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Mediterranean Diet and Metabolic Diseases

Edited by
Michael Chourdakis and Emmanuella Magriplis

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About the Editors

Michael Chourdakis is an Associate Professor of Medical Nutrition–Hygiene at the School of Medicine of the Aristotle University of Thessaloniki, Greece. He has a strong interest in clinical trials (e.g., Principal Investigator of MIntS, NCT02383329, European Coordinator for the RE-ENERGIZE Study, NCT00985205) and is also the co-author of over 85 original publications, is the editor of three books on Clinical Nutrition (including the Greek version of the ESPEN Blue book) and of several chapters in clinical nutrition books in Greek, English, and German. He is a reviewer for over 12 peer-reviewed journals and serves as an assistant editor of two peer-reviewed journals. He is a member of various national and international societies, currently serving as the President of the Hellenic Society for Clinical Nutrition and Metabolism (GrESPEN) and was the IT-Officer of the European Society for Clinical Nutrition and Metabolism (ESPEN) between 2012–2017. He currently serves as the Guidelines' Officer for ESPEN (2020–24). He was a member of various national and international organizing and scientific congress committees and was the Chairman of the 1st Clinical Nutrition Congress held in Greece and the 24th ESPEN Course of Clinical Nutrition, which was held for the first time in Greece in 2017. He has participated as a lecturer and/or speaker in numerous national and international congresses/workshops/courses/LLL in more than 15 countries on 4 continents. Finally, he has been multi-awarded in 2017 and 2018 from the Faculty of Health Sciences of the Aristoteles University of Thessaloniki for his outstanding performance in various domains such as publishing, funds gathering, etc.

Emmanuella Magriplis is an Assistant Professor in Nutritional Epidemiology & Public Health at the Agricultural University of Athens (AUA), Greece. She has a strong interest in large epidemiological studies that investigate nutrition and health related diseases, mostly chronic diseases. She is the lead data analyst of the Hellenic National Nutrition & Health Survey (HNNHS). She has also collaborated on two other major studies including the European ATHLOS and an umbrella project PROgnostic Factor Evaluation—Systematic Searches, repOrting & Reviewing (PROFESSOR study). She simultaneously collaborates with the Hellenic Food Authority on public health prevention. Emmanuella Magriplis is a coauthor of 56 publications in peer-reviewed scientific journals, has contributed to the scientific editing and translation of five books, and has written three book chapters—all related to nutritional methodology, epidemiology, education, and public health nutrition. She is also a reviewer for more than 20 peer-reviewed journals and serves as a reviewing editor in two journals and has been a guest editor in over three journal-specific Special Issues. She completed her basic degree in Nutrition and Dietetics (BSc, McGill University) during which she received eight major scholarships and awards, one of which was from the Government of Canada (Natural Sciences and Engineering Research Council, NSERC), for academic excellence, having completed her studies at the top 15% of Canadian students in her field. She continued in the field of Epidemiology (MSc, University of London, LSHTM) gaining great expertise in Nutritional Epidemiology (PhD, Agricultural University of Athens, AUA).

Emmanuella Magriplis is currently affiliated with three universities other than the Agricultural University of Athens (AUA): Harokopio University, Aristoteles University of Thessaloniki, and United Arab Emirates University. For 3 years she was also affiliated with the University of Oxford (Centre for Statistics in Medicine, CSM) and worked on developing optimal methodological approaches for Systematic Review and Meta-analysis data extraction. A specific research project based on this work was published, with regard to heart failure, in a peer-reviewed journal. Emmanuella Magriplis is also currently the course coordinator and lecturer of Nutritional Epidemiology and Nutrition Education for undergraduate students. She also teaches Public Health Nutrition at the undergraduate and postgraduate level at AUA. She is also responsible for monitoring methodological and statistical research aspects for 5 Masters and 4 PhD students. Emmanuella Magriplis acts as a nutritional consultant for one of the largest Greek food manufacturing companies and is a member of the Hellenic Atherosclerosis Society and a board member of the Hellenic Nutrition Society. Emmanuella Magriplis has been recently elected as the vice president of a working group of the Hellenic Atherosclerosis Society, entitled "Epidemiology & Atherosclerosis Prevention" and has been also chosen to represent Greece at the European Commission Task Force responsible for setting Maximum Amounts of Vitamins & Minerals in Food Supplements and Fortified Foods.

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Editorial

Special Issue "Mediterranean Diet and Metabolic Diseases"

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The Mediterranean diet (MD) has been considered among the healthiest dietary patterns since a little over 50 years ago, Ancel Keys—as the key figure—provided evidence for the beneficial effects of the MD. Furthermore, MD is recognized by UNESCO as an "Intangible Cultural Heritage of Humanity" since it is an integral part of tradition and heritage as well as one of the healthiest and most sustainable dietary patterns due to the fact that its baseline is plant-based foods, non-refined grains and cereals, and of course extra virgin olive oil. The MD has been inversely associated with various chronic and metabolic diseases, including cardiovascular disease and obesity, as well as with further metabolic factors. However, in past decades studies have shown that countries in the Mediterranean basin are drifting away from this prudent pattern and are adopting a more Westernized diet. This drift is due to many multidimensional and region-specific influences, including socioeconomic, sociodemographic, environmental and cultural/ethnic, as well as factors that interfere with food preferences/dislikes, with accessibility to foods and with religious beliefs.

If present trends persist, it is expected that non-communicable diseases (NCD) will have a growing incidence, making the studies included in the present Special Issue (SI) imperative, since despite the first ecological and population-based data, the aspects of the MD that may promote health in respect to other lifestyle variables remain under investigation, as Balakoudi and colleagues concluded following a systematic review [1]. This SI contains multifaceted research articles and a systematic review, which have addressed these issues both in healthy individuals and in those with specifically defined disease states or risk factors. Specifically, this SI contains research that has been carried out in not only the general population, but also among patients with Type 1 diabetes mellitus (T1DM) [2] or dyslipidemia [3–5], as well as among firefighters who are proxy to healthy and physically fit individuals [6,7], adding valuable information to the pre-stated gap in knowledge.

A very interesting paper that has been included in the present SI examines MD adherence during the COVID-19 pandemic by Polish women diagnosed with T1DM2. The authors performed an online case control study during the peak of the second COVID-19 pandemic wave and used the Mediterranean Diet Adherence Screener (MEDAS) to assess the level of adherence to the MD. Overall, the authors found that the majority of participants had a moderate adherence and found that significantly more women with T1DM compared to healthy women adhered to olive oil, fruit and fish and seafood intake. However, a significantly larger percentage also exceeded butter consumption per day and did not adhere to red meat recommendations, indicating a higher saturated fat intake, a factor in contrast to the American Diabetes Association guidelines [8,9]. This is of importance considering the adverse effects of the COVID-19 virus on health, especially on individuals who are already at high risk, such as individuals with diabetes mellitus.

In another study, Formisano and her colleagues helped to address gaps among individuals with dyslipidemia. another risk factor for metabolic diseases, especially atherosclerotic cardiovascular disease. They aimed to evaluate how adherence to the MD affects the lipid

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profile in patients with dyslipidemia, using a retrospective design [3]. Elevated levels of low-density lipoprotein cholesterol (LDL-c) and triglycerides (TG), with low levels of high-density lipoprotein cholesterol (HDL-c), represent the most atherogenic dyslipidemic profile, which has been shown to be potentially ameliorated from a higher MD adherence. The authors reported the beneficial effects of a higher MD adherence on both HDL-c and TG levels, the latter coinciding with more frequent olive oil intake, the main denominator of the MD. Results on HDL-c were in agreement with a cross-sectional study [7] and an intervention study [6] on healthy volunteers also included in the issue [6], and results on HDL-c and TG are in agreement with the systematic review published on metabolic syndrome specific risk factors [1]. The authors found that nutritional counselling improved adherence, as was also suggested by Grabia and colleagues in their study on T1DM women [2]. The authors also addressed the main conflicting issue today with regard to recommended intakes of total saturated fats, and based on their findings they suggested that foods containing saturated fats may need to be distinguished when researched. This suggestion pertains to investigating the whole food instead of specific macronutrients, in order to consider interactions, instead of the nutrient alone.

Four of the studies included in this issue have been carried out in healthy volunteers [4–7]. Romanidou and colleagues reported that for a unitary increase in MD adherence, the ratio of total cholesterol to HDL-c decreased by 0.03 and HDL-c increased by 0.25 mg/dL in 460 firefighters, after adjusting for multiple confounders [7]. Two of the studies examined adults residing in the United Arab Emirates (UAE), one of the countries that makes up the Gulf Cooperation Council that has seen a rapid improvement in socio-economic status and a simultaneous dietary transition. This dietary transition, characterized by an increase in processed food and meat intake—both regarded as factors that act as a mediator to overweight and obesity, metabolic syndrome and other risk factors—has contributed to the estimated high mortality from NCD's in these regions in total (65–68%); in UAE, CVD accounts for 25% of all deaths, a value that reaches 29% in Abu Dhabi.

Jarrar and his colleagues evaluated urinary sodium excretion using 24-h urine samples, the ideal methodology for evaluating sodium intake from food and added salt during cooking or at the table [4]. Sodium is the mineral that has received great attention in past years, and it is widely accepted that intakes above 2300 mg increase the risk of hypertension. Sodium, other than salt, is found in high concentrations in processed foods and meat—foods that characterize Western-type diets—whereas it is low in fruit, vegetables, and legumes—foods that prevail in the MD. The authors reported that 67.4% of the population that was assessed exceeded the recommended intake of 5–6 g of salt per day, with an average of 10.4 g per day, although only 45.5% reported always adding salt to their food and only 20% were aware of their overconsumption.

These results in combination with the unhealthy dietary patterns reported by Ismail and colleagues in UAE adults [5] reveal the extent of the problem in this region. The authors performed an online study to assess dietary habits and other behaviors during the COVID-19 lockdown. This was imperative since such measures may affect food accessibility and may also trigger stress leading to a more frequent consumption of "comfort foods". Results showed that during the lockdown, almost half of the respondents consumed sweets, 1/5 also had sweetened drinks in their diet, over 1/3 of the population consumed salty snacks, and a little over 60% consumed animal protein at least once a day. These results underline that in addition to the dietary transition seen the past decades in this region, the pandemic has further triggered unhealthy dietary choices that may further increase metabolic diseases, and the authors agree with Grabia and colleagues [2] and recommend dietary counseling to increase fruits, vegetables, and other foods close to the MD pattern. Moreover, the importance of dietary counseling on the lipid profile in healthy [6,7] and dyslipidemic individuals [3] was evident by intervention studies included in the present SI.

Metabolic Syndrome is one among many metabolic diseases with a dramatic rise in the past years. It has been closely linked with the transition to a more Westernized diet and is inversely associated with the MD. In this SI, this relationship was examined by Balakoudi and colleagues through a systematic review that assessed the impact of MD adherence on various parameters of the metabolic syndrome as defined by NCEP-ATP III criteria1. These parameters included waist circumference (WC), blood pressure, fasting blood glucose, HDL-c and TG, with a total of 41 observational studies included, summing to 74,058 adults. In total, 23 studies evaluated the level of MD adherence on WC with a significantly inverse pooled effect being found. HDL-c was assessed by 39 studies (N = 31,800 individuals) and the pooled effect showed increased levels with higher MD adherence, while TG were found significantly lower, in agreement with other studies included in the Special Issue [3,6,7].

It has to be mentioned at this point that to date there is no specific value that can be used to define the ideal level for high MD adherence, an aspect that needs to be further investigated, especially following results from the 6-month intervention study performed by Sotos-Prieto and colleagues, which resulted in favorable changes in lipid profile, even with a non-significant slight increase to the MD adherence [6].

The intervention study included in this SI addressed how it can ameliorate adherence to the MD diet and how this improvement, if any, affects specific metabolic biomarkers and other anthropometrics related to CVD in firefighters [6,7]. The authors concluded that the MD may promote beneficial changes in specific lipid species, including HDL-c, all LDL-c sizes, TG, total cholesterol and ApoA/ApoB ratio, due to the high content of mono- and polyunsaturated fatty acid found in this dietary pattern [6].

Collectively, this SI includes an array of studies from various countries that address directly or indirectly the effects of MD on health and additionally address the influence of the COVID-19 pandemic, the new challenge of the decade. It effectively summarizes not only effects of specific nutrients, such as sodium and saturated fats, but also of whole foods as well, on specific risk factors and biochemical indices, as well as to end-points of diseases. Finally, it highlights the importance of addressing the best way of defining high/low adherence to the MD and the need for population-specific interventions and potentially developing new and innovative uniform tools that will lead to an increase of adherence and preserve the MD pattern.

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

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Article

The Effects of a Mediterranean Diet Intervention on Targeted Plasma Metabolic Biomarkers among US Firefighters: A Pilot Cluster-Randomized Trial

Mercedes Sotos-Prieto [1,2,3,*], Miguel Ruiz-Canela [4,5], Yiqing Song [6], Costas Christophi [3,7], Steven Mofatt [8], Fernando Rodriguez-Artalejo [1,2,9] and Stefanos N. Kales [3,10]

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Abstract: Metabolomics is improving the understanding of the mechanisms of the health effects of diet. Previous research has identified several metabolites associated with the Mediterranean Diet (MedDiet), but knowledge about longitudinal changes in metabolic biomarkers after a MedDiet intervention is scarce. A subsample of 48 firefighters from a cluster-randomized trial at Indianapolis fire stations was randomly selected for the metabolomics study at 12 months of follow up (time point 1), where Group 1 (n = 24) continued for another 6 months in a self-sustained MedDiet intervention, and Group 2 (n = 24), the control group at that time, started with an active MedDiet intervention for 6 months (time point 2). A total of 225 metabolites were assessed at the two time points by using a targeted NMR platform. The MedDiet score improved slightly but changes were non-significant (intervention: 24.2 vs. 26.0 points and control group: 26.1 vs. 26.5 points). The MedDiet intervention led to favorable changes in biomarkers related to lipid metabolism, including lower LDL-C, ApoB/ApoA1 ratio, remnant cholesterol, M-VLDL-CE; and higher HDL-C, and better lipoprotein composition. This MedDiet intervention induces only modest changes in adherence to the MedDiet and consequently in metabolic biomarkers. Further research should confirm these results based on larger study samples in workplace interventions with powerful study designs.

Keywords: Mediterranean Diet; metabolites; clinical trial; lipoprotein composition; biomarkers

1. Introduction

Currently, the understanding of diet-health relationships has gradually shifted from individual dietary components to overall dietary patterns that beneficially modulate metabolic physiology [1]. In this regard, several epidemiological and clinical studies have shown that the traditional Mediterranean-style eating pattern (characterized by high intake of fruits and vegetables, olive oil, legumes, whole grains, and fish and moderate consumption of white meat, dairy and wine during meals) has many health benefits [2,3], including beneficial changes in biomarkers of CVD risk [4,5] and lower risk of cardiovascular disease (CVD) [6–8].

However, the exact mechanisms of the benefits of the Mediterranean-style dietary pattern have yet to be understood. The application of metabolomics to measure changes in biological variables in response to dietary interventions has been proposed as a potential tool to discover biomarkers associated with healthier eating [9–13]. There is observational epidemiological evidence that acylcarnitines, Trimethylamine N-oxide (TMAO), some amino acids such as phenylalanine, glutamate as well as several lipid classes are associated with CVD risk [14]. While the effects of individual dietary ingredients on metabolome have been reported [15–20], only a few studies have focused on overall dietary patterns [21–26]. Some cross-sectional studies such as the Whitehall II study showed that a healthy diet was associated with specific fatty acids that reduced the risk of CVD [27]. In a British population, the association between the adherence to the MedDiet and cardiometabolic outcomes was mediated by baseline levels of acylcarnitines, sphingolipids, and phospholipids [24]. In the Supplementation en Vitamines et Mineraux Antioxydants (SU.VI.MAX) study, some metabolites were also cross-sectionally associated with dietary recommendations [28]. More recently, a metabolic signature of the Mediterranean Diet has been consistently identified in two large cohorts [26].

Importantly, studies analyzing changes in metabolites levels in response to MedDiet interventions are still scarce and inconclusive. In the Metabolic Syndrome Reduction in Navarra (RESMENA)study, after 2 months of an energy restricted MedDiet intervention, some significant changes in metabolites were shown but they were no longer observed after 6 months [22]. Additional evidence comes from the Prevention with Mediterranean Diet (PREDIMED) study, where several a priori-designed analyses found that the MedDiet may reduce the deleterious effect on cardiovascular or type-2 diabetes risk associated with 1 year changes in branched-chain amino acids [29,30], carnitines [31] and other metabolites. However, in most of these analyses, the 1 year metabolite changes were similar between the intervention and the control group, suggesting that the observed protective effect of the MedDiet could be due to other mechanisms.

Therefore, the objective of this study is to identify changes in plasma metabolic biomarkers associated with a MedDiet intervention within a subsample of a cluster-randomized controlled trial (Feeding America's Bravest) among firefighters. We hypothesize that the MedDiet intervention induces changes in metabolites within clinically relevant pathways.

2. Materials and Methods

2.1. Study Design and Participants

The overall study design, intervention strategies and primary outcomes of the Feeding America's Bravest trial have been previously reported [32]. Briefly, Feeding America's Bravest is a step-wedge cluster-randomized controlled trial within the 44 stations of Indianapolis Fire Department, which aims to compare a MedDiet Nutritional Intervention vs. an ad libitum Midwestern-style diet (control or no intervention) during 12 months. Group 1 (or the intervention group for 12 months) continued under a self-sustained continuation phase for another 12 months. Group 2 (initially controls) crossed over (at 12 months) to receive the active Mediterranean Diet Nutritional Intervention for 6 months followed by another 6 months of a self-sustained intervention phase. For this nested study, we randomly selected a sub-group of participants (n = 48) whose fire stations had been assigned to the MedDiet intervention (n = 24) or the control group (n = 24) for the previous 12 months. At that time (time point 1 for our study and 12 months follow up of the parent study), the intervention group (Group 1) continued under a self-sustained phase for another 6 months (time point 2 for our study or 18 months of the parent study) and the control group underwent the active MedDiet intervention for 6 months. Plasma metabolic biomarkers were analyzed at the two time points (Figure 1). The overarching Feeding America's Bravest protocol was approved by the Harvard Institutional Review Board (IRB16-0170) and is registered at Clinical Trials (NCT02941757). All participants provided informed consent for participation.

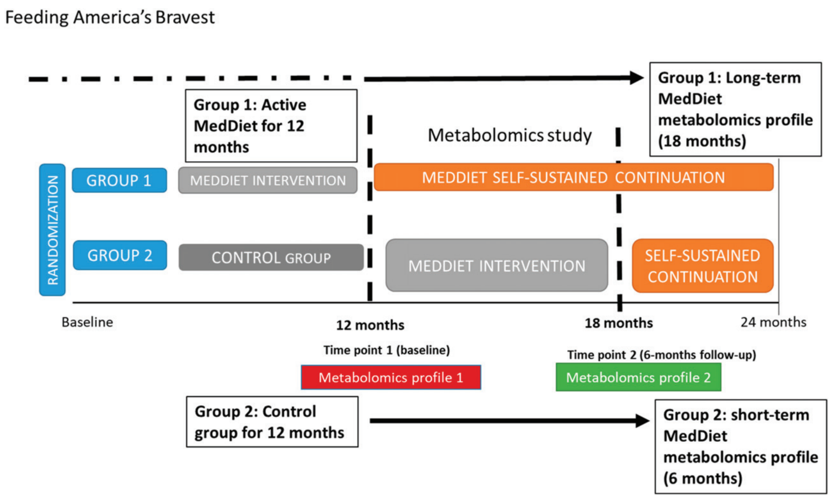

Figure 1. Study design and timeline of the metabolomics study within Feeding America´s Bravest parent study (step-wedge cluster-randomized control trial).

2.2. Mediterranean Diet Intervention

At the two time points of this study, data on sociodemographic characteristics, physical activity, sleep behaviors (a modified Pittsburgh Sleep Quality Index, where on a scale from 0 to 7 participants were asked to identify the statement which option best described their habitual level of physical activity over the past month [33]), food consumption based on a self- reported validated food frequency questionnaire [34] and a modified Mediterranean Diet scale [35], and anthropometric and clinical variables were assessed.

The MedDiet intervention has been described in detail elsewhere [32]. Briefly, it consisted of educational sessions and videos created by a certified nutritionist, leaflet and recommendations about the Mediterranean Dietand lifestyle, firefighter-tailored Mediterranean recipes (by modifying Firefighters´ favorite recipes according to the MedDiet principles by a chef and a nutritionist), in-site chef cooking demonstration, a firefighters' food pyramid, Mediterranean food samples and discount coupons to a large supermarket chain for specific Mediterranean Diet-compatible foods [32].

Adherence to the MedDiet was assessed by the validated modified Mediterranean Diet Score (mMDS) [35,36] and the PREDIMED score. (36) The mMDS range from 0 (lowest) to 51 (highest conformity to the MedDiet) [36] and consists of 13 domains including consumption of fast food, fruits, vegetables, legumes, nuts, sweet desserts, fried foods, ocean fish, breads and starches (consumed at home and the fire station), the type and frequency of alcoholic beverages, non-alcoholic beverages (consumed at home and the fire station) and the type of cooking oil or fat (consumed at home and the fire station). Each component ranged from 0 (less adherence) to 4 points (better adherence) except the type of alcohol (wine; 0–2 points) and the type of cooking oil or fat (0–5 points). Weighted scores was considered for domains evaluated at both the homes and fire stations based on the percentage of meals consumed at each location [36].

The PREDIMED score [37] consists of 14 questions; 12 of them are about food consumption frequency (olive oil consumption, vegetables, fruits, red/processed meats, butter/margarine, soda drinks, wine, legumes, fish/seafood, nuts, commercial sweets, sofrito consumption), and another two about food intake habits considered characteristic of the Spanish Mediterranean Diet (preference of poultry consumption instead of red meats, use of olive oil as main culinary fat). Each question was scored 0 or 1, with a total possible range of 0 to 14; higher scores indicate greater adherence to the MedDiet.

2.3. Collection of Plasma Samples

In this nested study, 12 h fasting blood samples were collected at time point 1 (baseline for this metabolomics study and 12 months for the trial) and time point 2 (6 months follow up for this metabolomics study and 18 months for the trial) of follow up; samples were kept cold and immediately processed to separate the plasma with a refrigerated centrifuge. Next, the 200 µL cryovials were placed at −80 °C.

2.4. Plasma Biomarkers Measurements

Metabolites were quantified in plasma samples from 83 individuals that had optimal values using high-throughput proton Nuclear Magnetic Resonance (NMR) metabolomics (Nightingale Health Ltd., Helsinki, Finland). This method provides simultaneous quantification of routine lipids, lipoprotein subclass profiling with lipid concentrations within 14 subclasses, fatty acid composition, and various low-molecular metabolites including amino acids, ketone bodies and glycolysis-related metabolites. Details of the experimentation and applications of the NMR metabolomics platform have been described previously [38]. All measured metabolites fall in the range of detection; representative coefficients of variations (CVs) for the metabolic biomarkers were published previously [39,40].

2.5. Statistical Analysis

Differences in baseline characteristics between the two groups were examined by *t*-test ANOVA for continuous variables (means ± standard deviation [SD]) or Chi-square for categorical data (percentages). Statistical analyses of the metabolites were performed on log-transformed data that were scaled to SD units to facilitate comparisons across metabolites. The effect of the MedDiet intervention between point 1 and point 2 in this analysis (6 months) was assessed using a linear mixed-effects model adjusted for age and sex. As many of the metabolites are biologically correlated, applying a multiple testing correction using all the 225 biomarkers would be too strict. Thus, account for multiple testing, Bonferroni correction was applied with significance level defined as 0.05/21 = 0.002, with 21 being the number of principal components that explained 99% of the variation in the NMR data.

