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Mediterranean Diet and Its Environmental Footprints Amid Nutrition Transition: The Case of Lebanon

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Received: 5 August 2019; Accepted: 15 October 2019; Published: 26 November 2019

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Abstract: Many Mediterranean countries, including Lebanon, are experiencing a shift in food consumption away from the traditional Mediterranean diet (MD), concomitant with the escalating burden of non-communicable diseases and dwindling environmental resources. Objective: to examine the adherence to the MD and its association with environmental footprints (EFPs), including water use, energy use, and greenhouse gas (GHG) emissions, among Lebanese adults. Data of Lebanese adults were drawn from the national food consumption survey (n = 2610). Assessment of dietary intake was conducted using a food-frequency questionnaire. Adherence to the MD was examined using four published MD scores. Metrics for the EFPs were calculated using a review of existing life cycle assessments (LCAs). For all MD scores, less than 13% of participants were in the highest tertile. After adjustments for covariates, two of the MD scores were associated with lower water use. For GHG, significant inverse associations were observed with all MD scores. Energy use was not associated with MD scores. Overall, low adherence to the MD among Lebanese adults was observed, together with an inverse association between adherence to the MD and water use and GHG emissions. These findings support and enforce ongoing efforts that aim to increase adherence to the MD in order to address health issues, as well as tackle environmental sustainability.

Keywords: Mediterranean diet; sustainable diets; environmental footprints; Lebanon

1. Introduction

Over the last few years, many countries of the Middle East and North Africa (MENA) have witnessed a gradual change in food consumption, marked by erosion of traditional diets and an increased predominance of Western diets [1]. Such a change, also named nutrition transition, is characterized by increased consumption of animal-derived food products that are high in energy, fat, added sugars, and salt, and a decreased intake of plant-based food, such as fruits, vegetables, dietary fibers, and complex carbohydrates [2–5]. Possible causes of this phenomenon are the pervasive propagation of Western culture and principles, together with the globalization of food production and consumption [6,7]. Through its distinctive changes in food and dietary intake, the nutrition transition is postulated as the main factor in the etiology of many diet-related diseases for which rates are surging in many countries of the MENA. These diseases included many non-communicable diseases (NCDs), such as obesity, heart disease, diabetes, hypertension, and some types of cancer [8]. Such a high prevalence of NCD has prompted national and regional authorities to call for the formulation of dietary guidelines and recommendations to promote the consumption of balanced diets that could prevent and decrease the risk of NCDs [9]. These guidelines did not account for the impact of such dietary patterns on the environment in a region that suffers from water deprivation, land degradation, and excessive energy use [10].

Food production, distribution, and consumption are arguably the major human activities with a direct impact not only on human health but also on environmental sustainability [11]. Environmental footprints (EFPs) characterized by land, water, and energy use, along with greenhouse gas (GHG) emissions, are the major environmental impacts of personal food consumption and are expected to become even more prominent with the rapidly growing human population [12–14]. As such, both health and environmental perspectives need to be accounted for when re-forming food systems and dietary patterns [1,15–17], giving rise to the notion of sustainable diets. Sustainable diets are defined as those diets that are protective of the environment and health, affordable, easily accessible, culturally acceptable, and nutritionally adequate, simultaneously optimizing natural and human resources, and contributing to food and nutrition security [18]. The Rockefeller Foundation–Lancet Commission on Planetary Health stated that the shift to sustainable diets could potentially improve health and decrease the environmental impacts of food production and consumption [19], paving the way toward the Sustainable Development Goals (SDGs), specifically those related to health, water use, climate change, and sustainable agricultural practices.

The Mediterranean diet (MD) was proposed as an example of not only a healthy but also a sustainable diet [20]. Though no single definition exists for this diet, it is agreed that the MD represents a constellation of complex cultural expressions specific to countries of the Mediterranean basin and which include Mediterranean food, namely fruits, vegetables, and olive oil, as well as other characteristic lifestyle behaviors [21]. The health benefits attributed to this diet include protection against obesity, cardiometabolic risk factors, and diseases, including cancer [22–24]. Recently there were several reports in the literature examining the sustainability aspects of the MD in terms of its EFPs, cultural suitability, and economic cost, in addition to its effects on health. The results of these reports showed that adherence to a MD could reduce the environmental impact of food consumption while offering significant health benefits [25]. It is important to note, however, that such conclusions ought to be contemplated through a context-specific lens, especially that EFPs are largely dependent on the available agricultural/environmental resources and practices [26].

Lebanon is a Mediterranean country that, like other countries of the MENA region, is experiencing an increased prevalence of these diet-related diseases concomitant with documented shifts in dietary intake [22,27]. Previous research in the country revealed a gradual erosion of the Lebanese Mediterranean Diet (LMD) and an increased prevalence of the Western dietary pattern [15]. Most of this research recommended a higher adherence to the LMD and limiting consumption of the Western diet. These recommendations are solely driven by the health consequences of food consumption and did not take into account the EFPs associated with dietary intake. This is of significant impact, especially when considering that Lebanon has scarce natural environmental resources, particularly water and energy [10]. Therefore, this study aimed to investigate the adherence to the MD and its association with EFPs, including water use, energy use, and GHG emissions, among Lebanese adults. A secondary objective of this study was to identify the contribution of various food groups to EFPs. The results of this study will provide the needed evidence for a holistic approach to food policy and dietary guidelines, an approach that takes into consideration health and environmental impact [28,29].

2. Materials and Methods

2.1. Survey Design

Data used in this study were taken from the national food consumption survey that took place in Lebanon between May 2008 and August 2009. A detailed description of the protocol and design of the survey is found elsewhere [23,24]. In brief, the survey followed a stratified cluster design, with the households constituting the primary sampling units. The strata were the Lebanese Governorates, while the clusters were selected further at the level of districts in both urban and rural areas. The number of households drawn from each cluster was proportional to the size of that cluster. From each household, only one adult (20 years of age or older) was chosen. The age was selected to start at 20 years given that, in Lebanon, adults at that age become increasingly independent than younger adults (18–20 years), especially with regard to the selection of their dietary intake options. For households with more than one adult available, one was picked randomly, using the Kish method [30]. Subjects had to be conversant in either Arabic or English to be included in the survey. Women who were pregnant and lactating, as well as subjects with mental disabilities, were excluded. Migrants and refugees were not included in this survey. The survey sample consisted of 2610 subjects. The distributions of the sample population across age, sex, and governorates were similar to that of the Lebanese general population as estimated by the Central Administration of Statistics (2007) [31]. In the survey, the response rate was 89.3%. This high rate was due to the fact that the team of field workers were highly trained in techniques that elicit interest in the study and hence increase participation. In addition, though no monetary compensation was provided, participants were offered dietary advice (if they wished) at the end of the interview. Ethical approval for the design and conduct of the survey was obtained from the Institutional Review Board at the American University of Beirut. All participants provided a signed written consent form before enrollment in the study.

