Nutrition, Metabolism & Cardiovascular Diseases (2022) **32**, 2772–2781

Available online at www.sciencedirect.com

Nutrition, Metabolism & Cardiovascular Diseases

journal homepage: www.elsevier.com/locate/nmcd

Good for the heart, good for the Earth: proposal of a dietary pattern able to optimize cardiovascular disease prevention and mitigate climate change

Annalisa Giosuè [a,1], Francesca Recanati [b,1], Ilaria Calabrese [a], Katarzyna Dembska [b], Simona Castaldi [c], Francesca Gagliardi [d], Marilena Vitale [a], Olga Vaccaro [e], Marta Antonelli [f,*], Gabriele Riccardi [a]

[a] *Department of Clinical Medicine and Surgery, "Federico II" University of Naples, Naples, Italy*
[b] *Independent researcher, Italy*
[c] *Dipartimento di Scienze e Tecnologie Ambientali Biologiche e Farmaceutiche, Università degli studi della Campania Luigi Vanvitelli, Caserta, Italy*
[d] *Dipartimento di Economia Politica e Statistica, Università degli Studi di Siena, Siena, Italy*
[e] *Department of Pharmacy, "Federico II" University of Naples, Naples, Italy*
[f] *Division Impacts on Agriculture, Forests and Ecosystem Services (IAFES), Foundation Euro-Mediterranean Center on Climate Change (CMCC), Viterbo, Italy*

Received 7 June 2022; received in revised form 26 July 2022; accepted 1 August 2022
Handling Editor: A. Siani
Available online 9 August 2022

KEYWORDS
CVD prevention;
GHG emissions;
Dietary pattern;
Sustainability

Abstract *Background and aims:* Human and planetary health are inextricably interconnected through food systems. Food choices account for 50% of all deaths for cardiovascular diseases (CVD) – the leading cause of death in Europe – and food systems generate up to 37% of total greenhouse gas (GHG) emissions.
Methods and results: Based on a systematic revision of meta-analyses of prospective studies exploring the association between individual foods/food groups and the incidence of CVD, we identified a dietary pattern able to optimize CVD prevention.. This dietary pattern was compared to the current diet of the European population. The nutritional adequacy of both diets was evaluated according to the European Food Safety Authority (EFSA) recommended nutrient intake for the adult population, and their environmental impact was evaluated in terms of carbon footprint (CF).

As compared to the current diet, the desirable diet includes higher intakes of fruit, vegetables, wholegrains, low glycemic index (GI) cereals, nuts, legumes and fish, and lower amounts of beef, butter, high GI cereals or potatoes and sugar. The diet here identified provides appropriate intakes of all nutrients and matches better than the current Europeans' one the EFSA requirements. Furthermore, the CF of the proposed diet is 48.6% lower than that of the current Europeans' diet.
Conclusion: The transition toward a dietary pattern designed to optimize CVD prevention would improve the nutritional profile of the habitual diet in Europe and, at the same time, contribute to mitigate climate change by reducing the GHG emissions linked to food consumption almost by half.

* Corresponding author. Via Garbini 51–01100, Viterbo, Italy.
E-mail address: marta.antonelli@cmcc.it (M. Antonelli).
[1] These authors contributed equally to this paper.

https://doi.org/10.1016/j.numecd.2022.08.001

1. Introduction

Food production and consumption have a major impact on human and planetary health. Dietary patterns have changed dramatically in the past fifty years, with the relevant increase in the consumption of animal-based foods rich in calories, fat, and sugar threatening the health and well-being of populations and environment [1]. Poor quality diets and malnutrition are the biggest risk factor for non-communicable diseases [2] and cause 41 million deaths each year (71% of all deaths) globally [3]. In Europe, cardiovascular diseases (CVD) are responsible for about 45% of all deaths (4 million deaths per year) [4], with food choices accounting for as much as 50% of all CVD deaths [5,6]. The adoption of a healthy diet is thus crucial for CVD prevention [7].

Food systems are also associated with multifaceted environmental impacts, such as competition over land and water resources and anthropogenic greenhouse gas (GHG) emissions [8,9]. Up to 37% of total net anthropogenic GHG emissions are linked to food systems [10,11], mainly including methane (from ruminants, manure management, and rice production), nitrous oxide (due to natural processes in agriculture and manure management, as well as the use of synthetic fertilizers), and carbon dioxide (e.g., during transports and food processing) [12]. Recent estimates have shown that GHG global emissions associated with animal-based food production are about twice to those associated with plant-based food production [13]. At the level of single food items, the difference in carbon footprint (CF) – i.e., GHG emission per kg of food – between plant and animal-based food can be as high as two orders of magnitude, with beef meat accounting for highest values [14,15]. According to United Nations, food production will need to increase 70% by 2050 compared to 2009 to meet the global food demands from a growing and increasingly urbanized population, with dietary preferences associated with economic growth [16]. In a business-as-usual scenario, food-related GHG emissions will grow by 87% by 2050, as well as the demand for resources, such as land and water, which would exceed planetary boundaries putting at risk key ecosystem processes [15]. The need to shift toward more plant-based diets and food waste reduction is the core of the European Union's Farm to Fork Strategy [17].

The purpose of this article is to provide appropriate scientific support for the adoption of food choices able to optimize CVD prevention and, at the same time, mitigate climate change, with a focus on Europe. To this aim, we first defined the desirable food consumption based on the results of a systematic review of the evidence linking the intake of individual foods/food groups to the risk of CVD (i.e., coronary heart disease (CHD), stroke, and sudden death) in meta-analyses of prospective studies. This optimal dietary pattern was then compared to the current food choices of the Europeans. The nutritional adequacy of both the proposed and the current dietary pattern was assessed in relation to the European Food Safety Authority (EFSA) guidelines, and their environmental impact was evaluated in terms of CF by using a comprehensive dataset of CF of food commodities [14].

2. Methods

2.1. Identification of the desirable dietary pattern for the optimization of CVD prevention

The procedure has been extensively described elsewhere [7]. In brief, a systematic review of the literature was carried out by two reviewers (A.G. and I.C.), searching in the electronic database PubMed for the evidence linking the consumption of individual foods/food groups to the risk of CVD (i.e., CHD, stroke, and sudden death) in prospective studies as summarized in the meta-analyses published up to August 31, 2020. Among 6793 articles retrieved from the literature search, 138 met the criteria for inclusion in the systematic review.