Cross-sectional linear associations between the adherence to the mMDS score and metabolite concentrations at both time points for both the MedDiet intervention and control groups were obtained using a linear regression model adjusted for age and sex. The analyses were performed using ggforestplot R package (version 0.0.2) and the linear mixed-effects model was fitted with the nlme R package (version 3.1.-144).

3. Results

3.1. Participant Characteristics

Characteristics of the 48 participants at time point 1, and changes after 6 months follow up (time point 2), are summarized in Table 1. Of the 48 participants at time point 1, 44 (92%) were followed up and provided dietary information and anthropometric measures at time point 2. Information for the plasma metabolites were available for n = 47 at baseline and n = 36 at the end of follow up (Supplementary Materials Figure S1). There were no statistically significant differences in the adherence to the mMDS or PREDIMED score at time 1 and after the 6 months follow up within and between groups. Similarly, no differences were seen for age or sex (Table 1).

Table 1. Characteristics of the firefighters participating in the Feeding America's Bravest intervention study.

	Time Point 1 (n = 48)			Time Point 2 (n = 44 *)				
	12 Months MedDiet Intervention (n = 24)	Control Group (n = 24)	p-Value	18 Months MedDiet Intervention (n = 22)	Control Group After a 6 Months of Active MedDiet Intervention (n = 22)	p-Value	p-Value (Follow Up-Baseline) Intervention Group	p-Value (Follow Up-Baseline) Control Group
Sex, male (%)	91.7	95.8	0.55	84.6	94.1	0.39	N/A	N/A
Age (years)	47.5 (6.7)	47.6 (8.6)	0.95	45.9 (6.7)	49.9 (8.4)	0.17	N/A	N/A
PREDIMED score (0–14 points)	6.1 (2.1)	6.6 (2.1)	0.31	6.4 (1.9)	6.7 (1.9)	0.64	0.48	0.64
mMDs score (0–51 points)	24.2 (6.5)	26.1 (4.9)	0.27	26.0 (6.5)	26.5 (5.6)	0.81	0.23	0.52
Fast food consumption (0–4 points)	2.8 (0.94)	3 (0.61)	0.47	2.76 (0.83)	2.69 (0.63)	0.79	0.06	0.13
Fruit (0–4 points)	1.56 (0.61)	1.65 (0.79)	0.70	1.62 (0.56)	1.71 (0.69)	0.693	0.62	0.71
Vegetable (0–4 points)	1.8 (0.93)	2.11 (0.69)	0.314	1.70 (0.85)	2.06 (0.56)	0.16	0.07	0.11
Sweet desserts (0–4 points)	1 (0.69)	1.24 (0.75)	0.340	0.85 (0.69)	1.35 (0.61)	0.04	0.05	0.84
Cooking oil or fat use at home (0–5 points)	3.0 (2.20)	2.88 (1.99)	0.57	3.85 (1.77)	3.59 (1.87)	0.70	0.07	0.56
Fried food consumption (0–4 points)	0.12 (0.47)	0.35 (0.78)	0.27	0.46 (0.88)	0.71 (0.98)	0.49	0.33	0.33
Breads and starches at home (0–4 points)	2.70 (1.82)	2.39 (1.97)	0.63	1.15 (1.80)	1.41 (1.62)	0.92	0.07	0.21
Ocean fish (0–4 points)	0.78 (0.88)	0.53 (0.72)	0.37	0.39 (0.87)	0.65 (0.86)	0.42	0.09	0.33
Non-alcoholic beverage at home	2.61 (1.72)	3.06 (1.39)	0.41	2.85 (1.41)	3.11 (1.45)	0.61	0.12	0.38
Alcoholic beverages (0–4 points)	1.06 (1.26)	0.94 (1.14)	0.78	1.31 (1.43)	1.12 (1.22)	0.61	1.0	0.58
Wine (0–2 points)	1.58 (0.51)	1.89 (0.31)	0.03	1.61 (0.51)	1.82 (0.39)	0.22	0.35	0.33
Legumes (0–4 points)	3.05 (0.87)	3.06 (0.87)	0.99	3.15 (1.28)	2.53 (1.12)	0.17	0.04	0.04
Nuts (0–4 points)	2.40 (1.09)	2.6 (0.9)	0.57	2.69 (1.11)	2.47 (0.71)	0.61	0.09	0.29

Pairwise comparisons over time include only those participants with complete information at baseline and at the end of follow up (n = 23). * At the end of follow up, 44 participants provided information about diet, n = 36 plasma serum and diet information, and 30 participants were assessed for anthropometric and other cardiovascular risk factors (Figure S1). Thus, mMDS and PREDIMED included n = 44 for the analysis at the end of follow up and for the comparisons.

3.2. The 6 Month Effect of the MedDiet Intervention

Figure 2 shows the 6 months effects of the intervention in the most relevant metabolites pathways. Data on the effect of the intervention in all the metabolites studied by group are presented in Table S1. The main subgroups affected by the intervention were the lipids and lipoproteins. Specifically, we observed a reduction in LDL-C, ApoB/ApoA1 ratio, remnant cholesterol, and higher HDL-C, and other subfractions such as lower cholesterol in L-VLDL-C, S-VLDL-C, L-LDL-C, M-LDL-C, S-LDL-C lipoproteins, and the composition of the lipoproteins after 6 months of intervention. Of note, these associations did not reach statistical significance after correcting the *p*-values for multiple testing (except for a decrease in M-VLDL-CE and an increase in lactate).

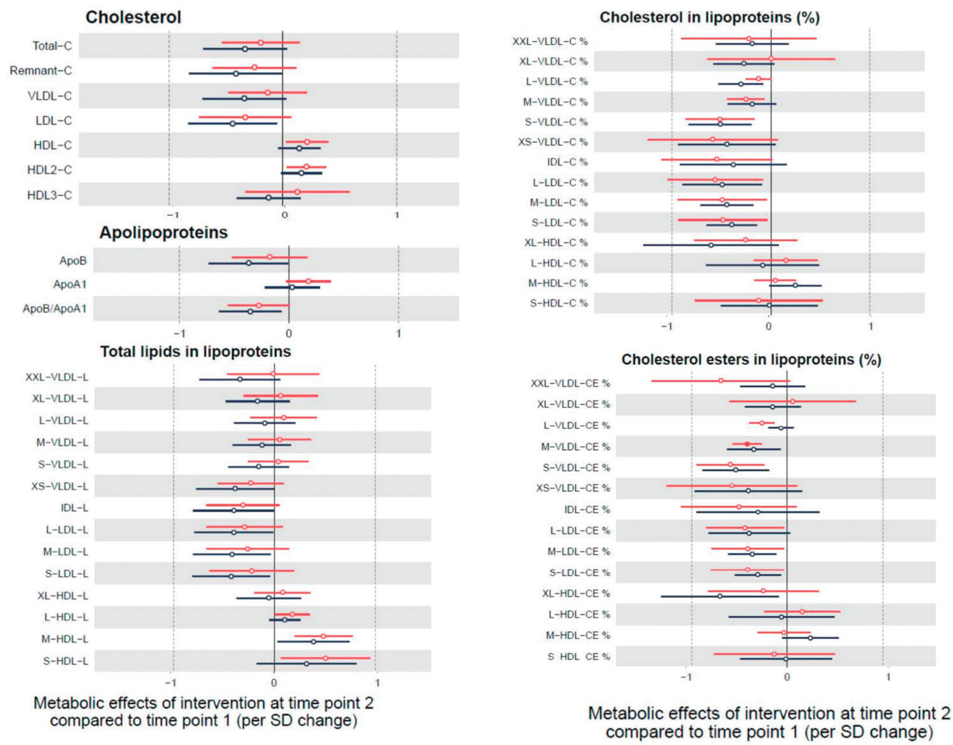

Figure 2. Metabolic effects of the intervention after 6 months follow up (time point 2) compared to baseline (time point 1) (linear mixed models adjusted by age and sex). Results show changes by SD in each metabolite per unit change in mMDS score and are displayed by hollow points. Only those significant results (after correction of multiple testing) are indicated by filled points along with their 95% confidence intervals. In black is shown Group 1 (the intervention group for 12 months) that continued under a self-sustained continuation phase for another 6 months. In red is shown Group 2 (control) that received the active Mediterranean Diet Nutritional Intervention for 6 months.

3.3. Cross-Sectional Association between Mediterranean Diet Adherence and Biomarkers

We also examined the cross-sectional linear association between biomarkers and adherence to the MedDiet at point 1 and 2 of this study, regardless of the participant's group at baseline and follow up. Results were similar at both time points, although somewhat higher effect sizes where observed at time 2 where all participants had received at least 6 months of the MedDiet intervention (Figure 3). A 1 unit difference in mMDS score was associated with lower total lipids in lipoproteins of different sizes (VLDL, LDL) and ApoB/ApoA1 ratio, lower concentrations of a marker of inflammation (Glyc A), lower concentrations of branched chain amino acids and higher polyunsaturated fatty acids (PUFAs) and Docosahexaenoic acid (DHA) (Figure 3). We further included all the participants grouped together and analyzed the association between unit changes in the MedDiet score and SD changes in metabolic markers. We found a similar pattern in the results, but not significant, with a tendency to higher lipoprotein particle size with higher MedDiet scores (Figure S2).

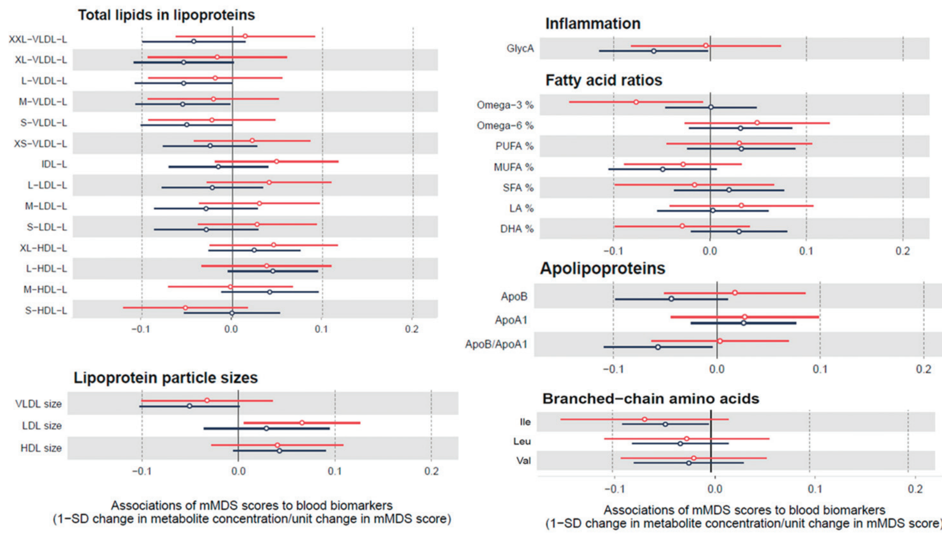

Figure 3. Cross-sectional association between biomarkers and adherence to the MedDiet for all participants at time point 1 and time point 2. Red lines show the results for the participants at baseline and black lines for the participants at follow up. Results show changes by SD in each biomarker per unit change in mMDS score and are displayed by hollow points along with their 95% confidence intervals.

Similar results were found when we used the PREDIMED score instead of the mMDS (Figure S3).

4. Discussion

In this sub-study of firefighters in Indianapolis participating in a cluster-randomized MedDiet intervention trial, we found that the MedDiet intervention was associated with favorable changes in markers of cardiovascular risk, specifically those related to the lipid metabolism (cholesterol, lipid composition, or cholesterol esters in the VLDL, IDL, and LDL lipoprotein subclasses, and ApoB/ApoA ratio) that were non-significant after correcting for multiple testing (except for a decrease in M-VLDL-CE). When the adherence to the MedDiet was measured with a self-reported scale (mMDS), the direction of the association with metabolites was similar at both time points (baseline and 6 months after the follow up).

Our results highlighting the changes in plasma metabolites related to lipid metabolism are in line with other studies [20,26]. A recent investigation that identified a metabolic signature of adherence to the MedDiet showed that out of 67 metabolites, 45 were lipids followed by 19 amino acids, 2 vitamins and 1 xenobiotic [26]. Although we used a different methodology and a different set of biomarkers, and thus we could not replicate this metabolic signature, our results support that the MedDiet may induce changes in relevant lipid species and subclasses related to atherogenic risk. In fact, the MedDiet is high in healthy fats (>35–40% of the total energy) mostly from monounsaturated fatty acids (MUFAs) (olive oil mostly) and PUFAs (from nuts and fish), and therefore the results are not surprising. In the firefighter population, we previously reported good correlation between nutrient intake from the food frequency questionnaire and the corresponding plasma biomarkers (omega-3, Eicosapentaenoic acid (EPA), and DHA) [36]. In line with these results, we found that changes in the MedDiet scores showed some tendency to be associated with fatty acids (an increase in PUFA% specifically DHA% in the expense of MUFA%). Although olive oil is a main component of the MedDiet, previous research found that higher consumption of this oil was linked to changes in omega 3, but not MUFA concentrations [36,41,42]. In addition, the average olive oil consumption in the firefighters is only approximately 0.5 tbsp/day, which is similar to other US cohorts [43] but much lower than in a Spanish cohort (4 tbsp/day) [44]. Nonetheless, it looks like changes in omega 3 to fatty acid ratio, PUFA to FA ratio and DHA to FA ratio increase with changes in the adherence to the MedDiet. This is in line with other studies [20,36], and suggests that those biomarkers could serve as indicators of adherence to the MedDiet.

We found that the MedDiet intervention induced a decrease in total cholesterol, remnant-C, VLDL-C and LDL-C and an increase in HDL-C and HDL2-C. Many studies have already demonstrated the effect of the MedDiet on total lipid metabolism, especially reducing total cholesterol and increasing HDL-C [45]. For example, the PREDIMED study, a randomized control trial, found that those in the MedDiet intervention (with olive oil or nuts) over 6 months had an increase in HDL-C but not a reduction in LDL-C [45]. Other studies support that replacing dietary saturated fatty acids (SFAs) with PUFA reduces the plasma LDL-C and subsequently the risk of cardiovascular disease [46–48].

In our study, we also observed a decrease in large, medium and small LDL fractions such as total lipids, cholesterol, particle concentration or cholesterol esters. Similarly, the MedDiet intervention decreased total cholesterol and cholesterol esters in the large, medium and small VLDL. Literature shows that VLDL concentrations are related directly or indirectly in the development of atherosclerosis [49]; for example the fatty acid composition of VLDL is critical for the activity of lipoprotein lipase and the formation of proatherogenic LDL and VLDL remnants [50]. In the FINRISK cohort, increased risk of cardiovascular disease was associated with all VLDL, IDL, and LDL subclasses, while the L- and M-HDL subclasses were associated with lower risk [51]. Despite the evidence of the role of these metabolites in CVD development, few studies have studied the effect of a MedDiet intervention in different lipids composition of lipoproteins or its subfractions. Interestingly, our results on lipid subfractions agree with a recent publication using the same metabolomic approach, where 47 participants were randomized to a SFA-rich diet, a MUFA-rich diet or a MED diet for 8 weeks. Additionally, in another study, compared to the control group, those participants that replaced SFAs with PUFAs reduced the lipoprotein particle concentration [52]. Finally, olive oil consumption modifies the lipid composition of VLDL [53] as well as the lipoprotein subfractions [54].

In our study, the effect was consistently shown in both groups, usually being stronger in the group undergoing a longer MedDiet intervention/exposure (MedDiet intervention + a self-sustained continuation phase), suggesting that the MedDiet induces favorable changes in metabolites related to CVD disease while the adherence to the MedDiet is sustained. For example, in our study, the ApoB/ApoA1 ratio was decreased in both groups after the intervention and also by adherence to the mMDS, which agrees with other short-term randomized trial with the MedDiet supplemented with olive oil, suggesting that these ratios may predict CVD beyond conventional lipid measures [55]. Finally, we found a significant association with lactate, a metabolite that was previously shown to increase the diabetes risk in the PREDIMED study [56]. However, we found that it occurs in the opposite direction.

Study Limitations

This was a pilot study with a small sample size. Possibly because of this, most associations lost statistical significance after correcting for multiple testing. However, results were in line with previous research, suggesting that a larger sample size would have retrieved significant results. In addition, the fact that we did not find differences in the mMDS adherence between groups may reflect selection bias since this is a sub-study within 400 firefighters participating in the Feeding America's Bravest trial, and participants willing to participate could potentially be healthier and more health conscious. Moreover, the control group had higher scores of mMDS at baseline and their scores were slightly improved during the intervention; however, the results were consistent in the cross-sectional analysis. We only adjusted for age and sex, since it was a randomized study with no significant differences between this sub-study and the parent study for the rest of the variables which suggests the need to perform a study that includes larger metabolites. In addition, we did not analyze other metabolites included in other studies nor at baseline for the parent study. In this pilot trial, Group 2 could be considered as the intervention group but Group 1 was not a pure control group because they already finished an active MedDiet intervention and began their self-sustained MedDiet phase. The changes in biomarkers in Group 1 (between time point 1 and 2) are more likely to reflect both residual effects of the MedDiet and continued effects from self-sustained diet intervention. Additionally, most of our participants were male and thus generalizability should be explored. In any case, the results in this study should be corroborated in larger clinical studies with longer follow up due to the pilot study nature and with a powerful study design.

5. Conclusions

This MedDiet intervention induces only modest changes in adherence to the MedDiet and consequently in metabolic biomarkers related to lipid metabolism. Further research should confirm these results based on larger study samples in workplace interventions with powerful study designs.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/12/12/3610/s1, Figure S1: Flowchart of participants at time point 1 and 2 of the Feeding America's Bravest trial, Figure S2: Associations of unit changes in mMDS score by SD changes in plasma biomarkers between month 6 (time point 2) and baseline (time point 1) in all participants grouped together, Figure S3: Association between biomarkers and the PREDIMED score adherence (cross-sectional analysis), Table S1: The 6 months effect of the Mediterranean Diet intervention on metabolic biomarkers (linear mixed model analysis with *p*-values corrected for multiple testing).

Author Contributions: All authors have participated sufficiently and meaningfully to the research study and the preparation of this manuscript. M.S.-P. formulated the study question and design, interpreted the results, and drafted the manuscript. M.S.-P. and M.R.-C. were involved in statistical modeling. M.S.-P., S.N.K., Y.S. and S.M. contributed to the conception and design of the study and acquisition of the data. All authors contributed to the interpretation of data and critical revision of the manuscript and approved the final version. M.S.P., M.R.-C. and S.N.K. share primary responsibility for the final content. All authors have read and agreed to the published version of the manuscript.

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nutrients

Article

Association of the Modified Mediterranean Diet Score (mMDS) with Anthropometric and Biochemical Indices in US Career Firefighters

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Abstract: The Mediterranean diet is associated with multiple health benefits, and the modified Mediterranean Diet Score (mMDS) has been previously validated as a measure of Mediterranean diet adherence. The aim of this study was to examine associations between the mMDS and anthropometric indices, blood pressure, and biochemical parameters in a sample of career firefighters. The participants were from Indiana Fire Departments, taking part in the "Feeding America's Bravest" study, a cluster-randomized controlled trial that aimed to assess the efficacy of a Mediterranean diet intervention. We measured Mediterranean diet adherence using the mMDS. Anthropometric, blood pressure, and biochemical measurements were also collected. Univariate and multivariate linear regression models were used. In unadjusted analyses, many expected favorable associations between the mMDS and cardiovascular disease risk factors were found among the 460 firefighters. After adjustment for age, gender, ethnicity, physical activity, and smoking, a unitary increase in the mMDS remained associated with a decrease of the total cholesterol/HDL ratio (β-coefficient −0.028, $p = 0.002$) and an increase of HDL-cholesterol (β-coefficient 0.254, $p = 0.004$). In conclusion, greater adherence to the Mediterranean diet was associated with markers of decreased cardiometabolic risk. The mMDS score is a valid instrument for measuring adherence to the Mediterranean diet and may have additional utility in research and clinical practice.

Keywords: Mediterranean diet; Mediterranean diet scores; anthropometrics; lipids; cardiometabolic risk

1. Introduction

Obesity, metabolic syndrome, and cardiovascular disease (CVD) have major impacts on US emergency responders, such as firefighters. These non-communicable, lifestyle-influenced conditions can put firefighters' career and life at risk [1–6]. The hazardous working environment, with risks of burns and physical trauma, air pollutants, physical and emotional stress, and shiftwork, causes additional stress to the cardiovascular system and may put firefighters at a higher cardiovascular disease risk with respect to the general population [7,8]. In fact, among US firefighters, sudden cardiac death is the leading cause of on-duty death, is, in most cases, due to underlying coronary heart disease and cardiomegaly, and is responsible for over 40% of duty-related deaths [9,10].

The number and proportion of CVD fatalities have remained relatively similar over the years, which suggests the need for more aggressive lifestyle-related interventions [11]. A recent study in older firefighters suggested that wellness programs can improve the cardiorespiratory function [12]. The eating and lifestyle patterns of firefighters often lead to obesity and have negative impacts on society by contributing to an increased rate of sick leave and increased healthcare expenses [13,14]. On the other hand, firefighters who follow a healthy lifestyle by exercising and maintaining a healthy weight are more likely to maintain high levels of cardiorespiratory fitness during aging [15].

The Mediterranean diet has been shown to reduce the risk of CVD and promote longevity in a variety of international settings [16–18]. There is also an increasing trend to introduce the Mediterranean diet at work as an intervention to prevent non-communicable diseases [19]. The existing evidence also suggests that adherence to the Mediterranean diet not only improves the physical health and wellbeing of workers but also may reduce work stress and blood pressure [20–22]. In two recent meta-analyses of Randomized Control Trials (RCT), the Mediterranean diet, also in combination with physical activity, was the only eating pattern which showed significant and beneficial effects on weight, body mass index (BMI) waist circumference, total cholesterol, high-density lipoprotein (HDL)-cholesterol, glucose, and blood pressure, without any evidence of adverse associations [23,24].

Various Mediterranean diet scores have been developed worldwide to quantify adherence to the Mediterranean diet [25–29]. In the ATTICA intervention in Greece, adherence was measured with the MedDietScore (0–55 items) [30,31], while the European Prospective Investigation into Cancer Nutrition (EPIC) group used the MED score (0–9 scale) [32,33]. Other adaptations include the Italian alternative Mediterranean diet score aMED (0–9 scale) [34] and the I-MEDAS from Israel (17-item questionnaire) [35]. The PREDIMED score, which is based on 14 items from the Prevención con Dieta Mediterránea in Spain, is also widely used [36,37]. However, the use of these scores in different populations, cultures, and ethnicities has been questioned, as they may not be directly adaptable to different ethnic and social groups [38].

In the US, a Mediterranean diet score was constructed specifically to measure adherence to the Mediterranean diet in career firefighters and is known as the modified Mediterranean Diet Score (mMDS) [39].

"Feeding America's Bravest" is a cluster-randomized-controlled trial that aimed to assess the efficacy of a Mediterranean Diet intervention in 60 fire stations in two Indiana (USA) Fire Departments [40]. To assess Mediterranean diet adherence, the aforementioned mMDS was used. Its validity versus previously validated questionnaires [41,42] was established using a sample of firefighters participating in "Feeding America's Bravest" [43]. The aim of the present study was to further corroborate the validity of the mMDS as a measure of Mediterranean diet adherence by examining its cross-sectional associations with anthropometric indices, blood pressure, and biochemical parameters in participants of the "Feeding America's Bravest" study.

