y M 18% F 28% 19-30 y M 18% F 13% PA recommendations met by: 12-18 y M 35% F 23% 19-30 y M 77% F 71% For 7-11 y adherence to recommendations was not shown but 84% were norm-active (>7 hours/week).

				7-8 y: UW 10%; NW 67%; OW 17%; O 5%. *9-13 y*: UW (M 10% F 9%); NW (M 75% F 71%); OW (M 14% F 17%); O (M 2% F 3%). *14-18 y*: UW (M 7% F 8%); NW (M 78% F 76%); OW (M 12% F 14%); O (M 3% F 2%). *19-30 y*: UW (M 3% F 4%); NW (M 64% F 54%); OW (M 26% F 23%); O (M 7% F 18%)
Matana *et al.* (2022) [63] Croatia	KIDMED questionnaire†		*KIDMED index score (0-12) expressed as m*edian (IQR): 6 (3) *level of adherence:* poor 19% medium 61% good 20% No significant differences between gender were found.	Youngest participants shown the higher adherence compares the others ($p <$ 0.001), showing higher intake of fruit, vegetables, fish, nuts, pasta or rice, olive oil consume, dairy products consumption for breakfast, and yogurt or cheese generally. Poor adherence to MD was more prevalent in overweight and obese participants, despite no significative associations between diet and BMI category were found. Positive associations were found between PA and adherence to MD and to positive dietary behaviors.

§ Same study population; † self-administered; * Administered by trained professional; ° method of administration not specified

FFQ: food frequency questionnaire; 24h-R: 24-h recall; SFAs: saturated fatty acids; M: males; F: females; TS: total sample; PA: physical activity; PUFA: poly unsaturated fatty acids; y: years; MUFA: mono unsaturated fatty acids; ALA: a-linolenic acid; DHA: docosahexaenoic acid; EPA: eicosapentaenoic acid; SSBs: sugar-sweetened beverages; Q: quartile; MD: Mediterranean Diet; BMI: body mass index; MVPA: moderate to vigorous physical activity; SRS: milk-reference; AMS: adapted and fortified milk formulas- adapted milk; MedDiet adherence score (0-14, <5 low; 6-7 medium; >8 high) ;HEI: Healthy Eating Index (0-80); KIDMED: MD Quality Index for children and adolescent (0-12, ≤ 3: insufficient dietary habits, 4-7: relatively sufficient dietary habits, ≥ 8: sufficient dietary habits); MedDiet Score: MD Score (0-55); Recommended dietary intake index (0-10); SHEIA15: Swedish Healthy Eating Index for Adolescents 2015 (0-9). BMI: body mass index (kg/m2): UW: underweight; NW: normal weight; OW: overweight; O: obese; WC: waist circumference (cm); WHtR: waist to height ratio.

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Study 2

Adherence to the Mediterranean Diet and Its Association with Sustainable Dietary Behaviors, Sociodemographic Factors, and Lifestyle: An Online Survey in Italian and US University Students

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Abstract

Background The declining trend of the adherence to Mediterranean Diet (MD) and shift toward Western-type dietary patterns involve different age groups across the world, including young generations. University students are particularly involved in this process as university life exposes them to the risk of developing unhealthy dietary behaviors and diet-related chronic diseases in later life.

Purpose This cross-sectional was aimed to investigate the level of adherence to the MD and its association with sociodemographic and anthropometric variables, and lifestyle-related factors, including the adoption of sustainable dietary behaviors, in two national representative samples of university students (18-24 years) living in Italy (IT) and in the United States (US).

Materials and Methods The adherence to the MD and sustainability of dietary behaviors were assessed by applying the KIDMED questionnaires and the Sustainable-HEalthy-Diet (SHED) index, respectively. Both instruments provide a total score. In addition, the SHED index includes six sub-scores (i.e., Healthy Eating, Sustainable Eating, Place of Purchase of Fruits and Vegetables, Prepared Meals, Water and Soda).

Results The final samples consisted of 1434 and 1485 Italian and American students, respectively. Most of participants had an average adherence to the MD (IT: 55%; US: 47%). In both populations, meeting physical activity recommendations, having a high SHED index score, mainly consuming plant-based foods, being prone to purchase and eat healthy and sustainable dishes, and regularly attending the university canteen were the most powerful predictors of having a high adherence to the MD.

Conclusion In this connection, a major promotion of the MD as a sustainable dietary pattern may be an effective strategy for its revitalization. Considering the positive influence that university canteen attendance has on students' eating habits, campuses and university dining services represent a unique opportunity to build a supportive environment that educates students about the effects of their actions and fosters human and planetary health.

Keywords

Mediterranean Diet; sustainable diet; healthy eating; food-related behavior; online questionnaire; young adults

3.2.1 Introduction

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organisation (WHO) have described sustainable diets as "dietary patterns that promote all dimensions of individuals' health and wellbeing; have low environmental pressure and impact; are accessible, affordable, safe, and equitable; and are culturally acceptable […] for present and future generations" [1]. Based on this, the concept of sustainable diets sheds light on the importance of long-term effects related to the food system [2], which contributes to greenhouse gas emissions for more than 25% [3] and is the main responsible also of other environmental indicators, e.g., freshwater eutrophication and soil acidification [4,5].

In this context, the promotion of food patterns that feed the world's growing population while giving equal priority to human and environmental health is increasingly important [2,3,6–8]. According to the FAO and WHO's definition [1], the Mediterranean Diet (MD) includes all the key components (i.e., food security and accessibility, healthy food, respect for environment and biodiversity, fair trade, locality/seasonality, protection of culture, heritage, and skills) to be recognized as a proper example of a healthy and sustainable diet [9–13]. The MD is mainly characterized by a generous intake of plant-based products such as grains, fruits, vegetables, legumes, nuts, and herbs, a moderate consumption of white meat, fish, eggs, and dairy product, a low intake of red meat and processed meat, and the use of olive oil as the main seasoning [14,15]. The MD contributes to biodiversity protection through the promotion of local, fresh, and seasonal foods [16]. More recently, its low environmental impact has been also recognized [10,11]. At the same time, a high adherence to the Mediterranean dietary pattern has been widely associated with a lower risk of non-communicable diseases (NCDs) including diabetes, cancer, cardiovascular and neurodegenerative diseases, and total mortality [13,15].

Contrary to the MD, Western dietary models are typically characterized by an overconsumption of refined grains, meat and processed meat, processed and ultra-processed foods, ready-to-eat meals, snacks, and sugar-sweetened beverages, and a poor consumption of fruit and vegetables [17–20]. As a result, it is a leading cause of the obesity pandemic and the prevalence of NCDs worldwide [18,21–24]. At the same time, the adverse impact of animal-based food on environment is broadly acknowledged and a substantial reduction is strongly recommended to preserve the well-being of the planet as well as to promote human health [11,25–27]. However, in the last decades, the quantity and the availability of foods have increased in developed countries, resulting in a higher access to animal-based and energy-intensive foods. This has contributed to the globalization process of diets, shifting people's

eating habits toward Western-type dietary patterns across the world [24,28]. Since the 2000s the process of diet westernization has been observed also in Mediterranean regions, including Italy [29]. More recent evidence has confirmed this progressive shift from the MD in Italian adults as still ongoing [30–33].

In parallel to food globalization, other factors, such as the economic crisis, social and cultural influences have greatly affected people's way of life, accelerating the move away from the Mediterranean lifestyle [29,34]. The declining trend of adherence to the MD involves different age groups, including young generations, such as university students [35]. The transition to university life is generally characterized by a greater independence from the family. In particular, the autonomy in purchasing and preparing meals exposes students to the risk of developing unhealthy dietary behaviors and diet-related chronic diseases in later life [36,37]. Promising results indicate that interventions to improve food awareness in university students may enhance positive eating habits in the short- and long-term well-being [38]. The identification of factors affecting university students' dietary behaviors allows a better understanding of what is needed to efficiently implement public health strategies to enhance dietary habits improve in young generations.

In this context, the present study aimed to assess the level of adherence to the MD and its association with sociodemographic and anthropometric variables, and lifestyle-related factors, including the adoption of sustainable dietary behaviors, in two national representative samples of university students living in Italy and in the United States (US).

3.2.2 Materials and methods

3.2.2.1 Participants

After approval of the local institutional review board in Italy (Research Ethics Board, 85797) and in the US (Institutional Review Board for Human Participants, IRB0144167), an online survey, self-administered on a dedicated platform (Qualtrics software, Version [May 2022] of Qualtrics. Copyright © [2022] Qualtrics), as conducted on two representative populations of Italian (case study 1) and American (case study 2) university students aged 18-24 years recruited through a marketing agency in May 2022. To obtain two representative samples of the university student population living in Italy and US, the gender distribution and the geographic area of residence in both countries were considered. Subject recruitment and online data collection had been continued until the sample size, previously set at 2800 students, was reached, equally divided between Italy and US (n=1400 each). Sample representativeness

was defined by considering the number of Italian university students (n=1,627,780) and US young adults (n=11,625,38) in 18-24 years range, as reported in the data record provided by National Institute of Statistics (ISTAT) and United States Census Bureau (USCB) for Italy and US, respectively, referred to on 1 January 2021. The sample size calculation was made by using G*Power calculator. Before starting the data collection, each participant provided informed consent.

3.2.2.2 Demographic data, health-related factors, and food habits

Sociodemographic and anthropometric information was self-reported by each subject. Age range, gender identity, academic status, field of study, region of university location, living place typology, region of origin or state of residence, and financial status were collected as categorical variables, and the number of categories changed depending on the type of information. Height and weight were reported without decimals places as cm or ft and kg or lbs for Italy and US, respectively. They were considered as continuous variables and used to calculate students' Body Mass Index (BMI) and estimate their weight status according to WHO's standard cutoffs (i.e., underweight <18.5, normal 18.5 – 24.9, overweight ≥ 25, obese ≥ 30) [39]. The physical activity level of participants was assessed through the two-item short version of the Nordic Physical Activity Questionnaire (NPAQ-short). NPAQ-short is a validated tool to assess compliance with WHO guidelines on physical activity and sedentary behavior [40], which recommend at least 150 min of Moderate Physical Activity (MPA) or 75 min of Vigorous Physical Activity (VPA), or an equivalent combination of Moderate to Vigorous Physical Activity (MVPA). The closed-ended version of the questionnaire with five answer options for both questions on time spent on MVPA and VPA in a typical week was used for this online survey. Based on the responses, students were classified as meeting to WHO recommendations if they performed at least 150-300 min of MVPA or 60-90 min of VPA or a combination of 90-150 min of MVPA and 30-60 min of VPA. Otherwise, the participants' physical activity was classified as below the guidelines.

Additionally, the students were asked to express the existence of some physiological status (i.e., pregnancy, breastfeeding) and pathologies (e.g., cardiovascular disease, diabetes, food intolerances or allergies), to report the frequency of having food at the university canteen in the last 6 months, to indicate the dietary pattern that most represented them (e.g., omnivore, vegetarian, etc..), and to express their willingness to purchase and consume healthy and sustainable dishes in the following months. The latter question was anticipated by the definitions of sustainable diets and planetary health plate provided by the FAO [1] and the EAT-

Lancet Commission, respectively [41]. Lastly, a question adapted from the questionnaire developed by Ohlau and colleagues [42] investigated the consumption frequency of plant-based ultra-processed meat alternatives foods.

3.2.2.3 Adherence to the Mediterranean Diet

Adherence to the MD was assessed by using the KIDMED questionnaire, a Mediterranean diet quality index validated in children and youths from 2 to 24 years [43]. It consists of 16 yes/no questions defined based on the principles of the MD. The score assigned to each response varied between -1 or +1. Positive scores were assigned to MD-representative eating habits such as daily consumption of fruit (≥ 1 unit), vegetables (≥ 1 unit), yoghurt (2 units) and/or some cheese (40 g); regular weekly consumption of fish (≥ 2 – 3 times), nuts (≥ 2 – 3 times) and legumes (> 1 time); having cereals or grains (bread, etc.) and dairy products (yoghurt, milk, etc.) for breakfast, habitual consumption of pasta or rice (≥5 days per week), and using olive oil at home. On the contrary, a negative score was assigned to eating behaviors not representative of the MD such as not having breakfast, having breakfast by eating commercial baked goods or pastries, having a daily and repeated consumption of sweets and candy, and eating at fast-food restaurants more than once a week. The final KIDMED score was calculated and reported as the sum of the scores for each question in a 0-12-point range, classifying the subjects in three level of adherence: high (total score ≥ 8 points); medium (total score 4–7 points) or low (total score ≤ 3 points).

3.2.2.4 Nutritional and environmental sustainability of dietary consumption

The sustainability of subjects' eating behaviors was assessed using a validated 30-item questionnaire specifically developed to measure the adoption of healthy and sustainable dietary patterns through the calculation of the Sustainable-HEalthy-Diet (SHED) Index [44]. The original version was slightly modified according to local eating habits and food products to better represent dietary patterns of the involved country populations. The SHED Index questionnaire investigates overall dietary consumption and consists of six sections from which six sub-scores have been calculated: Healthy Eating (HE), Sustainable Eating (SE), Fruits and Vegetable purchasing location (BFV), Ready meals, Water, and Soda. The HE and SE scores included 10 and 7 questions, respectively, on consumption of animal- and plant-based food, attitude towards salt and salty products, low-sugar foods, plant-based ultra-processed meat alternatives foods, organic food, beverages, waste sorting, and local foods. A 4-point Likert scale from "Almost never true" to "Almost always true" was used for both sections. The

corresponding scores to the answer options ranged 0 to 3, except for the scale applied to the first question of HE sub-section that was reversed. BVF and Water sections consisted respectively of 8 and 4 questions investigating the frequency of purchasing fruit and vegetables in different distribution channels (local *vs.* non-local) and the consumption of different types of water (tap vs. bottled) through a 4-point Likert scale from "Never" (score 0) to "Most of the time" (score 3). Ready meals and Soda scores included 6 and 2 questions, respectively, aimed at evaluating the frequency of consuming refrigerated, frozen, take-out or home-cooked foods, sugar sweetened and low-calorie sweetened beverages by applying a 6-point Likert scale from "Never" (score 0) to "Daily or almost daily" (score 5). Specifically, the calculation of the sub-scores for the BFV, ready meals, water, and soda sub-sections entailed a specific data processing according to which the score of each item has been multiplied for a specific correction coefficient [44]. The six sub-scores were calculated by summing the obtained scores in each section, and the final SHED Index score was computed as the sum of the six sub-scores. On this basis, higher scores were associated with healthier and more sustainable behaviors. In addition, based on the SHED Index score, the participants were divided into tertiles reflecting low (1st tertile), medium (2nd tertile), and high 3rd tertile) sustainability of dietary behaviors. Finally, the respondents were asked to indicate the percentage of plant-based food in their usual diet, by applying a 0-100% scale.

3.2.2.5 Statistical analysis

Descriptive and inferential statistics were performed for both case studies separately. The normality of the data distribution was evaluated and rejected through the Kolmogorov-Smirnov test. On this basis, results were expressed as median and interquartile ranges (IQRs) or as frequency and percentage for continuous and categorical variables, respectively. The non-parametric Kruskal-Wallis H test with Bonferroni post hoc test was used to explore and compare differences between continuous variables among subjects with different level of adherence to the MD (low, medium and high). The Pearson Chi-square test (χ^2) was applied to investigate possible associations between level of adherence to the MD and categorical variables. In addition, the non-parametric Spearman's rank correlation was applied to assess the degree of association between the continuous variables considered. Finally, univariate and multivariate logistic regression statistics were carried out to investigate which variables increased the likelihood of having a high adherence to the MD. In addition, differences between two countries were also investigated by using a non-parametric Mann-Whitney U test for independent samples and the Pearson Chi-square test for continuous and categorical variables,

respectively. The IBM SPSS Statistics for Macintosh, version 28.0 (Armonk, NY: IBM Corp) was used to perform all statistical analyses, considering a *p*-value less than 0.05 as statistically significant.

3.2.3 Results

3.2.3.1 Case study 1: Italian university students

A total of 1454 subjects filled out the online survey. After removing low quality records (n=20), the final sample consisted of 1434 students, representative of university students residing in Italy. Specifically, the time taken to complete the survey was considered as the quality criterion, and respondents who took less than 40% of the median time or more than 1 hour to fill out the questionnaire were excluded [45–47].

The median MD score was 6.0 (4.0-8.0) and the group of respondents having a medium level of adherence to the MD was the most prevalent (55%), followed by the high (28%) and low (17%) adherence group.

The answers to each question in the KIDMED questionnaire for the Italian sample are reported in Figure 1 and described below.

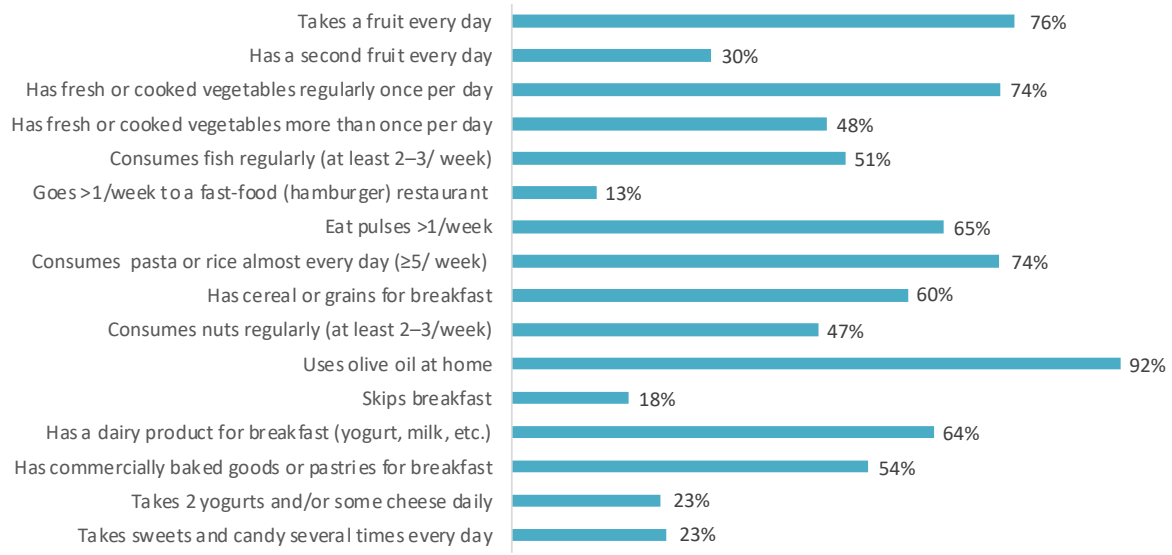

Figure 1. Replies to the KIDMED questionnaire for the Italian sample

Seventy-six percent of the students consumed one fruit in their daily diet, and 30% of them ate a second fruit every day. Vegetables were consumed once a day by 74% of the participants, and 48% reported consuming a second serving every day. In addition, 51% ate fish at least 2-3 times a week and 65% consumed legumes more than once a week. Cereals such as pasta or rice are consumed by 74% of students almost every day. More than 80% of students

had breakfast every day, of those 60% ate cereal or grains, 64% dairy products, and 54% baked goods or pastries for breakfast. Also, 23% stated consuming 2 yogurts and/or some cheese every day. In addition, 47% of participants regularly consumed nuts and 92% use olive oil at home. Finally, 13% of students went to fast food restaurant more than once a week and 23% ate sweets and candies several times a day.

Participants' data, such as socio-demographic information, BMI, physical activity level, and physiological status, are shown in Table 1 for the total sample and by adherence to the MD groups. The median age of the sample was 22.0 (20.0-23.0) and females were the majority (60%). Students' age showed a very weak positive correlation with the KIDMED score (Spearman's $\rho = 0.099$, $p < 0.001$). More than a third of the students came from southern regions or islands (39%), but considering the geographical location of the university, the distribution of the sample was more equally distributed across the country. Most of the students were undergraduates (64%), almost half were enrolled in human-social university programs (47%), more than one fourth (27%) followed a course in scientific-technological field, whereas food science and medicine programs were attended by 16% and 9% of students, respectively. In addition, 31% did not live with their parents at the time of the survey, and 18% reported not having enough to get by or prefer not to answer. Most students reported anthropometric measurements that were within the normal BMI range (67%), while 21% were found to be overweight or obese. MVPA recommendations were met by half of the sample (49%), 71% had no medical conditions, food intolerances or allergies, and 4 women were pregnant or lactating.

Adherence to the MD was significantly associated with academic status ($p = 0.002$), financial situation ($p = 0.022$), BMI categories ($p = 0.031$), and adherence to MVPA ($p < 0.001$).

Table 1. Socio-demographic characteristics, BMI, physical activity level, physiological and health conditions reported for the entire Italian sample and by level of adherence to the MD.

		Adherence to the MD			
	All (*n* = 1434)	**Low (n = 246)**	**Medium (n = 789)**	**High (n = 399)**	***p* Value**
Age (years)	22.0 (20.0-23.0)	21.0 (20.0-23.0)[b]	22.0 (21.0-23.0)[a]	22.0 (21.0-23.0)[a]	0.001[§]
Gender					0.305[†]
Males	562 (39.2)	86 (35.0)	307 (38.9)	169 (42.4)	
Females	860 (60.0)	160 (65.0)	473 (59.9)	227 (56.9)	
Not-binary/third gender	11 (0.8)	0 (0.0)	8 (1.0)	3 (0.8)	
Prefer not to say	1 (0.1)	0 (0.0)	1 (0.1)	0 (0.0)	
Geographical area of university location					0.145[†]
Northeast	290 (20.2)	40 (16.3)	162 (20.5)	88 (22.1)	
Northwest	384 (26.8)	60 (24.4)	204 (25.9)	120 (30.1)	
Center	321 (22.4)	58 (23.6)	179 (22.7)	84 (21.1)	
South or Islands	439 (30.6)	88 (35.8)	244 (30.9)	107 (26.8)	
Geographical area of origin					0.058[†]
Northeast	368 (25.7)	59 (24.0)	202 (25.6)	107 (26.8)	
Northwest	231 (16.1)	26 (10.6)	129 (16.3)	76 (19.0)	

Center	271 (18.9)	47 (19.1)	156 (19.8)	68 (17.0)	
South or Islands	564 (39.3)	114 (46.3)	302 (38.3)	148 (37.1)	
Academic status					0.002†
Undergraduate student	924 (64.4)	184 (74.8)	501 (63.5)	239 (59.9)	
Graduate student	324 (22.6)	35 (14.2)	186 (23.6)	103 (25.8)	
Single-cycle student	186 (13.0)	27 (11.0)	102 (12.9)	57 (14.3)	
Field of study					0.135†
Food	234 (16.3)	32 (13.0)	124 (15.7)	78 (19.5)	
Medicine	135 (9.4)	16 (6.5)	84 (10.6)	35 (8.8)	
Scientific-Technological	384 (26.8)	65 (26.4)	214 (27.1)	105 (26.3)	
Human-Social	676 (47.1)	131 (53.3)	365 (46.3)	26.6 (45.1)	
Other	5 (0.3)	2 (0.8)	2 (0.3)	1 (0.3)	
Living place typology					0.321†
In campus	78 (5.4)	6 (2.4)	48 (6.1)	24 (6.0)	
Outside campus by myself	77 (5.4)	9 (3.7)	46 (5.8)	22 (5.5)	
Outside campus with my partner	62 (4.3)	12 (4.9)	30 (3.8)	20 (5.0)	
Outside campus with roommates	282 (19.7)	56 (22.8)	147 (18.6)	79 (19.8)	
Parents' house	926 (64.6)	163 (66.3)	512 (64.9)	251 (62.9)	
Other	9 (0.6)	0 (0.0)	6 (0.8)	3 (0.8)	
Financial situation					0.022†
Not enough to get by	116 (8.1)	20 (8.1)	66 (8.4)	43 (10.8)	
Just enough to get by	421 (29.4)	87 (35.4)	229 (29.0)	30 (7.5)	
Worry about money for fun and extras	488 (34.0)	81 (32.9)	268 (34.0)	105 (26.3) 139 (34.8)	
Never have to worry about money	258 (18.0)	25 (10.2)	151 (19.1)		
I prefer not to answer	151 (10.5)	33 (13.4)	75 (9.5)	82 (20.6)	
BMI (kg/m²)	22.2 (20.1-24.5)	21.9 (19.6-24.2)	22.3 (20.1-24.9)	22.2 (20.2-24.2)	0.090§
<18.5 (underweight)	152 (10.6)	30 (12.2)	77 (9.8)	45 (11.3)	0.031†
18.5–24.9 (normal weight)	984 (68.6)	172 (69.9)	523 (66.3)	289 (72.4)	
25.0–29.9 (overweight)	243 (16.9)	33 (13.4)	153 (19.4)	57 (14.3)	
30.0–34.9 (obesity)	55 (3.8)	11 (4.5)	36 (4.6)	8 (2.0)	
MVPA recommendation					<0.001†
Not met	728 (50.8)	156 (63.4)	427 (54.1)	145 (36.3)	
Met	706 (49.2)	90 (36.6)	362 (45.9)	254 (63.7)	
Pregnancy or breastfeeding					0.470†
Yes	4 (0.3)	1 (0.4)	1 (0.1)	2 (0.5)	
No	1430 (99.7)	245 (99.6)	788 (99.9)	397 (99.5)	
Presence of pathologies, food intolerances or allergies					0.704†
Yes	415 (28.9)	76 (30.9)	228 (28.9)	111 (27.8)	
No	1019 (71.1)	170 (69.1)	561 (71.1)	288 (72.2)	

Data are presented as the median (IQRs) for continuous variables and as number (%) for categorical variables. § Nonparametric Kruskal-Wallis H test for independent sample with Bonferroni post hoc test. Different letters in the same line denote significant differences among adherence to MD groups. † Person Chi-square test. BMI: Body Mass Index; MVPA: Moderate to Vigorous Physical Activity.

The findings shown in Table 2 reflect the eating habits of Italian university students. By comparing the three groups, the SHED total index score and sub-scores were significantly higher in participants with higher MD scores ($p < 0.001$), except for the water score ($p = 0.004$). In addition, a weak significant correlation between KIDMED and SHED Index scores (Spearman's $\rho=0.352$, $p < 0.001$) and a significant association between the categories of adherence to the MD and the tertiles of SHED Index score have been observed ($p < 0.001$). Almost all students reported having an omnivorous diet, whereas a minority declared being flexitarian or pescatarian (6%), and vegetarian or vegan (4%). Overall, the students' diet was on average 50% plant-based, and this percentage was significantly greater in participants with

higher MD scores ($p < 0.001$). Also, 71% of the sample stated that they were willing to buy or eat healthy and sustainable dishes, and 55% used to consume plant-based ultra-processed meat alternatives foods, and of these 13% consume them on a weekly basis. Significative associations with the level of MD adherence were found both for willingness to purchase and consume healthy and sustainable dishes ($p < 0.001$) and for the habit of eating plant-based ultra-processed meat alternatives foods ($p = 0.003$). In contrast, the MD score of the students' diet was not significantly associated with the frequency of attendance of university canteen in the past 6 months, which was absent or very low in more than half of the sample.