The most common foods utilized worldwide were grouped according to their specific features and nutritional properties (i.e., processed meats, red meat, white meat, animal fat, tropical vegetable oils, fish, eggs, high GI refined cereals and potatoes, low GI refined cereals, wholegrains, legumes, nuts, non-tropical vegetable oils, fresh fruits, and vegetables). Dairy foods were not considered as a group because of their heterogeneity; in fact, the three major components (i.e., milk, yogurt, and cheese) have been evaluated separately. In addition, the scientific evidence on salt, beverages, and chocolate consumption in relation to the CVD risk was also reviewed.

The association between the consumption of each food group/item and cardiovascular outcomes was evaluated by comparing the relative risk (RR) and confidence intervals (CI) between the highest and the lowest consumption group. The reproducibility of the outcomes of different meta-analyses together with the magnitude of the RR and its CI have been considered as measures of the consistency and the strength of the association. Data from dose–response analyses were used to identify the amounts of foods associated with the lowest risk of events or, in the absence of statistically significant associations, the thresholds of intake above which an increased risk of CVD cannot be excluded. For each food group/item, the most updated and comprehensive dose–response meta-analysis was chosen as reference among the available ones. Data on CHD – including myocardial infarction, sudden death, and acute coronary syndrome – were used when those on CVD were not available. Meta-analyses including retrospective and/or case–control studies were excluded, as well as those conducted in populations with specific dietary habits (i.e., vegetarians and vegans) or with prior cardiovascular events and/or chronic diseases (e.g., diabetes, dyslipidemia, hypertension, etc.).

Within the proposed dietary pattern, foods associated with a reduced risk of CVD represent the preferential choices to reach the amounts linked to the maximal risk reduction. Foods with a neutral relationship with CVD incidence have been comprised in moderate amounts to not exceed the thresholds of intake above which an increased risk cannot be excluded. Foods associated with a clearly increased risk of CVD (i.e., beef, butter, potatoes, and sugar) have been included but in limited amounts, while foods to consume only occasionally (i.e., processed meats) have been left out, since the desirable intake is lower than 1 serving/week (see Table 2 Footnotes).

Of note, the desirable serving sizes of foods characterized by a high energy density (i.e., carbohydrate and fat-rich foods) can vary in relation to the individuals' energy needs, since they can facilitate weight gain if consumed in larger amounts than appropriate. Nevertheless, in the presence of overweight, it is appropriate to avoid discretionary foods (i.e., alcoholic beverages and chocolate) and added sugar (i.e., soft drinks and sugar).

2.2. Identification of the current dietary pattern of the Europeans

We downloaded food balance data from the website of the FAO (https://www.fao.org/faostat/en/#data/SCL), which were updated in April 2021. The food supply during each year is estimated as the sum of the total quantity of foodstuffs produced (including production, imports, and stock changes) minus exports, food use other than human feed (including animal feed, seeds for agricultural use, etc.), and food losses during food transport, storage, and processing.

We extracted from Food Balance Sheets (FBSs) the supply quantity of 42 food groups/items (kg/capita/year) in Europe as a geographical region (i.e., including Eastern, Northern, Southern, and Western countries) for the years 2014–2018. The data were properly arranged to group together food items similar for their nutrient composition and specific features, as outlined below. For instance, the supply quantities of "freshwater fish", "demersal fish", "pelagic fish", "marine fish", "cephalopods", "crustaceans", and "mollusks" were summed to obtain the amount available for consumption of the group "fish". When the supply quantity from FBSs of specific food groups/items relevant for the aims of the study were not available, such as processed meats, cheese, yogurt, pasta, wholegrains, and chocolate, we used data from other official databases. More specifically, "Statista" (https://www.statista.com), a statistics database for market research, was used to obtain data on the consumption of processed meats, cheese, yogurt, and pasta; "Global Dietary Database" (https://www.globaldietarydatabase.org), a comprehensive compilation of information on food and nutrient consumption levels in countries worldwide, was used for the consumption of wholegrains; data on chocolate intake in Europe were obtained from the "Centre for the Promotion of Imports from developing countries" (https://www.cbi.eu), an agency of the Ministry of Foreign Affairs.

The quantity of each food group/item available for consumption was converted from kg/capita/year to g/capita/week in order to derive the current weekly dietary pattern of the Europeans.

Since FBSs data do not consider food waste occurring with food distribution and consumption at the household level, we have performed separate evaluations after calculating, for each food group, the amounts of food available for consumption by subtracting the presumable

Table 1 Amounts of foods available for consumption by the Europeans compared to the desirable amounts considering the available scientific evidence on their relations with CVD risk.

Food group/item	Europeans' current food consumption (g/capita/week)	Desirable food consumption (g/capita/week)	Increase/decrease in consumption with respect to current one*
Wholegrains	404.6	1050	+159.5%
Fresh fruit	816.7	2800	+242.8%
Vegetables	1186.0	2800	+136.1%
Yogurt	222.7	1400	+528.8%
Low GI refined cereals	178.6	560	+213.5%
Non-tropical vegetable oils	217.3	175	−19.5%
Nuts	58.5	210	+258.9%
Legumes	39.2	320	+716.6%
Fish	287.7	700	+143.3%
White meat	371.0	300	−19.1%
Eggs	221.9	300	+35.2%
Milk	2422.0	750	−69.0%
Cheese	318.3	150	−52.9%
High GI refined cereals and potatoes	2184.0	200	−90.9%
Red meat	805.4	100	−87.6%
Butter and tropical vegetable oils	149.3	20	−86.6%
Processed meats	300.7	25	−91.7%
Chocolate	88.3	70	−20.7%
Sugar	836.8	105	−87.4%

Note: *calculated as follows: (utilized amount-advised amount)/utilized amount.

Table 2 Weekly plan of the desirable dietary pattern for the optimization of CVD prevention.