2. Materials and Methods

2.1. Study Population

In this cross-sectional study, we used baseline nutrition surveys to calculate the mMDS from a total study base of 486 career firefighters (428 firefighters were recruited from the Indianapolis Fire Department's 44 stations and 58 from the Fishers, Indiana Fire Department's 6 stations) who consented to and enrolled in the ongoing study "Feeding America's Bravest": Mediterranean Diet-Based Interventions to change Firefighters' Eating Habits and Improve Cardiovascular Risk Profiles between 28 November 2016 and 16 April 2018 [34,39]. We excluded firefighters who did not complete baseline anthropometric measurements or if their biomarker indices were missing (Figure 1). Recruitment, consent, and study procedures were carried out by trained staff of the National Institute for Public Safety Health, who work regularly with both or the respective fire departments.

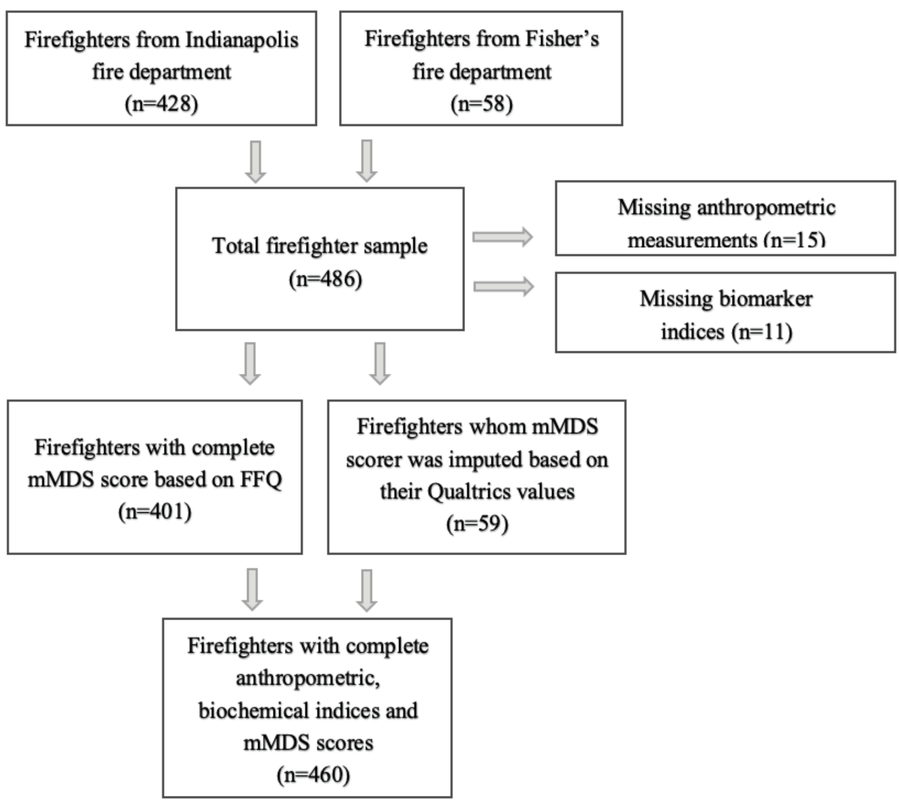

Figure 1. Flow chart for firefighters' sample selection. mMDS: modified Mediterranean Diet Score, FFQ: Food Frequency Questionnaire.

2.2. Dietary Assessment

A validated 131-item semi-quantitative Food Frequency Questionnaire (FFQ) [41] and the mMDS score [39] were used to quantify the firefighters' dietary intake patterns at baseline. The FFQ is a questionnaire previously developed by Yang et al. [39]. Two additional domains were added to the mMDS (nuts and legume consumption), and the score ranged between 0 = minimum adherence to the Mediterranean diet and 51 = maximum adherence to the Mediterranean diet. Because we had previously validated the mMDS in a Qualtrics survey with the Harvard FFQ [43] and more initial Indianapolis participants had complete FFQs, we calculated their mMDS score based on the FFQ and used a scaled value of the directly derived Qualtrics score for the Fishers firefighters who had not done an FFQ.

2.3. Physical Activity

Physical activity was calculated based on a 0–7 scale through a validated self-report scale (Self-Report of Physical Activity (SRPA)) embedded into our study questionnaire [44]. At baseline, the firefighters were asked to describe their physical activity levels over the past month using the following options: 0 = avoid walking or exertion (e.g., always use elevator, drive whenever possible instead of walking, biking, or rollerblading); 1 = walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration; 2 = 10 to 60 min per week; 3 = over one hour per week; 4 = run less than 1 mile per week or spend less than 30 min per week in comparable physical activity; 5 = run 1 to 5 miles per week or spend 30 to 60 min per week in comparable physical activity; 6 = run 5 to 10 miles per week or spend 1 to 3 h per week in comparable physical activity; and 7 = run over 10 miles per week or spend over 3 h per week in comparable physical activity.

2.4. Outcome Assessments

At baseline recruitment, the participants underwent blood pressure and anthropometric assessments as part of the initial study visit. Resting blood pressure was measured using an appropriately sized cuff in seated position for each firefighter. BMI was recorded for all study subjects in kg/m^2 from measured height and weight. Body fat (%) was estimated by a Bioelectrical Impedance Analyzer (BIA) [40,45].

Separately, the firefighters had biochemical indices assessed at fire department-sponsored medical examinations. We used the biochemical measurements gathered at the closest date from the date of study consent within the same 12-month period. Blood samples were also collected after an overnight fast at baseline and at follow-up. Using EDTA collection tubes, up to 15 mL of blood was collected. Plasma and serum were aliquoted, frozen at −80 °C, stored, and run in batches. Automated high-throughput enzymatic analysis was used to determine the blood lipid profiles of the firefighters. This analysis achieved coefficients of variation ≤3% for cholesterol and ≤5% for triglycerides, using a cholesterol assay kit and reagents (Ref:7D62–21) and triglyceride assay kit and reagents (Ref:7D74–21) by the ARCHITECT c System, Abbott Laboratories, IL, USA. The lipid measures included total cholesterol, triglycerides, total cholesterol/HDL ratio, HDL-cholesterol, and low-density lipoprotein (LDL)-cholesterol.

2.5. Covariate Assessment

We collected sociodemographic characteristics, medical history, lifestyle habits, and dietary intake from the study's comprehensive lifestyle questionnaire [40].

2.6. Statistical Analysis

Statistical analysis was performed using IBM Statistical Package for the Social Sciences (SPSS), version 19.0 (IBM Corp., Armonk, NY, USA). The normality of the quantitative variables was tested with the Kolmogorov-Smirnov test. The quantitative variables were expressed as mean ± standard deviation (SD) or as median (Q1, Q3), as appropriate. The qualitative variables were expressed as absolute and relative (%) frequencies.

Multivariable linear regression models were used to examine the association of mMDS with anthropometric, blood pressure, and biochemical variables, after adjusting for age, gender, race, physical activity, and smoking. Beta coefficients were reported with the corresponding standard errors (SE) and p values. Component items of the mMDS were compared between firefighters with high and low values of biochemical parameters using the chi-square test.

All tests were two-tailed, and statistical significance was considered for p values < 0.05.

2.7. Ethics Statement

The overarching "Feeding America's Bravest" protocol was approved by the Harvard Institutional Review Board (IRB16-0170) ethics committee and is registered at Clinical Trials (NCT02941757). All participants provided signed informed consent for participation. The participants who met the criteria for enrollment in the intervention were all informed about their right to decline participation to the intervention or to withdraw at any time as per the Declaration of Helsinki, and the participants who decided to enroll gave full informed consent as per the protocol of the research [40].

3. Results

3.1. Sampling Procedure and Outcome

A sample of 460 firefighters from the two fire departments had complete data for analysis in the current study and represented 95% of all participants who consented to the parent clinical trial (Figure 1).

3.2. General Characteristics of the Firefighters

The majority of the firefighters were males (94.4%), with a mean age of 46.7 years (SD 8.3 years). Firefighters' personal characteristics are shown in Table 1. The mean mMDS in the study population was 21.88 (SD 6.68). The majority of the firefighters were overweight/obese, with an average body fat percentage of 28.10% (SD 6.55%).

Table 1. Characteristics of the participants.

Characteristic	*N*	
Male gender, *n* (%)	448	423 (94.4)
Age (years), mean (SD)	460	46.7 (8.3)
Race, *n* (%)	311	
Caucasian		266 (85.5)
African American		39 (12.5)
Other		6 (1.9)
Currently smoking, *n* (%)	314	15 (4.8)
Physical activity *, *n* (%)	307	
Low		39 (12.7)
Medium		65 (21.2)
High		203 (66.1)
Hours sitting per week, median (Q1–Q3)	300	15 (10–24)
Number of meals at the firehouse, median (Q1–Q3)	309	3 (2–3)
FFQ mMDS, mean (SD)	460	21.88 (6.68)
Anthropometric variables		
BMI (kg/m^2), mean (SD)	460	30.01 (4.39)
Normal weight	74	16%
Overweight	156	34%
Obese	230	50%
Waist circumference (cm), mean (SD)	459	99.7 (12.5)
Body fat percentage (%), mean (SD)	458	28.10 (6.55)
Blood pressure variables		
Resting SBP (mmHg), mean (SD)	460	125.5 (11.2)
Resting DBP (mmHg), mean (SD)	460	79.1 (6.8)

Table 1. *Cont.*

Characteristic	***N***	
Biochemical variables		
Total Cholesterol (mg/dL), mean (SD)	460	197.1 (37.7)
HDL-Cholesterol (mg/dL), mean (SD)	460	48.5 (11.4)
LDL-Cholesterol (mg/dL), mean (SD)	452	123.5 (32.6)
Total Cholesterol/HDL ratio, mean (SD)	460	4.26 (1.32)
Triglycerides (mg/dL), mean (SD)	459	126.0 (76.6)
Glucose (mg/dL), mean (SD)	460	99.5 (19.6)

* Physical activity. Low: did not participate regularly in programmed recreation, sport, or heavy physical activity. Medium: participated regularly in recreation requiring modest physical activity, such as golf, horseback riding, calisthenics, gymnastics, table tennis, bowling, weight-lifting, yard work. High: participated regularly in heavy physical exercise such as running or jogging, swimming, rowing, skipping rope, running in place, or engaging in vigorous aerobic activity such as tennis. basketball, or handball. FFQ: Food Frequency questionnaire, mMDS: modified Mediterranean Diet Score, SD: Standard Deviation, BMI: body mass index, SBP: systolic blood pressure, DBP: diastolic blood pressure, HDL: high-density lipoprotein, LDL: low-density lipoprotein.

3.3. Association of the Modified Mediterranean Diet Score with Anthropometric and Biochemical Indices

The association of mMDS with the participants' anthropometric measures, blood pressure, and biochemical variables is shown in Table 2. When the mMDS scores were categorized into quartiles, multivariate analysis adjusted for age and gender revealed statistically significant inverse associations of mMDS quartiles with BMI (p = 0.030), waist circumference (p = 0.002), body fat percentage (p = 0.002), and total cholesterol/HDL ratio (p = 0.007), whereas there was a positive association with HDL-cholesterol (p = 0.002).

Table 2. Association of the mMDS (categorized into quartiles) with anthropometric measures, blood pressure, and biochemical variables.

	mMDS						
Risk Factor	**1st Quartile**	**2nd Quartile**	**3rd Quartile**	**4th Quartile**	***P* Trend ***	***P* Trend †**	***P* Trend ‡**
Number of subjects	106	122	118	114			
Anthropometric variables							
BMI (kg/m^2)	30.59 (4.06)	30.14 (4.82)	30.17 (4.70)	29.16 (3.77)	0.023	0.030	0.914
Waist circumference (cm)	102.0 (11.6)	100.6 (13.6)	99.3 (12.9)	96.8 (11.0)	0.001	0.002	0.685
Body fat percentage (%)	28.96 (5.64)	28.61 (6.38)	28.42 (7.06)	26.42 (6.75)	0.005	0.002	0.886
Blood pressure variables							
Resting SBP (mmHg)	125.7 (10.8)	124.7 (11.4)	126.6 (12.7)	125.1 (9.5)	0.980	0.836	0.515
Resting DBP (mmHg)	79.6 (7.2)	78.8 (6.7)	79.3 (6.3)	78.6 (7.1)	0.418	0.522	0.927
Biochemical variables							
Total Cholesterol (mg/dL)	200.2 (36.6)	193.1 (37.0)	198.2 (41.4)	197.5 (35.4)	0.894	0.876	0.742
HDL-Cholesterol (mg/dL)	45.6 (10.1)	48.6 (11.9)	48.7 (11.5)	50.9 (11.4)	0.001	0.002	0.022
LDL-Cholesterol (mg/dL)	127.3 (32.7)	119.5 (30.1)	124.4 (35.3)	123.6 (32.2)	0.703	0.690	0.587
Total Cholesterol/HDL ratio	4.60 (1.31)	4.19 (1.58)	4.27 (1.28)	4.03 (0.96)	0.004	0.007	0.020
Triglycerides (mg/dL)	140.8 (85.9)	118.4 (62.7)	129.2 (88.4)	116.9 (65.7)	0.071	0.107	0.364
Glucose (mg/dL)	99.9 (14.3)	100.9 (23.2)	98.6 (20.5)	98.6 (18.9)	0.450	0.594	0.770

* unadjusted; † adjusted for gender and age; ‡ adjusted for age, gender, race, physical activity, and smoking.

After further adjustment for subjects' ethnicity, physical activity, and smoking (Table 2), being in a higher mMDS quartile remained significantly inversely associated with the total cholesterol/HDL ratio ($p = 0.020$) and positively associated with HDL-cholesterol ($p = 0.022$).

3.4. Effects of a Unitary Increase in the Modified Mediteranean Score on Anthropometric Measures, Blood Pressure, and Biochemical Indices

The association of mMDS with subjects' anthropometric measures, blood pressure, and biochemical variables, as a continuous variable, was further analyzed using linear regression models (Table 3).

Table 3. Effect of a unitary increase in the mMDS on anthropometric measures, blood pressure, and biochemical variables.

	Linear Regression Models					
	Adjusted by Gender and Age			Adjusted by Age, Gender, Race, Physical Activity, and Smoking		
Risk Factor	B Coefficient	SE	p Value	B Coefficient	SE	p Value
Anthropometric variables						
BMI (kg/m^2)	−0.080	0.030	0.008	−0.026	0.038	0.490
Waist circumference (in)	−0.114	0.031	<0.001	−0.045	0.039	0.241
Body fat percentage (%)	−0.141	0.043	0.001	−0.028	0.057	0.627
Blood pressure variables						
Resting SBP (mmHg)	−0.041	0.076	0.590	0.004	0.107	0.969
Resting DBP (mmHg)	−0.056	0.046	0.223	−0.037	0.062	0.552
Biochemical variables						
Total Cholesterol (mg/dL)	−0.160	0.264	0.546	−0.289	0.332	0.385
HDL Cholesterol (mg/dL)	0.254	0.075	<0.001	0.286	0.100	0.004
LDL Cholesterol (mg/dL)	−0.193	0.230	0.402	−0.341	0.300	0.256
Total cholesterol-HDL ratio	−0.028	0.009	0.002	−0.030	0.010	0.002
Triglycerides (mg/dL)	−1.010	0.532	0.058	−0.909	0.644	0.159
Glucose (mg/dL)	−0.137	0.135	0.313	−0.155	0.186	0.404

SD, standard deviation; B, unstandardized Beta coefficient; SE, standard error.

Multivariate linear regression analysis, adjusting for subjects' age and gender, revealed that a unitary increase in the mMDS was significantly inversely associated with BMI (β-coefficient −0.080, $p = 0.008$), waist circumference (β-coefficient −0.114, $p < 0.001$), body fat percentage (β-coefficient −0.141, $p = 0.001$), and total cholesterol/HDL ratio (β-coefficient −0.028, $p = 0.002$), whereas it was positively associated with HDL-cholesterol (β-coefficient 0.254, $p < 0.001$). After further adjustment for subjects' ethnicity, physical activity, and smoking, mMDS was significantly associated with a lower total cholesterol/HDL ratio (β-coefficient −0.030, $p = 0.002$), whereas there was a positive association of mMDS with HDL-cholesterol (β-coefficient 0.286, $p = 0.004$).

3.5. Effects of Single Components of the Modified Mediteranean Score on Anthropometric Measures, Blood Pressure, and Biochemical Indices

Examining component food items of the mMDS and total cholesterol/HDL ratio, total cholesterol-HDL ratio, and blood glucose, fast-food consumption was positively associated with a total cholesterol/HDL ratio >6 ($p = 0.003$) and with triglycerides levels ≥150 mg/dL ($p < 0.001$). Sweet desserts consumption was associated with a total cholesterol/HDL ratio >6 ($p = 0.004$) and with triglycerides levels ≥150 mg/dL ($p = 0.002$), while lower consumption of fruits and vegetables was associated with a total cholesterol/HDL ratio >6 ($p = 0.049$). Fried food consumption was associated with a total cholesterol/HDL ratio >6 ($p = 0.004$) and with triglycerides levels ≥150 mg/dL ($p = 0.037$), and consumption of non-alcoholic beverages at home was associated with glucose levels ≥100 mg/dL ($p = 0.036$). No other statistically significant associations were observed (Appendix A Table A1).

4. Discussion

Our study shows that greater adherence to a Mediterranean diet, as measured by higher mMDS, was favorably associated, as expected, with various anthropometric and biochemical parameters after adjustment by age and gender. After further adjustment for ethnicity, physical activity, and smoking, a higher mMDS remained associated with a lower total cholesterol/HDL ratio and increased HDL-cholesterol. These results are generally in agreement with those of our previous larger study in a different Midwest firefighter cohort of 780 career male firefighters. The study sample was representative, as the participants had similar demographics, anthropometrics, and dietary habits to those of their entire fire departments and other mid-Western firefighters [39]. In our former cross-sectional study, the results indicated that a higher mMDS was associated with HDL-cholesterol and with lower LDL-cholesterol when adjusted for age, BMI, and physical activity and that the firefighters who adhere the most to the Mediterranean diet had a 35% lower risk of prevalent metabolic syndrome [39]. Taken together, our findings are biologically plausible based on previous research and lend additional credibility and validity to the mMDS. The PREDIMED study also found similar results for the Mediterranean diet arms of the intervention, where a reduction of carbohydrates and the increase of monounsaturated dietary fatty acids (MUFA) resulted in lower cholesterol levels and increased HDL cholesterol levels [46]. Similar results were reported from another recent randomized control trial from Italy [47]. In summary, the present study is consistent with past research demonstrating that the Mediterranean diet has cardioprotective effects by improving HDL-cholesterol levels and the total cholesterol/HDL ratio [19,23,48].

Regarding anthropometrics, our results adjusted for age and gender were consistent with previous findings associating the Mediterranean diet with BMI, waist circumference, and weight loss [19,34,49–52]. However, we found no statistically significant associations, after further adjusting for ethnicity, physical activity, and smoking status. Similarly, several other scores such as the Mediterranean Diet Scale (MDScale), Mediterranean Food Pattern (MFP), MD Score (MDS), Short Mediterranean Diet Questionnaire (SMDQ), and MedDiet score were also not significantly associated with BMI [51,52]. The difference between our unadjusted and adjusted models may indicate an insufficient sample size in the current study.

In our study, there was no statistically significant association between the mMDS and glucose levels, consistent with previous research and the most recent RCT meta-analysis studies [23,24,53], although we did find that high consumption of non-alcoholic sugar-sweetened beverages at home was associated with higher glucose levels, as has been shown elsewhere [54,55]. Sweet desserts consumption was associated with a total cholesterol/HDL ratio >6 and with triglycerides levels ≥150 mg/dL. Firefighters with low fruit consumption were more likely to have a total cholesterol/HDL ratio >6. On average, the firefighters were consuming three servings of fruits and vegetables per day, in contrast with the recommendations of five or more daily servings of fruits and vegetables of the American Heart Association (AHA) [56]. Thus, our results highlight the need to increase the consumption of fruits and vegetables, because of their cardioprotective role, as an integral part of the Mediterranean diet [48,57,58]. In a recent study based on how the American population can adopt the Mediterranean diet, it was recommended that the American population should replace their usual desserts such us cookies, ice creams, pies, and sweet and creamy desserts with fresh fruits to optimize their health [59]. Increased fried food consumption was also associated with a total cholesterol/HDL ratio >6 and with triglycerides levels ≥150 mg/dL. It is well documented that the quality of fried food depends on the type of the oil used for frying [60]. Even though the scores for cooking with oils or fats at home and at work were not associated with any of the indices, these scores were below 4, indicating that the consumed fat or oils were mostly oils and spreads other than olive oil (e.g., margarine, corn or vegetable oil, and other spreads). Because at baseline the firefighters were unlikely to use olive oil for cooking, their olive oil consumption was reduced, and they were missing a basic component of the Mediterranean diet which is very important for its anti-inflammatory and antioxidant benefits [61–63].

The major limitation of this study is its cross-sectional nature, which does not allow us to infer causation. Another limitation of our study is that the firefighters were mainly men (94.4%). However, this reflects the current demographic of the US career fire service. Our study was also subject to a degree of non-response bias, as the lifestyle questionnaires were completed online by firefighters and not during the face-to-face study visits.

One of our study's strengths is that the firefighters' anthropometrics included their body fat percentage and waist circumference, not only their BMI. In fact, BMI may cause some false positives due to the increased muscle mass of some firefighters [64]. Another strength is that all our data were collected using standardized procedures, which limits bias. Also, the mMDS was created so to cover the eating habits of the firefighters at work and at home for better accuracy [39]. Finally, one of the strengths of our study is that the previously validated instrument [43] we used to examine Mediterranean diet adherence was created for the American firefighters, based on their lifestyle, eating habits, nature of work (meals at home and at work), type of drinks, and alcohol consumption and therefore is a good-quality validated instrument for this population, as it is known that the quality of Mediterranean diet scores has been questioned in different populations [38].

5. Conclusions

In conclusion, greater adherence to a Mediterranean diet, as measured by a higher mMDS, was favorably associated with lower measures of cardiometabolic risk. In fully adjusted models including physical activity level and smoking, the associations of a higher mMDS with a lower total cholesterol/HDL ratio and increased HDL-cholesterol remained robust. The mMDS has now evidence of validity with respect to more established questionnaires and has been determined in relation to additional biologically plausible associations from two different and independent mid-western (US) firefighter cohorts. Therefore, the mMDS should be a valid tool for assessing the outcome of cluster-randomized controlled trials of Mediterranean lifestyle interventions in this population and similar ones. It may also have further utility not only in research but also in clinical practice.

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Appendix A

Table A1. Comparison of the single items of the modified Mediterranean diet scores (mMDS) according to biochemical indices.