Table 2. SHED sub-scores, SHED index and tertiles, and the other food-related habits reported for the entire Italian sample and by level of adherence to the MD.

		Adherence to the MD			
	All (*n* = 1434)	**Low (n = 246)**	**Medium (n = 789)**	**High (n = 399)**	***p* Value**
HE score	17.0 (13.0-20.0)	12.0 (8.0-16.0)[c]	17.0 (13.0-19.0)[b]	20.0 (17.0-23.0)[a]	<0.001[§]
SE score	13.0 (11.0-15.0)	12.0 (9.0-13.0)[c]	13.0 (11.0-15.0)[b]	14.0 (12.0-16.0)[a]	<0.001[§]
BFV score	28.0 (20.0-38.0)	24.0 (17.0-33.0)[c]	28.0 (20.0-37.0)[b]	31.0 (22.0-41.0)[a]	<0.001[§]
Ready meals score	16.0 (12.0-20.0)	15.0 (11.0-18.0)[c]	16.0 (12.0-20.0)[b]	17.0 (13.0-21.0)[a]	<0.001[§]
Water score	2.0 (-3.0-6.0)	1.0 (-3.0-5.3)[b]	2.0 (-3.0-6.5)[b]	3.0 (-2.0-7.0)[a]	0.004[§]
Soda score	-9 (-12.0- -7.0)	-9 (-11.0- -6.0)[c]	-9 (-12.0- -7.0)[b]	-11 (-13.0- -48.0)[a]	<0.001[§]
SHED Index Score	68.0 (55.0-81.0)	55.0 (42.8-68.0)[c]	67.0 (55.0-80.0)[b]	74.0 (64.0-87.0) [a]	<0.001[§]
1st tertile	432 (30.1)	134 (54.5)	243 (30.8)	55 (13.8)	<0.001[†]
2nd tertile	464 (32.4)	70 (28.5)	257 (32.6)	137 (34.3)	
3rd tertile	538 (37.5)	42 (17.1)	289 (36.6)	207 (51.9)	
% Plant-based foods in the diet	50.0 (38.0-67.3)	35.0 (20.8-45.0)[c]	50.0 (40.0-66.0)[b]	60.0 (49.0-73.0)[a]	<0.001[§]
Dietary pattern					<0.001[†]
Omnivore	1285 (89.6)	236 (95.9)	717 (90.9)	332 (83.2)	
Flexitarian	64 (4.5)	5 (2.0)	39 (4.9)	20 (5.0)	
Pescatarian	20 (1.4)	1 (0.4)	5 (0.6)	14 (3.5)	
Vegetarian	37 (2.6)	2 (0.8)	17 (2.2)	18 (4.5)	
Vegan	16 (1.1)	0 (0.0)	7 (0.9)	9 (2.3)	
Raw foodism	3 (0.2)	1 (0.4)	1 (0.1)	1 (0.3)	
Fruitarian	6 (0.4)	0 (0.0)	2 (0.3)	4 (1.0)	
Others	3 (0.2)	1 (0.4)	1 (0.1)	1 (0.3)	
Willingness to purchase and consume healthy and sustainable dishes					<0.001[†]
Very unlikely	44 (3.1)	7 (2.8)	22 (2.8)	15 (3.8)	
Unlikely	109 (7.6)	42 (17.1)	54 (6.8)	13 (3.3)	
Undecided	266 (18.5)	76 (30.9)	153 (19.4)	37 (9.3)	
Likely	707 (49.3)	112 (45.5)	404 (51.2)	191 (47.9)	
Very likely	308 (21.5)	9 (3.7)	156 (19.8)	143 (35.8)	
Frequency of eating plant-based ultra-processed meat alternatives foods					0.003[†]
Never/Rarely	652 (45.5)	136 (55.3)	355 (45.0)	161 (40.4)	
1-2 time/month	310 (21.6)	54 (22.0)	171 (21.7)	85 (21.3)	
≤ 1 time/week	279 (19.5)	35 (14.2)	154 (19.5)	90 (22.6)	
2-3 times/week	146 (10.2)	17 (6.9)	86 (10.9)	43 (10.8)	
4-5 times/week	33 (2.3)	3 (1.2)	19 (2.4)	11 (2.8)	
Daily or almost daily	14 (1.0)	1 (0.4)	4 (0.5)	9 (2.3)	

Attendance of the university canteen in the last 6 months					0.059 †
Never/rarely	814 (56.8)	152 (61.8)	450 (57.0)	212 (53.1)	
< 1 time/week	190 (13.2)	37 (15.0)	97 (12.3)	56 (14.0)	
1-2 times/week	216 (15.1)	35 (14.2)	118 (15.0)	63 (15.8)	
3-4 times/week	135 (9.4)	18 (7.3)	80 (10.1)	37 (9.3)	
5-6 times/week	54 (3.8)	2 (0.8)	33 (4.2)	19 (4.8)	
Once per day or more	25 (1.7)	2 (0.8)	11 (1.4)	12 (3.0)	

Data are presented as the median (IQRs) for continuous variables and as number (%) for categorical variables. § Nonparametric Kruskal-Wallis H test for independent sample with Bonferroni post hoc test. Different letters in the same line denote significant differences among adherence to MD groups. † Person Chi-square test. MD: Mediterranean Diet; HE: Healthy Eating; SE: Sustainable Eating; BFV: Fruits and Vegetable purchasing location; SHED: Sustainable-Healthy-Diet.

In Table 3, logistic regression analysis revealed that being compliant with MVPA recommendations, having a high SHED index score, including a large percentage of plant-based foods in their diet, and being prone to purchase and eat healthy and sustainable dishes were the most powerful predictors of having a high adherence to the MD, considering both univariate and multivariate analyses. From the univariate analysis, other factors, including being graduate student, following a plant-based dietary pattern, daily consumption of plant-based ultra-processed meat alternatives foods and attending the university cafeteria on a day-to-day basis, positively influenced the probability of being in the high adherence to MD group. Based on the same analysis, being obese significantly reduced the likelihood of having a high adherence to the MD. Finally, being females negatively affected the MD score only in the multivariate analysis.

Table 3. Logistic regression analysis for being in the high level of DM adherence (≥ 8 points) in the Italian sample considering a set of variables evaluated singularly (univariate analysis) or in combination (multivariate analysis).

	Univariate Analysis		**Multivariate Analysis**	
Variables	**OR (95% CI)**	***p* Value**	**OR (95% CI)**	***p* Value**
Age	1.069 (0.992-1.152)	0.078	1.045 (0.944-1.157)	0.395
Gender				
Males	-1-		-1-	
Females	0.834 (0.659-1.055)	0.131	0.679 (0.494-0.933)	0.017
Not-binary/third gender	0.872 (0.229-3.327)	0.841	0.317 (0.049-2.038)	0.226
Academic status				
Undergraduate student	-1-		-1-	
Graduate student	1.336 (1.013-1.761)	0.040	1.160 (0.791-1.702)	0.448
Other (single-cycle degree)	1.266 (0.897-1.788)	0.179	1.302 (0.820-2.068)	0.264
Field of study				
Food	-1-		-1-	
Medicine	0.700 (0.437-1.121)	0.138	0.616 (0.344-1.100)	0.101
Scientific-Technological	0.753 (0.529-1.071)	0.114	0.644 (0.422-0.982)	0.041
Human-Social	0.726 (0.527-1.000)	0.050	0.723 (0.489-1.067)	0.103
Other	0.500 (0.055-4.549)	0.538	0.861 (0.087-8.522)	0.898
Living place typology				
In campus	-1-		-1-	
Outside campus by myself	0.900 (0.452-1.794)	0.765	0.729 (0.297-1.792)	0.491
Outside campus with my partner	1.071 (0.523-2.196)	0.851	1.065 (0.433-2.621)	0.891
Outside campus with roommates	0.876 (0.507-1.512)	0.634	0.883 (0.420-1.855)	0.742
Parents' house	0.837 (0.506-1.382)	0.486	0.937 (0.462-1.901)	0.857
Financial situation				
Not enough to get by	-1-		-1-	

Just enough to get by	0.953 (0.595-1.525)	0.839	0.926 (0.543-1.578)	0.777
Worry about money for fun and extras	1.142 (0.721-1.808)	0.572	1.094 (0.653-1.832)	0.733
Never have to worry about money	1.336 (0.817-2.183)	0.248	1.090 (0.620-1.914)	0.765
BMI (kg/m^2)				
18.5–24.9 (normal weight)	-1-		-1-	
<18.5 (underweight)	1.011 (0.696-1.470)	0.953	1.393 (0.792-2.451)	0.249
25.0–29.9 (overweight)	0.737 (0.531-1.022)	0.067	0.629 (0.349-1.132)	0.122
30.0–34.9 (obesity)	0.409 (0.191-0.877)	0.022	0.284 (0.073-1.107)	0.070
MVPA recommendation				
Not met	-1-		-1-	
Met	2.259 (1.781-2.867)	<0.001	2.220 (1.666-2.958)	<0.001
SHED Index tertiles				
1st tertile	-1-		-1-	
2nd tertile	2.872 (2.032-4.060)	<0.001	2.099 (1.413-3.118)	<0.001
3rd tertile	4.287 (3.076-5.974)	<0.001	2.651 (1.783-3.943)	<0.001
% Plant-based foods in the diet	1.028 (1.022-1.034)	<0.001	1.023 (1.014-1.031)	<0.001
Dietary pattern				
Omnivorous	-1-		-1-	
Plant-based‡	2.392 (1.682-3.402)	<0.001	1.471 (0.935-2.315)	0.095
Others§	1.435 (0.262-7.872)	0.677	0.916 (0.105-7.970)	0.937
Willingness to purchase and consume healthy and sustainable dishes				
No/maybe	-1-		-1-	
Yes	2.671 (1.988-3.588)	<0.001	1.747 (1.219-2.504)	0.002
Frequency of eating plant-based ultra-processed meat alternatives foods				
Never/Rarely	-1-		-1-	
1-2 time/month	1.152 (0.848-1.565)	0.365	0.842 (0.584-1.214)	0.357
≤ 1 time/week	1.452 (1.068-1.976)	0.017	0.778 (0.532-1.137)	0.195
2-3 times/week	1.273 (0.855-1.895)	0.234	0.636 (0.388-1.042)	0.072
4-5 times/week	1.525 (0.724-3.213)	0.267	0.886 (0.371-2.115)	0.784
Daily or almost daily	5.489 (1.813-16.617)	0.003	3.614 (0.816-16.011)	0.091
Attendance of the university canteen in the last 6 months				
Never/rarely	-1-		-1-	
< 1 time/week	1.187 (0.837-1.682)	0.336	1.272 (0.844-1.919)	0.251
1-2 times/week	1.169 (0.838-1.631)	0.357	1.057 (0.711-1.571)	0.786
3-4 times/week	1.072 (0.712-1.614)	0.739	0.832 (0.481-1.438)	0.510
5-6 times/week	1.542 (0.863-2.753)	0.144	0.683 (0.329-1.415)	0.305
Once per day or more	2.621 (1.178-5.834)	0.018	2.075 (0.790-5.450)	0.138

BMI: Body Mass Index; SHED: Sustainable-Healthy-Diet.
‡ Including vegetarian, vegan, flexitarian, pescetarian and fruitarian dietary patterns.
§ Including raw foodism and unspecified dietary patterns.

3.2.3.2 Case study 2: US university students

A total of 1510 subjects completed the online questionnaire. After the exclusion of 25 records due to poor data quality, the final sample was composed of 1485 participants, representative of university students residing in the US. The same quality criterion previously mentioned for the Italian sample was applied.

The median MD score was 5.0 (3.0-7.0) and almost the half of the sample (47%) had medium adherence to the MD, while 20% and 34% resulted having a high and low adherence, respectively.

The responses to each question in the KIDMED questionnaire for the US sample are reported in Figure 2 and described below.

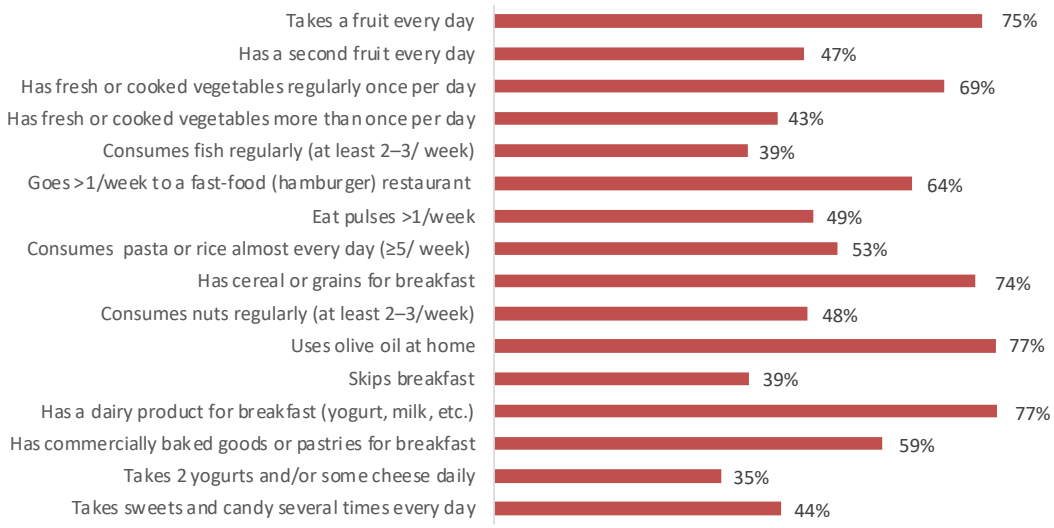

Figure 2. Replies to the KIDMED questionnaire for US sample

Fruit was consumed once a day by 75% of the students, of those 47% reported eating a second fruit every day. Seventy-four percent ate vegetables once a day, and 43% consumed a second serving every day. Considering protein-based foods, fish was consumed regularly by 39% of participants and 49% included legumes in their diet more than once a week. Pasta or rice was eaten by 53% of students 5 or more times a week. Breakfast was usually eaten by 61% of students, of these 74% consumed cereal or grains, 77% dairy products, and 59% baked goods or pastries for breakfast. In addition, 35% ate 2 yogurts and/or some cheese every day, 48% consumed nuts at least 2-3 times per week and 77% use olive oil at home. Lastly, 64% of students attended fast food restaurants more than once a week and 44% were used to eat sweets and candies many times every day.

The participants' information such as socio-demographic characteristics, physical activity level, physiological and health conditions are presented in Table 4 for the total samples and by adherence to the MD groups. The median age of the sample was 21.0 (19.0-22.0) and most of the respondents were females (59%). Many respondents came from the southern part of the country, both considering the geographical area of origin and university location. Over half of the students (67%) were undergraduate, with the majority attending courses in the human-social disciplinary area (46%), followed by subjects involved in scientific-technological (26%), food science (14%) and medical science (13%) programs.

In addition, more than a third lived with their parents (41%), and the minority of respondents reported economic insecurity or prefer not to answer (12%). More than half (52%) did not meet MVPA recommendation and declared having diseases or food allergies/intolerances (65%). Finally, 26 girls were pregnant or breastfeeding.

The level of adherence to the MD was significantly associated with gender, academic status, field of study, and compliance with MVPA recommendation ($p < 0.001$, for all the variables), living place ($p = 0.023$), financial situation ($p = 0.017$), and BMI categories ($p = 0.009$).

Table 4. Socio-demographic characteristics, BMI, physical activity level, physiological and health conditions reported for the entire US sample and by level of adherence to the MD.

Variables	All (n = 1485)	Adherence to the MD			
		Low (n = 499)	Medium (n = 695)	High (n = 291)	*p* Value
Age (years)	21.0 (19.0-22.0)	21.0 (19.0-22.0)[c]	21.0 (19.0-22.0)[b]	21.0 (20.0-23.0)[a]	<0.001[§]
Gender					0.001[†]
Males	557 (37.5)	153 (30.7)	273 (39.3)	131 (45.0)	
Females	876 (59.0)	321 (64.3)	400 (57.6)	155 (53.3)	
Not-binary/third gender	44 (3.0)	22 (4.4)	18 (2.6)	4 (1.4)	
Prefer not to say	8 (0.5)	3 (0.6)	4 (0.6)	1 (0.3)	
Geographical area of university location					0.354[†]
Northeast	317 (21.3)	107 (21.4)	145 (20.9)	65 (22.3)	
Midwest	316 (21.3)	105 (21.0)	138 (19.9)	73 (25.1)	
South	598 (40.3)	195 (39.1)	299 (43.0)	104 (35.7)	
West	254 (17.1)	92 (18.4)	113 (16.3)	49 (16.8)	
Geographical area of origin					0.310[†]
Northeast	308 (20.7)	106 (21.2)	136 (19.6)	66 (22.7)	
Midwest	327 (22.0)	110 (22.0)	145 (20.9)	72 (24.7)	
South	599 (40.3)	192 (38.5)	303 (43.6)	104 (35.7)	
West	251 (16.9)	91 (18.2)	111 (16.0)	49 (16.8)	
Academic status					<0.001[†]
Undergraduate student	989 (66.6)	391 (78.4)	431 (62.0)	167 (57.4)	
Graduate student	483 (32.5)	105 (21.0)	256 (36.8)	122 (41.9)	
Other (college students)	13 (0.9)	3 (0.6)	8 (1.2)	2 (0.7)	
Field of study					<0.001[†]
Food	211 (14.2)	45 (9.0)	109 (15.7)	57 (19.6)	
Medicine	185 (12.5)	62 (12.4)	87 (12.5)	36 (12.4)	
Scientific-Technological	378 (25.5)	117 (23.4)	182 (26.2)	79 (27.1)	
Human-Social	683 (46.0)	265 (53.1)	304 (43.7)	114 (39.2)	
Other	28 (1.9)	10 (2.0)	13 (1.9)	5 (1.7)	
Living place typology					0.023[†]
In campus	293 (19.7)	93 (18.6)	131 (18.8)	69 (23.7)	
Outside campus by myself	193 (13.0)	51 (10.2)	99 (14.2)	43 (14.8)	
Outside campus with my partner	135 (9.1)	45 (9.0)	60 (8.6)	30 (10.3)	
Outside campus with my roommates	213 (14.3)	61 (12.2)	112 (16.1)	40 (13.7)	
Parents' house	611 (41.1)	238 (47.7)	272 (39.1)	101 (34.7)	
Other	40 (2.7)	11 (2.2)	21 (3.0)	8 (2.7)	
Financial situation					0.017[†]
Not enough to get by	99 (6.7)	45 (9.0)	45 (6.5)	9 (3.1)	
Just enough to get by	495 (33.3)	178 (35.7)	228 (32.8)	89 (30.6)	
Worry about money for fun and extras	610 (41.1)	188 (37.7)	286 (41.2)	136 (46.7)	
Never have to worry about money	221 (14.9)	65 (13.0)	107 (15.4)	49 (16.8)	

I prefer not to answer	60 (4.0)	23 (4.6)	29 (4.2)	8 (2.7)	
MVPA recommendation					<0.001†
Not met	770 (51.9)	329 (65.9)	343 (49.4)	98 (33.7)	
Met	715 (48.1)	170 (34.1)	352 (50.6)	193 (66.3)	
Pregnancy or breastfeeding					0.690†
Yes	26 (1.8)	10 (2.0)	10 (1.4)	6 (2.1)	
No	1459 (98.2)	489 (98.0)	685 (98.6)	285 (97.9)	
Presence of pathologies, food intolerances or allergies					0.857†
Yes	960 (64.6)	178 (35.7)	241 (34.7)	106 (36.4)	
No	525 (35.4)	321 (64.3)	454 (65.3)	185 (63.6)	

Data are presented as the median (IQRs) for continuous variables and as number (%) for categorical variables. § Nonparametric Kruskal-Wallis H test for independent sample with Bonferroni post hoc test. Different letters in the same line denote significant differences among adherence to MD groups. † Person Chi-square test. BMI: Body Mass Index; MVPA: Moderate to Vigorous Physical Activity.

The results presented in Table 5 show the food-related habits of US students. The SHED index and SHED sub-scores, except for the water one, were significantly different among groups of participants distinguished according to the level of adherence to the MD ($p < 0.001$), being greater in those having a high adherence. This difference was also confirmed by the significant association observed between the level of adherence to the MD and the distribution among SHED Index score tertiles ($p < 0.001$) and the moderate correlation between KIDMED and SHED Index scores (Spearman's $\rho = 0.506$, $p < 0.001$).

The percentage of plant-based foods in the diet was also significantly different among the three MD adherence groups ($p < 0.001$), with the highest percentage being reported by students with a high adherence. In terms of other food-related habits, most of the sample was omnivorous (77%), 13% reported following a flexitarian or pescatarian diet, and 7% stated they were vegetarian or vegan. In addition, most of the students indicated that their purchase and consumption of healthy and sustainable dishes is likely or very likely (61%). In contrast, consumption of plant-based ultra-processed meat alternatives foods was not very common among university students, with most of them reporting to eat such products no more than 1-2 times a month (59%). Finally, the students' frequency of attendance of the university canteen was quite variable, with more than half of the participants (56%) attending the canteen at least 1-2 times per week in the last 6 months. Significant associations with the level of adherence to the MD were also found for the last 4 diet-related variables described above ($p < 0.001$).

Table 5. SHED sub-scores, SHED index and tertiles, and the other food-related habits reported for the entire US sample and by level of adherence to the MD.

Variables	**All (*n* = 1485)**	**Adherence to the MD**			
		Low (n = 499)	**Medium (n = 695)**	**High (n = 291)**	***p* Value**
SHED sub-scores					
HE score	15.0 (11.0-19.0)	12.0 (9.0-16.0)[c]	16.0 (13.0-19.0)[b]	19.0 (16.0-22.0)[a]	<0.001§
SE score	10 (8.0-13.0)	8.0 (6.0-11.0)[c]	11.0 (8.0-13.0)[b]	13.0 (11.0-17.0)[a]	<0.001§
BFV score	33.0 (23.5-44.0)	26.0 (19.0-36.0)[c]	34.0 (24.0-44.0)[b]	43.0 (33.0-57.0)[a]	<0.001§
Ready meals score	15.0 (10.0-19.0)	13.0 (9.0-18.0)[c]	15.0 (11.0-19.0)[b]	17.0 (13.0-21.0)[a]	<0.001§
Water score	6.0 (3.0-9.0)	6.0 (2.0-9.0)	6.0 (3.0-9.0)	6.0 (3.0-9.0)	0.072§

Soda score	-8 (-11.0- -6.0)	-8 (-11.0- -5.0)[b]	-9 (-12.0- -6.0)[a]	-8 (-11.0- -4.0)[c]	<0.001[§]
SHED index score	70.0 (55.0-87.0)	58.0 (46.0-71.0)[c]	71.0 (58.0-85.0)[b]	91.0 (74.0-110.0)[a]	<0.001[§]
1st tertile	465 (31.3)	261 (52.3)	174 (25.0)	30 (10.3)	<0.001[†]
2nd tertile	441 (29.7)	147 (29.5)	236 (34.0)	58 (19.9)	
3rd tertile	579 (39.0)	91 (18.2)	285 (41.0)	203 (69.8)	
% Plant-based foods in the diet	42.0 (27.0-60.0)	31.0 (20.0-46.0)[c]	45.0 (30.0-61.0)[b]	59.0 (40.0-75.0)[a]	<0.001[§]
Dietary pattern					<0.001[†]
Omnivore	1138 (76.6)	429 (86.0)	523 (75.3)	186 (63.9)	
Flexitarian	155 (10.4)	27 (5.4)	76 (10.9)	52 (17.9)	
Pescatarian	31 (2.1)	7 (1.4)	15 (1.4)	9 (3.1)	
Vegetarian	76 (5.1)	19 (3.8)	36 (5.2)	21 (7.2)	
Vegan	28 (1.9)	8 (1.6)	13 (1.9)	7 (2.4)	
Raw foodism	5 (0.3)	0 (0.0)	2 (0.3)	3 (1.0)	
Fruitarian	43 (2.9)	8 (1.6)	22 (3.2)	13 (4.5)	
Others	9 (0.6)	1 (0.2)	8 (1.2)	0 (0.0)	
Willingness to purchase and consume healthy and sustainable dishes					<0.001[†]
Very unlikely	48 (3.2)	22 (4.4)	16 (2.3)	10 (3.4)	
Unlikely	137 (9.2)	80 (16.0)	51 (7.3)	6 (2.1)	
Undecided	315 (21.2)	156 (31.3)	130 (18.7)	29 (10.0)	
Likely	675 (45.5)	189 (37.9)	369 (53.1)	117 (40.2)	
Very likely	310 (20.9)	52 (10.4)	129 (18.6)	129 (4.3)	
Frequency of eating plant-based ultra-processed meat alternatives foods					<0.001[†]
Never/Rarely	562 (37.8)	265 (53.1)	237 (34.1)	60 (20.6)	
1-2 time/month	316 (21.3)	103 (20.6)	156 (22.4)	57 (19.6)	
≤ 1 time/week	296 (19.9)	71 (14.2)	154 (22.2)	71 (24.4)	
2-3 times/week	170 (11.4)	37 (7.4)	97 (14.0)	36 (12.4)	
4-5 times/week	89 (6.0)	17 (3.4)	36 (5.2)	36 (12.4)	
Daily or almost daily	52 (3.5)	6 (1.2)	15 (2.2)	31 (10.7)	
Attendance of the university canteen in the last 6 months					<0.001[†]
Never/rarely	444 (29.9)	207 (41.5)	196 (28.2)	41 (14.1)	
< 1 time/week	215 (14.5)	62 (12.4)	113 (16.3)	40 (13.7)	
1-2 times/week	271 (18.2)	66 (13.2)	148 (21.3)	57 (19.6)	
3-4 times/week	279 (18.8)	80 (16.0)	138 (19.9)	61 (21.0)	
5-6 times/week	132 (8.9)	31 (6.2)	51 (7.3)	50 (17.2)	
Once per day or more	144 (9.7)	53 (10.6)	49 (7.1)	42 (14.4)	

Data are presented as the median (IQRs) for continuous variables and as number (%) for categorical variables. [§] Nonparametric Kruskal-Wallis H test for independent sample with Bonferroni post hoc test. Different letters in the same line denote significant differences among adherence to MD groups. [†] Person Chi-square test. MD: Mediterranean Diet; HE: Healthy Eating; SE: Sustainable Eating; BFV: Fruits and Vegetable purchasing location; SHED: Sustainable-HEalthy-Diet.