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Breakfast	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Egg n.1 -Wholegrain bread 30 g	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Cheese 30 g -Wholegrain bread 30 g	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Egg n.1 -Wholegrain bread 30 g	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Cheese 30 g -Wholegrain bread 30 g	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Egg n.1 -Wholegrain bread 30 g	-Milk 125 g -Wholegrain breakfast cereals 25 g or wholegrain rusks n. 2 -Fresh fruit 150 g or orange juice -Cheese 30 g -Wholegrain bread 30 g	-Wholegrain breakfast cereals 25 g or wholegrain rusks n.2 -Fresh fruit 150 g or orange juice -Butter 20 g -Wholegrain bread 30 g
Snack	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g	Wholegrain crackers or wholegrain plain biscuits 25 g
Lunch	-Poultry 100 g -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g	-Eggs n. 2 -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g	-Dried legumes 80 g -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g	-Fish 180 g -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g	-Fresh cheese 100 g -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g	-Dried legumes 80 g -Vegetables 200 g -Wholegrain bread 70 -Fresh fruit 150 g	-Poultry 100 g -Vegetables 200 g -Wholegrain bread 70 g -Fresh fruit 150 g
Snack	Yogurt 200 g	Nuts 30 g	Yogurt 200 g	Nuts 30 g	Yogurt 200 g	Nuts 30 g	Yogurt 200 g
Dinner	-Pasta 80 g -Dried legumes 80 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and nuts 30 g	-Parboiled rice 70 g -Fish 180 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and yogurt 200 g	-Pasta 80 g -Poultry 100 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and nuts 30 g	-Barley 70 g -Dried legumes 80 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and yogurt 200 g	-Pasta 80 g -Fish 180 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and nuts 30 g	-Corn tortilla 100 g -Beef 100 g -Potatoes 175 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and yogurt 200 g	-Fish 180 g -Potatoes 175 g -Vegetables 200 g -Dessert based on fresh fruit 100 g and nuts 30 g
Snack	Chocolate 10 g	Chocolate 10 g	Chocolate 10 g	Chocolate 10 g	Chocolate 10 g	Chocolate 10 g	Chocolate 10 g
During the day	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g	-Non-tropical vegetable oils 25 g -Sugar 15 g

Processed meats (i.e., 50 g of bacon, ham, turkey deli meat, sausages, etc.) might be consumed only occasionally (1 serving/2 weeks).
Cakes and sweets are permitted provided that the weekly allowance of the included ingredients (eggs, sugar, butter, chocolate, flour, etc.) is taken into account.
In the presence of overweight, it is appropriate to exclude discretionary foods and sugars and to reduce the consumption of refined carbohydrates and fat-rich foods.

waste as calculated by FAO [18] from the per capita food supply quantity provided by FBSs.

2.3. Assessment of the nutritional adequacy of the dietary patterns

To evaluate the ability of the proposed dietary pattern and of the current Europeans' diet to meet the recommended nutritional requirements, we have compared its nutritional composition with the most recent European recommendations for the adult population developed by EFSA. For three nutritional components (i.e., dietary cholesterol, added sugars, and GI), in the absence of data provided by EFSA, we have used the reference values established by other expert groups [19–21].

2.4. Assessment of the carbon footprint of the dietary patterns

The starting points for the CF assessment of diets was the database of CF of food items (kg CO_2/kg of product) by Petersson et al. [14] and the two considered dietary patterns providing the amounts of food to be considered. The database includes 3349 studies (ranging from scientific publications to Environmental Product Declaration – EPD) assessing the CF of 325 food items. The steps carried out in the study to calculate the CF of the weekly diets are as follows:

a. Mapping the food items of the CF database by Petersson et al. [14] to the food groups considered in the paper.
b. Calculation of the median CF for each food group (Supplemental Methods).
c. Calculation of CF of weekly diet (kg CO_2 eq./week) by multiplying the median CF of each food group (kg CO_2 eq./kg, using the *recommended* value in the CF database) times the weekly amounts (kg/week) provided in the two considered diets, and then by summing up all CF of the different food groups.

3. Results

3.1. Relations between food consumption and CVD risk

The optimal consumption of each food group in relation to the CVD risk was evaluated on the basis of the dose–response relationship with CVD incidence or mortality. These data allowed us to identify the amounts of foods associated with the lowest risk of events or, in the absence of statistically significant associations, the thresholds of intake above which an increased risk of CVD cannot be excluded – all the details (i.e., amount of consumption, RR, and 95% CI, reference paper) are provided in Supplemental Table 1.

Among foods inversely related to CVD, the maximal risk reduction was observed for a consistent and relevant consumption of fresh fruit, wholegrains – e.g., wholegrain bread and wholegrain breakfast cereals – refined cereals with low glycemic index (GI) – e.g., pasta, barley, and corn tortilla – and yogurt (Supplemental Table 1). Other food groups are linked to a decreased risk of CVD as well, but the strongest association is observed for a less frequent consumption; these are as follows: fish, legumes, nuts, non-tropical vegetable oils – e.g., extra-virgin olive oil, sunflower oil, and corn oil – and chocolate (Supplemental Table 1). A further increase in the consumption of these foods is not associated with any additional benefits.

The following food groups showed a neutral relationship with the risk of CVD when consumed in moderate amounts: white meat, milk cheese, and eggs. Data on higher consumption of these items in relation to cardiovascular outcomes are too scanty to draw conclusions on the shape and direction of the relationship (Supplemental Table 1). Among foods associated with an increased risk of CVD, there are some staple ones, like refined cereals with high GI (e.g., white bread, white rice) and potatoes. Consequently, their proposed amount of consumption takes into account not only the need to minimize the risk of CVD but also the necessity to avoid too stringent limitations in their consumption not feasible in the long term (Supplemental Table 1). Other food groups associated with an increased risk of CVD are animal fats and tropical vegetable oils – e.g., butter, cream, and palm oil – red meat – e.g., beef, pork, and lamb – and processed meats – e.g., bacon, sausages, and ham; these have stricter limitations, given the feasibility of their replacement with healthier items (Supplemental Table 1). Supplemental Table 2 presents data on the relationship between beverages, salt and added sugars intake, and the risk of CVD. Accordingly, the healthy adult population should limit the consumption of wine or beer (no more than 2 glasses or, respectively, 1 can per day) as well as that of tea or coffee (no more than 3 cups per day). Salt intake should be below 5 g per day. For added sugars, the evidence showed a CVD risk increase for daily amounts exceeding 65 g. However, it would be appropriate to limit the assumption below 5% of total daily energy intake, taking into consideration its overall potential health harm [21].