	Total Cholesterol-HDL Ratio > 6					Triglycerides ≥ 150 mg/dL					Glucose ≥ 100 mg/dL				
	No (N = 374)		Yes (N = 27)		p	No (N = 300)		Yes (N = 100)		p	No (N = 243)		Yes (N = 158)		p
	Mean	SD	Mean	SD	Value	Mean	SD	Mean	SD	Value	Mean	SD	Mean	SD	Value
Total mMDS	22.23	6.80	18.19	6.63	0.003	22.47	6.80	20.44	6.86	0.010	22.12	6.67	21.70	7.15	0.549
Single item mMDS															
Fast food consumption *	1.57	0.95	1.00	0.83	0.003	1.66	0.93	1.14	0.92	<.001	1.51	0.97	1.56	0.93	0.634
Fruit consumption	1.57	0.90	1.22	0.70	0.049	1.58	0.91	1.44	0.82	0.163	1.58	0.94	1.49	0.80	0.270
Vegetable consumption	2.56	1.06	2.44	0.93	0.586	2.53	1.05	2.63	1.08	0.396	2.56	1.07	2.54	1.03	0.841
Sweet desserts consumption	1.85	1.57	0.96	1.22	0.004	1.93	1.57	1.37	1.50	0.002	1.76	1.57	1.84	1.56	0.625
Cooking oil or fat use at home	2.12	1.85	1.63	1.74	0.185	2.12	1.86	1.99	1.84	0.554	2.22	1.83	1.88	1.86	0.073
Fried food consumption	1.56	1.18	0.89	0.93	0.004	1.58	1.19	1.30	1.10	0.037	1.47	1.18	1.58	1.17	0.374
Breads or starches consumed at home	1.75	1.48	1.67	1.52	0.782	1.82	1.47	1.50	1.51	0.062	1.73	1.49	1.77	1.48	0.805
Ocean fish consumption	1.64	1.14	1.70	0.99	0.765	1.67	1.13	1.57	1.12	0.459	1.66	1.07	1.61	1.21	0.700
Non-alcoholic beverages at home	2.66	1.13	2.44	1.37	0.339	2.69	1.14	2.50	1.17	0.144	2.74	1.12	2.50	1.18	0.036
Alcoholic beverages	2.09	1.57	1.78	1.48	0.317	2.02	1.60	2.24	1.44	0.224	2.03	1.59	2.13	1.54	0.516
Wine consumption	0.81	0.98	0.89	1.01	0.679	0.81	0.98	0.82	0.99	0.953	0.83	0.99	0.78	0.98	0.645
Legumes consumption	0.67	1.26	0.74	1.29	0.791	0.66	1.26	0.74	1.29	0.585	0.71	1.29	0.63	1.23	0.510
Nuts consumption	1.39	1.62	0.81	1.44	0.073	1.40	1.62	1.20	1.61	0.277	1.32	1.59	1.41	1.66	0.612

* Fast-food consumption per week (score 0–4), i.e., frequency of choosing options such as McDonalds, Burger King, Kentucky Fried Chicken, etc.

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Effects of a Mediterranean Diet, Dairy, and Meat Products on Different Phenotypes of Dyslipidemia: A Preliminary Retrospective Analysis

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Abstract: Background: Dyslipidemia is one of the major causes of atherosclerotic cardiovascular disease (ASCVD) and a Mediterranean Diet (MD) is recommended for its prevention. The objectives of this study were to evaluate adherence to an MD at baseline and follow-up, in a cohort of dyslipidemic patients, and to evaluate how different food intakes can influence lipid profile, especially how different sources of saturated fatty acids impact lipid phenotype. Methods: A retrospective analysis was conducted on 106 dyslipidemic patients. Clinical characteristics, lipid profile, and food habits data were collected at baseline and after three months of follow-up with counseling. Adherence to an MD was evaluated with a validated food-frequency questionnaire (MEDI-LITE score). Results: The cross-sectional analysis showed that higher consumption of dairy products correlated independently with higher levels of total cholesterol (TC), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C) and with lower triglycerides (TG) levels. Instead, lower HDL-C and TG levels and higher TC levels were independently associated with higher consumption of meat products. Adherence to an MD significantly improved after the follow-up period, from a mean value of 10 ± 3 (median 10, IQR 8–12) to 13 ± 2 (median 14, IQR 12–15), $p < 0.0001$. Conclusions: Dyslipidemic patients benefit from counseling for improving their adherence to an MD. The high intake of dairy products was associated with less atherogenic hyperlipidemia, which was characterized by higher levels of TC and HDL-C as compared withs the intake of an excessive amount of meat products, which was associated with higher levels of TC and TG and lower levels of HDL-C.

Keywords: Mediterranean diet; saturated fatty acids; ASCVD prevention

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1. Introduction

Dyslipidemia is a major cause of atherosclerotic cardiovascular disease (ASCVD) [1–3]. In particular, the most atherogenic form of dyslipidemia is associated with diabetes, insulin resistance conditions, and familial combined hypercholesterolemia, and it is characterized by elevated levels of low-density lipoprotein cholesterol (LDL-C) and triglycerides (TG), and low levels of high-density lipoprotein cholesterol (HDL-C) [4,5]. Considering the different risk factors for ASCVD, diet plays a key role [6]. A Mediterranean diet (MD) is the main dietary model recommended for the prevention of ASCVD [7] and is the reference diet model of the 2019 European Society of Cardiology/European Atherosclerosis Society (ESC/EAS) guidelines for the management of dyslipidemia [8]. In patients affected by hyperlipidemia, the MD recommends low intake of saturated fatty acids (SFAs), at least less than 10% of total energy intake (i.e., <7% in patients with hypercholesterolemia). Consequently, moderate restriction of milk and dairy product consumption should be balanced by a limited intake of meat and meat products [9], in particular, the preferred consumption of milk and dairy products should not exceed 180 g/day, while no more than 80 g/day of meat and meat products should be consumed [10]. Low-fat cheeses and semi-skimmed milk should be preferred for patients with dyslipidemia [11], and processed meats should not be recommended [12]. A high prevalence of plant-based food, such as whole grains, vegetables, and fruits are highly advisable according to the MD in order to reach a total amount of carbohydrates between 45 and 55% of total energy intake, and 25–40 g per day of total dietary fiber [8]. Furthermore, the MD encourages a moderate amount of seafood, regular consumption of olive oil, and increased physical activity [13,14]. A reduction in sugar intake and elimination of alcohol consumption is recommended for patients with hypertriglyceridemia [15].

In recent years, several studies have investigated the relationship between diet and ASCVD risk. Different studies have mostly recommended that consumption of SFAs is not recommended for prevention of ASCVD and increased LDL-C levels [16,17], while recent epidemiological studies in the literature support the fact that SFAs do not increase the risk of ASCVD [18]. The Prospective Urban and Rural Epidemiology study (PURE) was a large observational study that clarified the relationship between macronutrient intake and mortality, concluding that SFA intake did not influence mortality rate, while high carbohydrate intake was associated with higher mortality risk [19]. In the European Prospective Investigation into Cancer and Nutrition (EPIC) study, a significantly lower mortality was observed among subjects with the highest intake of saturated fatty acids as compared with those with minimum intake [20]. In a recent meta-analysis, de Souza et al. checked the relationship between SFAs intake and cardiovascular mortality and did not observe an increased risk of ASCVD events in subjects with a high consumption of SFAs as compared with those with low consumption [21]. Therefore, ASCVD risk may be influenced by the dietary source of SFAs, mainly represented by dairy and meat products. Meat consumption is considered to be a dietary risk factor for atherogenic dyslipidemia [12]. De Oliveira et al. reported, on the one hand, that a higher intake of SFAs from meat products is related to the development of ASCVD; on the other hand, a lower ASCVD risk is correlated to a higher intake of SFAs from dairy products [22]. However, the literature is still controversial regarding the relationship between meat and dairy products intake and alterations in lipid profile. Therefore, this study aims to evaluate adherence to an MD at baseline and at follow-up in a cohort of dyslipidemic patients and to evaluate how different food intakes can influence the lipid profile, especially how different sources of saturated fatty acids act on the lipid phenotype.

2. Materials and Methods

2.1. Study Design and Subjects

In the current study, a retrospective analysis was performed on the medical charts of 106 patients, 53 women and 53 men, suffering from different forms of hyperlipidemias. All subjects had been referred to the outpatient section of the Lipid Clinic, IRCCS Policlinic San Martino Hospital, University of Genoa, Italy, from February to July 2019. The exclusion criteria were age <18 years, active neoplasm, malignant hematological disease, endocrinopathy, inflammatory bowel disease, connective tissue disease, chronic and acute liver disease, congestive heart failure (NYHA class III–IV), acute and chronic nephropathy (GRF < 45 mL/min according to the Chronic Kidney Disease—Epidemiology Collaboration equation), acute and chronic infection, and therapy with hormones (including insulin) or with recombinant cytokines.

At baseline, height and weight, blood pressure, and smoking habits were recorded during a medical evaluation and body mass index (BMI) and the risk score (RS) were calculated. Blood test results provided a complete lipid profile (total cholesterol, high-density lipoprotein cholesterol, and triglycerides), tested without lipid lowering treatment and analyzed by an experienced physician who specialized in the management of hyperlipidemias. The LDL-C level calculation was performed using the Friedewald formula. Patients' food habits at the time of the first evaluation (baseline) were assessed using a validated food frequency questionnaire, i.e., the MEDI-LITE score [10,23]. At the follow-up visit, i.e., after three months, weight and blood pressure were reported, as well as BMI and the blood lipid profile were recalculated; food habits were re-assessed using the same food frequency questionnaire, however, participants responded referring to the period between the baseline and the follow-up.

Informed written consent for the use of personal data was obtained from patients. The study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of IRCCS Policlinic Hospital San Martino in Genoa (Italy) (project number 44/2021).

2.2. Dietary Assessment

Food intake and adherence to an MD were assessed in common clinical practice through the MEDI-LITE score, which is a food frequency questionnaire that had been previously proposed and validated [10,24]. Daily and weekly food intake were evaluated by nine questions regarding foods recommended by the MD. The highest consumption of fruits, vegetables, cereals, legumes, fish, and olive oil corresponds to a score of 2, a score of 1 represents average consumption, and a score of 0 indicates the lowest consumption. Conversely, a score of 2 corresponds to the lowest consumption of meat and meat products, dairy products, and alcohol; a score of 1 indicates average intake; and a score of 0 represents the highest intake. The final score obtained ranged from 0 (low adherence to the MD) to 18 (high adherence to the MD) points.

Lifestyle Intervention

A lipid lowering diet based on the ESC/EAS guidelines for the management of dyslipidemias [8], was proposed to all patients. Lipid intake ranged between 25 and 35% of the daily kcal, with cholesterol lower than 300 mg/day and saturated fats <7% of the total kcal. The protein and carbohydrate intakes were 15–25% and 45–55% of the total daily kcal, respectively. Normal weight and overweight patients were advised to perform moderate-intense exercise at least 30 min per day. The following four different types of diets were administered, in an outpatient setting, after anthropometric and biochemical parameter evaluation:

- General advice with weekly counseling on food frequency for patients with primary hypercholesterolemia and normal weight patients.
- General advice with counseling on food frequency for non-overweight patients with mixed hyperlipemia or hypertriglyceridemia or with a reduction in alcohol and carbohydrates.
- General advice based on the frequency of food and control of food with an overall energy intake of 1700 kcal/day for overweight women.
- General advice based on the frequency of food and control of food portions with a total energy intake of 2100 kcal/day for overweight men.

The compositions of the diets are reported in Supplementary Table S1.

2.3. Statistical Analysis

Statistical analysis was performed using SPSS Statistics 25, Version 25.0 (SPSS Inc., Chicago, IL, USA) (https://www.ibm.com/it-it/analytics/spss-statistics-software, accessed on 31 March 2021). Detailed statistical analysis is reported in the Supplementary Materials.

3. Results

3.1. Characteristics of the Population and Adherence to an MD

The general characteristics of the study population at baseline are shown in Table 1. The median age was 55 (IQR 45–64) and the 106 patients were equally male and female. Most of them (n = 98, 92.5%) were natives of Liguria, a region in the North-West of Italy, while six patients were born in South America (5.7%) and one subject came from each of UK and Romania. Most of the enrolled patients (except two subjects) did not practice moderate physical activity for more than 15 min every day. The comedications used by patients are reported in Supplementary Table S2.

Table 1. Characteristics of all 106 dyslipidemic patients.

VARIABLE	VALUE
Sex [F/M: *n*; %]	53 (50.0%)/53 (50.0%)
Age [years: mean ± SD; median; IQR]	54 ± 14; 55 (45–64)
Weight [kg: mean ± SD; median; IQR]	73.9 ± 17.3; 72.5 (60.0–84.0)
BMI [kg/m^2: mean ± SD; median; IQR]	26.1 ± 4.7; 25.8 (22.6–29.2)
SBP [mm/Hg: mean ± SD; median; IQR]	137 ± 17; 135 (128–146)
DBP [mm/Hg: mean ± SD; median; IQR]	82 ± 9; 80 (77–88)
Smoking habits [Never + Past/Current: *n*; %]	84 (79.2%)/22 (20.8%)
Risk SCORE [%: mean(SD; median; IQR] Low-Risk: <1% [*n*; %] Moderate-Risk: ≥1% and <5% [*n*; %] High-Risk: ≥5% and <10% [*n*; %] Very-High-Risk: ≥10% [*n*; %]	4.0 ± 6.3; 1.4 (0.6–4.2) 41 (38.7%) 41 (38.7%) 10 (9.4%) 14 (13.2%)
TC [mg/dl: mean ± SD; median, IQR]	245 ± 55; 248 (210–278)
HDL-C [mg/dl: mean ± SD; median, IQR]	57 ± 19; 53 (42–66)
LDL-C [mg/dl: mean ± SD; median, IQR]	159 ± 51; 154 (130–189)
TG [mg/dl: mean ± SD; median, IQR]	186 ± 156; 127 (97–208)

Abbreviations: M = male, F = female, BMI = body mass index, SBP = systolic blood pressure, DBP = diastolic blood pressure, IQR= Interquartile range, TC = total cholesterol, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol, TG = triglycerides.

The mean MEDI-LITE score for the patients was 10 ± 3 (median 10, IQR 8–12) points. A regression analysis of the lipid profile adjusted for sex, age, BMI, and smoking habits showed that the presence of a higher MEDI-LITE score was independently correlated with higher levels of HDL-C levels (β ± SE 1.099 ± 0.413, r = 0.253, p = 0.009) and TC (β ± SE 1.353 ± 0.449, r = 0.283, p = 0.003) and lower levels of TG (β ± SE 3.712 ± 2.272, r = 159, p = 0.105). LDL-C levels did not correlate with the MEDI-LITE score.

3.2. Cross-Sectional Analysis: Relationship between Lipid Profile and Different Food Categories

Table 2 shows the number of patients based on the MEDI-LITE scores obtained for specific food categories. Lipid levels normalized by sex, age, BMI, and smoking habits were divided according to food categories and the score assigned (Table 2). Independent sample comparison tests were preliminarily performed. Patients with fruit intake >300 g/day had significantly higher levels of TC and HDL-C than those who ate <150 g/day or between 150 and 300 g/day. The levels of TC and HDL-C were significantly lower in subjects who ate fewer vegetables (<150 g/day) than in moderate and higher consumers of vegetables (150–300 and >300 g/day, respectively). No statistically significant differences were observed in the serum levels of LDL-C. Patients who consumed more meat and meat products (>120 g/day) had significantly lower levels of TC and HDL-C than moderate (80–120 g/day) and low (<80 g/day) meat consumers, while levels of TG were significantly higher in the latter (<80 g/day) than subjects who ate >120 g/day. LDL-C levels did not vary significantly. Patients who consumed the most (270 g/day) dairy products had significantly higher levels of TC, HDL-C, and LDL-C and lower levels of TG than patients with the lowest intake of dairy products (<180 g/day). No alcohol consumption was significantly associated with higher levels of TC and HDL-C and significantly lower levels of TG than alcohol consumption by patients. None differences in LDL-C levels have been observed in different alcohol consumer groups.

Table 2. Lipid profile and patient distribution according to food categories and the score assigned.

	Patients [*n*, %]	TC [Median, IQR]	HDL-C [Median, IQR]	LDL-C [Median, IQR]	TG [Median, IQR]
Fruit					
<150 g/day	26 (24.5%)	238 (229–250)	52 (42–58)	156 (148–164)	220 (142–270)
150–300 g/day	20 (18.9%)	238 (232–247)	54 (48–66)	161 (147–164)	209 (132–227)
>300 g/day	60 (56.6%)	251 (239–259)	59 (51–68)	163 (150–165)	149 (134–225)
p-value †		$p = 0.003$ <150 vs. >300 g/day $p = 0.01$ ($p = 0.003$) 150–300 vs. >300 g/day $p = 0.04$ ($p = 0.01$)	$p = 0.03$ <150 vs. >300 g/day $p = 0.04$ ($p = 0.01$)	NS	NS
Vegetables					
<100 g/day	36 (34.0%)	237 (230–249)	51 (45–60)	155 (149–164)	217 (145–235)
100–250 g/day	32 (30.2%)	249 (238–257)	57 (51–70)	163 (155–164)	145 (126–222)
>250 g/day	38 (35.8%)	249 (238–259)	57 (52–68)	164 (149–166)	149 (137–217)
p-value †		$p = 0.01$ <100 vs. >250 g/day $p = 0.02$ ($p = 0.008$) <100 vs. 100–250 g/day $p = 0.06$ ($p = 0.02$)	$p = 0.04$ <100 vs. >250 g/day $p = 0.10$ ($p = 0.03$) <100 vs. 100–250 g/day $p = 0.06$ ($p = 0.02$)	NS	NS
Legumes					
<70 g/week	50 (47.2%)	245 (233–255)	55 (49–67)	162 (149–164)	157 (134–229)
70–140 g/week	46 (43.4%)	246 (236–259)	56 (50–68)	164 (150–165)	149 (148–163)
>140 g/week	10 (9.4%)	239 (237–254)	56 (49–61)	157 (128–227)	216 (153–231)
p-value †		NS	NS	NS	NS
Cereals					
<130 g/day	40 (37.7%)	247 (233–259)	57 (50–68)	162 (149–165)	150 (130–230)
130–200 g/day	20 (18.9%)	244 (237–256)	58 (50–64)	163 (155–165)	180 (137–230)
>200 g/day	46 (43.4%)	243 (235–253)	55 (49–62)	163 (149–165)	198 (139–227)
p-value †		NS	NS	NS	NS
Fish					
<100 g/week	32 (30.2%)	240 (232–252)	55 (45–64)	161 (149–164)	212 (125–252)
100–250 g/week	58 (54.7%)	248 (236–258)	59 (50–67)	164 (149–165)	150 (133–220)
>250 g/week	16 (15.1%)	241 (237–254)	54 (50–63)	150 (149–165)	209 (150–231)
p-value †		NS	NS	NS	NS
Meat Products					
>120 g/day	21 (19.8%)	236 (228–249)	48 (40–56)	158 (148–165)	228 (169–270)
80–120 g/day	31 (29.2%)	240 (233–249)	53 (49–61)	155 (148–164)	214 (139–230)
<80 g/day	54 (50.9%)	253 (240–259)	60 (52–69)	164 (156–165)	147 (127–212)
p-value †		$p = 0.001$ <80 vs. >120 g/day $p = 0.001$ ($p < 0.0001$) <80 vs. 80–120 g/day $p = 0.06$ ($p = 0.02$)	$p < 0.0001$ <80 vs. 80–120 g/day $p = 0.06$ ($p = 0.02$) <80 vs. >120 g/day $p < 0.0001$ ($p < 0.0001$)	NS	$p = 0.008$ <80 vs. >120 g/day $p = 0.009$ ($p = 0.003$)
Dairy Products					
>270 g/day	51 (48.1%)	249 (240–259)	58 (52–68)	164 (150–166)	145 (127–216)
180–270 g/day	11 (10.4%)	237 (231–255)	53 (42–61)	161 (152–165)	219 (149–240)
<180 g/day	44 (41.5%)	240 (233–253)	53 (47–66)	156 (148–164)	211 (138–258)
p-value †		$p = 0.01$ <180 vs. >270 g/day $p = 0.02$ ($p = 0.005$)	$p = 0.074$ <180 vs. >270 g/day $p = 0.04$	$p = 0.02$ <180 vs. >270 g/day $p = 0.02$ ($p = 0.006$)	$p = 0.02$ <180 vs. >270 g/day $p = 0.04$ ($p = 0.01$)

Table 2. *Cont.*

	Patients [*n*, %]	TC [Median, IQR]	HDL-C [Median, IQR]	LDL-C [Median, IQR]	TG [Median, IQR]
Alcohol					
>2 AU/day	35 (33.0%)	239 (233–254)	54 (47–67)	157 (149–164)	213 (147–234)
1–2 AU/day	34 (32.1%)	241 (234–252)	53 (48–60)	161 (149–164)	180 (124–236)
<1 AU/day	37 (34.9%)	253 (242–260)	59 (54–68)	164 (150–165)	146 (134–213)
p-value †		$p = 0.009$ 1–2 vs. <1 AU $p = 0.02$ ($p = 0.006$) >2 vs. <1 AU $p = 0.04$ ($p = 0.01$)	$p = 0.01$ 1–2 vs. <1 AU $p = 0.05$ ($p = 0.02$) >2 vs. <1 AU $p = 0.12$ ($p = 0.04$)	NS	>2 vs. <1 AU $p = 0.01$
Olive Oil					
Occasional	3 (2.8%)	255 (233–259)	60 (43–63)	166 (166–166)	150 (149–234)
Frequent	5 (4.7%)	247 (245–248)	59 (51–71)	163 (155–169)	135 (106–230)
Regular	98 (92.5%)	243 (235–256)	56 (49–67)	162 (149–165)	191 (134–228)
p-value †		NS	NS	NS	NS

Abbreviations: AU = Alcoholic Unit; NS = Non-statistically significant. † Independent samples Kruskal–Wallis tests. Significance values have been adjusted by the Bonferroni correction for multiple tests. Unadjusted *p*-values have been also reported.

Finally, the relationships among the lipid profile (TC, HDL-C, LDL-C, and TG adjusted for sex, age, BMI, and smoking habits) and all food categories considered in the baseline analysis was investigated through a cross-sectional multivariate analysis (details of the statistical analysis are reported in Table 3. Higher consumption of dairy products correlated independently with higher levels of TC, HDL-C, and LDL-C and with a lower level of TG. Instead, lower levels of HDL-C and TG and higher levels of TC were independently associated with higher consumption of meat and meat products. Finally, a lower level of TC also correlated independently with the frequent use of olive oil. No other statistically significant differences were observed in LDL-C levels.

Table 3. Multivariate analysis on baseline lipid profile in all 106 patients.