Looking at the results of both univariate and multivariate logistic regression analysis, the strongest predictors of high adherence to the MD were be older, meeting MVPA recommendation, having a higher SHED Index score, having a higher percentage of plant-based foods in the diet, the willingness to purchase and eat healthy and sustainable dishes, eating plant-based ultra-processed meat alternatives foods daily, and attending the university canteen, especially 5 or more times a week (Table 6). Among other factors, only when assessed separately in the univariate analyses, being female or not-binary, attending human-social degree programs, and living with parents versus staying in campus significantly reduced the likelihood of having high adherence to the MD. On the contrary, according to the univariate analyses,

being graduate student, having a financial confidence, and following a plant-based diet significantly increased the probability of having a high MD score.

Table 6. Logistic regression analysis for being in the high level of DM adherence (≥ 8 points) in the US sample considering a set of variables evaluated singularly (univariate analysis) or in combination (multivariate analysis).

	Univariate Analysis		Multivariate Analysis	
Variables	**OR (95% CI)**	***p* Value**	**OR (95% CI)**	***p* Value**
Age	1.229 (1.141-1.324)	<0.001	1.192 (1.086-1.309)	<0.001
Gender				
Males	-1-		-1-	
Females	0.699 (0.538-0.908)	0.007	1.104 (0.796-1.531)	0.555
Not-binary/third gender	0.325 (0.114-0.926)	0.035	0.503 (0.143-1.775)	0.285
Academic status				
Undergraduate student	-1-		-1-	
Graduate student	1.663 (1.277-2.166)	<0.001	1.032 (0.735-1.448)	0.857
Other (college students)	0.895 (0.197-4.075)	0.886	1.588 (0.319-7.901)	0.527
Field of study				
Food	-1-		-1-	
Medicine	0.653 (0.406-1.049)	0.078	0.849 (0.519-1.585)	0.575
Scientific-Technological	0.714 (0.482-1.057)	0.092	1.003 (0.626-1.609)	0.989
Human-Social	0.541 (0.376-0.779)	<0.001	0.697 (0.447-1.088)	0.112
Other	0.587 (0.213-1.619)	0.304	0.584 (0.148-2.305)	0.443
Living place typology				
In campus	-1-		-1-	
Outside campus by myself	0.931 (0.603-1.435)	0.745	0.808 (0.473-1.382)	0.437
Outside campus with my partner	0.928 (0.570-1.510)	0.762	0.928 (0.516-1.668)	0.802
Outside campus with my roommates	0.751 (0.485-1.162)	0.198	0.863 (0.510-1.462)	0.584
Parents' house	0.643 (0.456-0.907)	0.012	1.106 (0.713- 1.716)	0.653
Financial situation				
Not enough to get by	-1-		-1-	
Just enough to get by	2.192 (1.064-4.515)	0.033	1.634 (0.714-3.739)	0.245
Worry about money for fun and extras	2.869 (1.409-5.843)	0.004	2.088 (0.926-4.708)	0.076
Never have to worry about money	2.849 (1.339-6.062)	0.007	1.971 (0.828-4.693)	0.125
MVPA recommendation				
Not met	-1-		-1-	
Met	2.535 (1.938-3.317)	<0.001	1.834 (1.331-2.526)	<0.001
SHED Index tertiles				
1st tertile	-1-		-1-	
2nd tertile	2.196 (1.384-3.484)	<0.001	1.241 (0.753-2.044)	0.397
3rd tertile	7.828 (5.209-11.766)	<0.001	2.923 (1.826-4.678)	<0.001
% Plant-based foods in the diet	1.029 (1.023-1.035)	<0.001	1.018 (1.010-1.026)	<0.001
Dietary pattern				
Omnivorous	-1-		-1-	
Plant-based‡	2.260 (1.706-2.993)	<0.001	0.861 (0.596-1.242)	0.422
Others§	1.396 (0.386-5.052)	0.611	1.040 80.196-5.515)	0.963
Willingness to purchase and consume healthy and sustainable dishes				
No/maybe	-1-		-1-	
Yes	3.366 (2.399-4.722)	<0.001	1.827 (1.225-2.725)	0.003
Frequency of eating plant-based ultra-processed meat alternatives foods				
Never/Rarely	-1-		-1-	
1-2 time/month	1.841 (1.244-2.726)	0.002	1.209 (0.770-1.899)	0.410
≤ 1 time/week	2.640 (1.809-3.853)	<0.001	1.252 (0.797-1.966)	0.330
2-3 times/week	2.248 (1.426-3.543)	<0.001	0.738 (0.428-1.274)	0.275
4-5 times/week	5.683 (3.444-9.378)	<0.001	1.219 (0.645-2.302)	0.542
Daily or almost daily	12.351 (6.676-22.850)	<0.001	2.725 (1.209-6.145)	0.016
Attendance of the university canteen in the last 6 months				
Never/rarely	-1-		-1-	
< 1 time/week	2.247 (1.404-3.596)	<0.001	1.664 (0.966-2.867)	0.067

1-2 times/week	2.618 (1.696-4.042)	<0.001	1.549 (0.932-2.574)	0.091
3-4 times/week	2.750 (1.791-4.223)	<0.001	1.649 (0.988-2.752)	0.055
5-6 times/week	5.993 (3.722-9.651)	<0.001	2.855 (1.543-5.281)	<0.001
Once per day or more	4.047 (2.499-6.554)	<0.001	2.212 (1.194-4.099)	0.012

SHED: Sustainable-HEalthy-Diet.
‡ Including vegetarian, vegan, flexitarian, pescetarian and fruitarian dietary patterns.
§ Including raw foodism and unspecified dietary patterns.

3.2.3.3 Comparison of the relevant outcomes between the two case studies

As it might be expected, both the median KIDMED score and the distribution of the samples among the three levels of adherence to the MD showed significantly higher adherence in the Italian sample ($p < 0.001$, for both variables). In addition, Italian participants were more likely to purchase and consume healthy and sustainable dishes and included more plant-based foods in their regular diet ($p < 0.001$, for both variables). However, looking at the distribution within dietary patterns, a higher percentage of US students reported eating an exclusively or partially plant-based diet ($p < 0.001$). In addition, the two countries were not comparable in terms of living place typology ($p = 0.023$), frequency of consuming plant-based ultra-processed meat alternatives foods, and university canteen attendance ($p < 0.001$, for both variables). Specifically, compared with Italian peers, a greater percentage of US students lived on campus, attended the canteen at least 1-2 times a week, and ate plant-based ultra-processed meat alternatives foods more than once weekly (data not shown). Consistent with the results of multivariate analyses, these three variables were found to be stronger predictors of high adherence to the DM in the US sample than in the Italian group.

Lastly, although no significant difference was found between Italian and US students in the distribution across tertiles of the SHED index, the total SHED index score was significantly higher in US participants ($p < 0.001$). However, delving into the SHED sub-scores, both HE and SE were significantly higher in the Italian sample ($p < 0.001$), as well as the Ready Meals score ($p < 0.001$). By contrast, BFV, Water, and Soda scores were significantly higher in US students ($p < 0.001$) (data not shown).

3.2.4 Discussion

This cross-sectional study provides insights on the eating habits of two representative samples of Italian and American university students, with the adherence to the MD as primary outcome. Following the growing interest in eco-friendly food patterns and the urgent need to shift people's eating habits toward healthier and more sustainable diets [48], the present survey

also aimed at investigating the relationship between adherence to the MD and the sustainability of students' dietary behaviors in a wider perspective by applying the recently proposed SHED index score [44], which includes information both about eating and food purchasing habits.

To the best of our knowledge this is the first investigation which applies simultaneously these two outcome variables (i.e., the adherence to the MD and the SHED index) to a young population represented by Italian and US university students. A recent literature review reported a low adherence to the Mediterranean model and a progressive shift away from the MD principles also among different populations of university students living in Mediterranean regions [35]. However, our results on the Italian sample showed a greater prevalence of medium-to-high adherence to the MD than previous studies conducted on smaller non nationally representative student populations in Northern [49,50], Central [51], and Southern Italy [50]. It is worth noting that these samples were not nationally representative and measured the adherence to the MD by applying scores other than KIDMED [43]. Data on the adherence to the MD among US students are limited [52]. In particular, in a study conducted in the southeastern US [52] by using MEDAS questionnaire, half of the sample had a low MD score [52]. At the same time, previous research has shown that the eating habits of young adults in the US are poor in fruit, vegetables, and legumes [53–55].

In the Italian sample, consistently with what has been reported by Lo Moro and colleagues [49], age was poorly correlated with adherence to the MD, obesity reduced KIDMED score, whereas better adherence to the MD has been associated with a proper level of physical activity. Also, in this study, males showed higher adherence to the MD, in contrast with what found in the sample enrolled in the North [49] and Central of Italy [48].

Similar to what found in this study for Italian students, compliance with physical activity guidelines and being female emerged as factors that increased and decreased, respectively, the adherence to the MD among US students. Older subjects and graduate students had a better adherence to the MD. These results are consistent with the MD adherence observed in another sample of US students, in which the mean MD score was reported by age group (i.e., under 18, 18-24, and 25-34), showing higher adherence in older students [52]. In addition, a prospective study pointed out a shift of US university students' choice priorities during freshman in college [56]. Above all, financial constraints increase food insecurity and poorer dietary outcomes such as low intake of fruit, vegetables, and whole grains and overconsumption of added sugars, sugary drinks, and fast-foods [56–58]. In this connection, those US students stated to have enough money to get by or a better financial status were more adherent to the MD. Similar to

what was reported in previous works, US students residing at campus had healthier eating habits [59], especially when compared with peers living with their parents [60].

The degree of sustainability of food behavior, assessed through the SHED index score [44], was found to be significantly correlated to the level of adherence to the MD, of which it is a strong predictor in both countries. A significant correlation between the two scores has previously been observed in two adult populations of the Mediterranean Basin [44,61]. Additionally, eating a plant-based diet and willingness to purchase and consume healthy and sustainable dishes emerged as a predictor positively influencing Italian and US students' eating habits. This result was to be expected given the large amount of plant-based foods shared by these patterns and MD, and is in accordance with earlier studies performed on Belgian [62] and Israeli [63] cohorts. Furthermore, a recent systematic review [64] pointed out that university students with healthier lifestyles and diets have more sustainable food consumption behaviors. Finally, students who regularly attend the university canteen were found to be more adherent to the MD. This positive role of the cafeteria was mostly evident among US students as even respondents sporadically attending the canteen were more likely to have a high adherence to the MD; in contrast, only a daily attendance of the university cafeteria was observed to positively affect the adherence to the MD among Italian students. Such discrepancies however may be influenced by the higher number of Italian students who reported never or rarely attending the cafeteria compared to their US peers.

Finally, a regular consumption of ultra-processed plant-based meat alternatives foods emerged as a factor that positively influenced the MD score, especially in US students. This result underlined a crucial concept recently emphasized by WHO [65]: although the health benefits associated with large consumption of plant-based food are widely recognized, generalization is not possible. Indeed, it is essential to prefer minimally processed plant-based food as whole cereals, fruit and veggies, pulses, seeds, and nuts, and to limit the consumption of highly processed products such as sugary drinks, snacks, and sweets, as well as ultra-processed plant-based foods that mimic animal products.

To the authors' knowledge, no previous studies have assessed MD adherence and sustainable food consumption in a large sample of Italian and US university students. The representativeness of the studied populations, in terms of gender and geographical distribution, is the main strength of our work. Other socio-demographic information and behavioral variables potentially associated with eating habits were also evaluated to provide a better overview of the factors facilitating or discouraging sustainable dietary behaviors in university students. Notwithstanding the SHED Index questionnaire, used to investigate further aspects of students'

sustainable food behaviors, was validated on a different population. Despite this, the positive correlations found between MD and SHED Index scores in both Italian and US populations, as already reported in the literature, are promising. By contrast, the validated KIDMED questionnaire specifically developed and widely used to assess the adherence to the MD (primary outcome) in young populations has been applied. However, given the wide age range to which it can be applied (2-24 years old), the questionnaire does not investigate alcohol consumption, whose assessment would be relevant when evaluating the eating habits of young adults, given the high rates of binge drinking among juveniles highlighted by recent reports [66–68]. Furthermore, the KIDMED questionnaire does not allow discrimination between fresh or minimally processed foods and ultra-processed products. Based on the principles of MD, the type of food is a key aspect that should be taken into consideration to make a more thorough assessment of MD adherence. Looking ahead, it is desirable to develop a more detailed tool to assess the DM adherence by also taking into account the habit of consuming ultra-processed foods. Lastly, the application of a self-administered online survey represents a convenient solution being an easy-to-use tool that requires little effort, but it may increase the possibility of recall and misreporting bias.

3.2.5 Conclusion

The current study assessed the MD adherence in two representative samples of Italian and US university students, delving into the relationship between MD score and sustainability of food behaviors, as well as other factors acting as predictors of students' eating habits.

Generalizing, a medium adherence to the MD in Mediterranean and non-Mediterranean university student populations and a strong relationship between adherence to the MD and sustainable dietary behaviors have been observed. These results pointed out the necessity of implementing public interventions to shift university students' eating habits towards plant-based diets, as the MD.

In this connection, a major promotion of the MD as a sustainable dietary pattern may be an effective strategy for its revitalization, especially among young adults such as university students, who show greater consciousness and attention to current environmental issues than older populations. Considering the large number of young adults attending universities and the positive influence that regular university canteen attendance has on students' eating habits, campuses and university dining services represent a unique opportunity to build a supportive

environment that educates students about the effects of their actions and fosters human and planetary health.

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Study 3

The Effect of Menu Re-ordering on the Carbon Footprint of Dietary Choices in University Dining

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Abstract

Background Creating a decision-making environment that promotes sustainable food choices is a priority for both the individual and society.

Purpose This study aimed at encouraging plant-based menu choices by re-ordering the menu according to the carbon footprint values.

Material and Methods The project was conducted in a dining service of the University of California Los Angeles, where students could order their meals choosing among different menu options customizable with various ingredients. The order of ingredients was changed twice: at first from the most to the least impactful in terms of carbon footprint; subsequently, the order was reversed. At both times, all sales data were recorded.

Results A total of 279,219 and 288,527 items were selected respectively during the first and the second intervention. A significant association was found between menu reordering and customers' choices for almost all food categories considered (all $p < 0.001$). Overall, even if the choice of beef options was not decreased, results showed that diner students were more likely to choose low-carbon options when these were placed at the top of the list, pointing out that food selection was impacted by ingredient placement in the menu list.

Conclusions These findings highlight the need for a multi-level strategy focused on raising students' awareness of the environmental impact of animal-based foods, particularly beef

Keywords

University students; dining hall; menu; nudging; climate change; carbon footprint

3.3.1 Introduction

The effects of global warming are increasingly visible, such as higher ambient temperatures, changing rainfall, rising ocean levels, and an overall increase in the frequency and severity of meteorological events [1]. The latest 2019 estimates report exponential growth in food system-related greenhouse gas (GHG) emissions over the past three decades, accounting for 31% of all global human-related emissions that reflect current climate change [2,3]. Food systems represent one of the main causes of climate change and, at the same time, are negatively affected by it [4]. Interruption of the food production chain and declining crop yields are the result of the current alarming global weather situation that, if not resolved, will negatively influence the availability of safe and nourishing foods resulting in a greater risk of poverty, malnutrition, and hunger across the world [4–8].

Depending on the source, foods require specific production processes that affect environmental resources differently. The environmental pressure of different food groups might be expressed through different ecological implications (e.g., GHG emissions, cropland and water use, nitrogen, and phosphorus application) [9–11]. Taking GHG emissions into consideration, the abbreviation "carbon footprint" is often used as a summary indicator to quantify the environmental impact - expressed in terms of carbon dioxide equivalent emissions (Kg CO_2 eq)- associated with the production of a commodity or service considering the entire life cycle [12,13]. In particular, the carbon footprint of animal-source food is much higher than plant-based ones, whose environmental impact, in comparison, appears rather negligible. In addition, the GHG emissions from foods of animal origin are highly variable for example depending on the animal, how it is raised and processed [9,10,14]. Poultry and animal by-products, such as eggs, milk, and yogurt, are the least impactful land-based animal products in terms of carbon footprint. The highest GHG emissions are associated with the food chain represented by, for example, red meat, cheese, processed meat, and fish in descending order [15]. In particular, beef has four times the carbon footprint of chicken, pork, or fish [14]. However, GHG emissions of seafood products vary greatly depending on fishing methods [16], thus the transition to sustainable fisheries and aquaculture is a priority of GFCM Strategy 2030 [17].

Considering the crucial role of food systems in combating climate change and related problems, several policies need to be implemented to address this issue of global importance [4]. The quantity and typology of foods we choose to eat every day affect our health as well as the planet's well-being [10,18,19]; therefore, people's dietary choices are one of the main drivers

of the food systems transformation [20]. In this context, one of the most important and demanding challenges of our century is shifting people's eating habits toward healthy and sustainable diets [21,22] that primarily include a large and varied consumption of fruits, vegetables, and other plant-based foods, and a low intake of animal-based foods [23]. Considering the production of animal-source products has increased by more than 60% worldwide in recent decades, choosing foods with lower carbon footprint values becomes especially important [24]. To achieve this goal, comprehensive policies that include a multi-strategy approach need to be implemented. Among these, creating a decision-making environment that promotes sustainable food choices is a priority for both the individual and society [4,25]. Positively influencing people's choices through nudge intervention such as eliminating, adding to, or modifying decision factors is an approach to improving people's health [25] that can be easily deployed in food services, including university cafeterias [26,27].

The life period between adolescence and young adulthood represents a delicate time of transition and change in habits [28,29], offering opportunities to promote and support healthy eating behaviors. Among young adults, college students often eat their meals in dining halls. For this reason, dining services represents a strategic venue for the implementation of interventions to ensure healthy and sustainable diets for young populations, with the goal of preventing long-term health risks while simultaneously reducing the pressure and impact of food systems on the environment [30]. One of the most light-touch and low-cost nudge interventions is to change the layout of the menu by changing dishes' descriptions or, more simply, rearranging their positions [31,32], by taking advantage of people’s innate gaze-motion and memory tendencies [33].

In this connection, this intervention study aimed to increase climate friendlier dietary choices by reordering some customizable menu items according to their carbon footprint values (CO_2 eq).

3.3.2 Materials and methods

3.3.2.1 Setting and study design

This pilot study was conducted during the fall quarter 2021 at the University of California Los Angeles (UCLA) within the UCLA dining hall The Study at Hedrick. UCLA Dining Services provides breakfast, lunch, and dinner to the UCLA community serving a total of around 6.5 million meals per year, representing one of the biggest independent catering services in the United States. The Study at Hedrick can be attended by students on a meal plan, which

includes a prepaid number of meals and the ability to choose from a variety of foods and beverages without being influenced by price. Students could order their meals on-site, using an iPad. The menu configuration included different menu options (i.e., pizza, salads, skillets, bagels, and sandwiches) that were customizable by choosing from different food items. The menu configuration exactly as it was on the display is provide in supplementary information S1 as a description of menu options and customizable ingredients before the re-ordering intervention.

Firstly, the carbon footprint (g CO_2 equivalent) of each customizable item was determined using the Carbon Footprint Scorecard [34] developed by UCLA based on estimates of GHG emissions reported in the following three literature references: Heller & Keoleian 2014 [35], Clune *et al*. 2017 [36], and Hilborn *et al*. 2018 [37] (Figure 1).

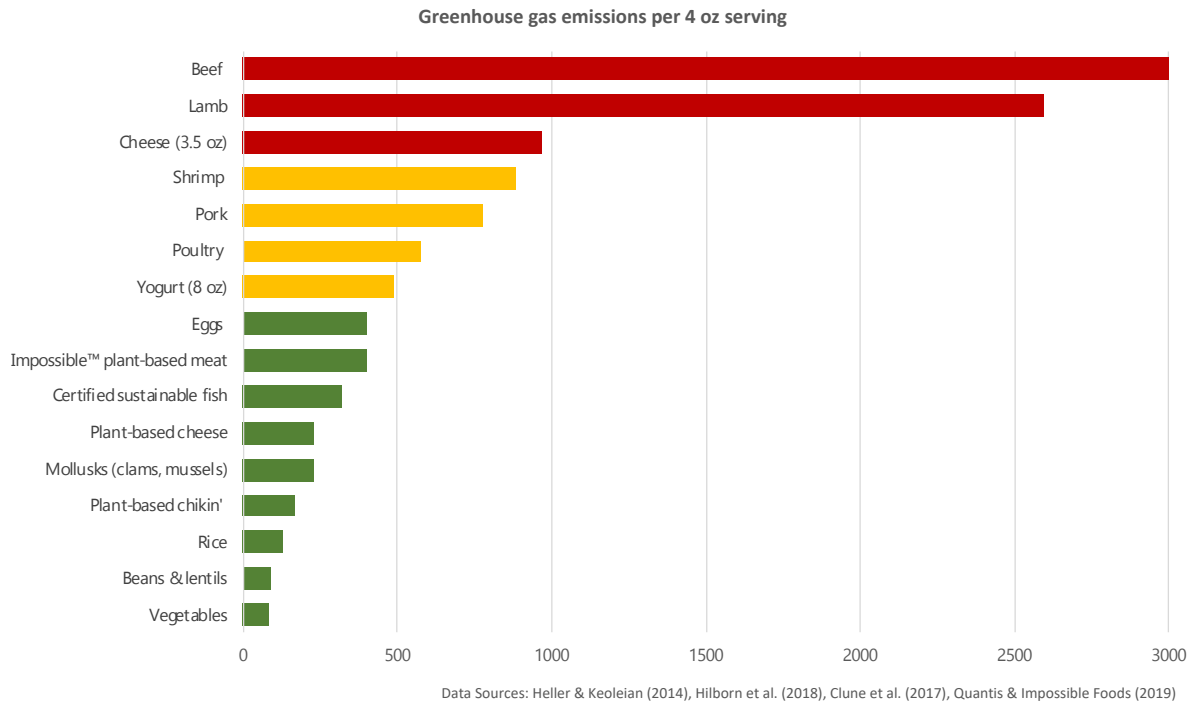


Figure 1 Carbon Footprint Scorecard developed by UCLA.

In addition, based on the Planetary Health Diet recommendations provided by the Eat-Lancet Commission [23], a daily value (DV) of the dietary carbon footprint was calculated and the food categories were ranked according to their contribution to it: low (0-25% of the DV), medium (25-50% of the DV) and high (>50% of the DV). This classification was made by considering the GHG emissions for one serving (i.e., 4 ounces) [34]. For items composed of multiple ingredients (e.g., herb cream cheese) the level of carbon footprint was estimated by considering only the main component of the recipe. This classification method was followed to

facilitate the possible future long-term implementation of this intervention. Also, most fish purchased and served at UCLA dining is certified as sustainable by the Seafood Watch of Monterey Bay Aquarium [38] and thus falls within low-carbon footprint food categories.

Normally, the customizable menu options and add on items are in alphabetical order, but during this study the order was modified twice. For the first 5 weeks (1st intervention), the customizable menu items and add on were listed in descending order, from the highest to lowest carbon footprint. Subsequently, for the following 5 weeks (2nd intervention), the order was reversed, and the items were sorted in ascending order, from the food with the lowest at the top of the list to the one with the highest carbon footprint at the bottom.

To further clarify, during the first intervention, at the top of the menu were high-carbon footprint items, or medium-carbon footprint items in case there were no high-carbon footprint foods for that menu type. In the second intervention, the menu always began with low-carbon food options.

3.3.2.2 Data collection

During both the first and second intervention, the food choices of all customers who dined at The Study at Hedrick were collected for 5 weeks by evaluating the sales data, which were recorded through the centralized MyMicros web-delivered reporting platform and exported to an Excel worksheet as the total quantity sold for each menu item during the two intervention periods.

3.3.2.3 Data analysis

Sales data for each customizable item were categorized into 13 unique foods with different carbon footprint levels: high (beef and cheese), medium (pork and poultry), and low (eggs, plant-based meat, certified sustainable fish, plant-based cheese, cereals, legumes, nuts, fruit, and vegetables). Binomial proportion tests were applied for two analyses that were performed to explore possible significant differences in sales distribution during the two periods considered. Our null hypothesis was that there was no difference in purchasing when we ordered the menu items by carbon footprint. The first test was run by summarizing the sales into the 13 food categories described above. The second analysis was applied by categorizing the sales based on their level of carbon footprint and by splitting them into two categories, namely, low-carbon items vs medium- or high-carbon items. Medium and high-carbon items were combined according to their position on the menu and to match the numerosity of low-carbon items. All statistical analyses were performed through the IBM SPSS Statistics for

Macintosh, version 28.0 (Armonk, NY: IBM Corp), *p*-value less than 0.05 was considered statistically significant.

3.3.3 Results

A total of 279,219 and 288,527 items were selected respectively during the first and the second interventions. As shown in Table 1, considering the diverse food categories some food typologies were selected more often during both interventions; the most chosen food categories were pork (~18%), poultry (~15%), and cheese (~18%) for animal-based product, and fruit (~11%) and vegetables (~16%) for plant-based ones.

Table 1 Distribution of the sales by food category during the two interventions.