3.2. Amounts of foods available for consumption in Europe compared to the desirable ones for the optimization of CVD prevention

The weekly amounts of each food group currently available for consumption by the Europeans are shown in Table 1, together with the corresponding desirable amounts for the prevention of CVD and the changes in consumption (%) needed to this aim.

Except for fish and yogurt, whose current consumption is lower than the desirable one, European populations utilize higher amounts of all foods of animal origin with respect to what would be advisable. This is particularly remarkable for the consumption of red and processed meat (overten-fold higher than desirable) as well as milk and cheese. Conversely, the amounts of almost all plant-based foods (i.e., wholegrains, fruit, vegetables, nuts, and legumes) consumed by Europeans are lower than the desirable ones. High GI refined foods and added sugars are, however, relevant exceptions, since the current intake dramatically exceeds the desirable.

3.3. Weekly plan of the desirable dietary pattern for the optimization of CVD prevention

The desirable amounts of the various foods have been used to propose a weekly plan as shown in Table 2. In some occasions, specific food items have been included rather than food groups; therefore, the serving size of certain items (e.g., pasta and barley) belonging to the same food group (i.e., low GI refined cereals) may be slightly different according to the variations of their energy content.

As shown in Table 2, the resulting dietary pattern consists of main meals and snacks with a structure not dissimilar from that currently adopted by European adult populations and employs all food groups, but with different amounts from the current ones.

3.4. Nutritional adequacy

The energy content and nutrient composition of the current dietary pattern of the Europeans are shown in Supplemental Table 3 together with that of the desirable diet for the prevention of CVD and the recommended intakes by the EFSA guidelines. Despite the desirable pattern of food consumption provides fewer calories than the current one, it is fully adequate according to the requirements defined by the EFSA. Regarding protein intake, it is within the recommended range in both cases, while total fat intake slightly exceeds the recommendations. However, the desirable pattern is characterized by a better distribution of fat. In fact, it reduces saturated fat intake from 14% to 10% of total energy intake, fully complying with the World Health Organization (WHO) [22] and the ESC/EAS recommendations [19]. Similarly, the desirable pattern provides a lower amount of dietary cholesterol (slightly less than 300 mg/day, as proposed by ESC/EAS Guidelines) than the current one. Also, monounsaturated fatty acids and omega-3 fatty acids, especially the long-chain ones, are nearly four-fold higher in the desirable dietary pattern than in the current one.

Regarding carbohydrates intake, both dietary patterns are in line with the recommendations. However, the substantial diversity in carbohydrates quality results in a lower GI and a lower content of added sugars in the desirable pattern compared to the current one. This latter characteristic allows the proposed dietary pattern to fulfill the sugar intake recommendation by the WHO [21], while the current intake is about three-fold higher than the recommended one. As for fiber, both dietary patterns provide $\geq$25 g/day; however, the desirable dietary pattern, which is rich in wholegrains, vegetables, and fruit, supplies about 10 g of extra fiber per day.

Finally, the two patterns are adequate for micronutrient intake, with the only exception of selenium, which is slightly below the recommended amount. Of note, the desirable dietary pattern nearly doubles the intake of vitamins A, C, D, and folic acid compared to the current one (Supplemental Table 3).

3.5. Environmental impact

The CF of the current and the desirable dietary pattern for reducing CVD risk are shown in Table 3.

The CF of the various food groups were evaluated using the data included in the database by Petersson et al. [14]. Shifting from the current to the desirable dietary pattern would reduce to a large extent the weekly CF, as the former accounts for 38.7 kg CO_2 eq. per capita, while the latter amounts to 19.9 kg CO_2 eq. per week. In the current pattern of food consumption, red meat, milk, and cheese combined account for about 70% of the weekly CF (Table 3, 1st column). More specifically, red meat, with a weekly intake of about 800 g per capita, accounts for the overwhelming majority of the total CF (53.1%). By reducing red and processed meat, as well as milk, high GI refined cereals and potatoes, as in the desirable dietary pattern, the CF would be drastically reduced (−25.4 kg CO_2eq.). Despite some food groups in the proposed dietary pattern are present in larger quantities than in the current one (i.e., wholegrains, fruit, vegetables, low GI refined cereals, nuts, legumes, yogurt, fish, and eggs), their impact on the weekly CF does not counterbalance the CF reduction due to the lower consumption of other food groups (+8.2 vs. −26.9 kg CO_2 eq.). Overall, the transition toward the proposed dietary pattern would reduce the CF of the current diet of the Europeans by 48.6% (Table 3 and Fig. 1), mainly as a result of the increased consumption of plant-based foods in replacement of animal-derived foods.

Further reduction in the CF of the desirable dietary pattern can be obtained by refining the selection of food items within the food groups (Fig. 2). For example, by consuming only fatty fish (4 times per week; scenario A), additional 1.27 kg CO_2 eq. per capita per week can be avoided, corresponding to an overall reduction of CF of 51.9% with respect to the current diet; this would also beneficially impact the CVD risk [23]. Additional benefits would be induced by substituting the weekly portion of 100 g of red meat in the proposed dietary pattern with white meat (−54.1% with respect to the current diet; scenario B). These two dietary choices would induce a total reduction of the CF of the current diet up to almost 57.4%.

Furthermore, by selecting only fruit and vegetables produced in open field and by excluding those produced in greenhouse or frozen (scenario C), on average, further 1.3 kg CO_2 eq. per capita per week can be avoided, corresponding to an overall reduction of 52% in CF with respect to the current dietary pattern. Altogether, these refinements in food selection (for fish, meat, vegetables, and fruit) would reduce the CF by a further 12%.

4. Discussion

The present article has shown that the current Europeans' food choices are not in line with what would be required

Table 3 CF of the current dietary pattern of the Europeans compared to the CF of the desirable one for the optimization of CVD prevention.