VARIABLE and PREDICTORS	β	SE	*p*-Value	r^2	F (*p*-Value) †
TC				0.317	4.952 (<0.0001)
Fruit (high intake: >300 g/day)	2.373	1.434	0.101		
Vegetables (high intake: >250 g/day)	2.628	1.429	0.069		
Legumes (high intake: >140 g/day)	1.292	1.726	0.456		
Cereals (high intake: >200 g/day)	−0.387	1.186	0.745		
Fish (high intake: >250 g/day)	0.594	1.830	0.746		
Meat products (low intake: <80 g/day)	4.784	1.408	0.001		
Dairy Products (low intake: <180 g/day)	−2.596	1.160	0.028		
Olive Oil (Frequent use)	−5.495	2.868	0.058		
Alcohol (low intake: < 1 AU/day)	2.082	1.340	0.124		
HDL-C				0.268	3.904 (<0.0001)
Fruit (high intake: >300 g/day)	1.791	1.353	0.189		
Vegetables (high intake: >250 g/day)	1.626	1.347	0.230		
Legumes (high intake: >140 g/day)	1.53	1.627	0.350		
Cereals (high intake: >200 g/day)	−0.328	1.118	0.770		
Fish (high intake: >250 g/day)	−0.766	1.726	0.658		
Meat products (low intake: <80 g/day)	5.359	1.328	<0.0001		
Dairy Products (low intake: <180 g/day)	−2.433	1.094	0.048		
Olive Oil (Frequent use)	−2.643	2.704	0.331		
Alcohol (low intake: < 1 AU/day)	1.034	1.264	0.416		

Table 3. *Cont.*

VARIABLE and PREDICTORS	β	SE	*p*-Value	r^2	F (*p*-Value) †
LDL-C				0.149	1.540 (0.149)
Fruit (high intake: >300 g/day)	0.406	1.187	0.733		
Vegetables (high intake: >250 g/day)	1.700	1.229	0.171		
Legumes (high intake: >140 g/day)	0.301	1.515	0.843		
Cereals (high intake: >200 g/day)	0.038	1.013	0.970		
Fish (high intake: >250 g/day)	−0.602	1.589	0.706		
Meat products (low intake: <80 g/day)	1.186	1.246	0.344		
Dairy Products (low intake: <180 g/day)	−2.190	0.976	0.028		
Olive Oil (Frequent use)	−4.877	2.663	0.071		
Alcohol (low intake: < 1 AU/day)	0.840	1.185	0.481		
TG				0.233	3.202 (0.002)
Fruit (high intake: >300 g/day)	−6.806	7.468	0.364		
Vegetables (high intake: >250 g/day)	−9.251	7.474	0.219		
Legumes (high intake: >140 g/day)	−0.479	9.005	0.958		
Cereals (high intake: >200 g/day)	3.714	6.225	0.552		
Fish (high intake: >250 g/day)	0.955	9.530	0.920		
Meat products (low intake: <80 g/day)	−19.321	7.358	0.010		
Dairy Products (low intake: <180 g/day)	15.326	6.065	0.013		
Alcohol (low intake: < 1 AU/day)	−9.931	7.080	0.164		
Olive Oil (Frequent use)	17.823	14.928	0.235		

Abbreviations: TC = total cholesterol, HDL-C = high-density lipoprotein cholesterol, LDL-C = low-density lipoprotein cholesterol, TG = triglycerides. Dependent variable were TC, HDL-C, LDL-C and TG (bold text) and were adjusted for sex, age, BMI and smoking habits. Predictors were fruit intake (<150 g/day = 0, 150–300 g/day = 1 and >300 g/day = 2), vegetables intake (<100 g/day = 0, 100–250 g/day =1 and >250 g/day = 2), legumes intake (<70 g/week = 0, 70–140 g/week = 1 and >140 g/week = 2), cereals intake (<130 g/day = 0, 130–200 g/day = 1 and >200 g/day = 2), fish intake (<100 g/week = 0, 100–250 g/week = 1 and >250 g/week = 2), meat products intake (>120 g/day = 0, 80–120 g/day = 1 and <80 g/day = 2), dairy products intake (>270 g/day = 0, 180–270 g/day = 1 and <180 g/day = 2), alcohol consume (>2 AU/day = 0, 1–2 AU/day = 1 and <1 AU/day = 2) and olive oil use (Occasional = 0, Frequent = 1 and Regular = 2). Abbreviation: β = angular coefficient, SE = standard error, r^2 = square correlation coefficient, F = F-value, *p*-values for predictors, † *p*-value for model fitting significance.

3.3. Follow-Up Analysis

Thirty-four patients (32.1%) did not attend the follow-up visit, and therefore were excluded from the follow-up analysis. Thus, demographical and clinical characteristics of the remaining 72 patients are reported in Table 4. The median follow-up period was 12 weeks (10–13 weeks).

Adherence to an MD significantly improved after the follow-up period, from a mean value of 10 ± 3 (median 10, IQR 8–12) to 13 ± 2 (median 14, IQR 12–15) with $p < 0.0001$ (Table 4). Overall, the number of patients with higher scores in the specific food categories considered in the MEDI-LITE score increased significantly, with the exception of olive oil and cereal consumption which did not statistically differ from baseline (Supplementary Table S3).

Nutritional counseling was effective for improving weight, BMI, and lipid profile excluding HDL-C levels. The addition of a nutraceutical or lipid-lowering drug was further effective in reducing TC, LDL-C, and TG levels (Table 5).

Table 4. Characteristics of the 72 dyslipidemic patients included in follow-up analysis.

VARIABLE	VALUE
Sex [F/M: *n*; %]	34 (47.2%)/38 (52.8%)
Age [years: mean ± SD; median; IQR]	55 ± 13; 55 (48–64)
SBP [mm/Hg: mean ± SD; median; IQR]	138 ± 17; 136 (130–150)
DBP [mm/Hg: mean ± SD; median; IQR]	83 ± 10; 81 (78–89)
Smoking habits [Never + Past/Current: *n*; %]	55 (76.4%)/17 (23.6%)
Risk SCORE [%: mean(SD; median; IQR] Low-Risk: <1% [*n*; %] Moderate-Risk: ≥1% and <5% [*n*; %] High-Risk: ≥5% and <10% [*n*; %] Very-High-Risk: ≥10% [*n*; %]	4.3 ± 7.0; 1.5 (0.7–4.1) 25 (34.7%) 31 (43.1%) 6 (8.3%) 10 (13.9%)
Lipid Lowering Intervention	
Diet alone [*n*; %]	31 (43.1%)
Lipid-lowering Nutraceuticals [*n*; %]	13 (18.1%)
Lipid-lowering Drugs [*n*; %]	28 (38.9%)

Abbreviations: M = male, F = female, IQR = Interquartile range, SBP = systolic blood pressure, DBP = diastolic blood pressure.

Table 5. Variation in anthropometric measures, MEDI-LITE score, and lipid profile after the nutritional counseling.

VARIABLES	Baseline [Mean ± SD; Median; IQR]	Follow-up [Mean ± SD; Median; IQR]	Absolute Variation [Mean ± SD; Median; IQR]	Percentage Variation [%]	*p*-Value †
Weight [kg: mean ± SD; median; IQR]	75.7 ± 17.5; 74.3 (62.5, 84.0)	72.8 ± 15.8; 71.0 (60.0, 83.5)	−2.5 ± 3.5; −2.0 (−3.3, 0)	−3.2%	<0.0001
BMI [kg/m^2: mean ± SD; median; IQR]	26.3 ± 4.7; 26.0 (22.9, 28.8)	25.2 ± 4.0; 25.5 (22.1, 27.4)	−9 ± 1.2; −0.6 (−1.2, 0)	−3.3%	<0.0001
MEDI-LITE [Points: mean ± SD; median; IQ range]	10 ± 3; 10 (8, 12)	13 ± 2; 14 (12, 15)	3 ± 3; 3 (1, 5)	+43.4%	<0.0001
TC [mg/dl: mean ± SD; median, IQR]					
Diet alone	249 ± 36; 255 (222, 267)	207 ± 54; 204 (158, 248)	−42 ± 54; −23 (−87, −1)	−16.2%	0.002
Lipid-lowering Nutraceuticals	257 ± 39; 261 (232, 270)	211 ± 39; 204 (190, 213)	−38 ± 34; −42 (−67, 0)	−15.1%	0.046
Lipid-lowering Drugs	238 ± 67; 234 (179, 294)	170 ± 30; 173 (140, 196)	−83 ± 61; −73 (−119, −33)	−29.3%	<0.0001
HDL-C [mg/dl: mean ± SD; median, IQR]					
Diet alone	58 ± 21; 53 (42, 67)	60 ± 20; 54 (47, 68)	0 ± 7; 0 (−3, 4)	2.5%	0.641
Lipid-lowering Nutraceuticals	58 ± 26; 46 (40, 63)	55 ± 17; 50 (40, 72)	0 ± 9; 0 (−2, 7)	3.4%	0.753
Lipid-lowering Drugs	54 ± 15; 52 (42, 66)	50 ± 12; 48 (40, 61)	−2 ± 8; −3 (−5, 4)	−2.5%	0.383
LDL-C [mg/dl: mean ± SD; median, IQR]					
Diet alone	161 ± 35; 150 (138, 187)	123 ± 47; 129 (83, 170)	−32 ± 49; −22 (−78, 0)	−18.6%	0.026
Lipid-lowering Nutraceuticals	180 ± 33; 179 (154, 196)	132 ± 34; 131 (102, 145)	−39 ± 37; −39 (−52, −9)	−22.6%	0.068
Lipid-lowering Drugs	146 ± 60; 147 (95, 185)	90 ± 29; 100 (70, 112)	−71 ± 50; −66 (−111, −22)	−38.3%	0.001
TG [mg/dl: mean ± SD; median, IQR]					
Diet alone	184 ± 123; 130 (103, 254)	129 ± 66; 111 (85, 167)	−39 ± 83; −17 (−44, 0)	−15.2%	0.025
Lipid-lowering Nutraceuticals	192 ± 149; 119 (102, 208)	125 ± 56; 102 (90, 177)	−54 ± 104; −10 (−81, 0)	−16.8%	0.173
Lipid-lowering Drugs	218 ± 228; 138 (104, 206)	152 ± 105; 123 (90, 158)	−80 ± 200; −45 (−63, 0)	−16.7%	0.013

Abbreviations: BMI = body mass index, IQR= Interquartile range. † *p*-values for dependent samples nonparametric Wilcoxon Signed Ranks Test between baseline and follow-up values.

4. Discussion

The main purpose of this study was to evaluate the influence of different eating habits on the lipid profile of patients suffering from dyslipidemia.

A preliminary result is that greater adherence to an MD based on MEDI-LITE scores correlated with a better lipid profile characterized by higher levels of HDL-C and lower levels of TG, which is a finding that is strongly supported by the scientific literature [24]. Moreover, a recent study highlighted that high MEDI-LITE total scores were associated with low prevalence of dyslipidemia [25]. The results for fruits and vegetables intake showed an association with higher total cholesterol and HDL, but these data also indicate adherence to an MD and the effect on lipid profile may be mediated by dairy and olive oil consumption.

One of the main results of this study is the different impacts on the lipid profiles of patients with excessive consumption of meat and dairy products according to the MEDI-LITE scores. In fact, subjects with higher meat consumption had atherogenic dyslipidemia with significantly lower levels of HDL-C and higher levels of TG, while higher levels of TC and LDL-C were balanced by higher levels of HDL-C and lower levels of TG in patients with higher consumption of dairy products. These findings are questionable with respect to the dietary recommendations of the 2019 ESC/EAS guidelines for the management of dyslipidemia [8] which recommend an SFA intake less than 10% of the total caloric intake (i.e., about 22 g of SFAs considering a daily total caloric intake of 2000 kcal), and less than 7% in dyslipidemic patients, without distinguishing the food sources (i.e., meat or dairy products). In the literature, the effect of SFAs on ASCVD risk has been extensively studied but is not yet fully understood. Two large prospective analysis, the Nurses' Health Study (NHS) [26] and the Health Professionals Follow-Up Study (HPFS) [27], on the one hand, reported that an increase in consumption of SFAs was related to increased risk of an ASCVD event [28]. On the other hand, a recent prospective study (PURE) clearly highlighted that the higher the consumption of SFAs, the lower the cardiovascular mortality, even in large consumers [19]. A similar correlation emerged in the EPIC study's cohort of subjects, i.e., a minimum intake of SFAs was associated with significantly higher total mortality as compared with a maximum intake of SFAs [20]. A possible match point was proposed by the MESA study which prospectively observed a higher incidence of ASCVD events in patients who consumed more SFAs from meat, while SFAs from dairy products were associated with a decrease in ASCVD occurrence [22].

Furthermore, the correlation between ASCVD risk and higher meat consumption could also be due to the pro-atherogenic effect of some biomolecules in meat, such as choline, carnitine, and lecithin. Conversely, dairy products provide micronutrients and vitamins with a proven protective effect on the risk of ASCVD. In addition, Lordan et al. [29] highlighted the anti-inflammatory properties of dairy products because of their content in inhibitors of the platelet activating factor (PAF). The latter biomolecule is a lipoid factor of thrombosis and inflammation and plays a pivotal role in atherogenesis and atherosclerosis progression. To date, the protective effect of PAF inhibitors present in dairy products has been confirmed in vitro [30] and in vivo in both animals and humans [31]. Furthermore, beneficial anti-inflammatory properties for fermented dairy products have been hypothesized due to the presence of specific bacteria such as lactic acid bacteria and bifidobacteria, as well as the presence of specific fermentation products [32].

In brief, the source of SFAs could have different impacts on the ASCVD risk, in fact, most of the correlation studies between ASCVD and SFAs conducted in the USA, of a population consuming large quantities of meat products [33,34], have shown an increase in ASCVD risk proportional to the consumption of SFAs [26,27]. Conversely, the latter correlation between SFA consumption and ASCVD risk is negative in European patients [20] whose prevalent source of SFAs is represented by dairy products [35].

Moreover, the cross-sectional analysis highlights that frequent use of olive oil correlates with lower levels of TC; a meta-analysis by George, E. S. et al. reported that TC levels decreased linearly with high consumption of polyphenols olive oil [36].

The follow-up analysis showed that adherence to an MD and lipid profile levels improved with dietary counseling. In fact, it is known that nutritional counseling improves adherence to an MD, as highlighted in a recent study by Sialvera, T.E. et al., in which a positive change in lipid profile levels was also observed [37]. Overall, we observed a statistically significant shift from the categories with the lowest MEDI-LITE scores to those with the highest scores, except for olive oil and cereals, whose consumption was already high at the baseline. The reduction in dietary intake of SFAs has mostly been encouraged in accordance with current ESC/EAS guideline recommendations [8]. However, the reduction in meat products was preferred, and the categories of both high and medium consumption were reduced. Conversely, moderate consumption of dairy products was encouraged despite the high and low consumption categories. Further research and scientific debate will be needed to adapt the correct dietary recommendations to the results of the recent scientific literature [38].

Furthermore, dietary counseling was effective in reducing BMI, and the efficacy of dietary intervention in the treatment of weight is well known in the literature [39]. The use of lipid-lowering nutraceuticals had a valuable impact on the lipid profile as compared with diet alone and their effects have been previously highlighted in the literature [14,40,41].

The main limitation of the present study was the relatively small sample size analyzed; thus, the findings should be considered as preliminary. Other limitations are the lack of information about physical activity, employment, and family income; however, these indicators could be homogeneous as most patients live in the same local geographic area. Finally, the use of a food frequency questionnaire may be subject to recall bias.

5. Conclusions

In conclusion, high intake of dairy products was associated with a balanced hyperlipidemia, characterized by higher levels of TC and HDL-C, while a diet with an excessive amount of meat products caused a form of mixed atherogenic dyslipidemia with higher TC and TG levels and lower HDL-C levels. In the light of these findings and according to the recent literature, dietary recommendations should distinguish between SFA sources (i.e., meat products or dairy products) rather than suggesting a general reduction in SFA intake. In addition, dietary counseling is effective in improving adherence to MD in dyslipidemic patients.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13041161/s1: Supplementary Table S1, Composition of diets for overweight patients; 1.1 General advice with counselling on weekly food frequency for patients with primary hypercholesterolemia and normal weight patients; 1.2 General advice with advising on food frequency in non-overweight patients with mixed hyperlipemia or hypertriglyceridemia or with reduction in alcohol and carbohydrates; 1.3 General advice based on frequency of food and control of food with an overall energy intake of 1700 kcal/day for overweight women; 1.4 General advice based on frequency of food and control of food portions with a total energy intake of 2100 kcal/day for overweight men; 1.5 Statistical Analysis; Supplementary Table S2, Comedications used by the 106 patients; Supplementary Table S3, Variation of patient distribution according to food categories and the score assigned.

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Assessment of Sodium Knowledge and Urinary Sodium Excretion among Regions of the United Arab Emirates: A Cross-Sectional Study

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Abstract: Non-communicable diseases (NCDs) such as cardiovascular disease, cancer and diabetes, are increasing worldwide and cause 65% to 78% of deaths in the Gulf Cooperation Council (GCC). A random sample of 477 healthy adults were recruited in the United Arab Emirates (UAE) in the period March–June 2015. Demographic, lifestyle, medical, anthropometric and sodium excretion data were collected. A questionnaire was used to measure knowledge, attitude and practice regarding salt. Mean sodium and potassium excretion were 2713.4 ± 713 mg/day and 1803 ± 618 mg/day, respectively, significantly higher than the World Health Organization (WHO) recommendations for sodium (2300 mg/day) and lower for potassium (3150 mg/day). Two-thirds (67.4%) exceeded sodium guidelines, with males 2.6 times more likely to consume excessively. The majority of the participants add salt during cooking (82.5%) and whilst eating (66%), and 75% identified processed food as high source of salt. Most (69.1%) were aware that excessive salt could cause disease. Most of the UAE population consumes excess sodium and insufficient potassium, likely increasing the risk of NCDs. Despite most participants being aware that high salt intake is associated with adverse health outcomes, this did not translate into salt reduction action. Low-sodium, high-potassium dietary interventions such as the Mediterranean diet are vital in reducing the impact of NCDs in the UAE.

Keywords: urinary sodium excretion; urinary potassium excretion; salt; sodium; non-communicable diseases; United Arab Emirates

1. Introduction

Chronic diseases are long-lasting conditions with continuous effects, and include cardiovascular disease (CVD), chronic respiratory disease (CRD), cancer and type 2 diabetes (T2D). Globally, their incidence is increasing becoming a growing burden to global economies and people's quality of life. Collectively, these non-communicable diseases (NCDs) are the leading cause of death globally [1], making it a significant priority in healthcare systems. In some countries, up to 40% of those dying from NCDs are younger than 60 years of age [1].

The rapid improvement in the socio-economic status of the countries making up the Gulf Cooperation Council (GCC) (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates (UAE) has contributed to changing food consumption patterns, lifestyle habits and health status over the last four decades, with diet quality decreasing through the addition of more processed Westernized food. These changes have resulted in an increasingly sedentary lifestyle, high blood pressure and obesity, known to be major risk factors of NCDs [2,3]. Thus, it is not surprising that CVD is the major cause of morbidity and mortality in the Gulf region [4]. It is estimated that NCDs cause between 65% and 78% of deaths in the GCC member countries [5].

In particular, the lifestyle of the Emirati population has changed considerably in the last 40 years due to rapid improvement in socio-economic indicators in the UAE. This transition has led to less physical activity and altered eating habits, including increased intake of processed foods. These changes, in addition to the adoption of a Western lifestyle and diet, have led to the rise in prevalence of overweight, obesity and the risk of metabolic syndrome in the UAE. In the UAE, CVD accounts for more than 25% of all deaths countrywide, however, this has increased in the major metropolitan center, accounting for 29% of all deaths in the Emirate of Abu Dhabi [6].

Diet, environmental factors, lifestyle, physical inactivity and genetics have been shown to contribute to the risk of NCDs [1]. Control of these primary risk factors could reduce the incidence of some NCDs by up to 80% and cancers by 40% [1]. As such, in recent years, there has been a significant effort to improve diet and increase physical activity to control the prevalence of NCDs. Hypertension is the most common outcome of excessive sodium intake independent of age and is a key risk factor for many NCDs [7]. Globally, over 7.5 million people die from hypertension-related complications per year, which surpasses deaths from tobacco smoking (5 million), obesity (2.8 million) and cholesterol (2.6 million) [8]. Hypertension, secondary to excessive salt consumption, is a major risk factor for CVD, responsible for 62% of strokes and 49% of coronary heart disease (CHD) [7]. In the UAE, approximately 30% of the population is hypertensive, [9] and the disease is thought to be widely underdiagnosed [10]. High salt intake is considered one of the major contributors to premature adult death in developed and developing countries [11]. A systematic review and meta-analysis of 5508 participants across 61 studies showed that higher salt intake was associated with significantly increased risk of stroke, stroke mortality and coronary heart disease [11]. Unfavorably high sodium intake remains prevalent worldwide and varies widely, ranging from 4–17 g/day, with mainland China having the greatest intake, and some less developed island nations the lowest [12], but for many countries it remains well above the World Health Organization (WHO) recommendation of less than 5 g of salt intake per day [13]. The UK Food Standards Agency highlighted in 2012 that 75% of salt intake comes from processed foods and proposed that a reduction in the sodium content of processed food and drink would be required to achieve the recommended daily intake in the community [14,15].

Alongside appropriate sodium consumption, ensuring adequate intake of potassium is vital to ensuring normal mineral homeostasis and healthy blood pressure. Potassium is the paired ion for sodium in a range of different physiologies—from nerve transmission to renal function. Having adequate potassium in the diet ensures that the kidney is able to remove sodium from the plasma, and hence allows more effective regulation of blood pressure. While frank potassium deficiency (hypokalemia) is well understood and monitored, chronic, insufficient dietary intake is not, despite being associated with an increase in systolic blood pressure, and in the face of declining diet quality, insufficient intake is becoming more common [16]. Despite its important role in health, potassium intake has not been investigated in the UAE, however, globally, it has been reported that there is widespread dietary insufficiency, and this is likely to be mirrored in the Gulf region.

The impact of diet on NCDs is critical, and dietary approaches such as the Mediterranean diet have been suggested to have a role in improving health outcomes globally. The Mediterranean diet, with its high fruit and vegetable and low meat and processed food content, is an effective way to reduce salt and sodium intake, leading to a subsequent improvement in health outcomes [17]. Its high vegetable content also lends itself to improving potassium intake—making it an effective intervention to reduce hypertension [17].

There are numerous methods used for assessing salt intake, including estimation by weighing ingested food, dietary recall questionnaires, estimating the salt content of food before ingestion and taking measurements of 24-h (hr) sodium excretion [18]. Measurement of 24-h urinary sodium excretion is considered to be the golden standard for estimating daily sodium intake on the premise that the majority (90–95%) of sodium ingested is excreted via the urine [18].

The aim of this study was to assess sodium intake using 24-h urinary sodium excretion from a sample of the healthy UAE population and to assess their knowledge, attitudes and practices (KAP) surrounding salt intake.

2. Materials and Methods

2.1. Study Design and Participants

A cross-sectional study with an anonymized self-reported questionnaire and the collection of 24-h urine for the assessment of sodium, potassium and creatinine excretion was conducted between March 2015 and June 2015 in the UAE. The questionnaire consisted of items to assess participants' attitudes, behavior and knowledge (KAP) regarding salt consumption and knowledge. The sample size was calculated based on the following formula to be representative of the UAE, with a confidence interval level of 95%.

Sample size of an unknown population was calculated by Cochrane's formula ($n = z^2 \times p \times (1 - p)/e2$), with z = level of confidence (for a level of confidence of 95%, z = 1.96); p = the estimated proportion of the population that presents the characteristic of having high knowledge $p = 0.5$; e = margin of error accepted, e = 0.05; N (sample size) = 385 participants, plus 20% estimated dropouts = approximately 461 participants. Hence, a sample of 530 healthy individuals were recruited to participate in the study from the seven Emirates (Abu Dhabi, Dubai, Sharjah, Ajman, Ras Al Khaimah, Fujairah and Umm Al Quwain) aged between 20 and 65 years. Two methods were used for recruitment: face to face recruitment at community, school or university events and posters displayed in shopping malls, health centers, schools and university hostels. The WHO/PAHO (2010) protocol for 24-h urine collection and analysis was used. Four age groups were considered for recruitment in the current study; 20–30, 31–40, 41–50 and 51–65 years old with a ratio of 1:1 male to female. This demographic was used to ensure a sample of the 'healthy' population—participants older than 65 are likely to have comorbid disease which may have affected the urine analysis. All participants provided written informed consent to participate in the study.

A screening questionnaire was designed to collect data regarding demographic information, lifestyle habits, past medical history, medication and current health status. Questionnaires were administered by the research team. Exclusion criteria at screening were those with self-reported chronic diseases (i.e., heart disease, using medication for hypertension, renal failure, liver disease), pregnant and lactating women, those on diuretics and women who had their menstrual period during the time of urine collection. Inclusion and exclusion criteria are summarized in Table 1. Inclusion criteria at screening were participants aged 20 to 65 years for both genders, non-pregnant and non-lactating, no known chronic kidney disease, renal failure, hypertension with medications and liver diseases, no medical condition(s) or medication(s) known to affect urination and able to collect 24-h (hr) urine. Exclusion criteria following urine collection included those that were unable to collect adequate urine within the 24-h time period (i.e., volume < 500 mL), and creatinine levels below 500 or above 2000 mg/day, which is equivalent to <9 or >26 mg/kg of body mass for female participants and <13 or >29 mg/kg of body mass for male participants [19]. Forty-one participants were excluded due to limited urine sample collection (<500 mL urine) or being unable to effectively urinate into the collection bottle, and 12 participants due to creatinine levels below 500 mg. The creatinine cutoffs were used to screen for renal abnormalities that may have skewed the results [19]. One urine sample was also excluded during testing due to abnormalities, leaving 476 urine samples for the final urine analysis, alongside 477 questionnaire responses. The enrolment process of the study participants is shown in Figure 1.