Food category (n*)	**1st intervention** Highest carbon items at the top and lowest ones at the bottom (*n*= 279,219)	**2nd intervention** Lowest carbon item at the top and highest at the bottom (*n* = 288,527)	***p* Value**
High carbon footprint (n=15)			
Beef (n=2)	7,208	7,304	0.430
Cheese (n=13)	53,281	49,540	<0.001
Medium carbon footprint (n=21)			
Pork (n=15)	50,361	48,849	<0.001
Poultry (n=6)	42,388	40,585	<0.001
Low carbon footprint (n=37)			
Eggs (n=6)	11,536	14,624	<0.001
Plant-based meat (n=3)	2,797	2,887	0.238
Certified sustainable fish (n=2)	2,645	2,864	0.003
Plant-based cheese (n=4)	3,389	3,746	<0.001
Legumes (n=4)	4,840	7,794	<0.001
Nuts (n=1)	3,529	5,037	<0.001
Cereals (n=1)	1,124	1,768	<0.001
Fruit (n=4)	31,098	32,956	<0.001
Vegetables (n=12)	42,992	49,400	<0.001

Data are reported as absolute number. Binomial proportion test was applied by considering a *p*-value less than 0.05 as statistically significant.
* n reflects number of foods represented by the category

Table 2 shows the proportion of high/medium- carbon and low-carbon items sales for both item placement conditions (top vs bottom). Overall, results highlighted that proportion of high/medium-carbon and low-carbon sales was significantly different between two interventions (both *p* values < 0.001), highlighting that diner students were more likely to choose low-carbon options when these were placed at the top of the menu (2nd intervention) (OR = 1.22; 95% CI = 1.21, 1,23). The same effect of placement can be observed for items with

a medium to high carbon footprint during the first intervention when they were placed at the top of the menu.

Table 2 Distribution of sales for item (high/medium carbon vs low carbon) by item placement condition.

Item sales	Item placement condition		
	1st intervention Highest carbon items at the top and lowest ones at the bottom (n = 279,219)	**2nd intervention** Lowest carbon item at the top and highest at the bottom (n = 288,527)	***p* Value**
High/medium carbon	175,269 (51.1)	167,450 (48.9)	<0.001
Low carbon	103,950 (46.2)	121,077 (53.8)	<0.001

Data are reported as absolute number and frequency (% of total sales over 5 weeks). Binomial proportion test was applied by considering a p-value less than 0.05 as statistically significant.

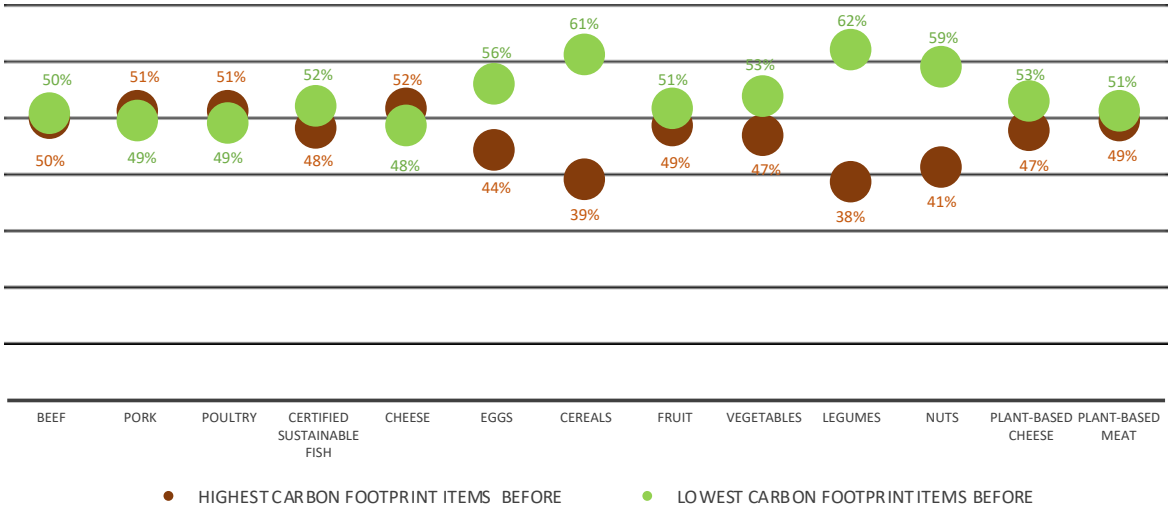


Figure 2 Percentages of total sales over both two interventions for each food category.

The Figure 2 shows that the sales of all plant-based options significantly increased during the second intervention (i.e., low carbon footprint item at the top). Most notably legumes, cereals, and nuts were the foods with the largest increase, followed by vegetables, plant-based cheese, and fruit. Among animal-based foods, eggs and certified sustainable fish options rose as well. Conversely, fewer sales were recorded for food items such as cheese, poultry, and pork, when they were placed at the bottom. In addition, no significant changes were recorded for beef and plant-base meat options.

3.3.4 Discussion

The present study provides more evidence on the effects of strategic menu reordering to encourage the purchase of low-carbon footprint options in university dining services. Generally,

the placing of lower-impact options at the top of the menu (2nd intervention) resulted in higher sales as compared to when they were placed at the bottom of the menu (1st intervention). At the same time, the purchase of higher-impact items, such as pork, poultry, and cheese, decreased when they were located at the end of the list. Unfortunately, the beef sales were not impacted by the menu reordering and remained fairly stable even when listed at the end of the menu.

As noted in the literature, interest in using implicit interventions to drive people's food choices has been growing rapidly in recent years [39–42]. Notably, several studies have analyzed the impact of menu item placement on customers' food choices, showing mixed effects. Feldman and colleagues [43] suggested that people are more likely to select options positioned at the upper level of the menu because they are the most prominent, best remembered, and require less effort in the choice process, resulting in easier choices. Similar findings were recently found by Gynell *et al* [44], confirming that food placement can be an effective and promising strategy to encourage healthy eating choices, especially when implemented in an online menu. Consistent with our results, placing healthy snacks at the top of the menu resulted in a higher probability of being chosen by consumers than their placement in the middle or lower level of the menu.

Not all studies about menu item placement have been consistent. Some studies have shown opposite results, Choi and colleagues [45] highlighted the tendency of consumers to focus their attention on the center of the menu and select options from that area, while Dayan and Bar-Hillel [46] pointed out that diners prefer lower items as much as upper ones because they are attracted to both extremes of the list. However, these mixed results reported in the literature may be related to several factors such as the number of items, menu layout, number of panels (e.g., one-fold, two-fold, etc.), and different study populations.

Beef sales trends in our study may have been affected by the same gaze pattern reported by Dayan and Bar-Hillel [46]. The failure of the intervention on beef options could also be related to the large intake of beef in the United States, which could make it more difficult to discourage its consumption. In contrast, pork and poultry options were less popular during the second intervention, although are both widely consumed in the United States [47].

This study is an example of an implicit intervention to encourage low-carbon impact food choices in dining service. Reordering the menu from the lowest to the most environmentally impactful item led to 22% higher odds of selecting a low-carbon option in comparison to placing them below high carbon footprint food choices on the menu. This may be considered a small effect but considering the growth in the number of consumers eating out [48], the spread of self-service kiosks in food services [49], and being an intervention that is

easy to deploy and sustain over time, its implementation could contribute significantly to reducing GHG emissions in the long run. Also, implicit nudge techniques, such as item placement, do not deter people from making a purchase, but rather can gently push them toward healthier behaviors and, for this reason, are more readily accepted by food suppliers and consumers [50]. In addition, human beings tend to influence each other in behaviors, including food choices. For instance, people are more likely to choose healthy foods when other consumers also choose them [51]. Thereby, the implicit promotion of more sustainable menus in a real-life setting such as a university cafeteria, but also other dining contexts, could have a positive impact on the clients and an exponential effect on the community [52].

However, it is important to point out some inherent limitations of this research. First, the study was conducted by testing only the two opposite interventions (i.e., highest carbon at the top and lowest carbon at the bottom and vice versa) and not including a control data collection when the menu was in alphabetical order, as usual. This may have amplified the effect of the results, nevertheless, the increase in sales for items located at top of the menu was confirmed in both the first and the second interventions for the highest and lowest carbon items, respectively. Second, due to the study design that only relied on recording of sales data, it was not possible to obtain further information about costumers and investigate possible predictors of food choice or assesses the nudge effect over time. In addition, recruiting a sample of students and evaluating the intervention through their choices would have avoided possible biases related to different sales numbers between the two interventions. Overall, these aspects represent starting points for future studies aimed at deepening how the placement of dishes on the menu affects university students' food choices.

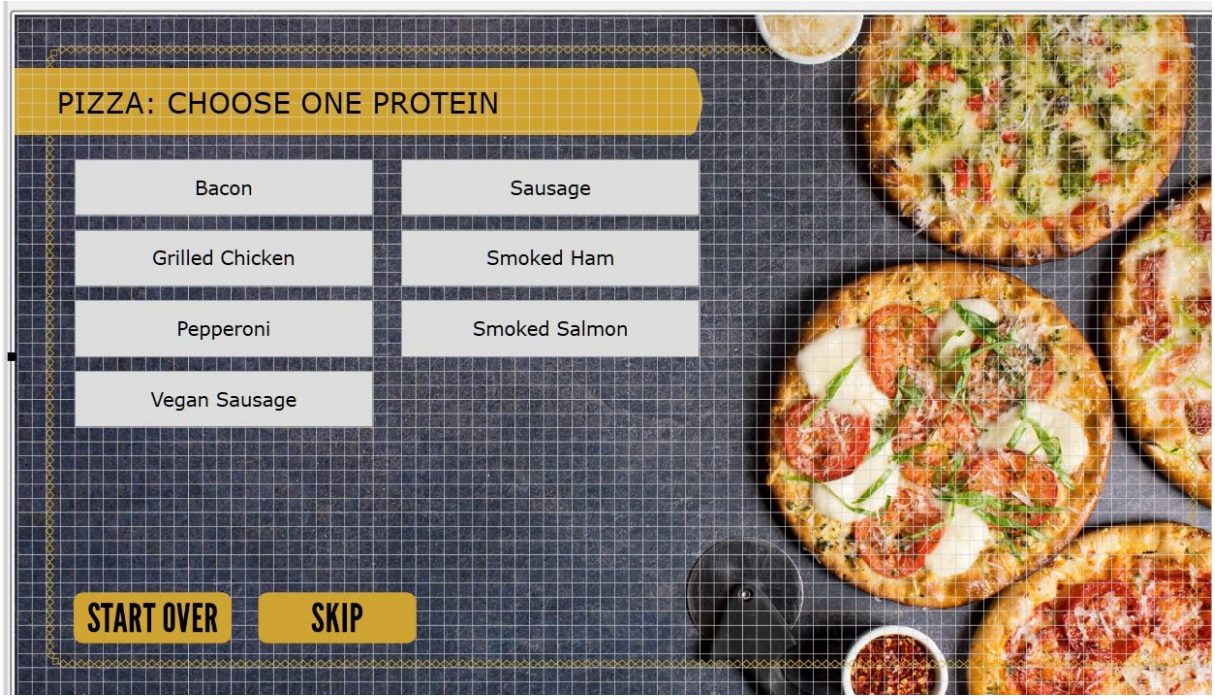
3.3.5 Conclusion

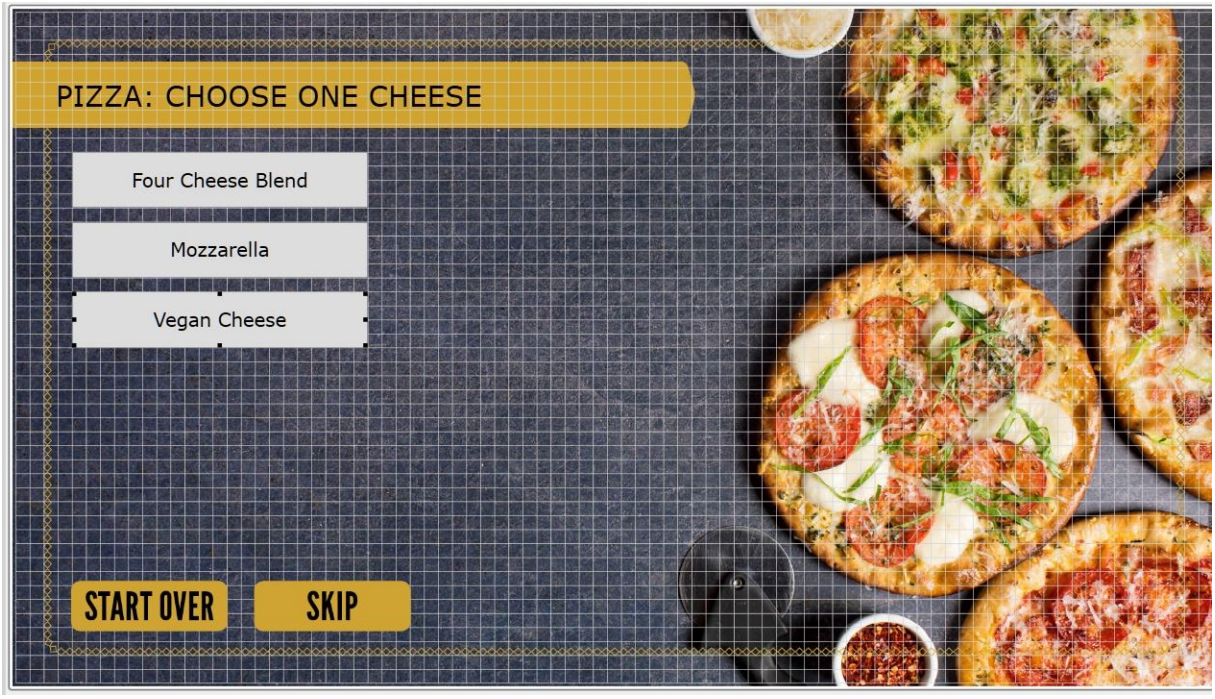
Overall, results demonstrated a positive impact of menu re-ordering to increase climate friendlier dietary choices and decrease consumption of foods with medium to high carbon footprint values. However, the choice of beef options was not decreased. This highlights the need for a multi-strategy strategy combining different types of interventions focused on raising students' awareness of the environmental impact of animal-based foods, particularly beef. Current strategies at UCLA to increase students' food literacy include university programs, seminars, Teaching Kitchen events, posters, and infographics with information about the carbon footprint of food in the dining halls, and high and low-carbon footprint icons added to online and in person menus. Given these promising findings from this study, menu re-ordering can be

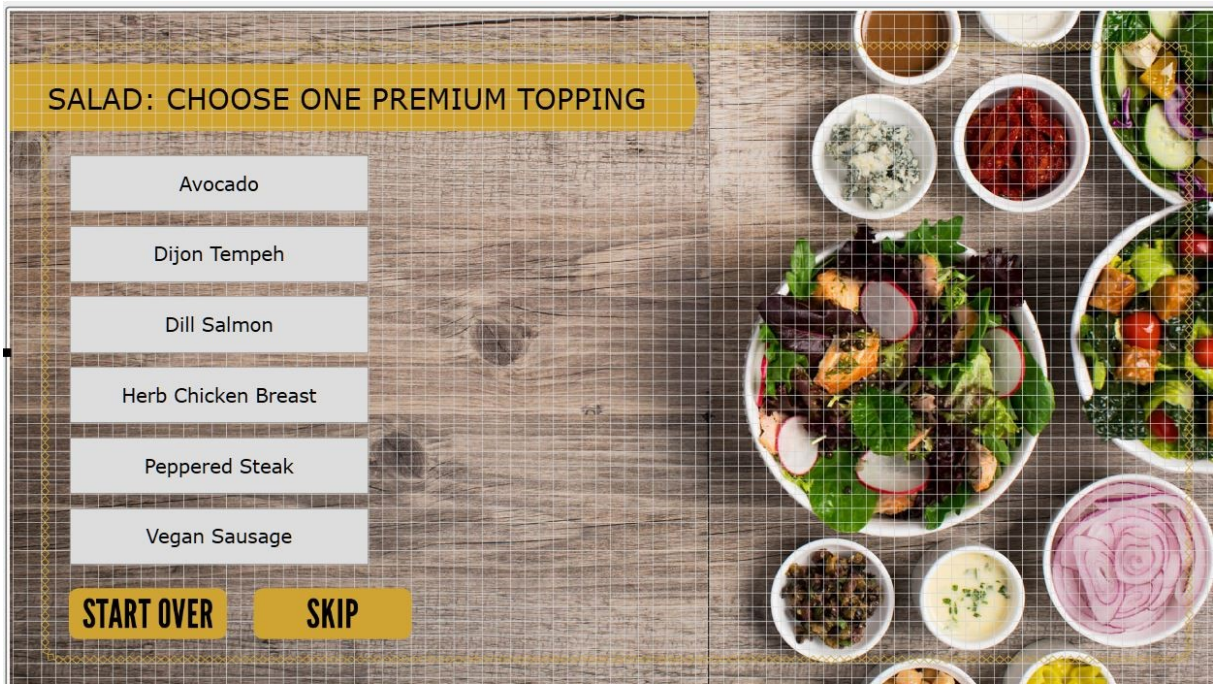
an easy approach to implement at UCLA restaurants, and in catering services in general, to encourage the purchase of low-carbon footprint menu options.

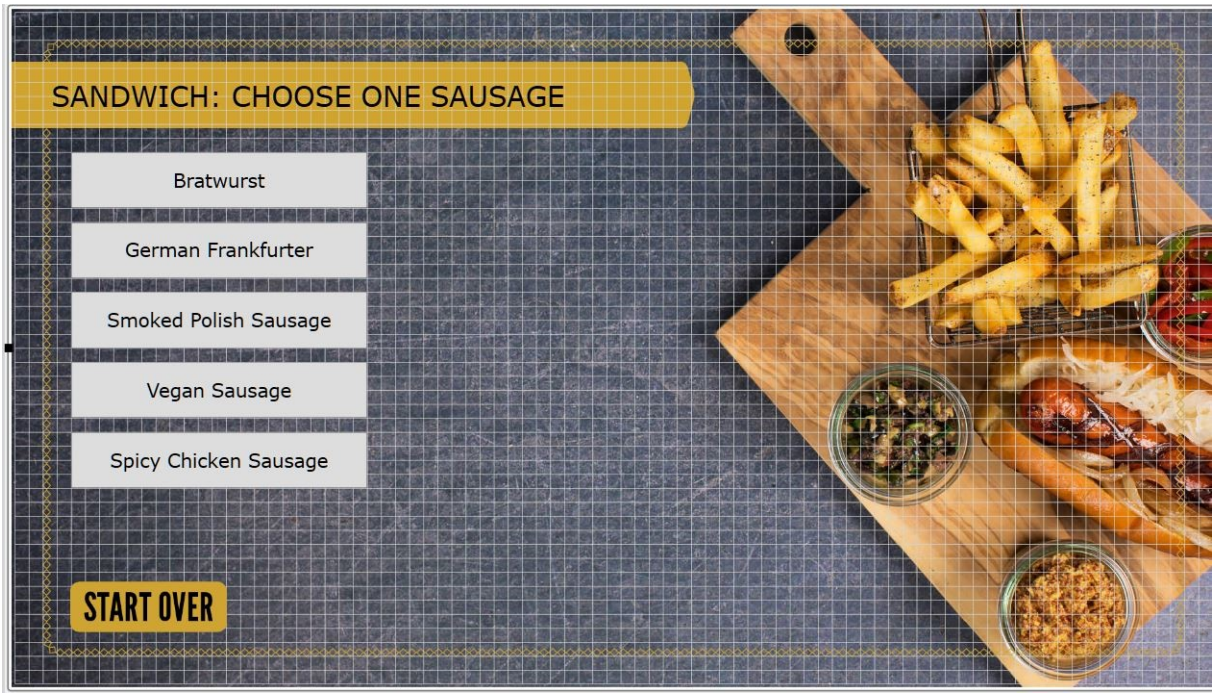
Supplementary information

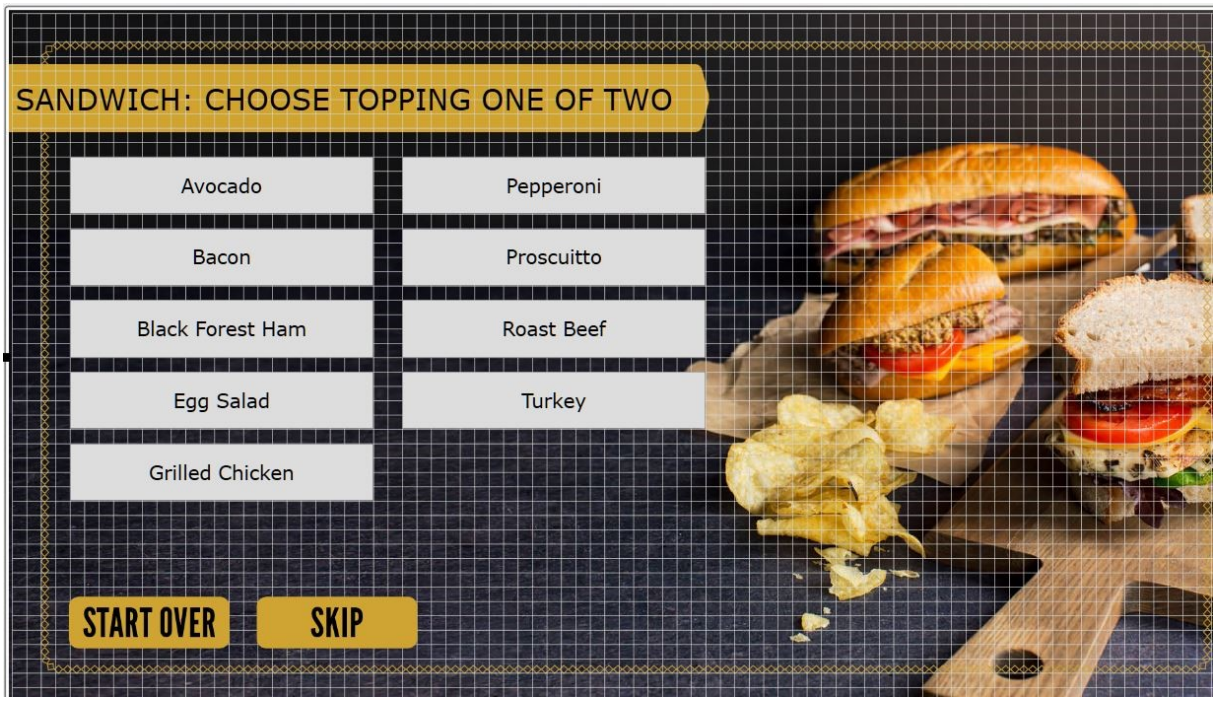
S1 Configuration of menu options and customizable ingredients before the re-ordering intervention.

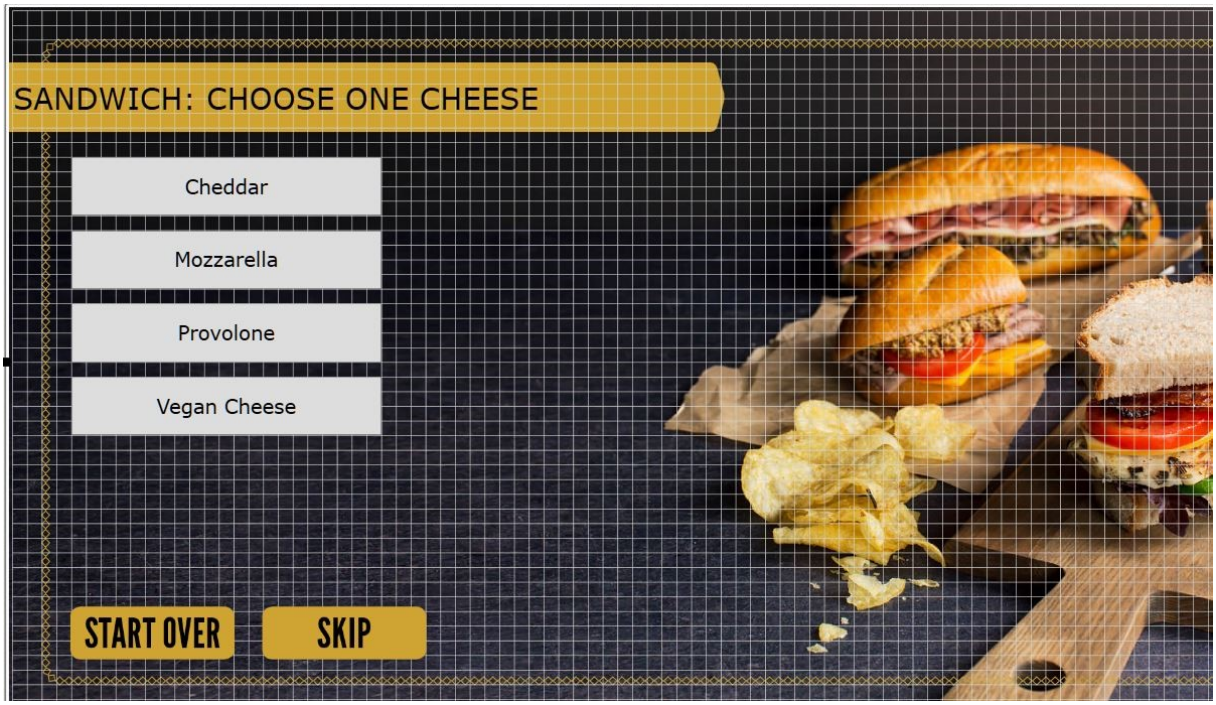


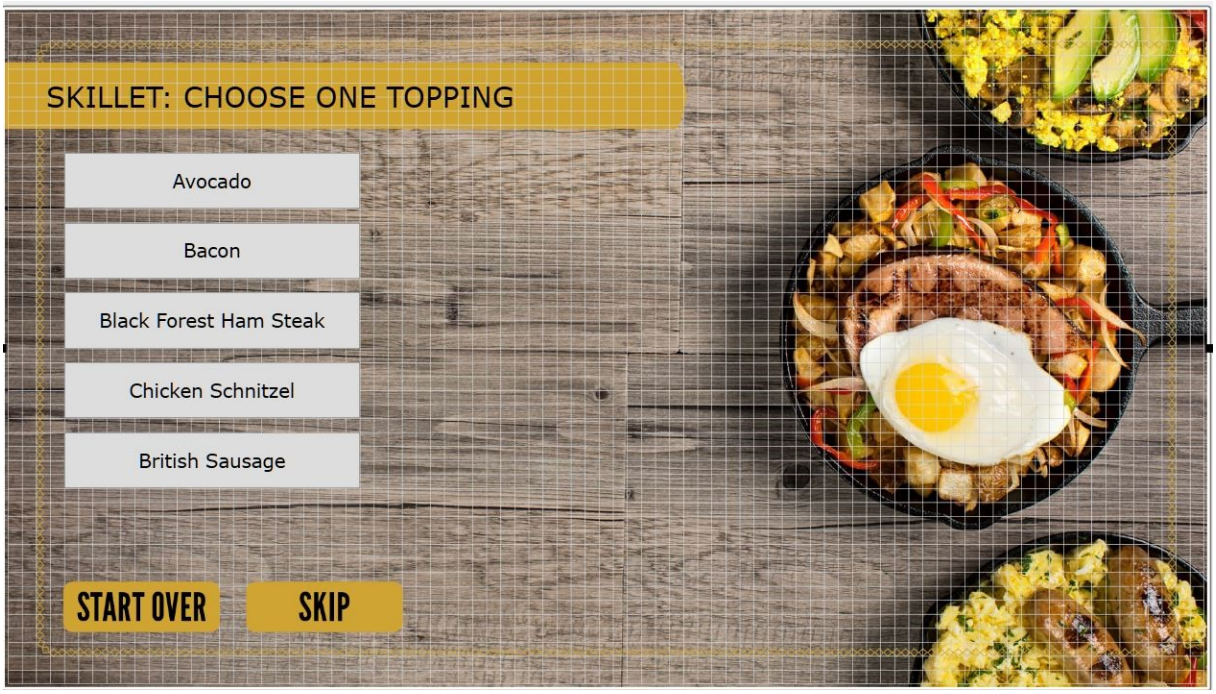


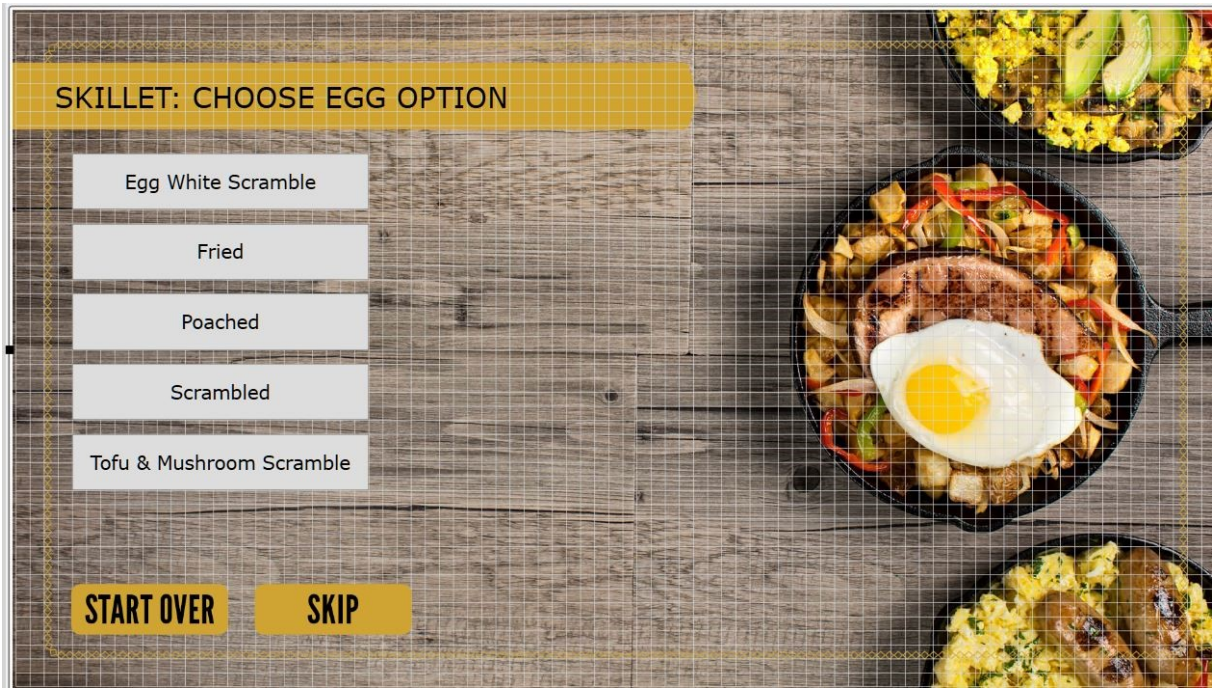

SALAD: CHOOSE ONE PREMIUM TOPPING
Avocado
Dijon Tempeh
Dill Salmon
Herb Chicken Breast
Peppered Steak
Vegan Sausage
START OVER
SKIP