Food group/item	CF of the Europeans' current food consumption* (kg CO^2 eq/week)	CF of the desirable food consumption* (kg CO^2 eq/week)	Variation of CF due to the transition from the current to the desirable food consumption
Wholegrains	0.31	0.81	+160%
Fresh fruit	0.40	1.38	+243%
Vegetables	0.73	1.71	+136%
Yogurt	0.51	3.18	+529%
Low GI refined cereals	0.16	0.49	+214%
Non-tropical vegetable oils	0.39	0.31	−19%
Nuts	0.08	0.29	+259%
Legumes	0.02	0.17	+716%
Fish	1.49	3.64	+143%
White meat	1.44	1.16	−19%
Eggs	0.71	0.96	+35%
Milk	3.48	1.08	−69%
Cheese	3.05	1.44	−53%
High GI refined cereals and potatoes	1.92	0.18	−91%
Red meat	20.53	2.55	−88%
Butter and tropical vegetable oils	0.59	0.08	−87%
Processed meats	1.80	0.15	−92%
Chocolate	0.28	0.22	−21%
Sugar	0.79	0.10	−87%
TOT. (kg$_{CO2eq}$/capita/week)	**38.7**	**19.9**	**−48.6%**

Note: *it refers to the corresponding amounts reported in Table 1.

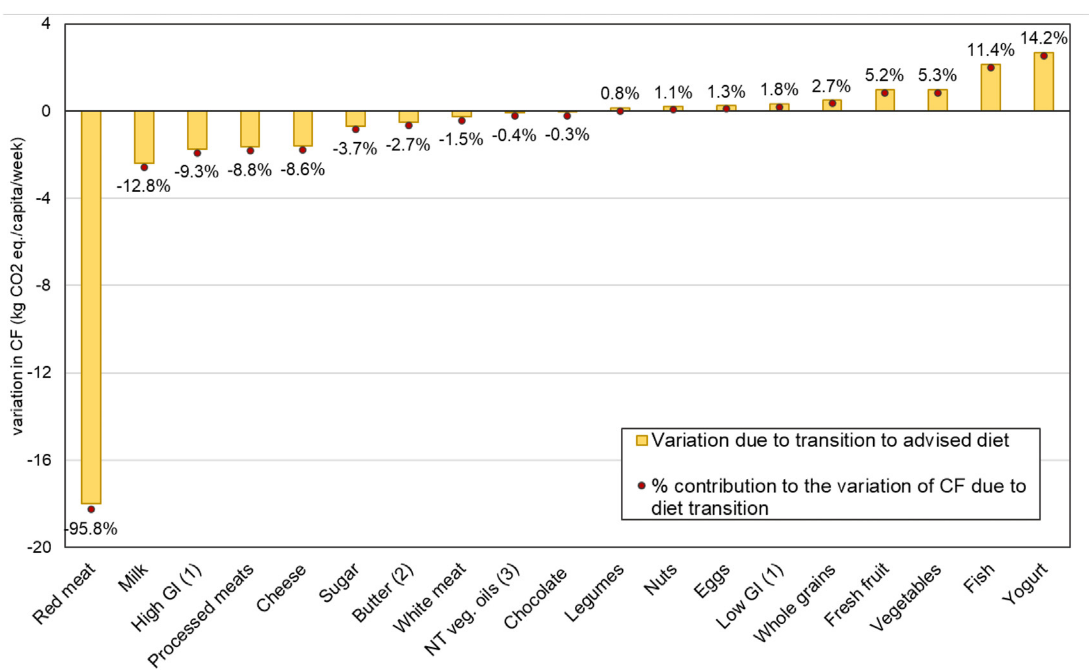

Figure 1 Contribution of each food group to the variation of the weekly CF obtained by the transition from the Europeans' current food consumption to the desirable one in absolute amounts (columns) and % of the global reduction.
(1) Refined cereals. (2) As well as other animal fat or tropical vegetable oils. (3) Non-tropical vegetable oils.

to optimize the prevention of CVD nor with environmental sustainability [24]. Moreover, the diet of the Europeans is not fully nutritionally adequate and is not completely consistent with the food-based dietary guidelines, as reported by the EU Farm to Fork Strategy [17]. The shift toward a healthier dietary pattern can be pivotal to improve the nutritional status and minimize the risk of CVD of the European populations [4], while contributing to mitigate climate change. The importance of a paradigm shift toward a more holistic One Health approach that looks at the interlinkages between human health, animal health, and the health of the planet should also be recognized.

A major strength of this study is the adoption of a systematic and reproducible method to evaluate the

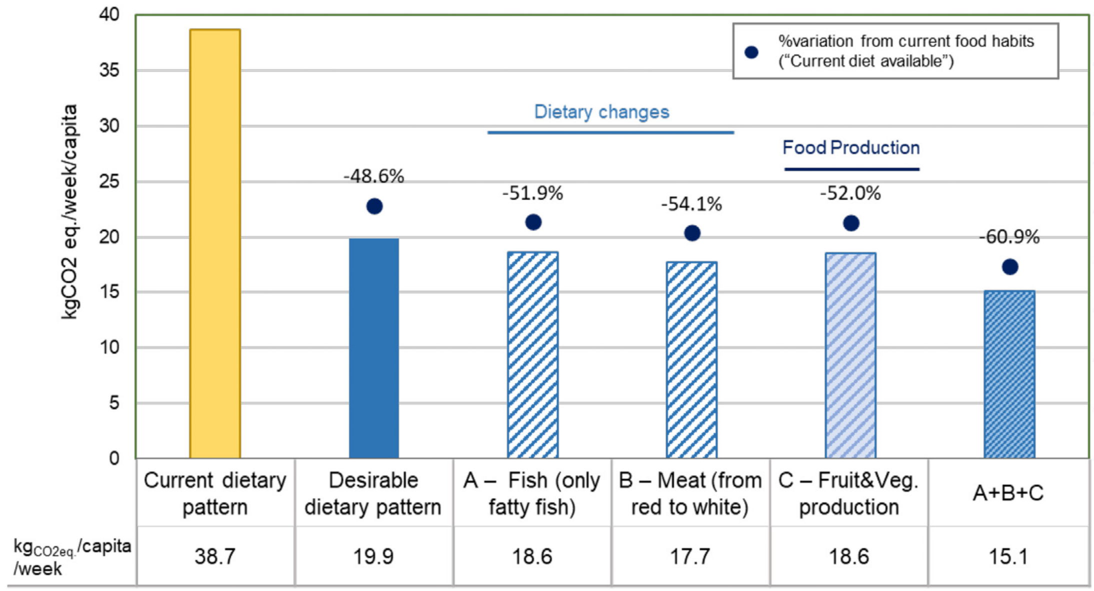

Figure 2 Reduction of the CF of the desirable dietary pattern due to the preferential choice of specific items within fish (A), meat (B), and fruit and vegetables (C).

association between the consumption of various food groups and hard health outcomes – namely fatal and non-fatal cardiovascular events. This method allowed us to avoid the use of complex algorithms which may lead to the overestimation of health advantages linked to the proposed diet, thus avoiding to get into some of the criticisms addressed to the EAT-Lancet Commission diet [24,25].