2.2. Data Collection

At the household, trained nutritionists conducted face-to-face interviews with subjects to complete a sociodemographic and lifestyle questionnaire, in addition to a food-frequency questionnaire (FFQ). A detailed description of both of these tools is found elsewhere. Overall, the sociodemographic and lifestyle questionnaire covered information related to sex, age, marital status, education level, crowding index, and place of residence. In this questionnaire, the lifestyle factors were physical activity, smoking, breakfast and snack consumption, and eating outside the house. The International Physical Activity Questionnaire (IPAQ) was used to examine physical activity [32]. Using the IPAQ, the physical activity of participants was divided into three levels: low, moderate, and high, depending on Met-minutes per week. The latter was generated by weighting various activities by their energy requirements [32]

Dietary intake was examined using an FFQ, which included 61 food items. The previous 12 months were used as a reference period for the FFQ. Common household measures were used to estimate the portion size consumed. For the frequency of consumption, four options were listed on the FFQ, including per day, per week, per month, and rarely/never. A panel of experts, including a dietician, a nutritionist, and an epidemiologist, designed the FFQ, which was later pilot tested on a sample of Lebanese adults to ensure clarity and cultural adaptability. The food composition database of the Nutritionist IV software was used to estimate the daily gram intakes of food items and their corresponding energy intakes [33].

2.3. Mediterranean Diet Scores

Numerous indices and scores were proposed to examine adherence to the MD [34]. For the purpose of this study, and in order to ensure a wide geographical representation, international indices from different countries around the Mediterranean Basin were selected (three international indices: Greece (aMED), Spain (rMED), and France (MEDDQI)). In addition, in Lebanon, there existed a context-specific index, the LMD; hence, the latter was also included in the study. The scoring of each index is described below.

The Lebanese Mediterranean diet score (LMD) was computed as per Naja et al. [18]. It is a nine-item index based on the consumption of fruits, vegetables, legumes, olive oil, burghul (crushed whole wheat), milk and dairy products, starchy vegetables, dried fruits, and eggs. Intakes of these various food groups were divided into tertiles. One, two, and three points were given for participants falling in the first, second, and third tertiles of consumption, respectively. These points were summed to obtain an LMD score for each participant. Higher scores indicated a better adherence to the LMD. The rMED index developed by Buckland et al., in 2009, consisted of 9 food groups/foods. A value of 0, 1, and 2 was assigned to the first, second, and third tertiles of intake of fruits, vegetables, legumes, cereals, fresh fish, and olive oil. For meat and dairy products, a reverse assignment of points was used, whereby higher intakes received lower scores. For alcohol, a score of two was assigned for moderate consumers and zero for those consuming above and below the sex-specific ranges. Using this scoring, the maximum possible rMED was 18, and the minimum was 0, corresponding to maximum and minimum adherence [35,36]. The Mediterranean Diet Quality Index (Med-DQI) was developed to characterize the French MD. It is based on the consumption of 7 foods/food groups: meats, olive oil, fish, cereals vegetables, and fruits, in addition to saturated fatty acids (SFA) and cholesterol. Recommended dietary intakes (for cholesterol and SFA) or population distribution (tertiles) (for meats, olive oil, fish, cereals, vegetables, and fruits) was used to assign 1, 2, or 3 points to participants. The assignment of the points was incremental for cholesterol and SFA and decremental for olive oil, fish, cereals, fruits, and vegetables. In order to keep consistency with the other scores, whereby a higher score indicates better adherence, the following formula was used to transform the MED-DQI scores [14-(MED-DQI)]. Accordingly, the best Med-DQI had a score of 14 and the poorest was 0 [37]. The Alternate Mediterranean diet score (aMed) was adapted by Fung et al in 2009 from the original MD scale developed by Trichopoulou et al. [38,39]. The aMed consists of ten items: vegetables (excluding potatoes), fruits, nuts, whole grains, legumes, fish, monounsaturated-to-saturated fat ratio, red and processed meats, and alcohol. A 0 or 1 point was assigned to participants consuming below or above the median intake from these food groups, respectively. The scoring was reversed for red and processed meat. One point was assigned for alcohol intake between 5 and 15 g/d. The aMed score ranged between 0 and 9, with the highest score indicating maximum adherence.

2.4. Derivation of Environmental Footprints (EFPs)

Water use, energy use, and GHGs per 1 kg of each of the food items/groups included in the FFQ were calculated using a review of existing LCAs, (Appendix A, Table A1). A detailed description of the LCAs that were included in the derivation of the EFPs metrics used in this study is available elsewhere [13]. In order to select the LCAs utilized in the study, priority was assigned to those conducted in Mediterranean or neighboring countries that possess a comparable climate to Lebanon.

For water, the use of both blue and green water (combined) was calculated per kg of food consumed, taking into consideration (1) domestically versus imported portion of each of the food items [39,40] whereby the two main countries by amount from where a certain food is imported were considered, and (2) the water stress index (WSI) [41]. The formula used to calculate water use was as follows:

Water use (adjusted) = (Water Use × %produced × WSI Lebanon) + (Water Use * %Imported Total * %ImportedCountry1 * WSICountry1) + (Water Use × %Imported Total × %ImportedCountry2 * WSICountry2).

The unit used to depict the GHG metric was kg CO2 eq/kg food consumed. For LCAs where the GHG emissions were reported in terms of CH_4 and N_2O, in addition to CO2, the below conversions were used:

$$CO_{2eq\ N2O} = X_{\ N2O} \times GWP_{\ N2O} \quad (1)$$

$$CO_{2eq\ CH4} = X_{CH4} \times GWP_{CH4} \quad (2)$$

where $X_{\ N2O}$ is N_2O released (kg), X_{CH4} is CH_4 released (kg), and $GWP_{\ N2O}$ and $GWP_{\ CH4}$ refer to the 100-year global warming potential of N_2O and CH_4 (N_2O: 265, CH_4:28) [42].