Table 1. Summary of inclusion and exclusion criteria.

Inclusion	Exclusion
Age 20–65	Renal or urinary pathology
Non-pregnant	Chronic disease
Non-lactating	Current menstrual period
No chronic kidney disease	24-h urine volume <500 mL
No medical conditions	Urine creatinine <500 mg or >2000 mg
Not currently taking prescribed medications known to affect urine	

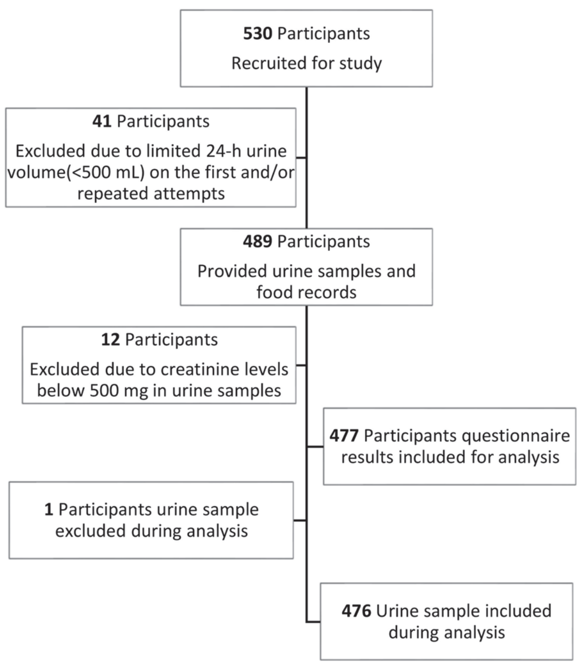

Figure 1. Flow diagram of the study design.

Participants were given full details of the study protocol with the opportunity to ask questions after which written informed consent to participate was sought. Each participant was allocated a personal identification number to provide anonymity and data confidentiality. Ethical approval for the study protocol was obtained from the UAE University (UAEU) Scientific Research Ethics Committee (Reference number: DVCRGS/36/2015).

2.2. Anthropometric Measurements

Body weight and height were measured for each participant and their body mass index (BMI) was calculated as weight (kg) divided by height (m) squared (kg/m^2). Height was recorded to the nearest 1 cm using a stadiometer (Seca Stadiometer, Seca Ltd., Birmingham, UK) and weight was recorded using a balance (Biospace Co., Seoul, Korea) to the nearest 0.1 kg having removed their shoes and heaviest clothing. An appropriately trained member of the research team took all the measurements [20].

2.3. Knowledge, Attitude and Practice (KAP) Questionnaire

Participants were asked to complete a self-reported questionnaire. The questionnaire assessed knowledge relating to salt and health outcomes, frequency of consumption and their perceived salt consumption, and was developed according to the WHO/PAHO recommendations for the assessment of population sodium intake and behaviors. The development and performance of the specific questionnaire has been described elsewhere [21].

2.4. 24-h Urine Collections and Analysis

A single timed 24-h urine collection was obtained for the estimation of sodium excretion. Participants were given written and verbal instructions for the 24-h urine collection procedure. A 3-L coded plastic bottle was given to each participant for urine collection. Participants were asked to discard the first urine of the day and to collect all urine in the plastic bottle provided over the following 24-h. Participants were also asked to write on a separate sheet the time and date at the start and end of the urine collection, indicating occasions they missed urination. Urine samples with less than 500 mL or those who missed urine collection were rejected and participants were asked to repeat the process on another day.

Urine analysis for sodium, potassium and creatinine were conducted in the College of Food and Agriculture laboratories at UAEU. For the measurement of sodium and potassium levels in the urine, 50 mL of the urine sample was mixed with 200 µL of 1% nitric acid. Analytical solutions were introduced to a Varian ICP-OES model 710-ES spectrometer for sodium and potassium measurements [18]. Urinary creatinine was measured using a Cary 50 MPR Micro plate Reader-Varian and the concentration determined using a standard curve [22].

2.5. Statistical Analysis

Continuous variables were summarized by means and standard deviations or medians and inter-quartile ranges (25th–75th percentile) as appropriate. Continuous variables were checked visually for any departure from normality using histograms and quantile-quantile plots (Q–Q plots). All continuous data were reasonably normally distributed and therefore no transformations were applied. Categorical variables from the KAP questionnaire were reported as the percentage of responses per category. The Student's *t*-test was used to compare the mean difference in sodium and potassium excretion in urine against the recommended dietary allowance. Measures of association for categorical variables were evaluated using a chi-square or Fisher's exact test as appropriate. All analyses were conducted using the Statistical Package for the Social Sciences (SPSS) version 21. All statistical significance was determined at 5%.

3. Results

3.1. Characteristics of the Study Population

A total of 530 participants provided urine specimens, out of which 41 participants were excluded due to limited urine sample collection (<500 mL urine), and 12 participants due to creatinine levels below 500 mg in the urine, to give a final sample size of 477. One urine sample was excluded from the sample during analysis, due to excessive creatinine levels, leading to one less participant in the urine analysis (n = 476). The mean age was 37.31 years (standard deviation (SD) = 12.5 years, range 20–65 years), of which 55% were female (Table 2). The mean weight, height and BMI for participants were 73.37 ± 15.4 kg, 165.8 ± 8.95 cm and 26.7 ± 5.15 kg/m^2, respectively (Table 2). The prevalence of underweight, normal weight, overweight and obese individuals was 3.14%, 37.11%, 36.06% and 23.69%, respectively.

Table 2. Summary of study population demographics (N = 477).

Variable	Mean ± SD
Age (years)	37.31 ± 12.5
Weight (kg)	73.37 ± 15.4
Height (cm)	165.8 ± 8.95
Body Mass Index (BMI)	26.7 ± 5.15
	N (%)
Emirates [1]	
Abu Dhabi (West)	137 (28.72)
Al-Ain (East)	150 (31.45)
Northern Emirates [2]	190 (39.83)
Age Category (years)	
20–30	156 (32.70)
31–40	113 (23.69)
41–50	123 (25.78)
51–65	85 (17.82)
BMI Classifications (WHO definition)	
Underweight (<18.5 kg/m^2)	15 (3.14)
Normal-weight (18.5–24.9 kg/m^2)	177 (37.11)
Overweight (25.0–29.9 kg/m^2)	172 (36.06)
Obese (30.0–34.9 kg/m^2)	113 (23.69)
Gender Distribution, N (%)	
Males	214 (44.86)
Females	263 (55.14)

[1] Geographic divisions of United Arab Emirates; [2] Dubai, Sharjah, Ajman, Umm Al Quwain and Fujairah.

3.2. *Major Findings of the Knowledge, Attitude and Practice (KAP) Questionnaire*

The knowledge, attitude and practice (KAP) questionnaire (Table 3) indicated that the majority of the participants added salt during cooking (N = 393; 82.4%) and while eating (N = 315; 66%). Most participants reported that they always or sometimes use stock cubes during cooking (N = 346; 72.6%), and 69.1% reported that they were aware that high salt intake could cause serious health problems. However, a large proportion (62.1%) thought that their salt consumption was within the recommended amounts, with 60% claiming to have tried to control their salt or sodium intake. Most of the participants (45.2%) reported that high salt intake was associated with high blood pressure, followed by kidney stones (18.7%) and obesity (17.8%), but only 11.7% associated it with heart disease, and 6.5% with T2D. More than 75% of the participants reported that they considered processed foods as a high source of salt.

Table 3. Knowledge, attitude and practice (KAP) of salt intake and participants' knowledge on health consequences (N = 477). * This question is multiple choice with more than one selection allowed.

	Gender				Age Category (Year)				
Do you Add Salt during Cooking (Missing Answers = 0)	**Male N = 214 (%)**	**Female N = 263 (%)**	**Total N = 477 (%)**	**Chi-Square (*p*-Value)**	**20–30 N = 156 (%)**	**31–40 N = 113 (%)**	**41–50 N = 123 (%)**	**51–65 N = 85 (%)**	**Chi-Square (*p*-Value)**
Never	46 (21.6)	38 (14.1)	84 (17.5)	5.60 (0.061)	28 (18.0)	26 (23.0)	13 (10.6)	17 (19.0)	20.01 (0.01)
Sometimes	80 (37.6)	96 (36.6)	176 (37.1)		65 (41.7)	42 (37.2)	46 (37.4)	23 (27.4)	
Always	88 (40.8)	129 (49.2)	217 (45.5)		63 (40.4)	45 (39.8)	64 (52.0)	45 (54.2)	
Do you Add Salt to Food at the Table (Missing Answers = 1)	**Male N (%)**	**Female N (%)**	**Total N = 476 N (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Never	71 (33.3)	90 (34.4)	161 (33.8)	2.12 (0.548)	54 (34.6)	31 (27.4)	40 (32.8)	36 (42.8)	12.71 (0.391)
Sometimes	93 (43.7)	122 (46.60	215 (45.2)		75 (48.1)	53 (46.9)	51 (41.8)	36 (42.8)	
Always	49 (23.0)	51 (19.0)	100 (21.0)		27 (17.3)	29 (25.7)	31 (25.4)	13 (14.3)	
Do you Use Stock Cubes during Cooking (Missing Answers = 0)	**Male N (%)**	**Female N (%)**	**Total N = 477 N (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Never	55 (25.8)	76 (28.6)	131 (27.4)	0.50 (0.779)	39 (25.0)	30 (26.6)	33 (26.8)	29 (34.1)	4.65 (0.794)
Sometimes	61 (28.6)	74 (28.2)	135 (28.4)		42 (26.9)	35 (31.0)	36 (29.2)	22 (25.9)	
Always	98 (45.5)	113 (43.1)	211 (44.2)		75 (48.1)	48 (42.5)	54 (44.0)	34 (40.0)	
How Much Salt do you Think you Consume (Missing Answers = 0)	**Male N (%)**	**Female N (%)**	**Total N = 477 N (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Too much	49 (23.0)	47 (17.6)	96 (20.0)	2.85 (0.240)	32 (20.5)	26 (23.0)	22 (18.0)	16 (19.1)	3.101 (0.928)
Just the right amount	125 (58.2)	171 (65.3)	296 (62.1)		96 (61.5)	70 (62.0)	80 (65.0)	50 (59.5)	
Far too little	40 (18.8)	45 (17.2)	85 (17.9)		28 (17.9)	17 (15.0)	21 (17.0)	19 (21.4)	
Do you Think that High Salt Diet could Cause Serious Health Problems? (Missing Answers = 0)	**Male N (%)**	**Female N (%)**	**Total N = 477** N (%)	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Yes	149 (69.6)	181 (68.8)	330 (69.1)	3.682 (0.158)	113 (72.4)	73 (64.6)	84 (68.4)	60 (70.0)	4.782 (0.780)
No	45 (21.0)	68 (25.8)	113 (23.7)		32 (20.6)	32 (28.3)	31 (25.2)	18 (23.7)	
Don't know	20 (9.3)	14 (5.4)	34 (7.2)		11 (7.1)	8 (7.1)	8 (6.56)	7 (8.4)	
What are the Health Problems Associated with High Salt Intake *	**Male N (%)**	**Female N (%)**	**Total N = 477N (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
High blood pressure	90 (42.1)	126 (47.9)	216 (45.2)	3.43 (0.414)	73 (46.8)	47 (41.6)	59 (48.0)	37 (43.5)	4.23 (0.624)
Kidney stones	43 (20.1)	46 (17.5)	89 (18.7)		31 (19.9)	22 (19.5)	21 (17.1)	15 (17.6)	
Obesity	38 (17.8)	47 (17.9)	85 (17.8)		25 (16.0)	23 (20.3)	18 (14.6)	19 (22.3)	
Diabetes	18 (8.4)	13 (4.9)	31 (6.5)		8 (5.1)	9 (8.0)	8 (6.5)	6 (7.1)	
Heart disease	25 (11.7)	31 (11.8)	56 (11.7)		19 (12.2)	12 (10.6)	17 (13.8)	8 (9.4)	
Do you Think Processed Foods are High in Sodium? (Missing Answers = 0)	**Male N (%)**	**Female N (%)**	**Total N = 477 (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Yes	159 (74.2)	207 (78.6)	366 (76.7)	1.620 (0.444)	123 (78.9)	88 (77.9)	88 (71.5)	68 (80.0)	6.578 (0.574)
No	55 (25.8)	56 (21.4)	111 (23.3)		33 (21.1)	25 (22.1)	35 (28.5)	17 (20.0)	
Do you do Anything on a Regular Basis to Control your Salt or Sodium Intake? (Missing Answers = 0)	**Male N (%)**	**Female N (%)**	**Total N = 477 (%)**	**Chi-Square (*p*-Value)**	**20–30 N (%)**	**31–40 N (%)**	**41–50 N (%)**	**51–65 N (%)**	**Chi-Square (*p*-Value)**
Yes	131 (61.2)	158 (60.1)	289 (60.6)	0.935 (0.626)	88 (56.4)	69 (61.1)	76 (61.8)	56 (65.9)	4.823 (0.764)
No	83 (38.8)	105 (39.9)	188 (39.4)		68 (43.6)	44 (38.9)	47 (38.2)	29 (34.1)	

3.3. High Levels of Sodium Secretion in the UAE Population within 24-h Urine Collection

The mean 24-h urine volume was 1338.3 ± 553 mL, with a range of 550–4000 mL. The mean sodium excretion in urine was 2713.4 ± 713 mg. The average values for sodium excretion in urine exceeded the WHO recommendations of sodium intake of less than 2300 mg (Table 4) [23]. Of the 476 participants, 320 (67.4%) had a sodium excretion above the WHO recommended level of 2300 mg. Males were more likely (51.6%) to exceed the WHO recommendation compared to females (odds ratio (OR): 2.60; 95% confidence interval (CI): 1.71 to 3.96; $p < 0.001$). However, there were no significant differences by age of those surpassing the recommendation (OR: 0.99; 95% CI: 0.98 to 1.02; $p = 0.98$).

Table 4. Mean sodium, potassium and creatinine urinary excretion and ratio of sodium to potassium (n = 476).

Nutrients	Mean ± SD	Recommendation	*p*-Value
Mean 24-h sodium excretion in urine (mg)	2713.40 ± 713	<2300 mg	<0.001
Mean 24-h potassium excretion in urine (mg)	1803.30 ± 618.03	>3510 mg	<0.001
Mean 24-h creatinine excretion in urine (mg)	1284.81 ± 607.0		
Mean 24-h creatinine (mg/kg body mass)	16.83 ± 4.84		
Mean 24-h creatinine (mg/kg body mass)—female	13.42 ± 1.95		
Mean 24-h creatinine (mg/kg body mass)—male	21.81 ± 3.80		
Mean 24-h urinary Na/K ratio	1.64 ± 0.55		

Mean urinary excretion for potassium and creatinine and the sodium to potassium ratio were 1803.30 ± 618.03 mg, 1284.81 ± 607.0 mg and 1.64 ± 0.55 mg, respectively (Table 4). While it is challenging to use potassium excretion to estimate intake, it is likely that it is well below the WHO recommendations of 3500 mg/day [24]. Moreover, mean urinary excretion for creatinine for female participants was 13.42 ± 1.95 mg/kg body mass, with a minimum to maximum reading of 10.23 to 19.87 mg/kg body mass, while for male participants it was 21.81 ± 3.80 mg/kg body mass, with a minimum to maximum reading of 13.60 to 28.63 mg/kg body mass (Table 4). Mean urinary excretions for sodium, potassium and creatinine for male and female participants according to the different age groups are shown in Figure 2.

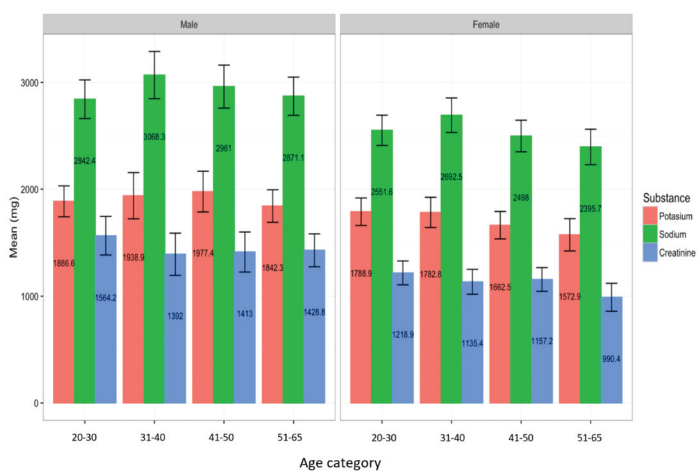

Figure 2. Mean creatinine, sodium and potassium levels for male (left panel) and female (right panel) participants according to age groups. The capped bars represent the 95% confidence intervals of the means.

4. Discussion

This study showed that sodium intake of the participants exceeds WHO recommendations with concurrent low intakes of potassium. Moreover, most of the participants were unaware that their consumption was beyond the recommended levels of the WHO, however, most were able to identify some common sources of sodium, such as stock cubes and processed foods, as well as its deleterious effect on health. To our knowledge, this is the first study in the UAE reporting 24-h urinary sodium excretion. A 24-h collection period is necessary to capture the marked diurnal variation in sodium, chloride and water excretion. Electrolyte excretion in healthy individuals normally reaches the maximum at or before midday, and the minimum at night towards the end of sleep [25]. This study is also the first to report on potassium excretion in the UAE, another critical indicator of dietary hypertension risk.

The results from the current study were similar to the results in a study conducted in Eastern Saudi Arabia that showed the mean intake of sodium assessed by 24-h sodium excretion to be 3200 ± 1100 mg/day and 2700 ± 850 mg/day for men and women, respectively [26]. Similar findings were noted in a Jordan study using 24-h urinary sodium excretion, which showed that the average sodium intake was 4100 mg/day (10.4 g/day salt) and sodium intake was higher in males, 4300 mg, compared with 4000 mg by females. It was clear that the Jordanian participants consumed at least double the current WHO recommended daily sodium amount of 2000 mg (5 g salt) [27]. Likewise, a study conducted in Oman using the National Nutrition Survey based on a 24-h dietary recall noted the average intake of salt to be 11–12 g/day [28], again significantly higher than the WHO recommendation. Two further studies analyzing food consumption in Kuwait [29,30] reported the average salt intake to be within 8–10 g/day. These results, and our own, are strong indicators that consumption of sodium exceeds the WHO recommendations in the GCC countries. It is well known high sodium intake is associated with hypertension and stroke, as well as contributes to myocardial infarction and heart and kidney failure [31,32]. Consequently, this prevalent increase in sodium consumption is likely to contribute to the incidence of NCDs in the UAE. Globally, the mean intake of sodium is high in East Asia, Central Asia, Eastern Europe, Central Europe and the Middle East/North Africa, in the range of 3900–4200 mg/day, which is equivalent to 9.75–10.5 g/day of salt [33], far exceeding the WHO recommendations, and is similar to our findings. While higher than the recommendations, the results of our study would suggest that the UAE was at the lower end of the scale of sodium intake in these geographic areas, however, comparisons between urinary excretion and sodium intake must be drawn with care. This may reflect the relatively high levels of education and other key socio-economic indicators when compared to these countries, which may manifest in more health-promoting behaviors. Urinary excretion of sodium as a function of intake has also been assessed in other nations, with generally higher socio-economic and health indicators. For example, in Japan and the United Kingdom (UK), sodium intake was 4470 ± 1600 mg/day and 3289 mg/day, respectively, and was attributed to a high intake of canned and processed foods [34,35].

High dietary sodium and low dietary potassium intakes are associated with hypertension and increased risk of cardiovascular disease (CVD) [36]. In the current study, the sodium to potassium ratio was 1.64 ± 0.55, suggesting that not only did sodium intake exceed WHO recommendations but insufficient dietary potassium was also prevalent. The amount of potassium excreted in 24-h urine is well correlated with dietary potassium intake [37]. A high urinary sodium–potassium ratio is an indicator of a need to reduce sodium and increase potassium intake [1,3]. The WHO has suggested that achieving guidelines for sodium and potassium intake would yield a sodium–potassium ratio close to 1.00 [23,24].

In our study, 67.4% of the participants exceeded the WHO recommendations for salt intake, with more males (51.6%) than females exceeding the recommendations. This finding is consistent with previous studies conducted in Kuwait, where males (74.7%) and females (50.9%) exceeded recommendations [29]. Similarly, a study conducted in Eastern Saudi Arabia also found that males tend to consume more sodium compared to females [26]. This finding is also consistent outside the GCC countries. In Brazil, 90% of the of study population exceeded WHO recommendations for salt intake with excess consumption again more common in males [38]. Another study aimed to estimate sodium intake in New York City, noting the mean sodium intake to be 3239 mg/day, with 81% of participants exceeding recommendations [39]. Brown et al. (2013), reported that sodium intake tends to be higher in men than women, based on 5693 participants recruited in 1984–1987 aged 20–59 years from 29 North American and European samples [31]; the findings again echoed those in our study. The sex differences in sodium excretion could have a number of causes, however, it is likely that increased appetite and calorie consumption is a major driver behind the variance. It is also possible that socio-cultural norms lead men to make more salt-heavy diet choices in both social and home situations, both in the UAE and globally. This is particularly relevant when viewed against the increased risk profile of a number of NCDs in men, and also makes it more challenging for males to meet sodium guidelines, as they are required to reduce their intake considerably compared to women.

The data on urinary potassium excretion is also of significant importance to the health of the population of the UAE. It is well known that potassium is a key part of effective blood pressure regulation, because of its role in effective sodium clearance. The mean potassium intake shown in this study was well below the WHO guidelines, providing opportunities for improvement of the health of the UAE. Encouraging a varied diet, high in fruit and leafy vegetables, would provide a ready means of improving health outcomes. Potassium is not amenable to fortification, due to the negative consequences of excessive intake and a flavor-masking effect of common chemical formats of the mineral, which means improving diet quality is the major means of increasing intake in the community.

It was also found that 82.5% of the participants in this study added salt sometimes or always during cooking, which is similar to that noted in Lebanon, where 100% of the participants have been found to add salt during cooking [40]. In the current study, the majority of participants reported that they added stock cubes and additional table salt while eating, sometimes or always. These findings are similar to the Lebanon study which showed that 60% of the participants used table salt [40]. Likewise, 61% of university students in the UAE reported adding salt while cooking, and 14% of the participants often added salt to food even before tasting it [21].

Despite the fact that 67.4% of the participants exceeded the WHO recommended salt intake in the current study, only 20.0% reported that their consumption was beyond the recommended threshold (Table 3). In light of our data showing widespread sodium excess, this suggests that many people are unaware of how much they are consuming. In this regard, education and public awareness programs are required so that the general population is more aware of salt portion sizes and the sodium content of processed foods, drinks and other foods in general.