Also, to account for potential criticisms usually addressed to diets including less meat and more plant-based foods [26], the proposed dietary pattern has been evaluated for its nutritional adequacy. Compared to the current diet adopted by Europeans, this pattern is characterized by a lower energy content and a lower intake of SFAs, cholesterol, added sugars, and high GI foods, as well as a higher intake of long-chain omega-3 fatty acids (almost 2 g/per day), monounsaturated fatty acids, and fiber. As such, it complies with current authoritative recommendations on the appropriate fatty acids composition of the diet for health promotion [27] and with dietary guidelines that recommend reducing food sources of SFA and replace them with those rich of mono and polyunsaturated fatty acids [19,22] – in particular long-chain omega-3 with well-known anti-inflammatory and anti-thrombotic properties [28–30]. Besides the preferential consumption of plant-based foods, the desirable dietary pattern includes moderate intakes of foods of animal origin like dairy products (especially the fermented ones), eggs, white meat, and fish. This allows us to avoid too stringent limitations not feasible in the long term and the risk of developing nutritional deficiencies [31]. As for carbohydrates rich foods, the proposed dietary pattern preferentially includes those of higher nutritional quality (i.e., wholegrains, low for GI refined cereals, and lower intake of added sugars), able to contribute substantially to the reduction of cardiometabolic risk [20,32,33]. Finally, the desirable diet fulfills the recommended intake of calcium, iron, and vitamin B12 [27].

The transition toward the proposed dietary pattern could also reduce by almost 50% the CF linked to food consumption in Europe. This is consistent with prior studies showing that dietary shifts are regarded as effective measures to contribute to global climate mitigation objectives [10,24]. Importantly, foods with the highest CF in the current diet are also those to be consumed in limited amounts (i.e., red and processed meat, high GI refined cereals, or potatoes) or moderate amounts (i.e., milk and cheese) for CVD prevention.

These findings can contribute to inform food-based dietary guidelines that integrate environmental sustainability into dietary recommendations. Notably, some of the current dietary guidelines have very high CF [34]. Despite the increasing evidence available, most of the countries that have issued dietary recommendations focus on health only [16]. Moreover, about a third of food-based dietary guidelines are incompatible with the recommendations issued in the Paris Agreement and other environmental targets [35]. It has been recently shown that plant-rich dietary patterns (as the Italian and Mediterranean ones) are the best in terms of CF [36]; in fact, a daily substitution of 10% of energy intake from beef and processed meat with legumes, nuts, vegetables, and certain types of seafood can generate substantial health improvements as well as a 33% CF reduction [37]. Minimally processed plant-based foods, such as fruits, vegetables, legumes, wholegrains, and low and high GI foods have the lowest CF. Nevertheless, production factors, such as the use of synthetic fertilizers as well as greenhouse and heating in the cultivation phase, can significantly contribute to climate change [38,39]. Therefore, to minimize the impact of diets on climate change, dietary choices should aim not only to change food distribution in the diet but also to choose, within each food group, the items with the lowest CF, with an emphasis on consumption of local and seasonal foods.

Current dietary habits are also characterized by a percent of food waste that has not been considered so far in this study. Food waste causes the additional emission of 10.33 and 6.87 kg CO_2 eq/capita/week in the current and the desirable dietary pattern, respectively (Supplemental Table 4). These emissions could be avoided through the complete elimination of food waste. This action could be particularly relevant, since among food groups for which an increased consumption would be desirable – given their beneficial impact on health – some are associated with a high proportion of food waste (i.e., wholegrains, low GI cereals, fruit, vegetables, and fish) (Supplemental Fig. 1).

A dietary pattern designed to minimize the risk of CVD can also be a tool to guide the physicians as well as other health professionals toward a more effective dietary intervention, within the effort to fill the gap of minimal or no training in evidence-based nutrition of most of them, resulting in no active engagement in educating their patients [40–42] – in a region where CVD, despite largely preventable, are still the leading cause of mortality and poor quality of life [5,43,44]. In addition, non-communicable disease account for 70–80% of healthcare costs in the European Union [17], and it can be speculated that the transition toward the proposed healthy dietary pattern might contribute to optimize the prevention of other widespread chronic diseases like cancer and neurodegenerative disease, thus leading to further advantages.

Some study limitations must be acknowledged. First, the proposed consumptions of the various foods are based on meta-analyses of observational studies with hard endpoints rather than randomized controlled trials (RCTs), which represent the best source of evidence among all the study designs. Yet, RCTs on diet and cardiovascular events are few, given the intrinsic limitations linked to test dietary changes in the long-term (e.g., compliance, single dietary changes, costs, statistical power, etc.). Prospective cohort studies, tough based on self-reported dietary assessments and limited by residual confounding, allow to evaluate the relationship between eating behaviors and hard endpoints in large, compliant, and representative populations over long periods [45].

Secondly, CF database presents limited data on different production systems (e.g., organic vs. conventional; intensive vs. non-intensive livestock systems).

5. Conclusion

This study clearly demonstrates that the transition from the current to the desirable dietary pattern for the optimization of CVD prevention could also reduce GHG emissions linked to food consumption in Europe almost by half. Furthermore, the dietary pattern, here, identified shown to be fully coherent with the reference values for nutrient intake established by EFSA, in contrast with the current Europeans' one. This study sheds light on the significant improvements that could be achieved in Europe with regard to CVD prevention and climate change mitigation through the adoption of the proposed diet by the adult general population. Within this context, the diet here identified might be a tool to ease the translation of the scientific evidence at the population level, thus responding to the urgent need of involving both health professionals and common people in informing and adopting the appropriate food choices for CVD prevention and climate change mitigation.