In this study, energy use was expressed by MJ/kg of food consumed. For all food items/groups considered in this study, the values for energy and GHG emissions were sourced from different LCAs.

2.5. Statistical Analyses

Data in this study were analyzed using Statistical Package for Social Sciences 22.0 (SPSS for Windows, 2013, Chicago: SPSS Inc.). To describe the sociodemographic and lifestyle characteristics of study participants, counts and frequencies were used. ANOVA and t-tests were used to compare EFPs/1000 Kcal by sociodemographic and lifestyle characteristics. In order to examine the association of adherence to the MD and the EFPs, multiple linear regression analyses were conducted, in which the EFP/1000Kcal was considered as the dependent variable and the score of the MD as the independent variable. In the multiple models, in addition to the MD scores, sociodemographic and lifestyle characteristics that were significantly associated with the EFPs in the univariate analyses were entered as independent variables. All statistical analyses were two-tailed, and statistical significance was set at a p-value < 0.05.

3. Results

In the study population, the daily average EFP estimates per 1000 Kcal for water use, energy use, and GHG were 995.79 ± 348.92 L, 14.46 ± 6.21 MJ, and 1.6 2 ± 0.68 kg CO2eq, respectively. Comparisons of the means ± SD of the three EFPs associated with dietary intake among categories of sociodemographic and lifestyle characteristics are displayed in Table 1. For water and energy use, subjects 40 years and younger had significantly higher estimates as compared to older participants. For GHG, compared to other age groups, participants aged between 30 and 40 had the highest estimate. For all three EFPs, females and married subjects had lower means/1000 Kcal ($p < 0.05$). In addition, for all three EFPs, participants with an education of university or higher had significantly higher estimates. Only for water use, residents of Beirut had a higher mean significantly as compared to those living outside Beirut. While there were no significant differences in water use and GHG among smokers and nonsmokers, the latter group had significantly higher energy use. Compared to participants who do not consume breakfast, those who do have lower water- and energy-use values. Snack consumption and eating outside the home were both associated with water use, whereby subjects who consume snacks (at least one per day) and eat outside the house (at least once per week) had higher means of water use (Table 1).

The contributions of consumption of the various food groups to water use, energy use, and GHG are displayed in Figures 1–3, respectively. A description of the food items included in each of the food groups is presented in Appendix A, Table A2. For water use, in the study population, red meat consumption contributed 17.4% to the total, followed by sugar-sweetened beverages (11.7%), whole milk and milk products (11.1%), and refined grains (7.6%) (Figure 1). The main contributors to energy use were sugar-sweetened beverages (23.5%), vegetables (18%), refined grains (12.5%), and whole milk and dairy products (6.5%) (Figure 2). Red meat, vegetables, fast foods, sugar-sweetened beverages, and refined grains were the food groups with the highest percent contributions to GHG (24.9%, 10.7%, 10.6%, 9.9%, and 8%, respectively) (Figure 3).

Table 1. Environmental footprints (EFPs) associated with the dietary intake (/1000 Kcal) across categories of sociodemographic and lifestyle characteristics (n = 2610).

	N (%)	Water (L/day) Mean ± SD	Energy (MJ/day) Mean ± SD	GHG (kg CO_2eq/day) Mean ± SD
Age (years)				
20–29	755 (28.9)	1011.1 ± 237.7 [a]	14.7 ± 5.2 [a]	1.6 ± 0.5 [a]
30–39	614 (23.5)	1031.9 ± 243.5 [a]	15.0 ± 5.6 [a]	1.7 ± 0.6 [b]
40–49	482 (18.5)	967.31 ± 249.4 [b]	13.8 ± 4.9 [b]	1.6 ± 0.6b [a]
≥50	759 (29.1)	968.9 ± 525.1 [b]	14.2 ± 8.1 [a,b]	1.6 ± 0.9 [a]
sex				
Male	1206 (46.2)	961.4 ± 353.5 [a]	13.6 ± 5.8 [a]	1.6 ± 0.7 [a]
Female	1404 (53.8)	1025.3 ± 342.4 [b]	15.2 ± 6.50 [b]	1.7 ± 0.7 [b]
Marital status				
Not married	1037 (39.9)	1032.7 ± 354.3 [a]	14.9 ± 6.6 [a]	1.7 ± 0.70 [a]
Married	1562 (59.8)	971.9 ± 340.9 [b]	14.2 ± 5.9 [b]	1.6 ± 0.66 [b]
Level of education				
Up to high school	1851 (70.9)	973.6 ± 370.4 [a]	14.1 ± 6.4 [a]	1.6 ± 0.7 [a]
University and higher	759 (26.1)	1049.7 ± 283.3 [b]	15.3 ± 5.8 [b]	1.7 ± 0.6 [b]
Crowding Index				
<1	965 (37.0)	1003.3 ± 412.2	14.7 ± 7.21	1.6 ± 0.8
≥1	1597 (61.2)	989.7 ± 307.4	14.3 ± 5.6	1.6 ± 0.6
Place of residence				
Outside Beirut	2327 (89.2)	989.7 ± 343.9 [b]	14.5 ± 6.3	1.6 ± 0.8
Inside Beirut	283 (10.8)	1046.8 ± 385.0 [a]	14.0 ± 5.8	1.8 ± 0.7
Physical activity level				
Low	1093 (41.9)	1002.2 ± 632.8	14.3 ± 6.3	1.6 ± 0.7
Medium	682 (26.1)	976.7 ± 340.2	14.1 ± 5.7	1.6 ± 0.6
High	531 (20.3)	993.1 ± 372.0	14.6 ± 6.4	1.6 ± 0.7
Smoking [c]				
Nonsmoker	1070 (41.0)	1003.2 ± 328.8	14.8 ± 6.0 [a]	1.6 ± 0.6
Current smoker	1530 (58.7)	991.5 ± 359.9	14.2 ± 6.4 [b]	1.6 ± 0.7
Breakfast consumption				
Do not eat breakfast	430 (16.5)	1036.7 ± 353.3[a]	14.7 ± 6.1 [a]	1.7 ± 0.8
Eat breakfast (≥1 time per week)	2168 (83.1)	987.0 ± 347.6[b]	14.4 ± 6.2 [b]	1.6 ± 0.7
Snack consumption				
Do not eat snacks	569 (21.8)	967.2 ± 347.8 [a]	14.2 ± 6.0	1.6 ± 0.6
Eat snacks (≥1 time per day)	1689 (64.7)	1014.7 ± 287.3[b]	14.7 ± 5.8	1.6 ± 0.6
Eating out				
Do not eat outside the home	1312 (50.3)	970.9 ± 390.8 [a]	14.1 ± 6.9	1.9 ± 0.7
Eat outside home (≥ once per week)	1279 (49.0)	1022.8 ± 295.0 [b]	14.6 ± 5.4	1.8 ± 0.6