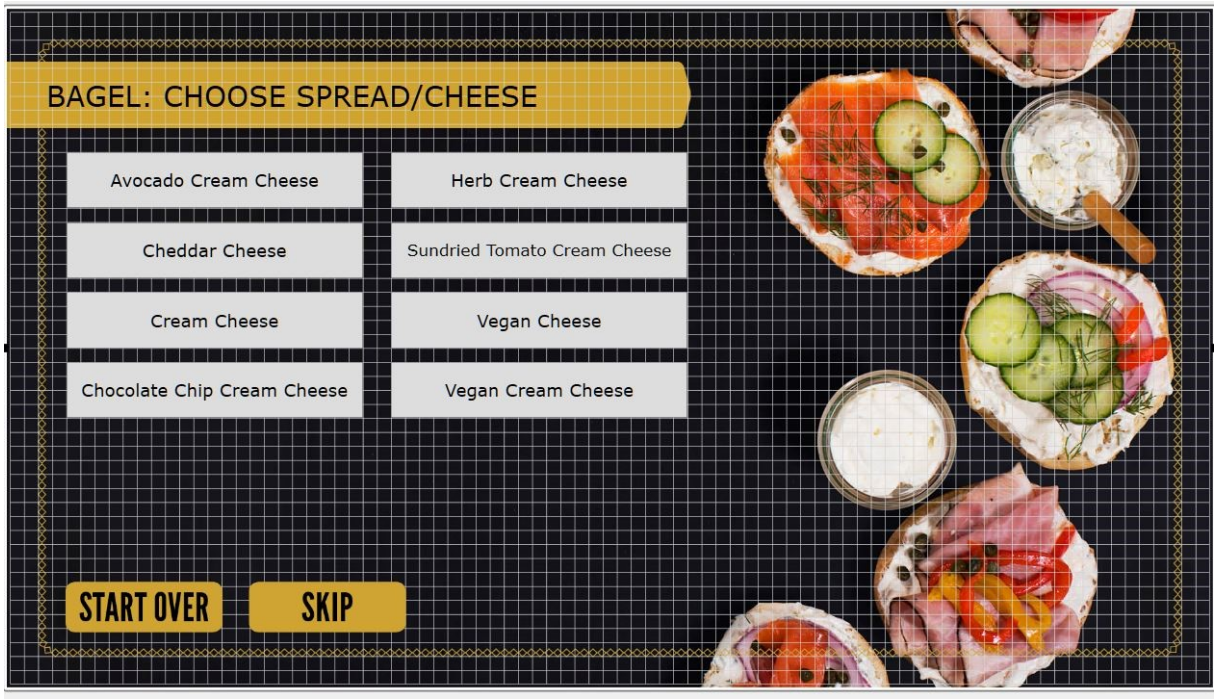

SANDWICH: CHOOSE ONE SAUSAGE
Bratwurst
German Frankfurter
Smoked Polish Sausage
Vegan Sausage
Spicy Chicken Sausage
START OVER

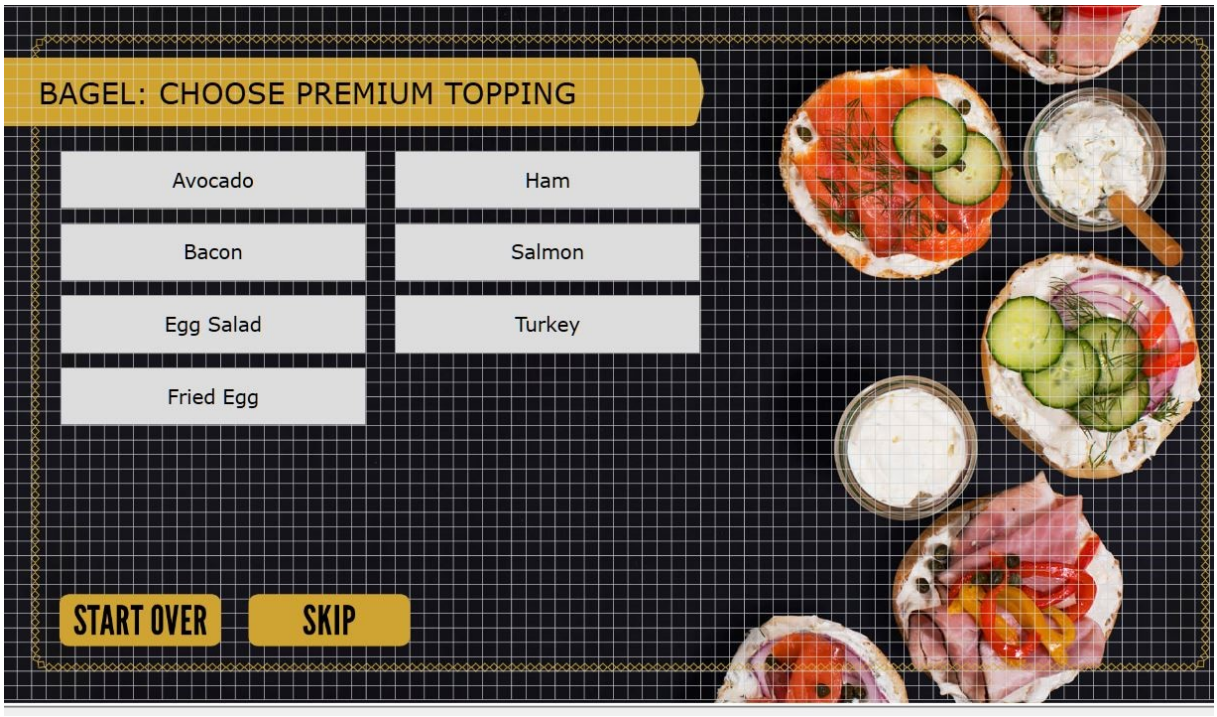

SANDWICH: CHOOSE TOPPING ONE OF TWO
Avocado
Bacon
Black Forest Ham
Egg Salad
Grilled Chicken
Pepperoni
Proscuitto
Roast Beef
Turkey
START OVER
SKIP


SANDWICH: CHOOSE ONE CHEESE
Cheddar
Mozzarella
Provolone
Vegan Cheese
START OVER
SKIP


SKILLET: CHOOSE ONE TOPPING
Avocado
Bacon
Black Forest Ham Steak
Chicken Schnitzel
British Sausage
START OVER
SKIP


SKILLET: CHOOSE EGG OPTION
Egg White Scramble
Fried
Poached
Scrambled
Tofu & Mushroom Scramble
START OVER
SKIP


BAGEL: CHOOSE SPREAD/CHEESE
Avocado Cream Cheese
Herb Cream Cheese
Cheddar Cheese
Sundried Tomato Cream Cheese
Cream Cheese
Vegan Cheese
Chocolate Chip Cream Cheese
Vegan Cream Cheese
START OVER
SKIP


BAGEL: CHOOSE PREMIUM TOPPING
Avocado
Ham
Bacon
Salmon
Egg Salad
Turkey
Fried Egg
START OVER
SKIP

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Study 4

Promoting Nutrition and Food Sustainability Knowledge in Apprentice Chefs: An Intervention Study at the School of Italian Culinary Arts – ALMA

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Abstract

Background Given the increasingly prevalence of eating out habit, optimizing food service through the provision of safe, healthy, and sustainable meals is an important public health strategy to improve people's eating habits.

Purpose This intervention study aims to assess nutrition knowledge and learning outcomes about food and diet environmental sustainability before and after an educational project in two samples of culinary students enrolled at the School of Italian Culinary Arts – ALMA (Italy).

Material and Methods Two online questionnaires were administered twice to each student, before and after the intervention. In addition, energy and nutritional contents as well as carbon and water footprints of menus prepared by the intervention group were analyzed as a measure of the acquired competencies.

Results A total of 264 and 252 apprentice chefs have been enrolled respectively in the control and in the intervention group (median age 21.0 years, 25.0% females). The level of nutrition knowledge significantly improved over time in both control ($p = 0.033$) and intervention ($p < 0.001$) group. On the contrary, food sustainability knowledge enhanced only in the intervention group when prospectively assessed ($p < 0.001$). The energy and nutrient composition of menus (n=57) was comparable, except for lower protein and higher fiber contents found in plant-based menus ($p < 0.001$). Among the proposed menus, a wide range of carbon and water footprint was reached. Plant-based offers showed a lower carbon footprint than the other menus categories ($p < 0.001$). As for water footprint, meat menus have been found significantly most impactful compared to fish ($p = 0.030$) and plant-based ones ($p = 0.033$) only when considering data adjusted on 1000 kcal. By applying 1000 g of CO_2 eq and 1000 L as maximum cut-offs per meal, 83% and 30% of menus were classified as sustainable, respectively. Comparing the different protein sources within the three menu categories, the only significant difference was found for red meat menus, which showed a higher impact than white meat ones only in terms of carbon footprint ($p < 0.001$).

Conclusion Based on these findings, the educational intervention strengthened by the work project effectively furthered future chefs' knowledge and raised their awareness of the diet, health, and environment trilemma.

Keywords

Chefs; culinary students; knowledge; nutrition; sustainability; sustainable menus; educational intervention

3.4.1 Introduction

It is widely recognized that dietary choices have an impact on the health status and natural resources. Unhealthy diets characterized by high levels of salt and poor consumption of plant-based products such as whole grains, fruits, vegetables, legumes, nuts, and seeds represent one of the top risk factors globally for mortality and morbidity [1], negatively influencing the economic balance for the increasing costs of public health. In parallel, the agri-food system is responsible for negative externalities contributing to land degradation, water use and pollution, biodiversity loss, and climate change [2]. For unit mass (g), the production of animal-based foods has a significantly higher detriment impact on the environment compared to plant-based products [3], for which a positive effect on non-communicable diseases (NCDs) incidence reduction is also recognized [4].

Eating out of home represents an increasingly rooted habit in modern life. As described by the Italian Federation of Public Enterprises (from Italian "*Federazione Italiana Pubblici Esercizi*", FIPE), this sector shows a sustained growth trend in terms of market value in Italy, having increased by 72% from 2000 to 2019, and is now recovering rapidly despite the contraction of the first phase of the Covid-19 pandemic [5]. Furthermore, daytime out-of-home consumption occasions are prevalent, with increasing penetration of take-away and home delivery, mainly chosen by young adults (25-34 years). A more selective consumer is emerging, driven by a greater sensitivity to environmental sustainability and health issues [5].

The collective catering service can implement public health strategies to drive consumer toward healthier food choices by realizing, through collaboration with chefs and culinary industry, institutional actions to strengthen local tradition, biodiversity, and food sustainability [6]. In this context, the optimization of this sector should involve different levels (e.g., food selection, food preparation, food communication) to improve the quality of the food supplied considering first food safety and health-enhancing criteria [7].

Due to the relevance of the collective catering services in promoting healthy and sustainable eating behaviors within the general population, it is necessary to provide chefs with adequate skills and proper practical tools to enable them to prepare nutritionally balanced, culturally acceptable, and eco-friendly meals [8,9]. To pursue this objective, chefs need to improve their nutrition knowledge and increase their awareness of the close relationship existing between food, health, and the environment. Given this, a European project coordinated by the Barilla Foundation [28] is aimed to provide chefs with knowledge and practical tools to promote sustainable diets through food services. Until now, owing to the collaboration with

leading partners including The School of Italian Culinary Arts - ALMA, a landmark document was drafted including the top ten recommendations to guide and inspire chefs to prepare sustainable menus through an integrative approach that focuses the attention on four main areas of action: sourcing, menus, daily activities, and communications [8].

In this context, the aim of this study is to determine the effectiveness of an educational intervention in a sample of apprentice chefs. This objective entails two main targets: the measurement of nutritional and food sustainability knowledge before and after the intervention; the calculation of the nutritional composition and environmental impact (in terms of carbon and water footprint) of the lunch menus developed by the participants at the end of the intervention, as a further estimate of the acquired knowledge. Furthermore, as secondary outcomes, the origin of the raw materials used by chefs and the satisfaction of the menus by canteen users were evaluated.

3.4.2 Material and methods

3.4.2.1 Participants and study design

This intervention study was conducted at The School of Italian Culinary Arts - ALMA, recognized as the premier education and training center for the Italian restaurant and hospitality industries at the international level, between April 2021 and October 2022. During this period, all students registered for three courses at ALMA were invited to participate in the study. Of these, two courses do not provide nutrition lessons (i.e., Cooking Techniques and Basic Pastry Techniques), therefore they were selected to recruit subjects for the control group, contrarily to the Advanced Course of Italian Cuisine in which the intervention group was recruited. To evaluate changes in students' knowledge about nutrition and food sustainability, two online questionnaires were administered twice to each student of the intervention group, at the beginning of the Nutrition lessons (1st - baseline - data collection, T0) and at the end of the Nutrition lessons (2nd - after 3 months - data collection, T1). Lectures addressing energy and nutrient content of food as well as food and diet impact on human health and environment were given to students as scheduled according to the school program. In addition, the students undergoing the intervention program were involved in a work project aimed to plan and prepare a nutritionally adequate and environmentally sustainable business lunch after the training.

At the same time, also students enrolled as a control group were invited to fill out the same two online questionnaires twice, 3 weeks apart.

Before filling out the questionnaire, all participants gave their approval by signing the informed consent form. The study protocol was approved by the Ethical Committee of the Area Vasta Emilia Nord (Prot. n. 41959/2021).

3.4.2.2 Questionnaires

A Nutrition Knowledge questionnaire (90 items) already validated for Italian university students [10] and an original Food Sustainability questionnaire (23 items), specifically developed for the study, were used to assess the learning outcomes. The Nutrition Knowledge questionnaire includes five constructs addressing the following main topics: experts' recommendation (6 items), nutritional content of food (49 items), health aspects of food and diet (10 items), relationship between diet and diseases (19 items), and proper food choices (6 items). According to the section, questions were multiple-choices and provided four to six possible answer options, or dichotomous offering two possible answer options (i.e., High content or Low content, Yes or No).

The Food Sustainability questionnaire includes two constructs: the first investigates the basic notions about food sustainability (9 items) while the second one delves into the environmental impact of food (14 items). Based on the construct, multiple-choice question with 4 possible answer options or dichotomous questions with 2 possible answer options (i.e., True or False, Yes or No, High impact or Low impact, I agree or I disagree) were set. In both questionnaires, for each question only one answer was correct, and 'I do not know' option was available to discourage missing data.

3.4.2.3 Intervention

The project consisted of two phases. First, a 24-hour theoretical training on nutrition and food and diet environmental impact was delivered as frontal lessons. Lectures tackled the topics described as follows: energy balance, body composition, macro and micronutrients, hydration status; food groups and Mediterranean Diet; daily meal distribution, nutrition analysis, and discretionary foods (e.g., coffee, chocolate, alcohol); functional proprieties of foods and cooking techniques; hunger and satiety, food allergies and intolerances; food sustainability. During the lessons, instructions about designing and preparing a business lunch were provided to students.

Subsequently, the students from each edition of the Advanced Course of Italian Cuisine of the 5 involved during the project were divided into different groups counting 4 or 5 subjects that were asked to put into practice the knowledge and skills they have acquired by developing

healthy and sustainable menus for a business lunch. Each meal consisted of a small vegetarian appetizer, a main course, and a fruit-based dessert with reduced sugar and saturated fatty acids (SFAs) content. To each group was assigned the formulation of a meat, fish, or plant-based (i.e., vegetarian or vegan) menu. Only those menus considered to be adequate from the technical, nutritional, and graphical perspective could receive approval by the teaching staff and finally prepared and served at the school canteen through lunch boxes. This service mode was preferred over the buffet to reduce the risk of infection due to the Covid 19 health emergency. The nutrition composition of menus as energy and nutrient content was evaluated through the Food Composition Database for Epidemiological Studies in Italy [11]. If an ingredient was not included in the database, a commodity with a similar nutritional profile was used as a substitute. Furthermore, the environmental impact of menus was assessed by estimating their carbon (g CO_2 eq) and water (L) footprint calculated through a dataset collecting greenhouse gas emissions and water use linked to the production and the subsequent steps of the supply chains of food commodities, up to distribution [12]. In this case, as suggested by the authors, the median value of the reference food category was considered for ingredients not reported in the database. Specifically, the nutritional profile and environmental impact were calculated for each proposal by summing all the ingredients present in each of the three courses that formed the menu.

In addition, the sustainability assessment of the raw materials used in the menus was extended by including information about the school's food supply system provided by bursar's office of ALMA, such as the use of locally sourced products and food quality schemes (e.g., geographical indications). The evaluation was carried out considering all food products used during the project, and the results were reported in aggregate form without distinction by menu.

Finally, menus were offered to students, staff, and guests in the in-house cafeteria at ALMA, where a description of each menu was displayed. The menu descriptions included the number of portions of fruit and vegetable provided by the menus compared to the nutritional recommendations, and the environmental impacts expressed as kilometers travelled by car and number of water bottles for carbon footprint and water footprint, respectively. In addition, the most environmentally sustainable menu among the different proposals (i.e., meat, fish, and plant-based option) was labelled with a logo. The definition of the best menu was determined by taking into account the nutritional composition and both environmental indicators evaluated. Business lunch could also be pre-ordered by diners through a dedicated section of ALMA's website.

After the consumption of the lunch menus, the canteen users (i.e., students, school staff or guests) could use a QR code to access a short questionnaire aimed at investigating their perception about the adequacy of the served portion size and their satisfaction with the selected menu.

3.4.2.4 Statistical analysis

The normality distribution Kolmogorov-Smirnov test was performed. According to the results, continuous variables were reported as mean and standard deviation (SD) or median and interquartile ranges (IQRs), while categorical variables were expressed as frequency and percentage.

In both the control and the intervention group subjects with low, medium or high nutrition or food sustainability knowledge were distinguished by subdividing them based on the tertiles of the knowledge scores at baseline. A descriptive analysis of the number of correct answers was also reported. The scores referred to nutrition and food sustainability knowledge are presented as median and interquartile range (IQR), as the distribution of these variables was not normal. Within and between group comparison analysis for continuous variables has been assessed by respectively applying the Wilcoxon non-parametric test for paired samples and the Mann-Whitney non-parametric test for independent samples. According to normal or non-normal data distributions, nutritional and environmental evaluation of menus are presented as mean ± SD or median and IQR, respectively. Comparison between different menu categories has been tested by parametric one-way ANOVA and non-parametric Kruskal-Wallis test, for nutritional values and environmental impacts, respectively. Comparison between categories was also performed by considering different dishes (i.e., appetizer, main course, dessert) separately. In all cases, Bonferroni post hoc test was applied to highlight differences in nutritional composition and environmental impacts. In addition, the Chi-squared test was applied to investigate associations between sustainability level and menu category. Further analyses were conducted to assess differences within each menu category, distinguishing between red and white meat, blue and other fishes, vegan and vegetarian menus, by applying Student's t-test for independent samples. Finally, assessment of commodities origin and canteen users' satisfaction were investigated through descriptive analysis and presented as number and percentages. All statistical analyses were carried out by IBM SPSS Statistics for Macintosh, version 28.0 (Armonk, NY: IBM Corp), taking $p < 0.05$ as significant level.

3.4.3 Results

3.4.3.1 Subjects characteristics

A total of 264 (median age: 22.0, IQR:19.0-25.0) and 252 (median age: 21.0, IQR:19.0-24.0) apprentice chefs have been enrolled respectively in the control and in the intervention group. In both two groups the majority was males (control 69%, intervention 81%) and subjects in the two samples were comparable for age. Regarding education background, the percentages of student from food science was significantly higher in the intervention group (control 28%, intervention 56%, $p < 0.001$).

3.4.3.2 Nutritional and food sustainability knowledge

Knowledge scores of control and intervention groups are shown for both data collections (T0 and T1) in Table 1. The level of nutrition knowledge assessed on a score from 0 to 90 points significantly improved over time in both control ($p = 0.033$) and intervention ($p < 0.001$) group. On the contrary, higher levels of food sustainability knowledge rated on a score from 0 to 23 points were found only in the intervention group when prospectively compared ($p < 0.001$).

The between-group comparison showed instead heterogeneous results, with higher median scores in the intervention group ($p < 0.001$) at the end of the intervention for both the outcome variables and a lower level of nutritional knowledge in the control group at the baseline ($p < 0.001$). Contrarily, students' food sustainability knowledge was comparable at baseline.

Table 1. Within and between-group comparison of knowledge scores (median IQR) obtained at baseline (T0) and T1.

Constructs	T0			T1			*p* Value§	
	Control *n* = 264	Intervention *n* = 252	*p* Value*	Control *n* = 264	Intervention *n* = 252	*p* Value*	C	I
NK								
NK 1 (0-6)	4 (3-5)	4 (3-5)	0.008	4 (3-5)	5 (5-6)	<0.001	0.002	<0.001
NK 2 (0-49)	35 (31-38)	37 (34-40)	<0.001	35 (32-38)	38 (36-41)	<0.001	0.301	<0.001
NK 3 (0-10)	7 (6-8)	7 (6-8)	0.428	7 (6-8)	8 (7-9)	<0.001	0.326	<0.001
NK 4 (0-19)	15 (12-16)	15 (13-17)	0.055	15 (13-17)	17 (15-18)	<0.001	0.017	<0.001
NK 5 (0-6)	4 (3-4)	4 (3-4)	0.930	4 (3-4)	4 (4-5)	<0.001	0.781	<0.001
Total (0-90)	64 (57-69)	67 (60-71)	<0.001	64 (59-69)	73 (68-76)	<0.001	0.033	<0.001
FSK								
FSK 1 (0-9)	5 (4-6)	5 (4-6)	0.456	5 (4-6)	7 (6-8)	<0.001	0.783	<0.001
FSK 2 (0-14)	7 (6-8)	7 (6-8)	0.354	7 (6-8)	9 (8-10)	<0.001	0.221	<0.001
Total (0-23)	12 (10-14)	13 (11-14)	0.397	13 (11-14)	16 (14-17)	<0.001	0.258	<0.001

*Non-parametric Mann-Whitney U test for independent samples for between-group analyses within each period. §Non-parametric Wilcoxon test for paired samples between periods within the control and intervention group separately. Possible scores for each questionnaire section are shown within brackets in the first column. NK: nutrition knowledge; FSK: sustainability knowledge score; NK 1: experts' recommendation; NK 2: nutritional content of food; NK 3: health aspects of food and diet; NK 4: relationship between diet and diseases; NK 5: proper food choices, FSK 1: basic notions about food sustainability; FSK 2: environmental impact of food; C: control; I: intervention.

In addition, Table 2 shows the percentages of correct obtained at baseline and at T1 in both groups, showing a good level of nutritional knowledge in both groups at baseline, mainly regarding the nutrient content of foods and the connection between diet and health status. On the other hand, food sustainability knowledge was lower in all students, regardless of the group.