Funding

I.C. is the recipient of a scholarship within the framework of "Progetto di Ricerca Finalizzata (RF_201602364513)".

Author contributions

A.G. and F.R. contributed equally to this paper. G.R., O.V., and M.A. conceptualized the project. A.G. and F.R. administered the project. I.C. and K.D. assessed the nutritional adequacy of the dietary patterns. M.V. curated data on foods available for consumption in Europe. F.R. and M.A. assessed the environmental impact of the dietary patterns. A.G., F.R., I.C., and M.A. curated the data, validated the results, and carried out the data visualization. A.G., G.R., F.R., and M.A. wrote the original draft of the manuscript. O.V., G.R., S.C., and F.G. reviewed manuscript. A.G., F.R., I.C., and M.V. edited the manuscript. All authors reviewed and approved the final manuscript. M.A. accepts full responsibility as guarantor of the work, conduct of the study, access to the data, and controlling the decision to publish.

Declaration of competing interest

G.R. is member of the Barilla Health and Well-being advisory board of the Nutrition Foundation of Italy and of 'Istituto Nutrizionale Carapelli'.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.numecd.2022.08.001.

References

[1] Lehmann B, Burlingame B, Clapp J, Solh M El, Kadlečíková M, Xiande L, et al. HLPE High Level Panel of Experts on Food security and nutrition: building a global narrative towards 2030. 2020. 1–112.
[2] Branca F, Lartey A, Oenema S, Aguayo V, Stordalen GA, Richardson R, et al. Transforming the food system to fight non-communicable diseases. BMJ 2019;364:l296. https://doi.org/10.1136/bmj.l296.
[3] World Health Organization. World health statistics. 2021.
[4] Wilkins E, Wilson L, Wickramasinghe K, Bhatnagar P, Leal J, Luengo-Fernandez R, et al. European cardiovascular disease statistics 2017, European heart Network, Brussels. Eur Cardiovasc Dis Stat 2017;34:3028–34.
[5] Global, regional, and National comparative risk assessment of 84 behavioural, environmental and occupational, and metabolic risks or clusters of risks for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study. Lancet (London, England) 2018;392:1923–94. https://doi.org/10.1016/S0140-6736(18)32225-6.
[6] Meier T, Gräfe K, Senn F, Sur P, Stangl GI, Dawczynski C, et al. Cardiovascular mortality attributable to dietary risk factors in 51 countries in the WHO European Region from 1990 to 2016: a systematic