[a,b] Values with different superscripts are significantly different at $p < 0.05$. [c] Smoking referred to cigarette as well as hookah.

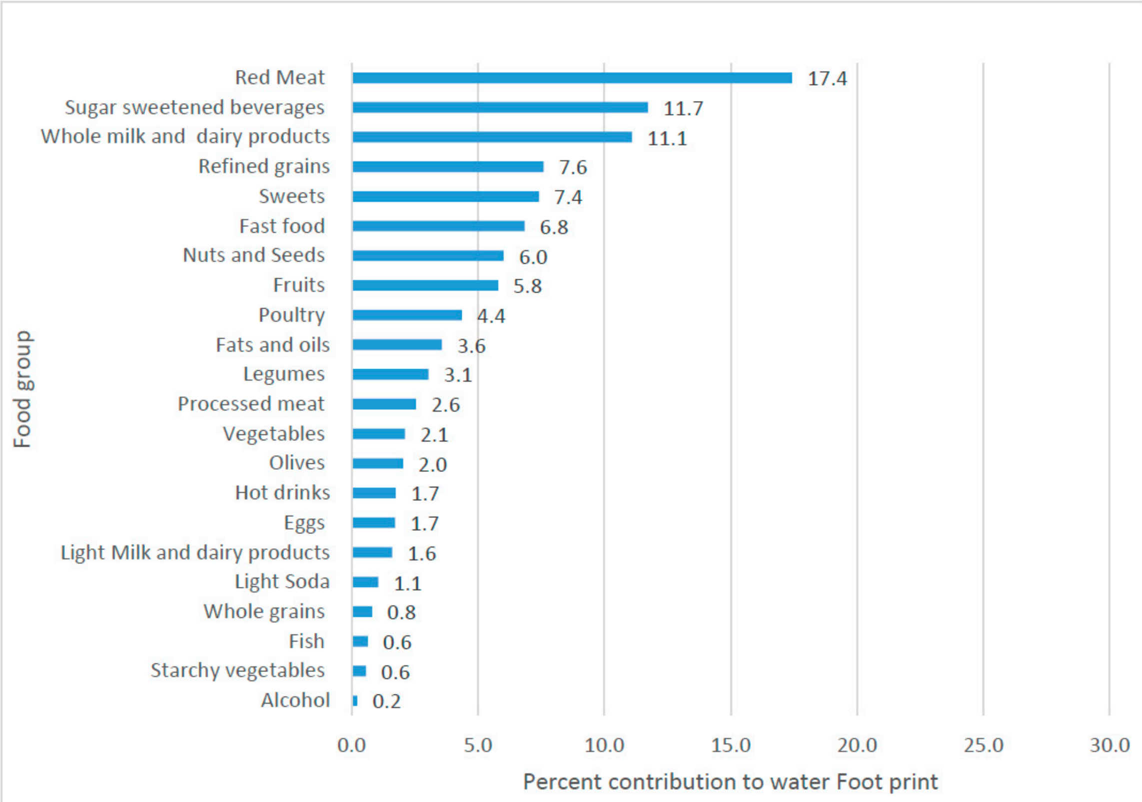

Figure 1. Percent contribution of various food groups to the total water use of dietary consumption.

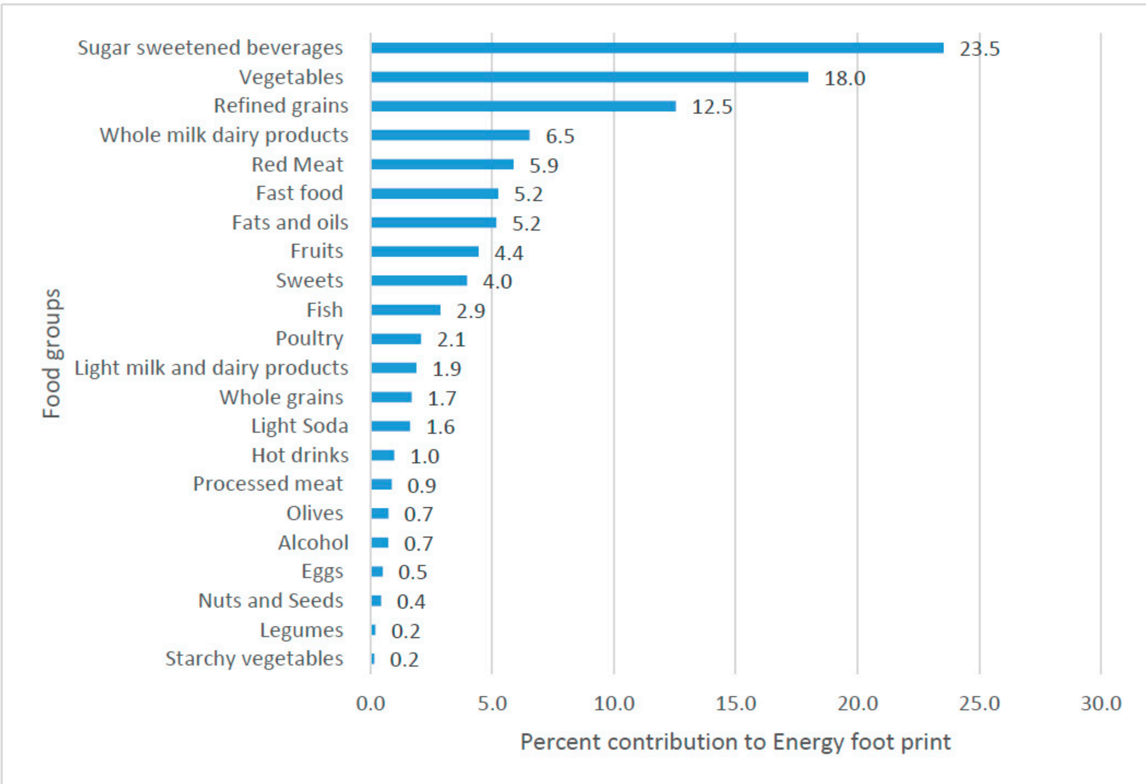

Figure 2. Percent contribution of various food groups to the energy use of dietary consumption.