Table 2. Descriptive analysis of percentage of correct answers and I do not know obtained at baseline (T0) and T1 in both groups.

Constructs	T0		T1	
	Control ***n*** **= 264**	**Intervention** ***n*** **= 252**	**Control** ***n*** **= 264**	**Intervention** ***n*** **= 252**
	Correct answers (%)	Correct answers (%)	Correct answers (%)	Correct answers (%)
NK				
NK 1 (0-6)	63 (19)	67 (21)	66 (19)	87 (10)
NK 2 (0-49)	70 (24)	75 (23)	71 (24)	77 (22)
NK 3 (0-10)	72 (25)	71 (27)	71 (25)	78 (19)
NK 4 (0-19)	74 (12)	76 (11)	76 (12)	86 (10)
NK 5 (0-6)	59 (22)	60 (22)	59 (23)	73 (21)
Total (0-90)	70 (22)	73 (21)	71 (22)	80 (19)
FSK				
FSK 1 (0-9)	57 (24)	59 (20)	58 (20)	74 (15)
FSK 2 (0-14)	50 (22)	52 (22)	52 (22)	63 (22)
Total (0-23)	53 (23)	54 (21)	55 (21)	67 (20)

Results are reported as the average percentage (SD) for each construct of both two questionnaires. NK: nutrition knowledge; FSK: sustainability knowledge score; NK 1: experts' recommendation; NK 2: nutritional content of food; NK 3: health aspects of food and diet; NK 4: relationship between diet and diseases; NK 5: proper food choices, FSK 1: basic notions about food sustainability; FSK 2: environmental impact of food.

The percentage of subjects undergoing the intervention having a high level of nutrition knowledge (score > 67) greatly increased over time (from 46% to 76%). At the same time, the number of subjects with a low level of knowledge (score ≤ 60) decreases (from 35% to 9%), while the control group remains largely stable. The same pattern was found in relation to the learning about food and diet environmental impact, with an increase in the share of apprentice chefs having a high level of knowledge (score > 13) (from 35% to 77%) and a decrease of those reporting low knowledge scores (score ≤ 11) (from 38% to 12%).

3.4.3.3 Features of the menus developed by the intervention group

3.4.3.3.1 Nutritional composition and environmental impact

3.4.3.3.1.1 Comparison between menu categories

The nutritional values of menus prepared by students enrolled in the intervention group are presented in Table 3. The different menu categories were comparable for energy, lipid profile, carbohydrates, and salt, whereas significant differences were found in proteins and fiber content. Specifically, proteins appeared higher in meat ($p = 0.003$) and fish menus ($p = 0.004$)

compared to plant-based ones. Conversely, fiber content was lower in meat and fish menus ($p < 0.001$).

Table 3. Energy and nutrient content (mean ± SD) of menus elaborated by the apprentice cooks enlisted in the intervention group.

Variable	Total *n* = 57	Meat *n* = 21	Fish *n* = 18	Plant-based *n* = 18	*p*-Value[1]
Energy (kcal)	893 ± 123	879 ± 127	880 ± 120	922 ± 123	0.482
Proteins (g)	35.0 ± 7.0	37.1 ± 5.5 [a]	37.3 ± 5.2 [a]	30.1 ± 8.0 [b]	0.001
(% Energy)	15.7 ± 2.9	16.9 ± 1.9	17.0 ± 1.7	13.1 ± 2.9	0.001
Fat (g)	31.8 ± 7.3	30.1 ± 8.2	30.5 ± 5.8	34.9 ±7.0	0.083
(% Energy)	32.0 ± 5.7	30.6 ± 5.3	31.3 ± 5.6	34.2 ± 6.0	0.137
Saturated fat (g)	8.6 ± 4.0	8.9 ± 3.2	8.4 ± 1.7	8.4 ± 6.2	0.889
(% Energy)	8.7 ± 3.9	9.1 ± 3.1	8.7 ± 1.7	8.2 ± 5.9	0.760
Carbohydrates (g)	114.0 ± 16.8	112.8 ± 14.2	111.2 ± 16.7	118.1 ± 19.7	0.445
(% Energy)	51.2 ±4.8	51.6 ± 5.2	50.6 ± 4.8	51.1 ± 4.4	0.811
Sugars (g)	30.8 ± 9.6	29.9 ± 8.5	29.7 ± 6.7	33.1 ± 12.8	0.479
(% Energy)	13.9 ± 4.1	13.7 ± 3.7	13.5 ± 2.6	14.5 ± 5.6	0.746
Fiber (g)	15.0 ± 5.9	12.1 ± 3.7 [b]	12.6 ± 3.9 [b]	20.8 ± 5.8 [a]	<0.001
(% Energy)	3.3 ± 1.2	2.8 ± 0.8	2.9 ± 0.8	4.5 ± 1.1	<0.001
Salt (g)	2.2 ± 2.3	2.4 ± 2.9	2.2 ± 1.9	1.8 ± 1.9	0.746

1 Main effect from one-way ANOVA test with Bonferroni post hoc test. Different letters in the same row indicate significantly different values ($p < 0.05$).

As shown in Table 4, among the proposed menus, a wide range of carbon and water footprint was reached. Plant-based menus shown a lower carbon footprint than the other menus categories ($p < 0.001$), also considering energy adjusted data on 1000 kcal. Conversely, water footprint was not significantly different among the three menu typologies, unless referring to L of water on 1000 kcal the meat menus have been found significantly most impactful compared to fish ($p = 0.030$) and plant-based ones ($p = 0.033$).

Table 4. Carbon and water footprints (median IQR) of menus elaborated by the apprentice cooks enlisted in the intervention group.

Variable	Total *n* = 57	Meat *n* = 21	Fish *n* = 18	Plant-based *n* = 18	*p*-Value [1]
Carbon Footprint ($g\ CO_2$ eq)	729.8 (488.4-973.0)	837.8 [a] (690.1-1241.1)	875.5 [a] (688.8-988.6)	419.1 [b] (313.1-518.9)	<0.001
Water Footprint (L)	1088.4 (942.4-1257.4)	1169.0 (1011.0-1463.6)	990.3 (877.3-1182.3)	1074.7 (998.5-1245.2)	0.169
Carbon Footprint ($g\ CO_2$ eq/1000 kcal)	847.3 (541.8-1052.5)	1018.8 [a] (853.7-1480.7)	1010.9 [a] (710.6-1119.9)	419.0 [b] (376.4-565.9)	<0.001
Water Footprint (L/1000 kcal)	1224.6 (1045.3-1375.0)	1358.8 [a] (1197.9-1620.2)	1138.2 [b] (1014.6-1332.9)	1176.4 [b] (1013.7-1299.6)	0.042

1 Main effect from Kruskal-Wallis test with Bonferroni post hoc test. Different letters in the same row indicate significantly different values ($p < 0.05$).

By applying the impact targets suggested by the Barilla Foundation [13] corresponding to a maximum of 1000 g of CO_2 eq emitted and 1000 L of water used for the preparation of a single menu, 83% (n=47) and 30% (n=17) of the menus were classified as environmentally sustainable according the two established cut-offs, respectively. However, applying both the

standards, sustainable menus were reduced to 26% (n=15), mostly represented by the fish category (n=8), followed by plant-based (n=4) and meat (n=3) offers (Figure 1).

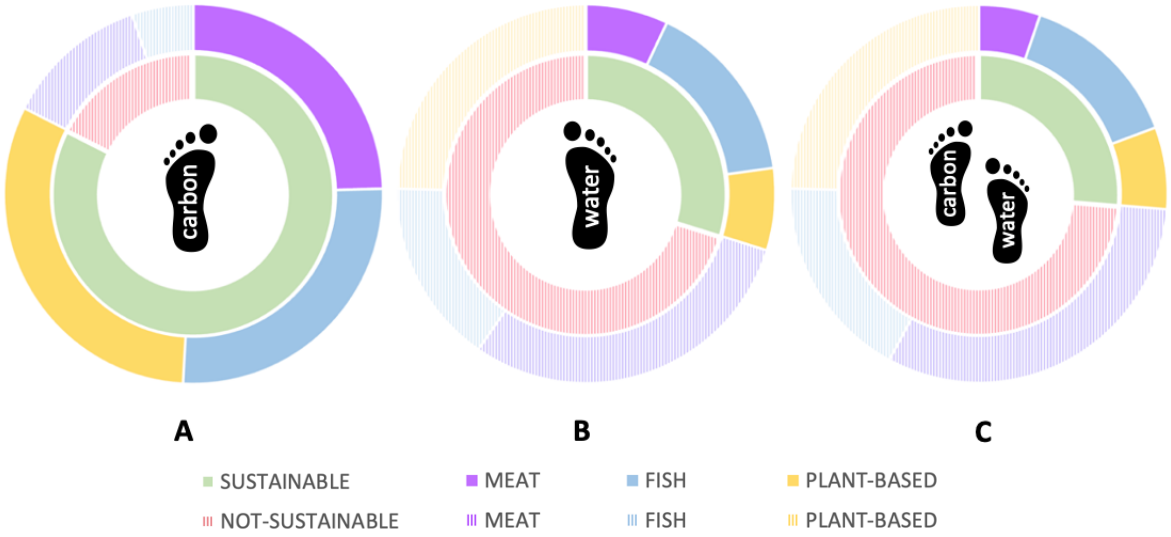

Figure 1. Percentages of sustainable and not-sustainable menus according to carbon footprint (< 1000 g CO_2 eq) and water footprint (< 1000 L of water) cut-offs. The internal circle refers to percentage on total menus, whereas the external circle accounts for each menu category (i.e., meat, fish and plant-based). The assessment considers both carbon and water footprints separately (A and B) and combined (C).

The Chi-square test showed a significant association between the distribution of menus between being within or above the environmental sustainability thresholds and the menu category only when their carbon footprint was considered ($p = 0.024$). According to the carbon footprint cut-off, most sustainable menus were plant-based (n=18), while the majority of non-sustainable menus included meat (n=7).

3.4.3.3.1.2 Comparison within menu categories

As shown in Table 5 and Table 6, the characteristics of the menus included in each category appeared mostly homogeneous. For meat menus, the nutritional profile and water footprint were comparable between red and white meat, in contrast, the carbon footprint of red meat menus was significantly higher ($p < 0.001$). No differences were found for environmental impacts within fish and plant-based categories, on the other hand, SFAs content of fish-based menus was significantly lower in recipes with blue fishes, and significant differences were found for protein ($p = 0.009$) and salt ($p = 0.002$) content when comparing vegan and vegetarian menus. In particular, vegan menus were lower in protein content but higher in salt.

Table 5. Nutrition analysis (mean ± SD) of different typologies of meat, fish, and plant-based menu.

Variable	Meat			Fish			Plant-based		
	Red *n* = 11	White *n* = 10	*p* Value [1]	Blue fish n = 4	Other n = 14	*p* Value [1]	Vegan n = 10	Vegetarian n = 8	*p* Value [1]
Energy (kcal)	843 ± 68	920 ± 164	0.190	850 ± 124	889 ± 122	0.831	913 ± 80	934 ± 168	0.093
Proteins (g)	36.3 ± 3.8	38.0 ± 7.0	0.258	35.3 ± 4.6	37.9 ± 5.3	0.836	29.1 ± 4.7	31.4 ± 11.1	0.009
(% Energy)	17.3 ± 1.9	16.6 ± 1.9	0.736	16.7 ± 1.6	17.1 ± 1.8	0.853	12.8 ± 2.6	13.3 ± 3.5	0.218
Fat (g)	27.6 ± 6.2	32.9 ± 9.4	0.368	25.9 ± 6.6	30.8 ± 5.8	0.916	36.2 ± 6.7	33.3 ± 7.3	0.819
(% Energy)	29.6 ± 6.1	31.8 ± 4.2	0.360	31.1 ± 4.3	31.4 ± 6.0	0.579	35.6 ± 5.7	32.3 ± 6.3	0.931
Saturated fat (g)	8.7 ± 3.6	9.2 ± 2.9	0.646	7.8 ± 2.7	8.6 ± 1.4	0.018	7.8 ± 2.7	8.6 ± 1.4	0.172
(% Energy)	9.2 ± 3.4	9.1 ± 2.8	0.535	8.4 ± 3.0	8.7 ± 1.3	0.103	8.7 ± 7.8	7.6 ± 2.4	0.183
Carbohydrates (g)	110.0 ± 15.2	116.0 ± 13.0	0.912	111.5 ± 19.0	111.1 ± 16.7	0.663	114.7 ± 15.8	122.3 ± 24.3	0.428
(% Energy)	52.1 ± 4.8	51.1 ± 5.8	0.823	52.5 ± 4.2	50.1 ± 5.0	0.651	50.2 ± 4.6	52.3 ± 4.2	0.357
Sugars (g)	31.9 ± 6.6	27.7 ± 10.2	0.223	27.3 ± 5.6	30.3 ± 7.1	0.331	30.5 ± 8.4	36.5 ± 19.9	0.104
(% Energy)	15.2 ± 3.2	12.1 ± 3.7	0.543	12.9 ± 2.3	13.7 ± 2.8	0.923	13.3 ± 3.3	16.0 ± 7.6	0.067
Fiber (g)	13.1 ± 2.9	11.1 ± 4.2	0.197	11.9 ± 2.4	12.8 ± 4.3	0.349	18.7 ± 3.0	23.3 ± 7.5	0.171
(% Energy)	3.1 ± 0.7	2.4 ± 0.6	0.642	2.9 ± 0.6	2.9 ± 0.9	0.331	4.1 ± 0.8	4.9 ± 1.4	0.364
Salt (g)	3.0 ± 3.8	1.8 ± 1.3	0.080	2.4 ± 2.7	2.1 ± 1.7	0.275	2.7 ± 2.3	0.8 ± 0.6	0.002

[1] Student's t-test for independent samples.

Table 6. Environmental impacts (mean ± SD) of different typologies of meat, fish, and plant-based menu.

Variable	Meat			Fish			Plant-based		
	Red *n* = 11	White *n* = 10	*p* Value [1]	Blue fish n = 4	Other n = 14	p Value [1]	Vegan n = 10	Vegetarian n = 8	p Value [1]
Carbon Footprint (g CO_2 eq)	1379.7 ± 811.3	848.3 ± 261.2	<0.001	557.9 ± 97.9	909.2 ± 112.6	0.778	393.1 ± 149.5	505.0 ± 140.2	0.949
Water Footprint (L)	1282.3 ± 227.5	1129.3 ± 328.1	0.391	883.2 ± 158.9	1111.3 ± 293.1	0.398	1134.3 ± 123.9	1198.3 ± 664.4	0.074
Carbon Footprint (g CO2 eq/1000 kcal)	1609.3 ± 894.2	931.7 ± 295.5	<0.001	654.7 ± 23.8	1035.7 ± 156.8	0.102	436.6 ± 192.5	548.3 ± 151.9	0.908
Water Footprint (L/1000 kcal)	1517.1 ± 207.1	1239.5 ± 359.5	0.545	1036.1 ± 49.0	1257.3 ± 317.3	0.156	1250.1 ± 168.7	1317.4 ± 831.3	0.075

[1] Student's t-test for independent samples.

3.4.3.3.1.3 Comparison of single dishes between different menu categories

By comparing single dishes (i.e., appetizers, main courses, and desserts) between different menu categories, differences were mostly found among main courses (Table 7). Specifically, carbon footprint was significantly lower in plant-based menus ($p < 0.001$) similarly to proteins, which were found higher in meat ($p = 0.003$) and fish ($p < 0.001$) menus. In addition, SFAs and water footprint were significantly higher in meat menus compared to fish ($p = 0.030$ and $p = 0.022$, respectively) and plant-based ($p = 0.011$ and $p = 0.005$, respectively) ones. In addition, among the menu categories, the main course contributed differently to the total environmental impact of the menu. Indeed, meat and fish main dishes contributed more to the total menu carbon footprint than the plant-based counterparts ($p < 0.001$ and $p = 0.007$, respectively), while only meat main dishes showed the highest share of the total menu water footprint ($p < 0.001$). Looking at dessert environmental performance, the plant-based ones showed a higher contribution to carbon ($p <0.001$) and water footprint ($p = 0.004$) compared to meat menus but not to fish ones.

Table 7. Energy, nutrient content, and environmental impacts (median IQR) of three courses included in the menu.

	Total n = 57	**Meat *n* = 21**	**Fish *n* = 18**	**Plant-based *n* = 18**	***p* Value[1]**
Appetizer					
Energy (kcal)	133 (93-210)	116 (85-224)	126 (90-185)	145 (93-243)	0.818
Proteins (g)	4.2 (2.8-7.1)	4.2 (3.1-8.3)	4.3 (3.4-6.7)	4.0 (2.0-7.0)	0.672
Fat (g)	6.2 (3.1-10.4)	5.4 (3.8-9.3)	6.5 (2.4-10.5)	7.6 (3.5-10.5)	0.790
Saturated fat (g)	1.5 (0.8-2.5)	1.6 (1.0-2.7)	1.8 (0.5-2.9)	1.1 (0.5-2.2)	0.338
Carbohydrates (g)	13.8 (7.5-26.2)	13.9 (6.3-32.0)	13.8 (6.7-23.3)	15.4 (8.1-26.9)	0.872
Sugars (g)	2.4 (1.4-4.1)	2.4 (1.5-3.8)	2.3 (1.2-3.9)	2.5 (1.7-6.9)	0.620
Fiber (g)	2.1 (1.1-3.6)	3.2 (1.0-3.8)	1.8 (1.1-2.8)	2.2 (1.1-4.1)	0.637
Salt (g)	0.3 (0.1-0.8)	0.3 (0.1-0.8)	0.4 (0.1-1.2)	0.2 (0.1-0.5)	0.693
Carbon Footprint (g CO_2 eq)	90.5 (53.7-143.0)	101.9 (74.0-140.5)	106.1 (37.1-198.0)	77.7 (43.6-129.2)	0.231
Water Footprint (L)	151.9 (85.1-240.3)	151.9 (85.1-229.5)	143.9 (75.9-255.8)	151.4 (104.8-301.3)	0.917
Carbon Footprint (% CF menu)	12.8 (7.2-240.3)	10.3 (7.0-27.1)	11.3 (5.2-19.9)	18.8 (9.7-29.6)	0.117
Water Footprint (% WF menu)	13.9 (8.1-22.2)	13.3 (7.5-20.2)	13.6 (10.0-22.0)	15.8 (9.3-25.9)	0.627
Main course					
Energy (kcal)	450 (432-577)	479 (427-583)	501 (482- 548)	513 (411-581)	0.847
Proteins (g)	25.8 (21.4-28.9)	27.0 (21.8-30-1) [a]	28.0 (24.5-30.3) [a]	18.1 (16.1-23.9) [b]	<0.001
Fat (g)	14.1 (10.4-18.4)	14.3 (10.8-16.4)	14.4 (9.6-19.1)	13.2 (10.2-18.4)	0.993
Saturated fat (g)	2.9 (1.9-3.7)	3.6 (2.9-4.7) [a]	2.6 (1.7-3.7) [b]	2.6 (1.9-3.0) [b]	0.022
Carbohydrates (g)	68.3 (56.1-79.3)	63.8 (59.1-77.4)	69.7 (56.7-78.7)	71.2 (47.5-80.1)	0.835
Sugars (g)	8.2 (5.8-12.1)	9.1 (6.4-17.4)	7.1 (5.0-10.6)	9.0 (5.8-11.0)	0.319
Fiber (g)	7.7 (5.2-11.9)	5.7 (4.3-8.1) [b]	6.8 (5.0-9.8) [b]	13.5 (9.0-16.4) [a]	<0.001
Salt (g)	0.7 (0.3-1.7)	0.5 (0.3-1.7)	0.9 (0.4-1.8)	0.5 (0.3-2.4)	0.752
Carbon Footprint (g CO_2 eq)	467.7 (260.0-638.9)	557.8 (433.5-996.9) [a]	519.4 (395.5-697.8) [a]	175.5 (140.4-293.8) [b]	<0.001
Water Footprint (L)	574.3 (462.0-788.7)	740.5 (541.4-1032.6) [a]	561.5 (430.1-638.2) [b]	502.0 (450.7-687.7) [b]	0.010
Carbon Footprint (% CF menu)	65.2 (47.8-73.4)	69.0 (60.5-79.1) [a]	67.0 (55.6-78.7) [a]	49.6 (33.4-65.7) [b]	0.002
Water Footprint (% WF menu)	59.8 (46.7-67.2)	64.2 (58.5-72.2) [a]	58.3 (51.0-63.3) [b]	44.4 (39.4-60.0) [b]	0.001
Dessert					
Energy (kcal)	224 (179-301)	205 (176-293)	217 (176-253)	270 (203-370)	0.101

Proteins (g)	4.5 (3.0-6.4)	4.3 (3.0-5.9)	5.4 (2.7-6.7)	4.4 (3.9-6.4)	0.944
Fat (g)	10.3 (7.1-14.4)	8.7 (3.8-14.9)	10.5 (7.1-13.1)	11.4 (10.0-16.3)	0.092
Saturated fat (g)	2.8 (1.4-5.0)	2.6 (1.6-4.0)	3.9 (2.2-6.1)	2.3 (1.1-4.8)	0.406
Carbohydrates (g)	27.7 (19.4-36.2)	27.6 (19.4-34.9)	26.2 (18.3-34.1)	34.6 (18.2-43.4)	0.350
Sugars (g)	16.0 (13.7-19.5)	16.0 (12.7-19.0)	15.0 (13.1-24.8)	17.8 (14.7-19.5)	0.354
Fiber (g)	2.5 (2.0-4.4)	2.2 (1.3-4.4)	2.6 (2.0-3.8)	2.6 (2.0-3.8)	0.164
Salt (g)	0.1 (0.0-0.1)	0.1 (0.0-0.1)	0.1 (0.0-0.2)	0.1 (0.0-0.1)	0.850
Carbon Footprint (g CO_2 eq)	130.5 (88.9-158.6)	131.2 (90.1-169.1)	151.8 (108.4-197.5)	111.9 (73.1-134.8)	0.101
Water Footprint (L)	263.8 (216.0-391.5)	237.8 (204.4-278.7)	273.5 (216.6-349.9)	316.4 (245.1-474.2)	0.051
Carbon Footprint (% CF menu)	18.6 (14.7-26.9)	16.7 (7.5-21.8) [b]	18.9 (13.5-27.5) [a,b]	22.7 (18.1-38.1) [a]	0.004
Water Footprint (% WF menu)	25.1 (17.4-40.9)	22.1 (15.4-27.9) [b]	27.5 (20.4-35.6) [a,b]	38.3 (22.4-45.1) [a]	0.014

1 Main effect from Kruskal-Wallis test with Bonferroni post hoc test. Different letters in the same row indicate significantly different values ($p < 0.05$). CF: Carbon Footprint; WF: Water Footprint.

3.4.3.3.2 Origin of menus raw materials

Commodities has been defined as locally sourced if they complied with the criteria set out in the Article 2 of Law No. 61 of May 17, 2022, which establishes that "Zero-mile farm products are products from agriculture and animal husbandry located within a 70-kilometer distance from the place of sale, or otherwise from the same province as the place of sale, or from the place of consumption of the food service" [14]. Based on this definition, 78% of groceries were local products, mainly from North-Est Italian regions (72%). The percentage of locally sourced products was fairly homogeneous across food categories, the higher proportion was observed for fruit and vegetables, eggs, meat and non-alcoholic beverages (< 80%). However, in all categories at least two-thirds of products locally sourced, excepting for herbs and spices, for which the percentage was lower (55%). Conversely, herbs and spices category showed the highest proportion of quality certification (43%) along with alcoholic drinks (37%) and condiments (34%). Nevertheless, out of the total, only 13% showed food quality schemes and the most represented were organic certification and geographical indications, such as Protected Designation of Origin (PDO) and Protected Geographical Indication (PGI).

3.4.3.3.3 Canteen users' satisfaction

The satisfaction questionnaire (data not shown) was filled out mostly by subjects being male users (58%), from 18 to 29 years (74%), and mostly students (73%). Overall, meat menus were the most selected (37%), followed by plant-based (30%) and fish (17%) offers. The majority of users (80%) enjoyed the chosen menus and declared no leftovers (84%). Only 10% rated the portion sizes as abundant or excessive, while two thirds (65%) and a quarter (25%) of users considered them as adequate or meager, respectively. Lastly, the level of menu

appreciation assessed on a 5-point scale was medium-high (≥ 3) for 88% of the cafeteria customers and 83% enjoyed the educational project and the option to pre-order the meal.

3.4.4 Discussion

The present study was intended to assess the effectiveness of an educational intervention aimed at raising the future chefs' awareness and knowledge of the close connection between diet, health, and environment, as well as provide them with proper learning and skills enabling them to prepare nutritionally balanced and eco-friendly menus. The intervention was conducted at The School of Italian Culinary Arts (ALMA), where this project represents one of the educational initiatives addressing the topic of food sustainability.

The results of the self-administered questionnaires suggest that knowledge was medium-high in both groups at baseline. By comparing scores of control and intervention groups at the end of the intervention, the results proved the efficacy of the intervention in achieving learning outcomes about nutrition and food sustainability. Although knowledge of food sustainability improved only in the intervention group, an increase in nutritional knowledge was observed in both samples. This shift in the control group may be warranted by the setting, even though no direct intervention was provided to these students. Indeed, engagement in school life, sharing with schoolmates, and attending the indoor cafeteria may have exposed them to new stimuli and experiences leading to an increase in their knowledge. This hypothesis is supported by the Social-Ecological Model theory according to which the social-environmental sphere is a strong determinant in behavioral changes of individuals [15], including the role of peers in enhancing knowledge about food [16]. Social-Ecological Model has also been reported in the Ottawa Charter for Health Promotion [17] and advocates how individuals and the environment are extremely connected, representing the conceptual basis of public health "setting approach" interventions [18,19]. The lower nutritional knowledge of the control group at baseline could be related to their lower training in food science and the different admission requirements for the ALMA courses involved in the educational project. In fact, in contrast to Cooking and Basic Pastry Techniques Courses chosen as a control [21,22], the Advanced Course in Italian Cuisine chosen as intervention group represents a professionalizing course that required basic knowledge of cooking techniques, defined according to students' educational background. Only students who graduated from the Hospitality Academy or attended an equivalent cooking course, or with at least 2 years of kitchen experience, are eligible to enroll in the course [20]. For food sustainability, a poor baseline knowledge has been

observed in both groups. This finding probably reflects the current culinary programs mostly integrating nutritional components [9,23] without including other aspects of sustainability which are only recently becoming a subject of interest to be incorporated into dietary recommendations [24,25] and chef practice [26–28]. In addition, notions should be taught to culinary students not only through lectures, but more importantly by integrating them into culinary techniques to be applied in their future careers [29]. On this point, the integration of the nutrition program with key aspects of food sustainability, in combination with the preparation of nutritionally adequate and environmentally sustainable menus, is a notable strength of the study.