analysis of the Global Burden of Disease Study. Eur J Epidemiol 2019; 34:37–55. https://doi.org/10.1007/s10654-018-0473-x.
[7] Riccardi G, Giosuè A, Calabrese I, Vaccaro O. Dietary recommendations for prevention of atherosclerosis. Cardiovasc Res 2022;118: 1188–204. https://doi.org/10.1093/cvr/cvab173.
[8] Herrero M, Henderson B, Havlík P, Thornton PK, Conant RT, Smith P, et al. Greenhouse gas mitigation potentials in the livestock sector. Nat Clim Change 2016;6:452–61. https://doi.org/10.1038/nclimate2925.
[9] Poore J, Nemecek T. Reducing food's environmental impacts through producers and consumers. Science 2018;360:987–92. https://doi.org/10.1126/science.aaq0216.
[10] IPCC. Climate change and land: an IPCC special report. In: Clim Chang L an IPCC Spec Rep Clim Chang Desertif L Degrad Sustain L Manag Food Secur Greenh Gas Fluxes Terr Ecosyst; 2019. p. 1–864.
[11] Crippa M, Solazzo E, Guizzardi D, Monforti-Ferrario F, Tubiello FN, Leip A. Food systems are responsible for a third of global anthropogenic GHG emissions. Nat Food 2021;2:198–209. https://doi.org/10.1038/s43016-021-00225-9.
[12] Hjorth T, Huseinovic E, Hallström E, Strid A, Johansson I, Lindahl B, et al. Changes in dietary carbon footprint over ten years relative to individual characteristics and food intake in the Västerbotten Intervention Programme. Sci Rep 2020;10:20. https://doi.org/10.1038/s41598-019-56924-8.
[13] Xu X, Sharma P, Shu S, Lin T-S, Ciais P, Tubiello FN, et al. Global greenhouse gas emissions from animal-based foods are twice those of plant-based foods. Nat Food 2021;2:724–32.
[14] Petersson T, Secondi L, Magnani A, Antonelli M, Dembska K, Valentini R, et al. A multilevel carbon and water footprint dataset of food commodities. Sci Data 2021;8:127. https://doi.org/10.1038/s41597-021-00909-8.
[15] Springmann M, Clark M, Mason-D'Croz D, Wiebe K, Bodirsky BL, Lassaletta L, et al. Options for keeping the food system within environmental limits. Nature 2018;562:519–25. https://doi.org/10.1038/s41586-018-0594-0.
[16] FAO and FCRN. Plates, pyramids, planet Developments in national healthy and sustainable dietary guidelines: a state of play assessment. 2016.
[17] European Commission. Farm to Fork Strategy. DG SANTE/Unit 'Food Inf Compos Food Waste'. 2020. p. 23.
[18] Food and Agriculture Organization. Global food losses and waste—extend. Causes Prev 2011.
[19] Mach F, Baigent C, Catapano AL, Koskinas KC, Casula M, Badimon L, et al. 2019 ESC/EAS Guidelines for the management of dyslipidaemias: lipid modification to reduce cardiovascular risk. Eur Heart J 2020;41:111–88. https://doi.org/10.1093/eurheartj/ehz455.
[20] Augustin LSA, Kendall CWC, Jenkins DJA, Willett WC, Astrup A, Barclay AW, et al. Glycemic index, glycemic load and glycemic response: an International scientific consensus summit from the International carbohydrate quality consortium (ICQC). Nutr Metabol Cardiovasc Dis 2015;25:795–815. https://doi.org/10.1016/j.numecd.2015.05.005.
[21] Guideline. Sugars intake for adults and children. Guideline: sugars intake for adults and children. World Heal Organ 2018;57: 1716–22.
[22] Mensink RP, Organization WH. Effects of saturated fatty acids on serum lipids and lipoproteins: a systematic review and regression analysis. World Health Organization; 2016.
[23] Giosuè A, Calabrese I, Lupoli R, Riccardi G, Vaccaro O, Vitale M. Relations between the consumption of fatty or lean fish and risk of cardiovascular disease and all-cause mortality: a systematic review and meta-analysis. Adv Nutr 2022. https://doi.org/10.1093/advances/nmac006.
[24] Willett W, Rockström J, Loken B, Springmann M, Lang T, Vermeulen S, et al. Food in the Anthropocene: the EAT-Lancet Commission on healthy diets from sustainable food systems. Lancet (London, England) 2019;393:447–92. https://doi.org/10.1016/S0140-6736(18)31788-4.
[25] Zagmutt FJ, Pouzou JG, Costard S. The EAT-Lancet Commission: a flawed approach? Lancet (London, England) 2019;394:1140–1. https://doi.org/10.1016/S0140-6736(19)31903-8.
[26] Millward DJ, Garnett T. Plenary Lecture 3: food and the planet: nutritional dilemmas of greenhouse gas emission reductions through reduced intakes of meat and dairy foods. Proc Nutr Soc 2010;69:103–18. https://doi.org/10.1017/S0029665109991868.
[27] Dietary reference values for nutrients summary report. EFSA Support Publ 2017;14. https://doi.org/10.2903/sp.efsa.2017.e15121.
[28] Mozaffarian D. Dietary and policy priorities for cardiovascular disease, diabetes, and obesity: a comprehensive review. Circulation 2016;133:187–225. https://doi.org/10.1161/CIRCULATIONAHA.115.018585.
[29] Augustin LSA, Montagnese C, Calabrese I, Porciello G, Palumbo E, Vitale S, et al. Diet and cancer. In: Boffetta P, Hainaut P, editors. Encycl. Cancer. 3rd ed. Oxford: Academic Press; 2019. p. 471–500. https://doi.org/10.1016/B978-0-12-801238-3.65132-2.
[30] Tokgozoglu L, Hekimsoy V, Costabile G, Calabrese I, Riccardi G. Diet, lifestyle, smoking. Handb Exp Pharmacol 2022;270:3–24. https://doi.org/10.1007/164_2020_353.
[31] Craig WJ, Mangels AR, Fresán U, Marsh K, Miles FL, Saunders AV, et al. The safe and effective use of plant-based diets with guidelines for health professionals. Nutrients 2021;13. https://doi.org/10.3390/nu13114144.
[32] Riccardi G, Rivellese AA, Giacco R. Role of glycemic index and glycemic load in the healthy state, in prediabetes, and in diabetes. Am J Clin Nutr 2008;87:269S–74S. https://doi.org/10.1093/ajcn/87.1.269S.
[33] Riccardi G, Costabile G. Carbohydrate quality is key for a healthy and sustainable diet. Nat Rev Endocrinol 2019;15:257–8. https://doi.org/10.1038/s41574-019-0190-x.
[34] Kovacs B, Miller L, Heller MC, Rose D. The carbon footprint of dietary guidelines around the world: a seven country modeling study. Nutr J 2021;20(15). https://doi.org/10.1186/s12937-021-00669-6.
[35] Springmann M, Spajic L, Clark MA, Poore J, Herforth A, Webb P, et al. The healthiness and sustainability of national and global food based dietary guidelines: modelling study. BMJ 2020;370: m2322. https://doi.org/10.1136/bmj.m2322.
[36] Cambeses-Franco C, González-García S, Feijoo G, Moreira MT. Driving commitment to sustainable food policies within the framework of American and European dietary guidelines. Sci Total Environ 2022;807:150894. https://doi.org/10.1016/j.scitotenv.2021.150894.
[37] Stylianou KS, Fulgoni VL, Jolliet O. Small targeted dietary changes can yield substantial gains for human health and the environment. Nat Food 2021;2:616–27. https://doi.org/10.1038/s43016-021-00343-4.
[38] Maraseni TN, Cockfield G, Maroulis J, Chen G. An assessment of greenhouse gas emissions from the Australian vegetables industry. J Environ Sci Health Part B Pestic Food Contam Agric Wastes 2010;45:578–88. https://doi.org/10.1080/03601234.2010.493497.
[39] Clune S, Crossin E, Verghese K. Systematic review of greenhouse gas emissions for different fresh food categories. J Clean Prod 2017;140:766–83. https://doi.org/10.1016/j.jclepro.2016.04.082.
[40] Aspry KE, Van Horn L, Carson JAS, Wylie-Rosett J, Kushner RF, Lichtenstein AH, et al. Medical nutrition education, training, and competencies to advance guideline-based diet counseling by physicians: a science advisory from the American heart association. Circulation 2018;137:e821–41. https://doi.org/10.1161/CIR.0000000000000563.
[41] Reddy KR, Freeman AM, Esselstyn CB. An urgent need to Incorporate evidence-based nutrition and lifestyle medicine into medical training. Am J Lifestyle Med 2019;13:40–1. https://doi.org/10.1177/1559827618781764.
[42] Devries S, Agatston A, Aggarwal M, Aspry KE, Esselstyn CB, Kris-Etherton P, et al. A deficiency of nutrition education and practice in cardiology. Am J Med 2017;130:1298–305. https://doi.org/10.1016/j.amjmed.2017.04.043.
[43] Global regional. National disability-adjusted life-years (DALYs) for 359 diseases and injuries and healthy life expectancy (HALE) for 195 countries and territories, 1990-2017: a systematic analysis for the Global Burden of Disease Study 2017. Lancet (London, England) 2018;392:1859–922. https://doi.org/10.1016/S0140-6736(18)32335-3.
[44] Yu E, Malik VS, Hu FB. Cardiovascular disease prevention by diet modification: JACC health promotion series. J Am Coll Cardiol 2018;72:914–26. https://doi.org/10.1016/j.jacc.2018.02.085.
[45] Satija A, Yu E, Willett WC, Hu FB. Understanding nutritional epidemiology and its role in policy. Adv Nutr 2015;6:5–18. https://doi.org/10.3945/an.114.007492.