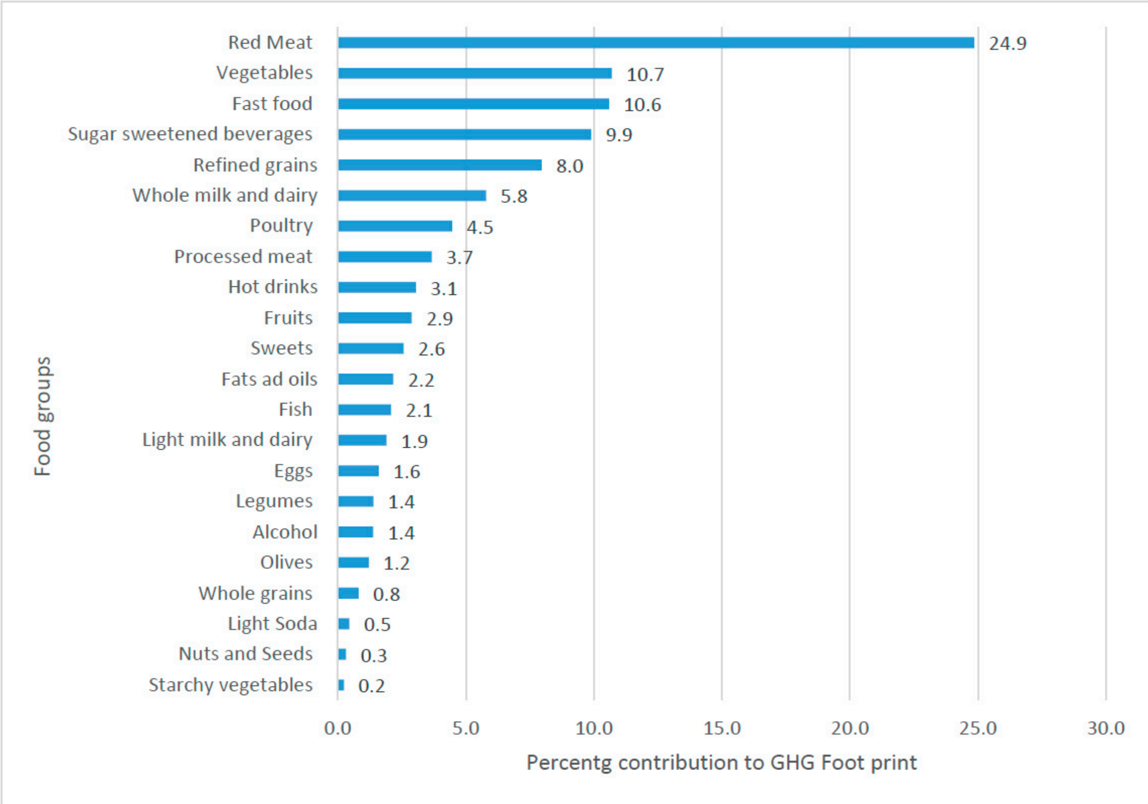

Figure 3. Percent contribution of various food groups to greenhouse gas (GHG) of dietary consumption.

A description of the score of the various MD indices among the study population is presented in Table 2. Fruits and vegetables were the two common food groups to all indices considered, and higher consumption increased the scores. Except for the MEDQQI, legumes were also considered a Mediterranean food group for the indices. On the other hand, and except for the LMD, red meat and/or meat products were negatively scored (Table 2). The distribution of the study population across the tertiles of the scores for the various MD indices considered in the study were also described in Table 2. For all indices, the majority of participants were in the second tertile, while less than 15% were in the third tertile (LMD: 12.8%, aMED: 8.8%, rMed: 6.8%, and MEDDQI: 7.2%).

Table 2. Description of the various Mediterranean diet indices (LMD: Lebanese Mediterranean Diet, aMED: Alternate Mediterranean Diet, rMED: Relative Mediterranean Diet, and MEDQQI: Mediterranean Diet Quality Index) and their corresponding adherence among the study population (n = 2610).

	LMD [a]	aMED [b]	rMED [c]	MEDQQI [d]
Food groups				
Whole grains	-	√ (+)	-	-
Cereals	-	-	√ (+)	√ (+)
Fruits	√ (+)	√ (+)	√ (+)	√ (+)
Dried fruits	√ (+)	-	-	-
Vegetables	√ (+)	√ (+)	√ (+)	√ (+)
Nuts and seeds	-	√ (+)	√ (+)	-
Legumes	√ (+)	√ (+)	√ (+)	-
Dairy products	√ (+)	-	√ (-)	-
Foods				
Burghul	√ (+)	-	-	-
Olive oil	√ (+)	-	√ (+)	√ (+)
Red meat and/or meat products	-	√ (-)	√ (-)	√ (-)
Fish	-	√ (+)	√ (+)	√ (+)
Eggs	√ (+)	-	-	-
Potatoes	√ (+)	-	-	-
Alcohol	-	√ (*)	√ (*)	-
Nutrients				
Cholesterol	-	-	-	√ (-)
SFA (%energy)	-	-	-	√ (-)
PUFA (%energy)	-	-		-
MUFA/SFA	-	√ (+)	-	-
Trans fat	-	-	-	-
Total number of components	9	9 [e]	9[f]	7[g]
Minimum possible score	9	0	0	0
Maximum possible score	27	9	17	14
Mean scores ± SD	17.5 ± 3.4	4.3 ± 1.7	14.3 ± 2.2	6.62 ± 2.0
Adherence to the MD	N (%)	N (%)	N (%)	N (%)
1st tertile (low adherence)	778 (29.8)	835 (32)	566 (21.7)	726 (27.8)
2nd tertile (moderate adherence)	1500 (57.5)	1545 (59.2)	1866 (71.5)	1697 (65)
3rd tertile (good adherence)	332 (12.7)	230 (8.8)	178 (6.8)	187 (7.2)