Considering the nutritional profile, the energy content of the lunch proposals ranged between 44-46% of daily energy intake considering 2000 kcal/die as the reference energy requirement for adults, exceeding the energy contribution that lunch should provide (i.e., 35-40%). However, taking into account that most of the diners were young males, it can be assumed that the daily energy requirement overcomes the energy reference and that, as a result, the contribution of lunch to daily energy intake drops to less than 40%, thus falling within the recommended range [30]. The distribution of macronutrients was also compliant with the Italian nutrition recommendations [31], according to which the energy content of main meals should be primarily covered by carbohydrates, accounting for 45-60% of lunch calories, followed by fat and protein, which should provide approximately 20-35% and 12-18% [31], respectively. In addition, the menus were found to have good fiber content, reaching about two-thirds of the suggested daily intake for Italian adults (i.e., 25 g) [31]. Lastly, both SFAs and sugar contents had not exceeded the suggested dietary targets for reducing the risk of chronic degenerative diseases, set at 10% and 15% of daily energy intake [31], respectively. In contrast, the average salt content of menus was nearly half the recommended maximum daily amount (5 g) [30], offering scope for improvements.

Overall, the nutritional composition was balanced across all menu categories, and this reflect the pre-established criteria which students had to comply with to subsequently prepare the menus. However, plant-based, meat-and-fish-based menus differed in protein and fiber content due to the ingredients in the main dish. Specifically, the protein content of plant-based menus was significantly lower than meat and fish menus. Although this study evaluated only one meal and not daily intake, this result is consistent with what was pointed out in a recent literature review according to which the total protein intake by adopting omnivorous, pescatarian, lacto-ovo-vegetarian, or vegan dietary patterns gradually decreased while remaining within the recommended dietary allowance [32]. At the same time, the high fiber

content of vegetarian and vegan menus is in line with the evidence from another systematic review, which concluded that lacto-ovo-vegetarians or vegans had greater intakes of high-fiber foods such as fruit, whole grains, and plant-based proteins compared to meat and fish eaters [33]. Nevertheless, given the lower digestibility of vegetable proteins, the energy distribution of plant-based menus might be improved by increasing protein content [34] and reducing fat, which is currently close to the upper limit of 35% of the energy intake.

From the environmental impact perspective, the carbon footprint of plant-based menus was found to be significantly lower than the others, even when adjusted for energy content. In contrast, a significantly higher water footprint was observed for the meat category only when the results were referred to 1000 kcal. The highest contribution to the environmental impact indicators is provided by the main protein sources, with ruminant meats as the most impactful, as already shown in the literature [3,12]. However, the combination of chosen ingredients exerts an influence on the final performance, especially considering the water footprint. Indeed, a larger proportion of plant-based ingredients leads to a reduction in greenhouse gas emission [35] but not always results in a lower water use, especially if the ingredients are legumes or nuts that necessitate a large water use during the irrigation process [36]. In this regard, the water consumption associated with fish, poultry, and eggs is lower than that of plant-based protein sources, namely legumes and nuts. Similarly, comparing milk and plant-based drinks, vegetable alternatives are more water impactful [12]. The percentage of sustainable menus according to the cut-offs suggested by Barilla Foundation within the SU-Eatable LIFE project [13] decreased dramatically when the water footprint was taken into account, especially for meat and plant-based menus. In addition, when considering the median contribution of single dishes to the carbon and water footprint of plant-based menus, main courses account for a lower share than the other categories, contrarily to desserts. This emphasizes the importance of reformulating desserts as a strategy to reduce the water footprint of plant-based menus as well as preferring poultry to enhance the environmental sustainability of meat-based menus.

To enable better interpretation of the results, it is relevant to point out the weaknesses of this study. Firstly, the environmental database, although recently developed based on the most updated and reliable scientific data, does not provide specific information for all types of ingredients. Furthermore, post-market steps, such as cooking, human excretion, and waste disposal, were not included in the impact assessment reported in the database. Another shortcoming of the menu analysis is related to the assessment of raw materials used. As information related to the first supplier, it was not provided by ALMA for most products and the origin of the food was identified with the last supplier, thus reducing the accuracy of the

assessment, probably overestimating the share of local products. Enhancing the traceability system would allow the school to easily identify areas for improvement by prioritizing local foods and increasing the purchase of products with organic and/or sustainable certifications (e.g., fair trade, sustainable fishing) or by supporting companies that comply with sustainable management practices. Given the multidimensionality of the food sustainability concept [37], which also entails economic aspects [38,39], menu analysis should incorporate the assessment of costs and the economic spill-over related to the procurement and processing of raw materials, with the aim of ensuring menus affordability and supporting local economy. These limitations emphasized the necessity of a holistic approach to food sustainability assessment. This consideration reflects what drawn from the analysis of over 50 initiatives addressed to kitchen staff, according to which there is a need of addressing relevant trade-offs (e.g., ingredients with a low carbon footprint can still have a high-water footprint), without focusing on single sustainability dimensions [8].

3.4.5 Conclusion

In conclusion, the present study was the first concrete example of incorporating nutrition and environmental sustainability into the practices of ALMA culinary students. The educational intervention proved to be effective in improving knowledge about nutrition and the environmental impact of food production and consumption, confirming the importance of promoting education on the related fields to intercept a central public health need in supporting dietary behavioral shift towards healthy and sustainable dietary choices. At the same time, these results helped to point out some weaknesses that should be improved in future educational initiatives targeted at food service professionals, first and foremost the Life Climate Smart Chefs project.

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Study 5

Validation of a Sustainability Knowledge Questionnaire in Italian Apprentice Chefs

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Abstract

Background Chefs' decisions can greatly improve the quality of the food offers and positively influence diners' dietary choices. To date, culinary students' knowledge of healthy and sustainable nutrition is still scarcely investigated and limited to the nutritional aspect of the diet, without considering the food sustainability aspects.

Purpose This study aimed at developing and validating a short questionnaire on Food Sustainability Knowledge (FSK) in Italian culinary students.

Material and methods A 23-item questionnaire was designed to investigate basic notions about food sustainability (Section 1, score range: 0-9) and the environmental impact of foods (Section 2, score range: 0-14). The study was performed at The School of Italian Culinary in Arts – ALMA located in Colorno, Parma (Italy), where the questionnaire was administered twice to the same students (Group 1) under identical conditions 3 weeks apart. In addition, the same questionnaire was administered once to another sample of students (Group 2) who attended classes on nutrition and food sustainability.

Results Data were obtained for 264 apprentice chefs (median age 22.0 years, IR: 19.0-25.0; 31% females) for Group 1 and 252 apprentice chefs (median age 21.0 years, IR: 19.0-24.0; 19% females) for Group 2. The results showed an acceptable internal consistency (Cronbach's $\alpha > 0.6$); a significant but low temporal stability with a sub-optimal correlation of the total score ($\rho = 0.475$, $p < 0.001$). However, the questionnaire performed well in distinguishing students with potentially diverse FSK, demonstrating the good validity of the instrument.

Conclusions To ensure the reliability of this short questionnaire in assessing the food sustainability knowledge in a larger and more diverse population of culinary students some revisions would be appropriate.

Keywords

Culinary students; chefs; sustainability; food; knowledge; questionnaire

3.5.1 Introduction

Sustainability of diet and food systems is increasingly a priority to ensure people's health and preserve the planet's ecosystems for next generations. Promoting a nutritional transition must necessarily include a change in individuals' eating habits and it should be based on several strategies, including improving the knowledge and awareness of multiple food system stakeholders to create a single sustainability vision [1,2] .

Due to the numerosity of facilities that provide food to communities, food services can reach a huge number of people, covering a crucial role in this transition process toward more resilient food systems [3,4]. Raw material selection, menu development, and customer outreach contribute to a conscious cuisine that supports and facilitates healthy and sustainable food selections. Thus, chefs' decisions can greatly improve the quality of the food proposition and positively influence customers' dietary choices [2–5]. In addition, the figure of chefs has increasingly become a reference not only for food preparation but also for aspects of human nutrition [6,7], extending its impact beyond the kitchen and increasing its ability to positively influence people's beliefs, business interests, and government actions [6]. This reinforces the key role of chefs as relevant stakeholders in promoting healthy and sustainable foods as a possible solution to address current nutritional and climate emergencies. Therefore, the training of future chefs should cover the practical aspects of restaurant management, such as food procurement and menu preparation, as well as improve their knowledge and dissemination skills [5].

In this connection, culinary students consider nutrition and sustainability as important aspects of dish development, recognizing the responsibility of their choices in influencing future food systems [8,9]. Although several culinary schools and organizations are now including nutrition and sustainability in their training programs [10–13], of culinary students' knowledge of healthy and sustainable nutrition is still scarcely investigated and limited to the nutritional aspect of the diet, without considering the food sustainability and environmental impact of foods [14,15].

Recently, the literature on the topic of food sustainability has grown and some questionnaires have been developed to explore the level of knowledge about it in both the general population [16–20] and university communities [21,22]. However, to date, no questionnaires aimed specifically at culinary students have been designed.

Based on this consideration, this study aimed at developing and validating a short questionnaire on Food Sustainability Knowledge (FSK) in Italian culinary students.

3.5.2 Materials and methods

3.5.2.1 Development of the questionnaire

A 23-item questionnaire was designed to investigate the knowledge on main aspect related to sustainable diets and environmental impact of foods. The questions were defined based on an FSK questionnaire already reported in the literature [16] and adapted according to the concepts outlined in the FAO report on Sustainable Diets and Biodiversity and the Double Pyramid 2016 drawn up by Barilla Foundation [1,23] and consultation with experts.

Initially, the questionnaire was tested with a pilot sample of 72 students, and some questions were revised based on these preliminary analyses (data not shown).

The questionnaire was divided into two constructs. Construct 1 (Basic notions about food sustainability) was composed of 9 multiple-choice questions related to the concept of sustainable diet, the Double Pyramid model, and indicators of environmental sustainability (i.e., carbon, water, and ecological footprint). Construct 1 was composed by 5 questions with 4 options with one correct answer and one "I do not know", and 4 questions included 3 options: 'True', 'False', or 'I do not Know'. Construct 2 (Environmental impact of food) consisted of 14 multiple-choice items on sustainability of different food commodities, the connection between human and planetary health, and food waste. Four questions offered 4 possible options with one correct answer and an 'I do not know'. The other 10 questions provided 3 options: 5 questions had 'High impact', 'Low impact', or 'I do not know', 4 questions 'I agree', 'I disagree', or 'I do not know', and 3 questions 'True', 'False', or 'I do not Know' as possible answers.

3.5.2.2 Subjects

Students attending The School of Italian Culinary in Arts – ALMA located in Colorno (Italy) were enrolled in this study. Subjects were eligible if they were registered at ALMA and followed a program in which lessons on food sustainability are not imparted, such as Cooking Techniques and Basic Pastry Techniques courses, or the Advanced Course in Italian Cuisine course, in which students were thought about nutrition and food sustainability. Before filling out the questionnaire, all participants gave their approval by signing an informed consent form. A personal alphanumeric code was assigned to each participant to assure complete anonymity.

3.5.2.3 Administration and validation of the Food Sustainability Knowledge questionnaire

The FSK questionnaire was administered twice to the students attended the Cooking Techniques and Basic Pastry Techniques courses (Group 1) under identical conditions. The two administrations were carried out online *via* Google Forms, 3 weeks apart, an interval long sufficient to avoid recall bias and short enough to avoid possible changes in participants' knowledge [24,25]. Students were asked to complete the questionnaire before the beginning of the lesson. In addition, the same questionnaire was administered to the students registered for the Advanced Course in Italian Cuisine (Group 2) at the end of the classes related to nutrition and food sustainability.

Based on the responses, a total FSK score (0-23 points) and two FSK sub-scores, for both sections, were obtained (Section 1 score range: 0-9; Section 2 score range: 0-14). This was calculated by assigning 1 point for correct answers and 0 for incorrect or "don't know" answers.

3.5.2.4 Statistical analysis

The sample size was defined according to the “rule of thumb” (*n*:p) [26]. Based on this rule, the number of respondents (*n*) and the number of questions (p) needs to be in a ratio of 10:1. Given the item number of the questionnaire (n=23), 230 was the minimum number of subjects required to perform validation.

Considering the Group 1, responses from baseline data collection (T0) were used to carry out item analyses, namely, item difficulty and item discrimination index.

Each question was evaluated using item difficulty index (percentages of correct responses for each single item) and item discrimination index (point-biserial correlation between the single-item score and the total score). Internal consistency was tested for both two constructs separately (Construct 1: Basic notions about food sustainability; Construct 2: Environmental impact of food) and for the total questionnaire by running the Cronbach’s alpha reliability test. Also, Spearman’s correlation was applied to measure the temporal stability (test-retest reliability), again considering the total score and the score of the two sections obtained at both baseline (T0) and follow-up (T1) by participants in Group 1. Lastly, construct validity was examined by applying a nonparametric Mann-Whitney U test for independent samples, investigating possible differences in scores, total and two sections separately, comparing students who were not educated on food sustainability issues (Group 1) and students who received food sustainability lessons (Group 2).

All statistical analyses were carried out with IBM SPSS Statistics for Macintosh, version 28.0 (Armonk, NY: IBM Corp) and the significance was settled to $p < 0.05$.

3.5.3 Results

3.5.3.1 Sample characteristics

In total, 674 students were enrolled in this study. However, 158 subjects were excluded because they were not at school during data collection or because they misspelled their personal alphanumeric code, making it impossible to match T0 and T1 data. Therefore, out of the total number of participants, 264 apprentice chefs (age 22.0 (19.0-25.0), 31% females) for Group 1 and 252 apprentice chefs (age 21.0 (19.0-24.0), 19% females) for Group 2 correctly completed the study requests and were included in the final analyses.

3.5.3.2 Single items analysis

The results of single items analysis are reported in Table 1 as item difficulty and discrimination indexes.

Table 1. Item analysis for the 23 questions of the FSK questionnaire.

Item	Item Difficulty (% Correct Answers)	Item Discrimination (*r* Value)
Construct 1: Basic notions about food sustainability		
1 – sustainable diet definition	79%	0.260
2 – animal-based foods	81%	0.250
3 – imported goods	50%	0.275
4 – red meat	68%	0.340
5 – seasonal and low-processed products	95%	0.309
6 – carbon footprint definition	32%	0.362
7 – water footprint definition	48%	0.368
8 – ecological footprint definition	34%	0.279
9 – Double Pyramid Model concept	32%	0.418
Construct 2: Environmental impact of foods		
10 – impact of milk	43%	0.010
11 – impact of fish	28%	0.157
12 – impact of pork	80%	0.314
13 – impact of pasta	64%	0.330
14 – impact of hard cheese	36%	0.254
15 – high impact foods	25%	0.381
16 – low impact foods	48%	0.329
17 – transportation and impact of fruit and vegetables	60%	0.266
18 – breeding and impact of meat	72%	0.323
19 – farming and cooking, and impact of cereals	28%	0.178
20 – impact of local products	22%	0.186

21 – eco-friendly diet and human health	75%	0.296
22 – food waste reduction	39%	0.314
23 – Mediterranean Diet as a sustainable model	86%	0.284

Items are reported divided into the two constructs

Most of the questions had a difficulty index between 0.2 and 0.8, whereas only for three items the percentage of correct answers was above 80% (two in the first and one in the second sections) but none were properly answered by the entire sample and none of the questions had a difficult index lower than 0.2. A slightly low correlation (item discrimination index <0.2) between total score and single items was found for 3 items of the "Environmental impact of foods" section and only one item, in the same section, showed a poor correlation index.

3.5.3.3 Reliability

A medium score was recorded at baseline considering both the total questionnaire and the two sections separately (Table 2). Overall internal consistency was acceptable (Cronbach's $\alpha = 0.656$), while a marginal reliability was found for section 1 (Cronbach's $\alpha = 0.574$) and section 2 (Cronbach's $\alpha = 0.490$).

Table 2. Internal consistency.

Section	Score range	Baseline FSK Score	Cronbach's Alpha
		Median (IQR)	
1 – Basic notions about food sustainability	0-9	5.0 (4.0-6.0)	0.574
2 – Environmental impact of foods	0-14	7.0 (6.0-8.0)	0.490
Total questionnaire	0-23	12.0 (10.0-14.0)	0.656

FSK: food sustainability knowledge.

From the test-retest reliability analysis (Table 3), a significant correlation was found between T0 and T1 both considering individual sections and the total questionnaire ($p < 0.001$, for all). However, only when considering the total questionnaire, an acceptable level of correlation was observed between total scores ($\rho = 0.475$, $p < 0.001$) and individual answers ($\rho = 0.426$, $p < 0.001$). In addition, a medium to high percentage of identical responses to the same item was found (62% for the total questionnaire and 60% and 63%, respectively, for section 1 and section 2).

Table 3. Temporal stability (test-retest reliability).

Section	Baseline SK Score (T0)	Follow-up SK Score (T1)	Correlation (Total Scores)		Correlation (Individual answers)	
	Median (IQR)	Median (IQR)	*rho*	*p*-Value*	*rho*	*p*-Value*
1 – Basic notions about food sustainability	5.0 (4.0-6.0)	5.0 (4.0-6.0)	0.347	<0.001	0.407	<0.001
2 – Environmental impact of foods	7.0 (6.0-8.0)	7.0 (6.0-8.0)	0.373	<0.001	0.434	<0.001
Total questionnaire	12.0 (10.0-14.0)	13.0 (10.3-14.0)	0.475	<0.001	0.426	<0.001

*Spearman's correlation test with significance of $p < 0.05$
FSK: food sustainability knowledge.

3.5.3.4 Validity

The total questionnaire score was significantly higher ($p < 0.001$) in Group 2 students who had classes on food sustainability compared to Group 1 respondents who, in contrast, did not receive food sustainability lessons. Even when considering individual constructs, students with potentially greater SFK showed higher scores ($p < 0.001$ for both).

Table 4. Construct validity.

Section	FSK score Group 1	FSK score Group 2	*p*-Value*
	Median (IQR)	Median (IQR)	
1 – Basic notions about food sustainability	5.0 (4.0-6.0)	7.0 (6.0-8.0)	<0.001
2 – Environmental impact of foods	7.0 (6.0-8.0)	9.0 (8.0-10.0)	<0.001
Total questionnaire	13.0 (10.3-14.0)	16.0 (14.0-17.0)	<0.001

* Test U di Mann-Whitney
FSK: food sustainability knowledge
Group 1: students enrolled in Cooking Techniques and Basic Pastry Techniques courses in which lesson on food sustainability were not provided
Group 2: students enrolled in Advanced Course in Italian Cuisine in which lesson on food sustainability were provided

3.5.4 Discussion

This study examined the reliability and validity of a brief self-administered questionnaire for assessing Italian culinary students' knowledge of the main issues related to food sustainability.

Analyzing item difficulty, for nearly all questions the correct answer rate fell within the recommended range of 0.2-0.8 [27,28], although three items were deemed apparently too easy, but, given their relevance to the topic, they were not excluded. Also considering item discrimination, four items in the second section should have been removed due to their low correlation with the total score (cutoff < 0.2) [24,27]. However, their exclusion did not lead to

an improvement in the reliability of the questionnaire. Thus, evaluating the results of the two analyses and the importance of the topic, all 23 questions were included in the final version of the questionnaire.

Regarding internal consistency, even if the suggested minimum requirement is 0.7 [24,29], several authors have previously recognized a Cronbach's alpha value above 0.6 [30–33] as acceptable. On this basis, our questionnaire revealed acceptable overall internal consistency reliability (Cronbach's $\alpha = 0.656$). It is worth noting that the value of Cronbach's alpha is usually related to the number of items [34]; in fact, looking at the two individual constructs, lower internal consistency values were found (Cronbach's $\alpha < 0.6$) than for the overall questionnaire. This discrepancy related to the lower number of questions is consistent with the results of a questionnaire on nutritional knowledge addressed to Italian university students [35]. As suggested by the authors [35], an increased number of items may improve the internal consistency of individual constructs and the overall questionnaire. At the same time, however, a longer questionnaire may result in a decline in attention during completion.

In terms of instrument stability over time, the correlation for both individual section scores at baseline (T0) and follow-up (T1) was sub-optimal ($r < 0.5$). However, an acceptable correlation was observed considering the total score.

Noteworthy, the questionnaire performed well in distinguishing students who were expected to have a higher FSK (Group 2) from those who did not have a food sustainability background (Group 1), proving the good validity of the instrument.

Comparison with other questionnaires is difficult owing to the topic and target population of our study. Nevertheless, some questionnaires on the topic of food sustainability are reported in the literature. Among these, a 49-item questionnaire was developed for the Spanish adult population to explore knowledge and attitudes about food sustainability [16]. An adapted version of the same questionnaire was used to investigate the same outcomes in a population of Saudi adults [20]. In both studies, possible differences related to gender and age group were investigated [16,20]. Two other questionnaires were developed for the Portuguese (40-item) [17] and Taiwanese (32-item) [18] population to delve into the components of food literacy, including knowledge of food sustainability. Lastly, two studies explored the level of knowledge, perception, and expectations about food sustainability in higher education, specifically in a Spanish [22] and Georgian [21] university community, using a 28- and 24-item questionnaire, respectively. All of these studies differ from our questionnaire in terms of the target population, number of items, and type of questions, which are most of the time aimed at attitudes toward food sustainability rather than assessing knowledge. Considering the Italian

population, Aureli and colleagues recently validated a 12-item questionnaire [19]. Also in this example, the instrument is aimed at investigating the attitudes of individuals leaving out their actual knowledges [19].

At the same time, some instruments have been validated on culinary students, but they were aimed at assessing their nutritional knowledge, attitude toward food, and cooking skills [37–41]. Only a recent study [8] on American culinary students addressed the issue of food sustainability, delving into their attitudes and beliefs about the role of chefs in encouraging healthy diets and sustainable food systems. The students interviewed listed price, taste, and convenience as priorities when choosing food. However, they recognized the importance of encouraging healthy and sustainable food choices through food services [8]. In this regard, raising awareness among the next generation of chefs assumes paramount importance. Despite these interesting results, knowledges about food sustainability have not been previously investigated in culinary students.

This study has some strengths and limitations that need to be underlined. First, to the best of our knowledge, this is the first questionnaire designed to assess FSK in a sample of apprentice chefs. In addition, the small number of questions helps to reduce both the compilation time and the risk of respondents' distraction. Despite the novelty and importance of this study, some limitations should be pointed out. Overall, the weaknesses of this research are mainly related to the suboptimal values of Cronbach's alpha and correlation over time, particularly when considering the two individual sections. In addition, considering the low discrimination indices of some items in the second section, a revision of these questions would be appropriate to strengthen the reliability of this tool. However, there are arguments for treating these indices as guides for the developers rather than absolutes [24].

3.5.5 Conclusion

In conclusion, bearing in mind the close connection between the culinary business, sustainability of food production and preparation, food waste, environmental deterioration, and hunger [4], the assessment of chefs' expertise in food sustainability appears increasingly important. Therefore, this questionnaire serves as a valid and user-friendly tool to assess the food sustainability expertise of culinary students and develop tailored interventions to address their lack of knowledge and provide them with theoretical and practical skills to promote sustainable food choices in their future careers.

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Chapter 4 - Discussion

Study 6

Best Practices for Making the University Campus a Supportive Environment for Healthy and Sustainable Diets

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Abstract

Among universities' responsibilities, addressing sustainability-related issues by enabling a food environment which raises people's awareness and promotes the improvement of food offer and consumption is paramount. This article draws on recent literature evidence and virtuous examples provided by leading experts, with the purpose of outlining a conceptual model for fostering healthy and sustainable nutrition among the academic community through food services. To summarize, the connection between different academic departments, stakeholders, and students is crucial to gain the participation of the entire university society. At the same time, networking with food service companies is also relevant. Only by bringing together diverse expertise, skills, and experience will change in the university community will be possible to reach the common goal of making universities a supportive environment to ensure the well-being of the entire academic community on and off campus.

Keywords

University students, university community, food sustainability, healthy diets, canteens, food services

4.1 Introduction

Food system is a very complex reality which involves several actors, including food services, i.e., companies which provide foods for schools, hospitals, companies, universities, etc. [1]. A recent scientific report [2] shows that more than 18 billion of meals were served by food service in 15 European countries in 2013, 1,562 billion of which only in Italy. The analysis looked at several sectors, including the education one (e.g., kindergartens, schools, universities), where state entities rely on food sourcing based on tenders. For this reason, the implementation of sustainable public procurements turns out to play a crucial role in shaping the entire food system. Across Europe, many public authorities are enforcing sustainable public procurements by including environmental and social criteria besides the economic dimension [3]. In Neto [4], several sustainable criteria from European public procurement schemes for foodservice, at national or local level, were analyzed. Most of them are environmental criteria referring to production methods (e.g., organic agriculture), product seasonality, staff training in environmental aspects, transportation, menu planning (e.g., by lowering meat options and/or increasing vegetable availability), packaging, waste management, as well as sustainability certifications for marine and aquaculture food products. Tender specifications include also social, ethical and health indications mainly addressed to animal welfare, food safety and traceability, and fair trading [4].

From the results of a recent systematic review [5], the reduced use and recycling of resources (e.g., water, energy) and materials (e.g., paper, aluminum), food donation, and composting are the most commonly applied strategies to improve meal sustainability in food services, as they optimize resources consumption and reduce food waste. In parallel, other sustainable activities are performed, such as purchase of local food or organic products, waste sorting, meat reduction, use of eco-friendly packaging, portion reduction, reusing leftovers, etc.

Although less reported, some studies have emphasized the importance of planning healthy and sustainable menus and creating a food environment that facilitates consumers to make sustainable choices. In this context, a further literature review [6] pointed to several social responsibilities of educational institutions - specifically universities - such as the awareness-raising of individuals on sustainability principles. This outreach process may take place through a combination of different approaches, including educating people, building supportive environments, and engaging the community. Specifically, "top-down" and "bottom-up" strategies are the two complementary methods that can be followed. The former relies on guidelines or procedures established according to experts' vision to address common issues. On

the contrary, the latter seeks to define policies and guidelines based on the exploration of the communities' needs. Thus, it may be more effective in solving the real problems of the population [7]. Both have intrinsic limitations, top-down approaches tend to differ from the people's demands and be unwelcomed [8], whereas bottom-up solutions may receive scant support from governing bodies and fail due to a shortage of funds[9]. In general, a combination of the two methods is recommended to balance the weakness of both approaches [10].