Interestingly, about 60% of the participants claimed to be taking measures to control their salt intake, again similar to reports from Lebanon (65.8%) [40]. These findings are also similar to a study conducted in five sentinel countries of the Americas (Argentina, Canada, Chile, Costa Rica and Ecuador), where almost 90% of the participants reported excess intake of salt is associated with adverse health conditions, and over 60% of the participants indicated they were conscious of their salt intake and taking measures to reduce it. They also found that more than 30% of their participants believed that reducing dietary salt intake was highly important [41]. Most of these studies reported that the majority of the participants were aware that high salt intake was associated with adverse health outcomes, however, this awareness does not translate into effective behavioral change in salt reduction. These interesting findings have some important implications for strategies to reduce sodium intake. One of the mainstays of sodium reduction is public education, however, these results would indicate that the general knowledge is adequate. However, education campaigns on effective ways to reduce intake, while increasing potassium and hydration, would play a role in the general reduction in sodium across the UAE, alongside effective regulations and sodium targets.

The results of the current study indicate that there is prevalent high sodium and low potassium intake within the general population of the UAE, which consequently may increase the risk of hypertension, CVD and other NCDs. This emphasizes the need for coordinated salt reduction programs to aid in the reduction of NCDs in the UAE. Strategies such as educational campaigns, regulation of sodium content of widely consumed food items and setting targets for sodium intake will allow for a more cohesive approach to improving the health of the UAE in this regard. In the last two decades, a number of countries have put sodium reduction strategies in place, and they have generally been somewhat successful, however, there are still significant strides to be made [42]. The most effective population interventions are likely to be salt reduction targets in common food stuffs, specific to the geographical areas and the local cuisines. In the metropolitan centers of the UAE, this will likely need to target processed and fast foods, which are becoming more of a staple in the Emirati diet, however, future research to identify significant sources of sodium in the UAE is needed to guide policy makers. Other nations with successful sodium reduction strategies have used salt targets, typically between 5–8 g/day [42], to help guide these regulations and interventions. Decreasing the sodium consumption of the UAE will also require regulation of industry to offer more low-salt options, as well as improve standards on labeling and nutritional declaration on packaged foodstuffs.

The Mediterranean diet could play a role in combatting the widespread salt imbalance in the UAE. The Mediterranean diet is inherently low in sodium and high in potassium due to its high vegetable and low meat and processed food content. The Mediterranean diet is also accessible to the local region, as it contains a number of similarities to traditional food practices in the Arab nations, such as an emphasis on vegetables, dairy, grains and spices, however, the Emirati cuisine traditionally features meat products more strongly [43]. The Mediterranean diet has been shown to reduce hypertension [44], however, there is some debate surrounding the role of sodium in this. Some authors have found that the Mediterranean diet does not readily offer reductions in sodium [45], however, this may be due to variations in adherence and specific components of the diet, as well as the amount of other minerals, such as potassium, which are abundant in plant-rich diets.

Despite the significant findings, a limitation of this study was that urinary sodium was assessed by a single 24-h urine collection and this may not represent the average sodium intake in a person due to daily individual variability. However, a single urine measurement is considered a more accurate measure of sodium intake at a population level [18], though it may possibly be less accurate for individuals. There is also a potential that the recruited population may have been broadly healthier, as they were likely more health conscious, better educated and possibly of a higher socio-economic status. Future studies should account for key socio-economic indicators, such as years of education and household income in both their recruitment and analysis to ensure a representative sample of the population. This may have led to an underestimation of the UAE's sodium intake found in this study. Additionally, while the KAP questionnaire used in this study captures some important facets of the participants' knowledge and behavior surrounding salt, there is further room for additional information, particularly surrounding important sources of sodium in the modern diet. An expanded questionnaire, and other measures such as food diaries, would provide more reliable information on the true intake of sodium, and how that compares to the participants' knowledge. Despite these limitations, the study described was statistically sound and powered to reliably identify the sodium practices in the UAE. The large sample, with demographically representative participants, and the validated analytical methods, are also strengths of the research presented here.

5. Conclusions

In this cross-sectional sample of the UAE population, the majority consumed salt well above the international WHO recommendations with a concurrent low intake of potassium, suggesting significant room for improvement in the intake of these minerals. There are significant differences by gender, with males more likely to exceed the WHO recommendations for salt and sodium intake.

It is imperative for communities, as well as local and national governments, to play a leading role in the development and implementation of salt reduction strategies, such as increasing adherence to the Mediterranean diet, as well as setting standards for industry. Future research should aim to validate these findings with larger studies, as well as to identify important sources of sodium in the diet of the UAE. Awareness programs should be established to educate the population about the risk factors for excess salt consumption. A nationwide assessment should be conducted to evaluate the level of the problem, and to enable identification of appropriate priorities for the implementation of population-based diet-related interventions to reduce the prevalence of NCDs and their associated rates of morbidity and mortality.

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Eating Habits and Lifestyle during COVID-19 Lockdown in the United Arab Emirates: A Cross-Sectional Study

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Abstract: The coronavirus disease is still spreading in the United Arab Emirates (UAE) with subsequent lockdowns and social distancing measures being enforced by the government. The purpose of this study was to assess the effect of the lockdown on eating habits and lifestyle behaviors among residents of the UAE. A cross-sectional study among adults in the UAE was conducted using an online questionnaire between April and May 2020. A total of 1012 subjects participated in the study. During the pandemic, 31% reported weight gain and 72.2% had less than eight cups of water per day. Furthermore, the dietary habits of the participants were distanced from the Mediterranean diet principles and closer to "unhealthy" dietary patterns. Moreover, 38.5% did not engage in physical activity and 36.2% spent over five hours per day on screens for entertainment. A significantly higher percentage of participants reported physical exhaustion, emotional exhaustion, irritability, and tension "all the time" during the pandemic compared to before the pandemic ($p < 0.001$). Sleep disturbances were prevalent among 60.8% of the participants during the pandemic. Although lockdowns are an important safety measure to protect public health, results indicate that they might cause a variety of lifestyle changes, physical inactivity, and psychological problems among adults in the UAE.

Keywords: United Arab Emirates; COVID-19; eating habits; lifestyle behaviors

1. Introduction

The novel coronavirus disease (COVID-19) pandemic has added various challenges and changes to human life worldwide, causing an unprecedented impact on human health, lifestyle, and social life, and has affected the local and international economy [1]. Following its first emergence in December 2019, in the city of Wuhan in China and its subsequent outbreak throughout the world in the following months it was characterized as a global pandemic by the World Health Organization (WHO) on 11 March 2020 [2]. On 28 September 2020, over 32.7 million confirmed cases of novel coronavirus and around 991,000 deaths worldwide were reported by the WHO [3]. In the United Arab Emirates (UAE) a total of 90,618 confirmed cases were reported in the same period [3]. In response to the rapid spread of the disease governments all around the world had to implement strict measures such as complete or partial lockdowns, isolation, quarantine and social distancing [4,5].

In the UAE, as a response to this outbreak, the government had to act quickly to contain the spread of the virus. Parallel with measures taken by most countries worldwide, complete and partial lockdowns were implemented, non-essential public places were closed, telework and distance learning was initiated, delivery services like delivering drugs to chronically ill patients were provided and sanitizing cities during night as part of the National Disinfection Program was implemented [6]. According to the World Bank, the total population of the UAE in 2019 was about 9.8 million [7]. However, nearly 75% of the population is concentrated in Abu Dhabi and Dubai as they have more than 3 million residents each. Moreover, the UAE is a multicultural country with expatriates and immigrants accounting for about 88% of the population [8]. Thus, this study provides unique opportunities to examine the impact of COVID-19 on lifestyle behaviors in the UAE.

There is no doubt that during times of confinement, food accessibility and availability may be affected, which in turn affects diet quality [9]. The imposed possibility of reduced income, job losses and anxiety about an uncertain future might lead the population to cut down expenditure including their expenses for food, making them go for more palatable, affordable and possibly unhealthy options [10]. Diet can affect many areas, but most importantly it can affect immune status [11] in the short term, a time during which heightened activity should be at its best. Available literature, however, has shown trends toward unfavorable dietary behaviors during the lockdown such as increased caloric intake, more frequent snacking, reduced consumption of fresh fruits and vegetable, and weight gain [10,12]. Traditionally, the diet in the UAE consists of fruits (such as dates), vegetables and fish and it is characterized by a high-fiber content and low fat and cholesterol content [13]; foods that characterize the Mediterranean diet and that are rich in vitamins A, D, C, folate, E and B-complex, required for an optimal immune response. Moreover, a large portion of UAE residents are from Arab countries in which fruits, vegetables and olive oils constitute key components of their diets. Therefore, it would be of interest to assess any shift in dietary habits during the COVID-19 situation.

Levels of physical activity were also negatively affected during quarantine [10,14,15]. Factors like complete lockdowns, closure of sport facilities and parks, and overall movement restrictions have reduced the ability to engage in physical activity. This was accompanied with an increase in sedentary behaviors related to quarantine, including distance learning and telework [16]. A meta-analysis on physical activity prior to COVID-19 pandemic revealed that a quarter of the population residing in the UAE had a sedentary lifestyle and were not engaged in any type of physical activity [17].

The emergence of infectious diseases reaching pandemic levels induces a huge psychological impact and distressed mental health symptoms in the population with anxiety being the most common as was shown following the Middle East respiratory syndrome coronavirus (MERS-CoV), severe acute respiratory syndrome coronavirus (SARS-CoV), and severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [18,19]. Anxiety and uncertainty along with food insecurity and restricted healthcare access might also impact individuals with eating disorders and obesity [20,21]. Multiple factors influence the extent of psychological impact of outbreaks including unknown means of virus transmission, future unpredictability, media misinformation, and quarantine [19,22]. Consequently, such stressful events strongly aggravate disturbed sleep patterns and insomnia, poor eating habits along with decreased levels of physical activity and increased sedentary behaviors [23,24].

This study aimed to investigate the effect of quarantine on eating habits, physical activity, stress and sleep behaviors among adult UAE residents using a formulated online survey. A comparison of lifestyle and dietary behaviors before and during the lockdown was also conducted to allow better understanding of the effects of Covid-19-induced confinement policies on lifestyle changes among the UAE residents. Dietary intake was examined during the lockdown to evaluate potential risks of nutritional inadequacies.

2. Materials and Methods

2.1. Study Design and Participants

To assess the effect of the coronavirus pandemic and the effect of lockdown on eating habits and lifestyle of residents of the UAE, a population-based (cross-sectional) study was conducted in the UAE between April and May 2020. Although cross-sectional studies are rarely used to compare before and after, since there is no temporal sequence, it is the best design to use when previous information is not available, in order to draw inferences. Considering the sudden outbreak of COVID-19, this study aimed to evaluate the effect of the pandemic by examining highly modifiable factors including lifestyle and dietary.

The target population included all adults ≥18 years and from all seven emirates, residing in UAE. These were invited to participate in an online survey using snowball sampling methods in order to guarantee a large-scale distribution and recruitment of participants. A total of 1012 participants (24.1% males) were included in this study.

A web link was retrieved for the survey and was distributed using e-mail invitations and social media platforms, e.g., LinkedIn™ (Mountain View, CA, USA), Facebook™ (Cambridge, MA, USA), and WhatsApp™ (Menlo Park, CA, USA). The first page of the survey included an information sheet and consent form indicating the participants' right to withdraw at any time. Consenting participants then chose their desired language and proceeded to complete and submit their responses. All data were collected anonymously with no indication of any personal information and participants were not rewarded. The study protocol was approved by the Research Ethics Committee at the University of Sharjah (REC-20-04-25-02) and the Social Sciences Research Ethics Committee at United Arab of Emirates University (ERS_2020_6106).

2.2. Survey Questionnaire

A multicomponent, self-administrated online survey was designed using Google document forms in English, Arabic, and French. This survey contained questions on dietary and lifestyle habits prior to and during the COVID-19 confinement. A researcher from the College of Health Sciences at the University of Sharjah (UAE) and a researcher from the College of Food and Agriculture at United Arab Emirates University (UAE) developed the draft of the survey in English. Questions were developed based on a previous national nutrition survey [25], the International Physical Activity Questionnaire Short Form (IPAQ-SF) [26] and the Copenhagen Psychosocial Questionnaire (COPSOQ-II) [27]. It was then translated and culturally adapted following an internationally accepted methodology [28,29]. The survey was later reviewed by the research team and was pilot tested with 25 people from the UAE. Following the pilot-testing, slight modifications were made to the survey. The online survey included 37 questions and was divided into seven sections: (1) socio-demographic background (10 questions): gender, age, marital status, number of children the participant has, education level, employment status, whether they were working or studying from home during the lockdown, weight change, perceived health status, and emirate of residence; (2) sources of information (2 questions): where do they obtain health and nutrition related information; (3) eating habits (8 questions): meal type, meal frequency, eating breakfast, skipping meals, reasons for skipping meals, water intake, and food frequency of specific foods; (4) shopping habits (5 questions): preparing a grocery list, stocking up on foods, using online shopping, reading food labels, and cleaning/sanitizing groceries; (5) physical activity (4 questions): exercising frequency, household chores frequency, computer time for work or study, and screen time for entertainment; (6) stress and irritability (4 questions): physical exhaustion, emotional exhaustion, irritability, and tension; (7) sleep (4 questions) sleep duration, sleep quality, sleep disturbances, and energy level. The full version of the questionnaire is available as a Supplementary File.

Questions on eating habits, physical activity, stress and irritability, and sleep were asked twice, once regarding the period before the pandemic (pre-COVID-19) and the other regarding the period during lockdown (during COVID-19).

2.2.1. Dietary Assessment

A total of 10 specific dietary questions were included in the questionnaire to assess frequency of specific food groups only during COVID-19 pandemic [30]. Food groups were included based on usual intakes of the population residing in the United Arab Emirates [31,32]. These characterize the basic Mediterranean type diet but also include food high in sugar and fat, observed to be recently trending in the UAE [25]. Specifically, the questionnaire included the following food groups: fruit, vegetables, milk and milk products, meat and meat products (red meat, chicken and fish), grains (bread, rice pasta), sweets, sugar sweetened beverages (ssbs), coffee and tea, and energy drinks. Response options included never; 1–4 times per week; once a day; 2–3 times a day; 4 or more times a day. Internal consistency of the food added in the food frequency questionnaire was evaluated using Cronbach's alpha for this section of the questionnaire specifically, to decrease false high internal consistency, since this test is affected by the length of the test [33]. A value of 0.81 was derived showing strong inter-relatedness of the food items, ensuring validity (Cronbach's alpha = 0.81, from a scale of 0 to 1.0; small cohort error variance of 0.34).

2.2.2. Physical Activity Assessment

A modified version of the International Physical Activity Questionnaire Short Form (IPAQ-SF) was used to assess frequency of physical activity pre-COVID-19 and during COVID-19 among surveyed participants [26]. Participants were asked to indicate "how many days per week did they engage in moderate to vigorous physical activity", and "how many days per week did they engage in household chores". They were also asked to indicate "how many hours per day did they spend on the computer for work or study", and "how many hours per day did they spend on screens for fun and entertainment".

2.2.3. Stress, Irritability and Sleep Assessment

Questions on stress and sleep were adopted from the second version of the Copenhagen Psychosocial Questionnaire (COPSOQ-II) with modifications [27]. Regarding stress and irritability, participants were asked to provide the frequency of experiencing physical exhaustion; emotional exhaustion; irritability; and tension. The same questions were asked once regarding the period before the pandemic (pre-COVID-19) and once during the pandemic. The response options included all the time; a small part of the time; part of the time; a large part of the time; all the time.

With regard to sleep, participants were asked if they experienced sleep disturbances including sleeping badly and restlessly; having difficulty to go to sleep; waking up too early and not being able to get back to sleep; waking up several times and found it difficult to get back to sleep; or none of the options. The questionnaire also included the following questions: "number of sleeping hours per night", "rating sleep quality", and "describing energy level during the day". The repose options for rating sleep quality were very good; good; poor. The repose options for describing energy level were energized; neutral; lazy. Questions were repeated twice, once about the period pre-COVID-19 and the second regarding the period during COVID-19.

2.3. Statistical Analysis

Categorical variables are presented as counts and percentages. The chi square test was used to determine the association between categorical variables, and the McNemar test was used to investigate the difference between categorical variables before and during the COVID-19 pandemic. A sub-analysis was also performed for weight and specific behavioral variables' differences between groups. Specifically, data were stratified (i) by sex, (ii) by age group (18–35 and ≥36 years), and (iii) level of education. Principal component analysis (PCA) was used to group related dietary practice into components [34]. The correlation of each food group with the underlying component was calculated with component loadings. In this analysis, values >0.3 were considered as having an effect in the component construction. Each participant was given a score based on the sum of the component loadings of each food group. The identified components were rotated (varimax rotation) to retrieve orthogonal, uncorrelated factors, decreasing variance errors. The Kaiser–Meyer–Olkin (KMO) measure of sample adequacy was used to assess PCA adequacy. Results were significant for p value < 0.05. Statistical analysis was performed using Statistical Package for the Social Sciences (SPSS) version 26.0 (IBM, Chicago, IL, USA).

3. Results

3.1. Demographic Characteristics

The survey was completed by 1012 participants. The sample distribution from different emirates was representative of the population distribution in the UAE. With the highest number of participants residing in Abu Dhabi and Dubai. More specifically, local coverage spreads over all regions in the UAE: 33.9% of participants live in the capital Abu Dhabi, 32.5% in Dubai, and 33.6% in Sharjah and northern Emirates. The majority of the participants completed the survey in Arabic (60.4%), followed by English (39.3%), and only 0.3% chose the French language. Comprehensive information relating to demographic characteristics of the study population is presented in Table 1. The majority of participants were females (75.9%), aged 26–35 years (29.1%), were married (56.4%), had no children (50%), completed a bachelor's degree (54.1%), worked full-time (53.3%), and were working or studying from home during quarantine (61.6%). Almost one third of the participants reported weight gain since the start of the lockdown (31%). However, 20.9% reported weight loss, 40.1% maintained their weight, and 7.9% did not know if there was a change in their weight. The majority of participants described their health status during the outbreak as very good (39.7%) and only 0.7% indicated poor health status.

Table 1. Demographic characteristics of study participants (n = 1012).

Characteristics	n	%
Gender		
Male	244	24.1
Female	768	75.9
Age (years)		
18–25	280	27.7
26–35	294	29.1
36–45	240	23.7
46–55	154	15.2
>55	44	4.3
Marital status		
Married	571	56.4
Single	403	39.8
Divorced	30	3.0
Widowed	8	0.8

Table 1. *Cont.*

Characteristics	*n*	%
Number of children		
None	506	50.0
1–2	230	22.7
≥ 3	276	27.3
Education level		
Less than high school	8	0.8
High school	111	11.0
College/Diploma	102	10.1
Bachelor's degree	547	54.1
Higher than bachelor's degree	244	24.1
Employment status		
Full-time	539	53.3
Part-time	44	4.3
Self-employed	31	3.1
Student	156	15.4
Unemployed	230	22.7
Retired	12	1.2
Working/studying from home		
Yes	623	61.6
No	309	30.5
Not applicable	80	7.9
Weight change during pandemic		
Lost weight	212	20.9
Gained weight	314	31.0
Maintained weight	406	40.1
Do not know	80	7.9
Perceived health state during pandemic		
Excellent	217	21.4
Very good	402	39.7
Good	284	28.1
Fair	102	10.1
Poor	7	0.7
Emirate of residence		
Abu Dhabi	343	33.9
Dubai	329	32.5
Sharjah	244	24.1
Ajman	52	5.1
Ras al Khaimah	20	2.0
Fujairah	16	1.6
Umm al Quwain	8	0.8

3.2. Source of Information

When asked about the most common source of information for health and nutrition updates, 69.1% and 67.8% of participants reported relying on social media applications, respectively (Table 2). Local and international health authorities were selected as the second source of information for both health and nutrition updates (65.4% and 48.7%, respectively).

Table 2. Source of health and nutrition information during COVID-19 pandemic (n = 1012).

Source of Information *	Health-Related Information, *n* (%)	Nutrition-Related Information, *n* (%)
Local and international health authorities	662 (65.4)	493 (48.7)
Social media	699 (69.1)	686 (67.8)
Healthcare professionals	409 (40.4)	462 (45.7)
Television	231 (22.8)	172 (17.0)
Newspapers	75 (7.4)	51 (5.0)
Friends and family	339 (33.5)	386 (38.1)

* As multiple responses were allowed, the total number of responses is greater than the number of surveyed participants and the percent of cases is displayed.

3.3. Eating Habits

Table 3 presents the eating habits of the study participants pre- and during the COVID-19 pandemic. Results showed a significant increase in the percentage of participants consuming mostly homemade meals during the pandemic and a significant reduction in those mainly consuming fast-food ($p < 0.001$). Moreover, the percentage of participants consuming five or more meals per day increased from 2.1% before the pandemic to 7% during the pandemic ($p < 0.001$). Also, the percentage of participants consuming breakfast increased from 66% to 74.2%, and the percentage of those skipping meals decreased from 64.5% to 46.2% during the pandemic ($p < 0.001$). Participants reported skipping meals mainly due to lack of time before the pandemic (62.3%), however, the main reason behind that was lack of appetite (36%). With regards to water intake, only 24.1% of participants consumed eight or more cups per day before the pandemic, and the percentage increased to 27.8% during the pandemic ($p = 0.003$).

Table 3. Eating habits pre- and during COVID-19 pandemic (n = 1012).

Variables	Pre-COVID-19 *n* (%)	During COVID-19 *n* (%)	*p*-Value (2-Sided)
Most consumed meals during the week *			
Homemade	838 (82.8)	974 (96.2)	<0.001
Frozen ready-to-eat meals	119 (11.8)	97 (9.6)	0.032
Fast food	270 (26.7)	80 (7.9)	<0.001
Restaurants [1]	289 (28.6)	58 (5.7)	<0.001
Healthy restaurants [2]	98 (9.7)	46 (4.5)	<0.001
Number of meals per day			
1–2 meals	470 (46.4)	369 (36.5)	<0.001
3–4 meals	521 (51.5)	572 (56.5)	0.009
≥5 meals	21 (2.1)	71 (7.0)	<0.001
Eating breakfast on most days			
Yes	668 (66.0)	751 (74.2)	<0.001
No	344 (34.0)	261 (25.8)	
Skipping meals			
Yes	663 (65.5)	468 (46.2)	<0.001
No	349 (34.5)	544 (53.8)	
Reasons for skipping meals (If the answer was yes) *			
To reduce food intake	143 (21.7)	136 (29.1)	0.011
Lack of time	410 (62.3)	143 (30.6)	<0.001
To lose weight	122 (18.5)	110 (23.6)	0.001
Lack of appetite	182 (27.7)	168 (36.0)	0.016
Fasting	68 (10.3)	120 (25.7)	<0.001

Table 3. *Cont.*

Variables	Pre-COVID-19 n (%)	During COVID-19 n (%)	p-Value (2-Sided)
Amount of water consumed per day			
1–4 cups	410 (40.5)	337 (33.3)	<0.001
5–7 cups	358 (35.4)	394 (38.9)	0.036
≥8 cups	244 (24.1)	281 (27.8)	0.003

* As multiple responses were allowed, the total number of responses is greater than the number of surveyed participants and the percent of cases is displayed. [1] Restaurants: included all ethnic restaurants (Asian, Middle Eastern, International, etc.), casual dining and family style restaurants; [2] healthy restaurants: included food outlets with the "Weqaya logo", restaurants categorized as "healthy" on food mobile apps (such as Zomato, Talabat, and Uber Eats) or catering services providing meal plan services based on nutritional needs (such as Kcal, right bite, Eat Clean ME, etc.).

The frequency of consumption for particular food products during the COVID-19 pandemic among residents of the UAE are presented in Table 4. Over half of the participants (51.2%) did not consume fruits daily, 37% did not consume vegetables daily, and 46.2% did not consume milk and dairy products on daily basis. However, 46.1% of the participants consumed sweets and desserts at least once per day, and 37.1% reported consuming salty snacks (chips, crackers, and nuts) every day.