[a] Naja F et al. Public Health Nutr. 2011 Sep; 14(9): 1570–8. [b] Fung et al., Circulation. 2009; 119: 1093–1100 [c] Buckland G et al. Am J Epidemiol. 2009 Dec 15; 170(12): 1518–29. [d] Gerber M. Public Health Nutr. 2006 Feb; 9(1A): 147–51. The (+) was used when a higher score was assigned to a greater intake, (-) was used when a higher score was assigned to a lower intake, (*) was used when the highest score was assigned for moderate intake [e] aMED score, only nuts were only included in the nuts and seeds [g] for the rMED score, the fruit group included nuts and seeds [g] for this pattern fruits and vegetables were combined into one group.

The results of the crude and adjusted linear regression analyses describing the associations among the various scores of the MD and EFPs among study participants are described in Table 3. After adjustment for various covariates, higher scores of rMED and MEDDQI were associated with lower estimates of water use (rMED: ß= −14.34, 95% CI: −19.92, −8.77; MEDDQI: ß = −34.69; 95% CI: −41.44, −27.94). For GHG estimates, the adjusted models showed significant inverse associations with the various scores considered in the study ($p < 0.05$). On the other hand, energy use was not associated with any of the scores of the MD indices (Table 3).

Table 3. Regression coefficients (ß) and 95% CI for the associations among EFPs (/1000 Kcal) and the scores of the various MD indices considered in this study (n = 2610).

	Water (L/day)		Energy (MJ/day)		GHG (kg CO_2eq/day)	
	Crude	**Adjusted [a]**	**Crude**	**Adjusted [b]**	**Crude**	**Adjusted [c]**
LMD	−4.94 (−8.84, −1.04)	−0.66 (−4.42, 3.09)	−0.09 (−0.16, −0.02)	−0.07 (−0.14, 0.004)	−0.02 (−0.02, −0.01)	−0.02(−0.02, −0.01)
aMED	−6.90 (−14.74, 0.93)	−6.48 (−13.97, 0.10)	0.11 (−0.03, 0.25)	0.13 (−0.012, 0.27)	−0.023 (−0.04, −0.01)	−0.02 (−0.01, −0.01)
rMED	−13.73 (−19.61, −7.85)	−14.34 (−19.92, −8.77)	0.01 (−0.10, 0.11)	−0.00 (−0.11, 0.11)	−0.03 (−0.04, −0.01)	−0.03(−0.04, −0.02)
MEDQQI	−32.69 (−39.26, −26.12)	−34.69 (−41.44, −27.94)	0.14 (0.02, 0.26)	0.19 (0.06, 0.32)	−0.05 (−0.06, −0.03)	−0.06 (−0.07, −0.05)

[a] Adjusted for age, sex, marital status, education level, place of residence, breakfast consumption, snack consumption, and eating out; [b] adjusted for age, sex, marital status, education, smoking, and breakfast consumption; [c] adjusted for age, sex, marital status, and education level.

4. Discussion

The main objectives of this study were to examine the adherence of food consumption patterns to the MD diet among Lebanese adults and to investigate the association of this adherence with EFPs, including water use, energy use, and GHG emissions. The findings of the study showed an overall low adherence to the MD, with the majority of participants falling between low and moderate adherence (1st and 2nd tertile of the MD scores) and only up to 13% of study participants with high adherence (3rd tertile). Furthermore, using two of the four MD scores considered in this study (rMED and MEDQQI), a higher adherence to the MD was associated with lower water use. Negative associations were observed between GHG emissions and adherence to the MD, as assessed by the four MD scores. In addition, in this study, the main food groups contributing to EFPs were examined. The results showed that red meat, sugar-sweetened beverages, and whole milk and milk products contributed most to water use. For energy use, sugar-sweetened beverages, vegetables, and refined grains were the main contributors. Red meat, vegetables, and fast foods were the food groups with the highest percent of contributions to GHG.

The low adherence to the MD found in this study is in accordance with the nutrition transition that many countries around the globe are witnessing, especially Mediterranean countries. In these countries, traditional diets rich in fruits and vegetables are gradually eroding and being replaced by more Western-type diets that are energy-dense and rich in simple sugars and saturated fats [43]. Analysis of trends of adherence to the MD, between years 1961–1965 and 2000–2003, in forty-one countries around the globe, showed that the majority of these countries tended to deviate from a Mediterranean-like dietary pattern with a remarkable decrease in Mediterranean Europe and the other Mediterranean country groups. The most significant shift was observed in the Mediterranean European countries, most notably Greece [44]. Along the line of these findings, a systematic review of the adherence to the MD in Greece and Cyprus showed a continuing downward path with time, transitioning from dietary patterns in the 50–60 s toward a more Westernized diet [45]. Such a decline in the compliance to the Mediterranean's healthy diet patterns was already foretold in 2005 in the Mediterranean Strategy for Sustainable Development report, developed by the United Nations Environment Program: "Mediterranean agricultural and rural models, which are at the origins of Mediterranean identity, are under increasing threat from the predominance of imported consumption patterns. This trend is illustrated in particular by the decline of the Mediterranean dietary model despite the recognized positive effects on health" [46]. That said, it remains important to underscore the fact that, in this study, a sizeable proportion of the population was found to be adherent to the MD. This finding indicated that the dietary intake in Lebanon has not totally shifted to a Western diet, and the country is still undergoing nutrition transition. Therefore, it is critical for public health efforts to intervene in order to revert this transition and promote adherence to the MD in the country.