Contextualized to higher education, the institutional and structural aspects of universities, including governance, management, and operations, should be considered. University governance encompasses the strategies and policies defined by institutional bodies and integrated into the university's mission to implement sustainable development, which includes the protection of workers, respect for minorities, improvement of infrastructure, involvement of local stakeholders in decision-making, and transparency of university resources' origin and use. On the other hand, management activities include all the techniques and tools that oversee social and environmental performance to ensure the well-being of the university community. Finally, the last sub-dimension of the university structure is represented by all operations aimed at tackling current environmental challenges such as climate change and resource use [11].

In this connection, universities can act through various initiatives to address several environmental sustainability-related issues (e.g., energy use, water consumption, transportation, etc.), including the improvement of food offer and consumption [6], due to the strong contribution of food systems to negative environmental externalities [12]. At the same time, the improvement of the food offer and the implementation of a supportive environment make university cafeterias strategic settings to advocate healthy and sustainable nutrition in both university staff and students [13]. The latter can be considered a crucial target not only because of the large number of involved students but also because the transition to university entails a greater student responsibility in food purchasing and preparation, especially for off-campus students, which is often associated with the adoption of unhealthy eating behaviors leading to an increased risk of being overweight and developing chronic disorders [14,15]. In view of this, establishing sustainable practices for university dining halls is of remarkable importance.

The purpose of this review is to provide a conceptual model to implement on university campuses for promoting healthy and sustainable diets among the academic community, especially through food services. The article conceptualization was inspired by recent literature evidence and practical examples provided by leading experts during the workshop entitled "Multi-strategic intervention to promote the implementation of a healthy and sustainable

university canteen policy" held in Parma, Italy, on the 29th of September 2022. The article is structured in next four sections. The first one emphasizes the urgency of promoting healthy and sustainable diets to deal with current global public health and planetary preservation challenges. The second section highlights the key role of catering services within food systems, describing theoretical principles and giving virtuous examples for building sustainable food services, while also providing a focus on the university setting. Next, the revision delves into the determinants of student food choices and assesses how an effective intervention should be designed to engage the entire university community in the process of shifting toward a more sustainable university food system. The article ends with a discussion on public food procurement, by illustrating the virtuous initiative of the University of California Los Angeles (UCLA) as an example to point out the relevance of connecting different stakeholders such as faculty, students, staff, and food service companies to foster the shift toward sustainable universities, suggesting how and by whom this transition should be managed and led.

4.2 Multiple dimensions of sustainable healthy diets

Currently, global food production accounts for 23-34% of total greenhouse gas emissions related to human activities [16,17] and 70% of freshwater withdrawals [18]. In addition, about 50% of the global habitable land is devoted to agriculture [17,19] and a waste of 931 million tons of food was estimated in 2019 [20]. At the same time, malnutrition conditions are a top cause of death and are still widespread among the global population; in particular, more than 700 million people are undernourished [21] and more than 2 billion are overweight or obese [22].

Healthy and sustainable diets are intended to promote the health and well-being of human beings whilst reducing the environmental impact of the food system [23]. Achieving this important goal for present and future generations requires a holistic approach that incorporates multiple dimensions [23,24] ranging from health outcomes (e.g., nutrient adequacy and food safety) and environmental impact (e.g., ecosystem stability and waste and loss reduction), to socio-cultural (e.g., food acceptability, gender equity, food security) and economic aspects (e.g., resilience, food affordability and profitability) [23,25].

Adopting sustainable dietary patterns [26] can have a huge and positive impact on both communities and the planet's health, reducing the risk of diet-related noncommunicable diseases and mitigating climate change and resource exploitation [27]. As suggested by the Eat-Lancet Commission, the planetary healthy diet is primarily based on non-starchy vegetables,

fruits, whole cereals, pulses, nuts, and unsaturated oils and low to moderate consumption of seafood and poultry, while limiting intake of red and processed meats, starchy vegetables, added sugar and refined grains [26]. However, the adoption of healthy and sustainable diets is a huge challenge for low-income populations, who cannot afford such dietary patterns [28]. For this reason, food affordability must be declined to reflect different income levels around the world [29].

4.3 Theoretical principles and virtuous examples for building sustainable food services

Within the food system, catering service owing to its contacts with several stakeholders, from primary production to final consumer, can influence the entire agri-food supply chain including people's food choices, thus playing a crucial role in community outreach, and enhancing the surrounding area [30]. In this regard, it is of paramount importance that the restaurant system addresses the current challenge of sustainability through a holistic perspective that covers not only environmental aspects but also gives equal prominence to the economic and social dimensions [31].

A recent study [30] explored the sustainability programs and practices currently implemented by the food catering sector with the purpose of assessing its contribution to achieving Sustainable Development Goals (SDGs) and compliance with the three domains of sustainability. Generally, the SDG 12 on sustainable production and consumption was found to be the most considered goal in all the analyzed programs. As outcomes, it establishes sustainable production and consumption patterns, a proper use of natural resources, as well as ensuring dignified jobs and fostering a sense of responsibility to the environment and society in the community. However, only the programs aimed at tackling all 17 SDGs simultaneously achieved the maximum level of sustainability in each declination. The most comprehensive programs found to address all SDGs are briefly reported below [30]. Eco Cook[1] is a consulting and certification program for the restaurant industry in Spain that aims to improve the performance of the entire restaurant industry through the reduction of natural resource use and operating costs. Green Globe Standards for Sustainable Tourism[2] is a certification developed in the United States that aims to enhance virtuous examples that optimize resource use and inspire positive shifts for guests, staff, and communities. Sustainable Restauration (from the

[1] https://www.ecocook.com/en/who-are-we/
[2] https://www.greenglobe.com

Italian "*Ristorazione Sostenibile*") 360 (RS 360[3]) is an Italian certification program which has been developed by partnering between individual organization and research entities. It provides companies and catering professionals with ten guidelines that cover three spheres of sustainability (i.e., social, economic, and environmental) and can be easily implemented in different contexts [30]. Benchmarks for this certification include various aspects of company management targeted to the promotion of the territory and well-being of the communities such as the selection of local and seasonal foods as well as eco-friendly cutlery and packaging, responsible handling of natural resources and food waste reduction, designing sustainable menus and clearly communicating them, ensuring business ethics and gender equality in team administration [32]. The three above-mentioned sustainability schemes can be adopted on a voluntary basis by restaurant services. More specifically, the Italian RS 360 certification lasts for two years during which spot checks may be conducted.

Another breakthrough initiative is the Menu of Change® designed and implemented by the Culinary Institute of America and the Harvard T.H. Chan School of Public Health. The project aims to leverage food service to provide healthy and nutritious meals to the community with a long-term vision on citizens and environmental well-being. The manifesto promotes transparency of food sources and preparation, giving importance to freshness, seasonality, culinary tradition, and local foods, valuing virtuous agricultural practices, preferring plant-based foods, whole-grain, and lightly processed products, using menu design and description to emphasize the flavor of dishes, reducing portions and waste through traceability, and using leftovers in new menus. In addition, the reduction of salt, added sugars and sugary drinks is recommended [33].

An extension of this initiative is called the Menus of Change University Research Collaborative (MCURC) and is currently active in several colleges and universities in the United States. MCURC is a network involving food service professionals, chefs, students, and administrators and represents a perfect example of the role of universities to encourage healthy and sustainable eating among the campus community to improve their health and reduce the food system's impact on the planet. The strength of the project lies essentially in the connection between different professionals and stakeholders [34].

[3] https://ristorazionesostenibile360.it

4.4 Determinants of eating behaviors in university students and the pivotal role of education in multi-strategy interventions

To thoroughly identify and understand determinants of people's behavior, it is important not to focus only on the intra-personal level, but to evaluate the food environment, which includes social network, physical context, and policy-related factors. Indeed, food environment is one of the main determinants of peoples' food choice [35] as it refers to the physical, economic, socio-cultural and policy conditions that shape access, affordability, safety, and food preferences [36]. According to this perspective, a multitude of intrinsic and extrinsic factors can positively or negatively influence students' eating behaviors and, therefore, life quality.

Subjects, specifically students, that are more conscious of current environmental issues are more prone to shift toward more sustainable eating habits, which tend to be instead less common in students with low awareness about food environmental [37]. Therefore, increasing students' literacy about health and environmental impact of food systems seems to be a promising strategy for raising awareness and building capacity to adopt food practices that enhance health and well-being [38]. To improve food and nutrition knowledge and food consumption in students as well as in whole university community, certain intrapersonal variables, such as attitude and self-efficacy towards healthy eating, can play an important role. On the other hand, at interpersonal, environmental, and macrosystem levels, social peer supportiveness, healthy food availability, and exposure to healthy eating campaigns are crucial to shape food choices [39]. Social norms (e.g., meal sharing) and situational factors (e.g., portion sizes, provision of sustainable options, stimulus strategies, time pressure, and palatability) appear to moderate personal factors, such as preferences or attitudes, related to sustainable eating.

Despite increasing people's knowledge represents the approach to overcome the lack of consciousness and facilitate commitment for adopting healthy and eco-friendly diets, a multi-strategic intervention is required to trigger a real shift toward more sustainable behaviors [13]. For a successful engagement of people, educational programs should include a declaration of commitment by individuals targeted by the intervention (e.g., single and/or multiple actors playing a role as service users or providers, such as university students/staff/managers or the catering staff company) and should rely on the mechanism according to which the learning process occurs through emulation of peers' behaviors [13]. Moreover, effective education programs should build a supportive environment, provide participants with benefits, and make them aware of the effect of the intervention itself, through some feedback regarding the

comparison between previous and current behavior of the involved subjects, either at individual or group level. The actors that should play a role in designing the educational programs could be represented by researchers and professors in Academia having the required expertise and knowledge in this area. Otherwise, external bodies should be involved in the process. In this context, food services in universities are the ideal framework for implementing effective people engagement on the topic of health and food sustainability, by developing long-term educational campaigns, by offering healthy and sustainable menus, and promoting users' engagement.

The renewal of university dining, through new menu proposals mainly based on plant-based ingredients, including local products (mainly if rapidly perishable), respecting seasonality and gastronomic tradition, as well as aimed at minimizing food waste even by reusing excess food, will turn into a win-win outcome. First, raising awareness of cafeteria customers may benefit the entire university community. On the other hand, due to the huge amount of food processed daily by the cafeterias, this transformation can lead to a significant reduction in its environmental impact, becoming a benchmark for the entire food sector [13]. In this regard, chefs play a key role in this food revolution, and it is important to increase their knowledge and skills to provide them with useful tools to design sustainable menus, and to foster educational programs, starting from the selection of raw materials up to the communication with staff and consumers [40,41].

4.5 A new concept of canteen supported by the entire university community

The promotion of healthy and sustainable diets should be championed by food services at both public and private levels, primarily through the establishment of food procurement standards [10,34]. Indeed, public procurement can contribute to enhance the sustainability of catering sector, directly through the definition of food purchase in state sector [42], and by extension, providing inputs and positively inspiring businesses in the private sector [43]. For instance, the supply of food in public catering services in Italy is regulated by the Ministerial Decree of March 10, 2020, which defined the "Minimum Environmental Criteria" (from the Italian "*Criteri Ambientali Minimi*") (CAM) for canteen and catering services and the supply of food products" to encourage the design and implementation of a canteen model with low environmental impact, that furthers proper nutrition and gastronomic culture according to the principles of Mediterranean Diet, with particular attention to use of organic and short supply chain commodities, products with quality certification in different percentages, tap or microfiltered water, electric vehicles for transporting food, avoidance of disposable materials

or non-eco-friendly packaging, purchase of energy-efficient equipment, and food waste minimization practices. In addition, the document provides specifications on environmental criteria for the food procurement of offices, universities, and barracks, including the reduction of animal protein and the increasing of plant-based ingredients [44].

The management of university dining services in Italy is partly entrusted to regional higher education authorities. For instance, in the Emilia Romagna Region, the Regional Authority for the Right to Higher Education (Er.Go) works very closely with the Universities on the territory to ensure that the needs of students are met. More specifically, it provides low-income undergraduate and graduate students with financial support and services including scholarships, housing, and dining services. With regard to food service, Er.Go is the body that defines the tender criteria for food procurement based on the CAM defined by the Ministerial Decree, and handles relations with the catering companies that have been awarded the tender. Through its position, regional higher education authorities play a crucial role in connecting food service companies and academies to achieve the common goal of ensuring that students, faculty, and staff have access to healthy and sustainable food [45].

However, the most cost-effective tender, namely the best value for money, is still the main criterion for choosing the catering company that will handle the food service, also in public university canteens [44], discouraging competitors to make a more challenging proposal and to bear the related costs. To enhance best practices in food services companies, the rational for contract award should overcome the economic advantage in favor of the long-term benefits of a sustainable food procurement both in terms of public health and natural resource preservation [46].

At the same time, to achieve a positive response from the university community, a public health intervention should follow a community-centered strategy, starting with the identification of student needs to address by designing tailored initiatives [47].

To give a concrete example, the Semel Healthy Campus Initiative (HCI) was founded in 2013 at the University of California Los Angeles (UCLA) with the vision of making the UCLA campus a supportive environment for improving the well-being of the entire university community. This ambitious goal has been pursued over the years to date by connecting different departments and stakeholders, as well as recognizing and mobilizing the assets of institutions and the strengths of individuals. Currently, Semel HCI comprises seven thematic working groups called Pods, including the EatWell Pod, which aims to ensure food security to the entire UCLA community through providing fresh and nutritious food and increasing people's food literacy, emphasizing the interdependence of human and planetary health. Among the most

impactful initiatives, the collaboration with the Teaching Kitchen Collaborative (TKC), whose goal is to use cooking workshops to educate students about proper food selection and preparation, should be mentioned. The participation in the aforementioned MCURC is an opportunity to share achievements referred to the food offer improvement in cafeterias (with the launch of health-oriented dining halls) and vending machines, including the creation of botanical gardens and the enhancement of local food procurement, beside the establishment of academic programs to explore the topic of food from a multidisciplinary perspective. Finally, the Semel HCI steering committee brings together various campus stakeholders, such as institutional figures, professors, students, and researchers, in monthly meetings that provide a time for discussion to come up with new ideas and strategies to guide the next phases of the project. In addition, annual progress reports are provided on the Semel HCI website [48].

In conclusion, as demonstrated by the described virtuous examples, the connection between different academic departments, stakeholders, and students is crucial to gain the participation of the entire university society. At the same time, creating networks with private food services companies is also relevant. Only by bringing together diverse expertise, skills, and experience, a shift in the university community will be possible to reach the common goal of making universities a supportive environment to encourage healthy and sustainable nutrition for the entire university community. In this connection, regional higher education authorities in Italy represent the ideal intermediary to lead the implementation of best practices in the process. Finally, the academy should monitor community engagement and perform perspective or "before-and-after" evaluations of achievements, with the goal of continually upgrading the university environment.

Author contributions

Conceptualization: C.F., B.B, A.R., F.S.; Funding acquisition: F.S.; Investigation: C.F., B.B., A.R., F.S.; Methodology: C.F., B.B., A.R., F.S.; Project administration: F.S.; Supervision: F.S.; Visualization: C.F.; Roles/Writing - original draft: C.F.; Writing - review & editing: C.F., B.B. F.S.

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Conflicts of Interest

The authors declare no conflict of interest.

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* of special interest

* * of outstanding interest

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Chapter 5 – Overall Conclusion

This Doctoral Thesis aimed to identify the best approaches to be followed for enhancing food literacy and fostering sustainable diets in higher education institutions, particularly through food services. In this regard, two lines of research were pursued in parallel, and a workshop was organized to provide a position paper based on the latest evidence in the literature and the experiences of the leading experts in the field. The first part was addressed at exploring the eating habits of young people, delving into the sustainability of university students' eating behaviors in order to determine the strongest predictors of adopting a healthy eating pattern in this specific target population. The role of university canteen was also considered and investigated in this light. Simultaneously, considering the pivotal role of chefs in promoting healthy food choices by providing users with healthy and sustainable menus, the second part aimed to explore nutrition and food sustainability knowledge in a sample of culinary students involved in an educational project.

As first research activity, a systematic review was conducted to assess adherence to dietary guidelines in young populations (2-35 years) living in Europe. Among the selected studies (n =29), most considered samples of children or adolescents, while a few studies were carried out on young adults (18-35 years). Overall, the results confirmed the current shift toward Western-style diets, characterized mainly by a low consumption of plant-based foods, such as vegetables, fruits, cereals, legumes, and nuts, and an excessive consumption of meat and meat products, sweets, and sugary drinks. Among nutrients, the intake of proteins, fats, saturated fats, and sugars overcame the recommended levels, while an insufficient fiber consumption was found. Furthermore, considering the MD, overall, European children, adolescents, and young adults showed only medium to low levels of adherence. These results showed little alignment of children, adolescents and young adults' eating habits with national dietary guidelines and nutritional recommendations. It is worth noting that due to the limited number of studies conducted on nationally representative samples over the past decade, drawing solid conclusions about the current dietary habits of the younger European generation is difficult, especially for young adults.

Subsequently, an online survey addressed to young adults (18-24 years old) enrolled in university was carried out. Specifically, this cross-sectional study explored the adherence to the MD and sustainability of dietary behaviors in two representative cohorts of Italian and American students, providing new evidence on the main drivers of dietary habits in this specific target population, considering different living contexts such as a Mediterranean and non-Mediterranean area. The results showed an average level of MD adherence in both samples and highlighted an active lifestyle, sustainable eating behavior, extensive consumption of plant-

based foods, willingness to buy and eat healthy and sustainable meals, and regular university cafeteria attendance as the main predictors of high MD adherence. In this context, it is crucial to make university dining services an enabling environment for promoting healthy and sustainable food choices among students and the academic community.

Given this, a pilot study tested the effect of reordering menu items as a "light touch" nudging strategy to encourage low-carbon food choices. The intervention was conducted in a dining hall at the University of California Los Angeles, where students could customize their lunch or dinner menu by choosing from several options without being influenced by price. The results showed a significant effect of item placement on users' decisions. In particular, eco-friendly options where preferred if placed at the beginning of the menu, while the same positive effect was not observed for beef options. These outcomes confirmed the effectiveness of an easy-to-implement nudging approach in a food service context, such as the university cafeteria. At the same time, the results also emphasize the need for a multi-strategy approach that includes outreach and education of students about the environmental impact of their food choices.

Raising awareness about nutrition and food sustainability issues among food service users is as important as increasing knowledge and skills of restaurant staff, especially chefs, on the same topics. In this connection, the second part of this thesis aimed to assess the knowledge of apprentice chefs on aspects of nutrition and food sustainability and to provide them with notions and practical skills for the preparation of healthy and sustainable menus. Specifically, the impact of the intervention was evaluated through the enrollment of a control and intervention sample of culinary students registered at the International School of Italian Cuisine (ALMA) in Parma (Italy). The effectiveness of the educational project was confirmed by the increased level of knowledge in the intervention group and the nutritional profile of the menus prepared by the chefs during a work project as part of the educational intervention. However, the menus environmental impact, assessed as carbon footprint and water footprint, revealed a high percentage of sustainable menus, especially plant-based, only when considering the carbon footprint. On the contrary, a few menus showed a water footprint within the sustainability threshold, regardless of the main protein source of the menus (meat, fish, animal by-products, or plant-based foods). The assessment of menu sustainability highlighted trade-offs within the environmental dimension, pointing out the need for a multi-factorial approach when addressing the concept of food sustainability.

The need for a holistic vision represents the key concept that also emerged from the discussion among leading experts on the central role of university dining services in improving the eating habits and overall well-being of students and academic communities. In particular,

based on the most recent evidence from the literature and concrete examples provided by experts, two key concepts emerged: building a supportive environment and engaging the community (Figure 1). The former includes food procurement criteria that prioritize seasonality, freshness, and origin of food, including the selection of eco-friendly materials and energy-efficient facilities. These factors together with chefs and kitchen staff training, the application of strategies minimizing food waste and proper management of leftovers, as well as ensuring social equity among university employees are crucial to offering sustainable menus. Community engagement emphasizes other important aspects such as the need for networking among various university and non-university stakeholders, identifying the needs of the academic community, raising awareness of health and food sustainability through educational campaigns, seeking the commitment of individuals, and providing them with benefits for this, and finally sharing the results achieved with all the involved people.

Figure 1. A conceptual best-practice model for making university food services an environment conducive to the promotion of healthy and sustainable nutrition.

Source: https://doi.org/10.1016/j.coesh.2022.100436

Chapter 6 – Future Perspectives

The conclusions of this Doctoral Thesis emphasized the pivotal role of higher education institutions in establishing long-term solutions to empower the academic community and make them actors of change in the transition to more sustainable foodways. Above all, enhancing food literacy and offering nutritious and sustainable food choices make food services the cornerstone of this process of change. The work presented in the present PhD thesis will serve as a basis to develop future activities in the context of the national project "ON Foods - Research and innovation network on food and nutrition Sustainability, Safety and Security – Working ON Foods"[4]. Specifically, the renewal of university dining environment will be covered by Spoke 7 addressed to "Behavior, education and policy". Within this framework the University of Parma is leading a research project aimed at developing educational and empowerment models focused on promoting healthy and sustainable eating in university cafeterias. Several activities will be conducted by partnering with University of Bologna, Council for Agricultural Research and Economics (CREA), University of Milano-Bicocca, and Regional Authority for the Right to Higher Education (ER.GO). Briefly, the project seeks to map the food behaviors, including plate waste, as well as the nutrition and food sustainability knowledge of Parma University students. This information will serve as a baseline for developing tailored informational campaign to raise consciousness of human and planetary health among canteen users, providing them with practical tool to engage them and improve their eating habits. In particular, the intervention will involve a re-designing of dining halls to create an enabling environment for proper food choices, the development of a digital application to provide diners with educational materials beyond the meal in the cafeteria, and the optimization of menus in terms of nutritional composition and environmental impact. In addition, students will be provided with an online curriculum that addresses various topics related to the interconnection between food, human well-being, and environmental preservation. The findings of the project will be used to establish guidelines for the implementation of innovative educational approaches to promote sustainable nutrition and healthy lifestyles through canteen in public educational institutions, also inspiring others catering services both locally and beyond.

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April 2021 – Present	Social media manager of the twitter profile of Ph.D. Course in Food Science
Jun– Oct 2022	Scientific supervisor for the International Workshop "Multi-strategic intervention to promote the implementation of a healthy and sustainable university canteen policy" held in Palazzo del Governatore, Parma, on the 29th of September 2022
Jan – Sep 2022	Tutoring activities addressed to high school students within the PCTO program (Pathways for Transversal Skills and Orientation)
May 2019 – Mar 2021	Nutrition education consultant on behalf of Madegus – University of Parma Spin-Off focused on nutrition education for children – www.madegus.com

PUBLICATIONS

Accepted 22nd Dec 2022	Journal: Current Opinion in Environmental Science & Health Title: Best Practices for Making the University Campus a Supportive Environment for Healthy and Sustainable Diets Authors: ***Franchini C**, Biasini B, Rosi A, Scazzina F* https://doi.org/10.1016/j.coesh.2022.100436
Accepted 28th Dec 2020	Journal: Nutrients Title: The EnergyKids Pilot Study: Comparing Energy Balance of Primary School Children during School and Summer Camp Authors: ***Franchini C**, Rosi A, Ricci C, Scazzina F* https://doi.org/10.3390/nu13010092

ORAL COMMUNICATIONS

Nov 9th – 12th 2022	Title: Promoting nutrition and food sustainability knowledge in future chefs as a public health strategy Authors: *Biasini B, **Franchini C**, Giopp F, Rosi A, Scazzina F* Congress: 15th European Public Health Conference Location: Berlin, Germany
Sep 19th – 21st 2022	Title: Promotion of nutrition knowledge and sustainability of dietary behaviors in different student populations Authors: ***Franchini C,** Scazzina F* Congress: 26th Workshop on the Developments in the Italian PhD Research on Food Science, Technology and Biotechnology Location: Asti, Italy
Jun 16th & 17th 2022	Title: The Effect of Logo and Dish Placement on University Students' Healthy and Sustainable Food Choices Authors: *Wongprawmas R, Andreani G, **Franchini C**, Biasini B, Rosi, A, Dolgopolova, I, Gómez M.I., Scazzina F, Menozzi D, Mora C, Sogari G* Congress: 11th Conference of the Italian Association of Agricultural

and Applied Economics
Location: Viterbo, Italy

Apr 4th – 6th 2022

Title: Nutrition knowledge and learning about food environmental impact in apprentice chefs before and after an intervention project

Authors: *Biasini B,* ***Franchini C****, Giopp F, Rosi A, Scazzina F*

Congress: Congresso Nazionale della Società Italiana di Nutrizione Umana (SINU)

Location: Napoli, Italy

POSTER COMMUNICATIONS

Oct 18th – 20th 2022

Title: The Effect of Menu Reordering on the Carbon Footprint of Dietary Choices in University Dining

Authors: *Bartolotto C,* ***Franchini C****, Carpenter C, Slusser W*

Congress: Teaching Kitchen Research Conference 2022

Location: Los Angeles, CA, United States

Apr 4th – 6th 2022

Title: Studies and educational interventions for the promotion of best practices in primary school canteens of Parma

Authors: *Fortini A, Biasini B, Rosi A,* ***Franchini C****, Bertolotti E, Scazzina F*

Congress: Congresso Nazionale della Società Italiana di Nutrizione Umana (SINU)

Location: Napoli, Italy

Sept 14th – 15th 2021

Title: Promotion of nutrition knowledge and sustainability of dietary behaviors in different target populations

Authors: ***Franchini C,*** *Scazzina F*

Congress: First Virtual Workshop on the Developments in the Italian PhD Research on Food Science, Technology and Biotechnology

Location: Palermo, Italy (online)

Nov 27th – 29th 2019

Title: The EnergyKids Project: a pilot study on primary school children's energy balance during school days and summer camp days

Authors: ***Franchini C****, Rosi A, Volta E, Scazzina F*

Congress: Congresso Nazionale della Società Italiana di Nutrizione Umana (SINU)

Location: Genova, Italy