The association between adherence to the MD and EFP was investigated in previous literature; however, this is the first study that provides evidence for this association from a country from the east side of the MD basin. In fact, in this study, a higher adherence to the MD was associated with lower water use and GHG emissions. In accordance with this finding, an earlier investigation of associations among various dietary patterns prevalent in Lebanon with EFPs showed that a Lebanese dietary pattern, which shares many features of the MD, had the lowest water and GHG footprint as compared to the Western and high-protein patterns [15]. These findings are of particular significance in Lebanon, where water resources are under stress from a growing population, rapid urbanization, economic growth, mismanagement of water, pollution, climate change, and ineffective water governance [47]. Estimates for water availability per person in Lebanon is more than six times below the global average (1383 to 8462 m^3) [48]. Furthermore, available data suggested that the water stress in the country will be further aggravated in the coming years, whereby the forecasted climate change is expected to further reduce rainfall by 6%–8%, snow cover by 40%, and prolong drought periods for every 1 °C of temperature rise [49].

The effect of adherence to the MD on water use and GHG found in this study corroborates with findings of reports from other countries which showed similar negative associations of adherence to the MD with water use and GHGs. For instance, in Spain, an analysis of EFPs associated with food consumption among 20,363 adults showed that better adherence to the MD was associated with lower water use and GHG emissions [14]. A study in Italy showed that adherence to the MD would result not only in health benefits but also significant reductions in the environmental food footprint on natural resources, especially water consumption [50]. Another study in Italy highlights that the MD has a lower environmental impact compared to the actual diet of the Italian population, possibly due to the bigger portion size and higher frequencies of consumption in the actual diet as compared to the recommendation of the MD, specifically for meat, processed meat, and meat substitutes [51]. Other studies examined the effect of shifts from current food consumption patterns to the MD and showed significant reductions in EFPs. For example, increasing adherence to the MD in Spain was shown to result in 72% and 33% reductions in GHG emissions and water use, respectively [28]. Furthermore, adherence to the MD in Italy would result in a 6.81% decrease in CO2 equivalent per family as compared to the average Italian diet [52]. A more recent study in Spain showed that increasing adherence to the MD would reduce water use by about 750 l/capita/day [53]. While in the US, shifting into a MD was found to deliver even better benefits of approximately 1679 L/capita/day net water savings [54].

The negative association between the MD with water use and GHG emissions could be in part attributed to the fact that the MD does not comprise animal products consumption, rather the majority of the MD indices score meat and dairy intakes negatively. Similar to the findings of this study, meat intake was repeatedly reported as the main contributor to water use and GHG emissions [55]. Among these animal-based foods, beef products seem to have the highest EFPs. In fact, in their review of the environmental impacts of beef production, the authors concluded that the water use and GHG emissions are typically higher per unit of edible product in beef systems than in any other livestock systems, even when corrected for nutritional quality [56]. Such evidence has led scientific bodies to advocate for limiting the consumption of red meat intake. According to the EAT-Lancet commission, in order to achieve a healthy and sustainable diet, the current consumption of red meat will have to be reduced by more than 50%, reaching a range between 0 and 28 grams per person per day [57]. In Lebanon, according to a national survey conducted in 2009 [58], the mean intake of red meat was 42.26 g/day/person, being almost double the higher end of the range of intake defined by the EAT LANCET commission and also double the optimal range of intake defined by the Global Burden of Diseases (GBD) study (18–27 g/day) [59]. Therefore, limiting meat intake seems to be a sensible public health recommendation that addresses health, as well as environmental resources, in Lebanon.

The results of this study showed that adherence to the MD was not associated with energy use. This finding is inconsistent with the findings of a previous study on the Lebanese Mediterranean dietary pattern that was found to be associated with lower odds of energy use as compared to other prevalent dietary patterns in Lebanon [15]. Furthermore, findings from other countries showed a negative association between adherence to the MD and energy use. For instance, the increased adherence to the MD pattern in Spain was shown to reduce energy consumption by 52% [28]. Additionally, when compared with the national Italian average diet, the MD revealed an improvement in the environmental performance of 1149.41 MJ annually [52]. The lack of association between the adherence to the MD and energy use in this study could be related to the fact the none of the MD scores adjust for the consumption patterns of sugar-sweetened beverages, which was found to be the major contributor to energy use.

In this study, older age, being a female, and eating breakfast were associated with lower EFPs, while subjects with a higher frequency of eating snacks and eating out had significantly higher EFPs. These findings could be the reflection of differences in dietary intake among these groups. In fact, previous research in the country showed that the younger compared to older subjects and males compared to females are increasingly becoming adherent to a Western type of diet [23,24]. Such differences are hallmarks of the nutrition transition that Lebanon and other countries in the MENA are experiencing [22,27,60].

A few limitations ought to be considered in the interpretation of the findings of this study. First, although the MD has been extensively researched, no single definition exists for this diet [61]. For this reason, in this study, four different indices, including a local index, were used to characterize the MD and its corresponding adherence. Second, in the absence of local data, the estimation of the EFPs required the reliance on LCAs conducted in other countries. However, every effort was exerted to identify LCAs within neighboring countries in the MENA region, or, otherwise, use LCAs from other countries that have comparable climate and environmental conditions to Lebanon. There are other limitations to the present study, which partially relate to the general limitations associated with using FFQ to measure dietary consumption. FFQ may be associated with large measurement error due to inaccuracies in estimating frequencies over the longer term and determination of pre-quantified food items and food portion sizes [62]. Nevertheless, studies have shown that the FFQ remains the most suitable dietary data collection tool in large epidemiological studies, as it provides information on an individual's habitual diet over longer periods of times and allows ranking of individuals according to food or nutrient intake [63]. Furthermore, the use of Nutritionist IV software to calculate estimations of food and nutrient intake may pose some limitations, since many factors render databases limited in terms of local applicability. Thus, it should be recognized that some degree of bias on a survey's outcome related to food variations among countries could possibly occur [64]. However, the used database was expanded and adapted to population-based food-intake surveys previously carried out in Lebanon, by chemically analyzing nutrient values of foods and popular mixed dishes in Lebanon and the Middle East, thus preventing the loss of detailed description of certain cultural food by pre-coded recipes [65]. It is important to note that the data used in this study dated back to 2009. However, these data come from the most recent national food consumption survey, given that, since that date, no such national surveys have been conducted. More recent studies on population subgroups in Lebanon showed that dietary intake seemed to continue to shift toward a more Western type of diet with a concomitant erosion of the traditional Lebanese diet [66–68]. The findings of these studies together with the increasingly dwindling environmental resources in the country further underscore the importance of the findings of this study. That said, the regular conduct of a national food-consumption survey is warranted to provide updated information on various aspects of dietary intake in Lebanon.

5. Conclusions

In light of the global population growth and the continued strains on natural resources, it is becoming increasingly evident that actions ought to be taken to attain a more sustainable lifestyle and preserve the planet for future generations. Individuals can contribute to halting environmental degradation by making informed sustainable dietary choices. The findings of this study put forward further evidence for a positive effect of adherence to the MD on the conservation and protection of environmental resources, including water and GHG emissions. In this context, the low adherence to the MD found in this study is rather alarming in a country with surging rates of NCDs and dwindling environmental resources. Public health interventions are needed to enhance the adherence to the MD by promoting it as not only a healthy diet but also a sustainable model of dietary intake. To achieve this goal, the Lebanese food system needs to be examined and addressed to promote adherence to the traditional Mediterranean diet.

Author Contributions: Conceptualization, F.N. and N.H; methodology, L.I. and M.C.C.; formal analysis, L.I.; resources, F.N. and N.H.; writing—original draft preparation, F.N. and R.H.; writing—review and editing, F.N. and N.H.; supervision, N.H.; project administration, F.N.; funding acquisition, F.N.

Funding: This research was partially funded by Global Compact Network Lebanon.

Acknowledgments: The authors would like to thank Jeremy Zidek from Futura Food, LLC for his assistance in estimating the EFPs in this manuscript.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Table A1. Estimated water use, GHG, energy use, and erosion per kg of each of the 61 food items featured in the food-frequency questionnaire (FFQ) used in this study.

Food Type	Water Use Total (L/kg)	GHG (kg CO2eq/kg)	Energy Use (MJ/kg)
Butter and ghee	4915.254	6.04	90
Vegetable oil	1971.662	1.56	44
Non-wine alcoholic beverages	1.290	0.92	3.52
Beer	5.292	0.92	3.49
Wine	866.957	2.89	19
Nescafe tea	117.473	0.35	1
Coffee Turkish	117.473	0.35	1
Cocoa	8090.551	0.238	2.99
Fruit juices bottled	2855.683	4.85	92
Fruit juices fresh	572.893	0.75	11.9
Soda regular	626.992	0.4335	13.71
Soda light	626.992	0.4335	13.71
olives	4134.232	3.90	21.34
Mayonnaise	2303.026	2.78	32.9
Cheese low fat	4391.153	14	88
Cheese regular	4391.153	14	88
Milk half skimmed	547.744	1.5	31.73
Milk Whole	547.744	1.5	31.73
Labneh	920.586	14	88
Yogurt regular	920.586	14	88
Yogurt low fat	920.586	14	88
Nuts and seeds	4942.693	0.42	5
Deep yellow/orange fruits	1119.156	0.42	5
Dried fruits	3764.766	6.42	86.15
Other/banana/apple	684.721	0.42	5.5
Strawberry	345.141	0.42	5.5
Citrus	511.120	0.42	5
Grapes	504.142	0.42	5.5
Breakfast cereals	484.323	0.86	19.5
Rice and rice products	1332.836	2.05	19.09
Cooked pasta	521.339	1.33	17.77
Bulgur	584.100	0.86	19.5
Cakes/cookies/doughnuts/muffins	484.323	1.02	13.75

Table A1. *Cont.*

Food Type	Water Use Total (L/kg)	GHG (kg CO2eq/kg)	Energy Use (MJ/kg)
Arabic sweets	453.868	1.02	13.75
White bread	507.968	0.86	19.5
Whole bread	507.968	0.86	19.5
Manaeesh	507.968	0.86	19.5
Pizza	507.968	5.35	11.6
Luncheon	8938.708	69	43
Sausages	8938.708	69	43
eggs	2709.950	4	11
Fish	1245.997	6.47	79.83
Meat	8938.708	69	43
Offals	7341.414	37.15	32.5
Poultry	3256.508	5.3	22
chocolate	8897.743	3.08	51.38
Ice cream	458.029	14	31.73
Honey jam sugar	631.910	0.71	8
Dark green/yellow vegetables	334.822	1.602	26.9
Legumes	2072.510	1.5	20.26
Potato	248.700	0.12	0.5
Potato chips	1244.367	0.54	6
Potato fried	1244.367	0.54	6
Tomato	22.031	1.20	16.04
Salad season	228.261	1.401	21.47
Corn and peas	557.034	0.423	2.7
Zucchini eggplant	134.295	1.602	26.9
Cauliflower	242.517	1.401	21.47
Falafel sandwich	3092.667	0.53	11.1
Shawarma sandwich	3485.023	40.43	24.89
Hamburger	3868.518	34.93	31.25

Table A2. Food items included in each of the food groups.

Food Group	Items
Fats and oil	Butter, ghee, vegetable oil, mayonnaise.
Alcohol	Non-wine alcoholic beverages, wine, beer.
Hot drinks	Turkish Coffee, Nescafe, tea, cocoa
Sugar-sweetened beverages	Bottled fruit juices, regular soda.
Light Soda	Soda light.
Fruits	Fruit juices fresh, deep yellow orange fruits, dried fruits, banana apple, strawberry, citrus, grapes.
Nuts and seeds	Nuts and seeds.
Light milk and dairy products	Low-fat cheese, milk half skimmed, low-fat yogurt.
Whole milk and dairy products	Regular cheese, whole milk, yogurt regular, labneh (strained yogurt).
Vegetables	Salad season, tomato, zucchini eggplant, cauliflower, dark green yellow vegetables.
Legumes	Legumes
Red meat	Meat, offals.
Fish	Fish.
Eggs	Eggs.
Poultry	Poultry.
Processed meat	Luncheon, sausages.
Fast food	Pizza, manaeesh, falafel sandwich, shawarma sandwich, hamburger, potato chips, potato fried.
Whole grains	Bulgur, whole bread.
Refined grains	Breakfast cereals, white rice, and rice products, pasta, white bread.
Sweets	Chocolate, ice cream, honey, jam, sugar, Arabic sweets, cakes, cookies, doughnuts, muffins.
Starchy vegetables	Potato, corn, and peas
Olives	Olives

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