Table 4. The frequency of consumption of particular foods during COVID-19 pandemic (n = 1012).

Food Items	≥4 Times/Day	2–3 Times/Day	Once/Day	1–4 Times/Week	Never
			n (%)		
Fruits	20 (2.0)	133 (13.1)	341 (33.7)	462 (45.7)	56 (5.5)
Vegetables	32 (3.2)	244 (24.1)	362 (35.8)	356 (35.2)	18 (1.8)
Milk and milk products	17 (1.7)	167 (16.5)	361 (35.7)	374 (37.0)	93 (9.2)
Meat/fish/chicken	32 (3.2)	133 (13.1)	440 (43.5)	383 (37.8)	24 (2.4)
Bread/rice/pasta	43 (4.2)	263 (26.0)	350 (34.6)	311 (30.7)	45 (4.4)
Sweets/desserts	29 (2.9)	106 (10.5)	331 (32.7)	437 (43.2)	109 (10.8)
Salty snacks	14 (1.4)	85 (8.4)	276 (27.3)	500 (49.4)	137 (13.5)
Coffee/tea	80 (7.9)	321 (31.7)	300 (29.6)	222 (21.9)	89 (8.8)
Sweetened drinks	18 (1.8)	51 (5.0)	156 (15.4)	340 (33.6)	447 (44.2)
Energy drinks	4 (0.4)	11 (1.1)	35 (3.5)	87 (8.6)	875 (86.5)

Additionally, 69.2% had tea or coffee at least once per day. Sweet drinks such as fruit juices and beverages were less popular among the study participants, as 44.2% reported never consuming them and an even higher percentage (86.5%) reported never consuming energy drinks during the pandemic.

A total of two components from the PCA output were derived, based on eigenvalue (at least 1) and scree plots obtained (Table 5). These two components explained 47% of the variance in eating behavior and were named based on the interpretation of the component loadings. The first pattern explained 31% of eating variation and was named "Western-type diet" since it was characterized by significantly positive loadings in dairy, meat, sweets, salted foods and vegetables. The second pattern explained 16% of the variance and loaded positively with ssbs and energy drinks and negatively on fruits and vegetables. Therefore, it was named "Free Sugars diet". A KMO of 0.78 was obtained, which is considered substantial.

Table 5. Component loading for the two major dietary patterns of the participants during COVID-19.

Food Groups	Western	Free Sugars
Fruits	0.2839	**−0.3807**
Vegetable	**0.3302**	**−0.4219**
Milk	**0.3247**	−0.1932
Meat	**0.3599**	−0.0732
Carbs	**0.3975**	−0.0764
Sweets	**0.3845**	0.2917
Salted Foods	**0.3356**	0.2776
Coffee/Tea	0.2457	−0.1641
Sweet Drinks	0.2678	**0.4929**
Energy Drinks	0.1575	**0.4433**
KMO	**0.78**	

KMO: Kaiser–Meyer–Olkin (KMO) test. The unique characteristics of each component (dietary pattern) are presented in bold. Marginally unique dietary characteristic for each component. Loadings ≥0.30 and ≤−0.30.

3.4. Shopping

The results revealed that the majority of participants prepared a shopping list beforehand (80.3%), started stocking up on foods during the pandemic (43.9%), did not order their groceries online (58.0%), read the food label before purchasing products (52.4%), and sanitized or cleaned groceries before storing them (71.9%) (Table 6).

Table 6. Shopping practices during COVID-19 pandemic (n = 1012).

Variables	*n*	%
Prepare shopping list		
Yes	813	80.3
No	199	19.7
Start stocking up on foods		
Yes	444	43.9
No	412	40.7
Already stocking up	156	15.4
Online grocery shopping		
Yes	425	42.0
No	587	58.0
Reading food labels		
Yes	530	52.4
No	113	11.2
Sometimes	369	36.5
Sanitizing/cleaning groceries		
Yes	728	71.9
No	113	11.2
Sometimes	171	16.9

3.5. Physical Activity

Figure 1a shows that 32.1% of the participants reported not engaging in any physical activity before the coronavirus pandemic, and the percentage increased to 38.5% during the pandemic ($p < 0.001$). Moreover, Figure 1b shows that there was a significant association between the frequency of performing physical activity during the pandemic and the reported change in weight among participants ($p < 0.001$). Of those who reported performing physical activity more than three times per week, 29.9% lost weight and 49.5% maintained their weight ($p < 0.001$). Furthermore, 40.3% of people who did not perform physical activity reported weight gain.

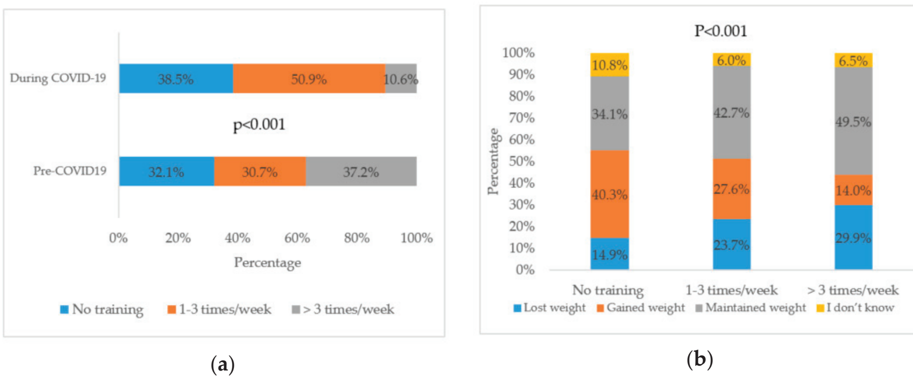

Figure 1. Physical activity pre- and during COVID-19 pandemic (**a**) Frequency; (**b**) Change in weight. The p values indicate the statistical significance of McNemar test. The p values indicate the statistical significance of chi-square test.

A significantly higher percentage of participants spent more than five hours per day on the computer for study or work purposes during the pandemic (47.6%) compared to before the pandemic (32%) ($p < 0.001$). Similarly, the percentage of participants spending more than five hours per day on screens for fun increased from 12.9% before the lockdown to 36.2% during the lockdown ($p < 0.001$) (Table 7).

Table 7. Daily activities pre- and during COVID-19 pandemic (n = 1012).

Variables	Pre-COVID-19 *n* (%)	During COVID-19 *n* (%)	*p*-Value (2-Sided)
Doing household chores			
Never	302 (29.8)	207 (20.5)	<0.001
1–3 times/week	404 (39.8)	333 (32.9)	<0.001
4–5 times/week	62 (6.1)	114 (11.3)	<0.001
Everyday	244 (24.1)	358 (35.4)	<0.001
Screen time for study or work			
None	188 (18.6)	160 (15.8)	0.004
1–2 h/day	282 (27.9)	136 (13.4)	<0.001
3–5 h/day	218 (21.5)	234 (23.1)	0.375
>5 h/day	324 (32.0)	482 (47.6)	<0.001
Screen time for entertainment			
Less than 30 min/day	113 (11.2)	62 (6.1)	<0.001
1–2 h/day	456 (45.1)	231 (22.8)	<0.001
3–5 h/day	312 (30.8)	353 (34.9)	0.053
>5 h/day	131 (12.9)	366 (36.2)	<0.001

3.6. Stress

Participants were asked to indicate the frequency of experiencing physical exhaustion; emotional exhaustion; irritability; and tension before and during the pandemic. Figure 2 presented the response distribution in percentages for each of the four stress parameters.

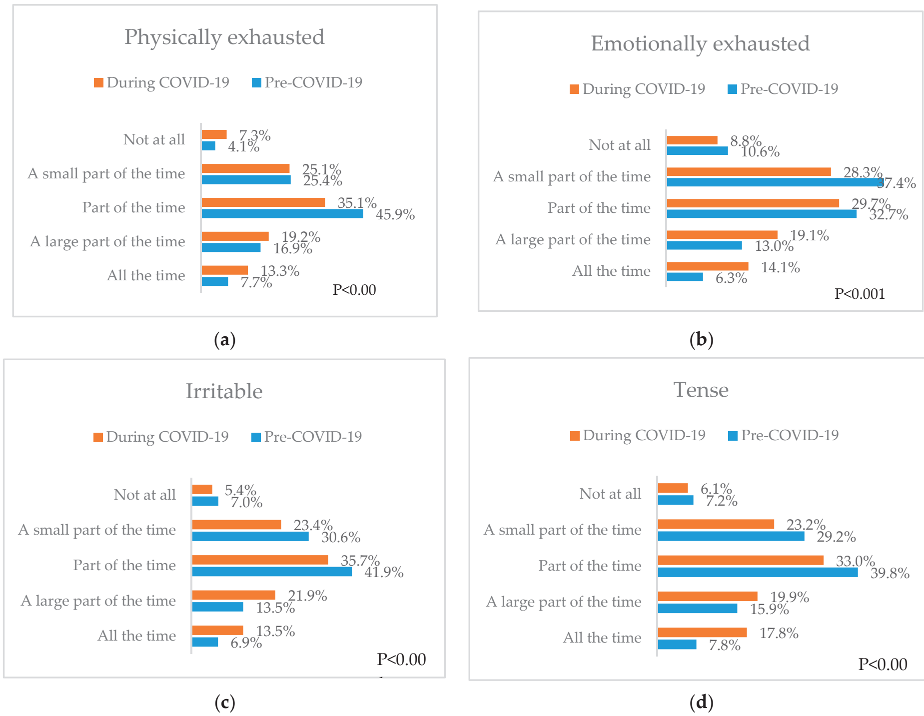

Figure 2. Stress and irritability pre- and during COVID-19 pandemic (**a**) Physical exhaustion; (**b**) Emotional exhaustion; (**c**) Irritability; (**d**) Tension. The *p* values indicate the statistical significance of McNemar test.

The results indicate a significant increase in the percentage of participants reporting all four stress parameters "all the time" during the coronavirus pandemic compared to before the pandemic (13.3% vs. 7.7% for physical exhaustion; 14.1% vs. 6.3% for emotional exhaustion; 13.5% vs. 6.9% for irritability; and 17.8% vs. 6.3% for tension) (all $p < 0.001$).

3.7. Sleep

Results showed a significant decrease in the percentage of participants who reported sleeping less than seven hours per night from 51.7% before the pandemic to 39% during the pandemic ($p < 0.001$) (Table 8). However, a higher percentage of participants reported poor sleep quality during the pandemic (28.1%) compared to before the pandemic (17.3) ($p < 0.001$), and sleep disturbances were also more common during the pandemic (60.8%) compared to before (52.9%). Consequently, 30.9% of the surveyed participants reported feeling lazy and less energized during the pandemic, compared to only 4.7% before the pandemic ($p < 0.001$) (Table 8).

An analysis of weight and behavioral factors by sex and age groups is depicted in Table 9. Significantly more males reported decreased engagement in physical activity (50% vs. 39.3%; $p = 0.013$) and increased screen time (54.5% vs. 51%; $p = 0.002$). Sleep disturbances increase was, however, significantly higher in females ($p = 0.011$). Moreover, those aged over 36 years reported a higher weight gain as well as an increase in the number of meals consumed per day ($p = 0.042$ and $p = 0.024$, respectively). Sleep duration and quality was most affected among participants aged 18–35 ($p < 0.001$). There was no significant association between different education levels and lifestyle changes (Table 9).

Table 8. Sleep pre- and during COVID-19 pandemic (*n* = 1012).

Variables	Pre-COVID-19 *n* (%)	During COVID-19 *n* (%)	*p*-Value (2-Sided)
Hours of sleep per night			
<7 h	523 (51.7)	395 (39.0)	<0.001
7–9 h	459 (45.4)	499 (49.3)	0.057
>9 h	30 (3.0)	118 (11.7)	<0.001
How would you rate your sleep quality			
Very good	308 (30.4)	282 (27.9)	0.134
Good	529 (52.3)	446 (44.1)	<0.001
Poor	175 (17.3)	284 (28.1)	<0.001
Did you experience any of the following *			
Slept badly and restlessly	251 (24.8)	285 (28.2)	0.057
Hard to go to sleep	199 (19.7)	358 (35.4)	<0.001
Woken up too early and not been able to get back to sleep	232 (22.9)	147 (14.5)	<0.001
Woken up several times and found it difficult to get back to sleep	187 (18.5)	334 (33.0)	<0.001
None	477 (47.1)	397 (39.2)	<0.001
Describe your energy level			
Energized	369 (36.5)	189 (18.7)	<0.001
Neutral	596 (58.9)	510 (50.4)	<0.001
Lazy	47 (4.7)	313 (30.9)	<0.001

* As multiple responses were allowed, the total number of responses is greater than the number of surveyed participants and the percent of cases is displayed.

Table 9. Lifestyle changes during COVID-19 pandemic by demographic factors (*n* = 1012).

Variables	All *n* = 1012	Gender			Age Group (Year)			Education Level		
		Female *n* = 768	Male *n* = 244	*p* Value	18–35 *n* = 574	≥36 *n* = 438	*p* Value	High School *n* = 119	Higher Degree *n* = 893	*p* Value
Weight, n, (%)										
Decreased	212 (20.9)	166 (21.6)	46 (18.9)	0.143	131 (22.8)	81 (18.5)	0.042	19 (16.0)	193 (21.6)	0.350
Same as before	486 (48.0)	376 (49.0)	110 (45.1)		273 (47.6)	213 (48.6)		62 (52.1)	424 (47.5)	
Increased	314 (31.0)	226 (29.4)	88 (36.1)		170 (29.6)	144 (32.9)		38 (31.9)	276 (30.9)	
Meals per day, n (%)										
Decreased	124 (12.3)	96 (12.5)	28 (11.5)	0.140	84 (14.6)	40 (9.1)	0.024	13 (10.9)	111 (12.4)	0.352
Same as before	628 (62.1)	464 (60.4)	164 (67.2)		342 (59.6)	272 (61.9)		69 (58.0)	559 (62.6)	
Increased	260 (25.7)	208 (27.1)	52 (21.3)		148 (25.8)	127 (29.0)		37 (31.1)	223 (25.0)	
Physical activity, n (%)										
Decreased	424 (41.9)	302 (39.3)	122 (50.0)	0.013	226 (39.4)	198 (45.2)	0.171	42 (35.3)	382 (42.8)	0.169
Same as before	438 (43.3)	346 (45.1)	92 (37.7)		258 (44.9)	180 (41.1)		61 (51.3)	377 (42.2)	
Increased	150 (14.8)	120 (15.6)	30 (12.3)		90 (15.7)	60 (13.7)		16 (13.4)	134 (15.0)	

Table 9. *Cont.*

Variables	All $n = 1012$	Gender			Age Group (Year)			Education Level		
		Female $n = 768$	Male $n = 244$	p Value	18–35 $n = 574$	≥36 $n = 438$	p Value	High School $n = 119$	Higher Degree $n = 893$	p Value
Screen time (entertainment), n (%)										
Decreased	72 (7.1)	67 (8.7)	5 (2.0)		46 (8.0)	26 (5.9)		8 (6.7)	64 (7.2)	
Same as before	415 (41.0)	309 (40.2)	106 (43.4)	0.002	222 (38.7)	193 (44.1)	0.150	49 (41.2)	366 (41.0)	0.984
Increased	525 (51.9)	392 (51.0)	133 (54.5)		306 (53.3)	219 (50.0)		62 (52.1)	463 (51.8)	
Sleep (h), n (%)										
Decreased	148 (14.6)	124 (16.1)	24 (9.8)		100 (17.4)	48 (11.0)		23 (19.3)	125 (14.0)	
Same as before	534 (52.8)	397 (51.7)	137 (56.1)	0.051	270 (47.0)	264 (60.3)	<0.001	59 (49.6)	475 (53.2)	0.302
Increased	330 (32.6)	247 (32.2)	83 (34.0)		204 (35.5)	126 (28.8)		37 (31.1)	293 (32.8)	
Sleep disturbances, n (%)										
Decreased	157 (15.5)	119 (15.5)	38 (15.6)		90 (15.7)	67 (15.3)		16 (13.4)	141 (15.8)	
Same as before	552 (54.5)	401 (52.2)	151 (61.9)	0.011	285 (49.7)	267 (61.0)	<0.001	58 (48.7)	494 (55.3)	0.135
Increased	303 (29.9)	248 (32.3)	55 (22.5)		199 (34.7)	104 (23.7)		45 (37.8)	258 (28.9)	

p value was based on chi-square test at 5% level.

4. Discussion

This population-based, cross-sectional study assessed eating habits and lifestyle behaviors among residences of the UAE, via an online survey during the COVID-19 pandemic between April and May 2020. The results indicate that the COVID-19 pandemic and the subsequent lockdown resulted in weight gain in about one-third of the respondents with changes in important and highly modifiable dietary and lifestyle behaviors that are considered essential for optimal somatic and psychological health. Specifically, participants also reported an increase in the number of meals consumed per day and a reduction in the percentage of skipping meals particularly breakfast during the pandemic. The present study also indicated that dietary habits were distanced from the Mediterranean diet principles and closer to "unhealthy" dietary patterns, characterized as high in energy but with low nutrient density; viewed as a detrimental combination for immune status. Although more homemade meals were prepared, a factor associated with healthy weight status, at the same time more non-nutritious foods were chosen, as well as being more frequently consumed (since an increase was also seen among frequency of meals per day). These data, therefore, are informative on the potential alterations of food prepared and consumed although at home.

In agreement with our study, the results from Kuwait, United States, Italy and France revealed an increase in caloric intake and indicated weight gain during the current COVID-19 home confinement [10,35–37]. Data from Kuwait, a close Gulf country to UAE, showed a significant increase in weight of respondents during the quarantine and the weight gain was 4.5 times higher among those consuming unhealthy diets [38]. The actual weight increase was not assessed in this study considering the short time interval of COVID-19 lockdown, however, the large percentage of the population that reported an increase in weight can be used as a proxy pertaining to changes in eating behavior and activity level. It has been suggested that the negative alterations in eating behaviors could be due to anxiety or boredom [39], lack of motivation to maintain healthy habits [40], or reduced availability of goods and limited access to food due to restricted store opening hours [41]. The prevalence of overweight and obesity in the UAE even before COVID-19 was high and has increased over time [42]. It is estimated that over one third of the population in the UAE is living with obesity with higher rates among females [43]. Thus, extra efforts are needed to reduce the burden of obesity and its risk factors especially during the COVID-19 pandemic.

Over half of the surveyed participants in this study did not consume fruits daily and about one third did not consume vegetables and dairy products on daily basis. Instead, almost half of the same population reported consuming sweets and desserts at least once per day and over one third consumed salty snacks daily. This transition towards a Westernized diet in the UAE was reported in 1998, where the consumption of fresh fruit and vegetables and of milk and dairy products was found low [32]. Moreover, in 2003, 77.5% of males and 75.7% of females in the UAE had less than five servings of fruit and vegetables per day [44]. Likewise, a recent study among Emirati adolescents revealed that only 28% of them met the recommended daily fruit and vegetable intake [45]. This is concerning especially as fruits and vegetables are an important source of fiber, vitamins, minerals, and antioxidants. Diets rich in antioxidants (such as the Mediterranean diet and Dietary Approaches to Stop Hypertension (DASH) diet) are vascular protective. The Mediterranean diet is recognized as an anti-inflammatory dietary pattern, focusing on high consumption of plant foods, low red meat and dairy and moderate consumption of monounsaturated fat sources such as olive oil [46]. Evidence suggests that the Mediterranean diet is associated with better health status, lower risk of chronic disease and inflammation as well as increased immunity [47–49]. The Mediterranean diet is not only a healthy dietary pattern, but is also a sustainable diet that has a lower environmental impact than the typical Western diet [50]. Moreover, mounting evidence indicates that the Mediterranean diet has a favorable effect on diseases related to chronic inflammation, including visceral obesity, type 2 diabetes mellitus and the metabolic syndrome [51–55]. Knowing that the prevalence of cardiovascular disease incidence is high in the UAE (40%) [56] and rates of dyslipidemia are strikingly elevated (72.5%) [57] makes it imperative that diets such as the Mediterranean diet should be encouraged to prevent the potentially negative effect of quarantine on dietary habits and overall health [41].

Due to the increase in obesogenic behaviors related to the COVID-19 pandemic, two dietary patterns were revealed among the studied population, named the "Western-type diet" and the "Free Sugars diet". These patterns indicate unhealthy eating behaviors during the period of the pandemic. This is in agreement with previous studies reporting a transformation of the diet in Eastern Mediterranean countries from a traditional Mediterranean diet to a more Westernized diet which is high in energy, saturated fat, cholesterol, salt, and refined carbohydrates, and low in fruits, vegetables, fiber, and polyunsaturated fats [25,58–60]. Therefore, current dietary behaviors in the UAE may not be effective against the COVID-19 virus since it can adversely affect the immune system response among other health factors. Furthermore, it is unclear whether these dietary patterns were due to the lockdown that followed the COVID-19 outbreak; however, the implications can be detrimental considering an adequate supply of macro- and micro-nutrients are essential for optimal immune function and response [11,61].

Amidst these passive changes in food behavior, some beneficial aspects emerged from this study, such as a significant increase in home-made food preparations, regular breakfast consumption and lower intakes of fast foods. Similarly, a consumer online based survey conducted by Ipsos across the Middle East and North Africa (MENA) region revealed that 57% out of the 5000 consumers who took part in the survey were preparing their own meals, and 79% were eating less often at restaurants [62].

Among the surveyed participants, more than one third reported a non-engagement in any physical activity during coronavirus pandemic lockdown. This was mostly observed among males in this study, with a simultaneously greater likelihood of increased sedentary time, compared to females. The findings of this questionnaire are in accordance with other studies indicating that the current COVID-19 pandemic had a dramatic impact on lifestyle behaviors globally, including diminished engagement in sports and physical activity in general [63–65]. Moreover, the "Effects of home Confinement on multiple Lifestyle Behaviours during the COVID-19 outbreak (ECLB-COVID-19)" international survey revealed that the COVID-19 pandemic had a negative effect on all levels of physical activity (vigorous, moderate, walking and overall) and increased daily sedentary time by more than 28% [14]. Similarly, in the current study the proportion of participants who spent more than five hours per day on screens for entertainment increased by 23.3%. Together with the unhealthy diet, the reduction of physical activity would not only contribute to weight gain, but also to an increase in cardiovascular risk during quarantine. Thus, awareness about the importance of regular physical activity and its benefits on overall health is necessary during such times [66,67]. It is also important to identify groups at a higher risk of unhealthy lifestyle behaviors during the COVID-19 pandemic to design interventions targeted towards these groups.

During the COVID-19 pandemic higher levels of anxiety, stress and depression have been observed among individuals [68–70]. In this study, the percentage of participants experiencing exhaustion, irritability, and tension more often during the coronavirus pandemic increased significantly. Sleep was mostly affected in females and needs to be further evaluated since it is linked with multiple endocrine functions, as well risk for obesity and depression. The risk of obesity is underlined by the significant increase in daily meal frequency among participants over 36 years with the majority being female. Also, despite WHO recommendations to minimize listening to unreliable news that could cause anxiety or distress and to seek information only from trusted sources [71], over two thirds of participants in this survey used social media as a main source for health updates. Studies have shown the negative and harmful effect of misinformation overload "infodemic" on the mental health of individuals [72,73]. Moreover, stress and anxiety could disrupt sleep quality during the night and energy levels during the day. Results of the current survey indicated a 10.8% increase in participants reporting poor sleep quality and 26.2% increase in those feeling lazy during the pandemic. Xiao and his co-workers found a significant negative correlation between anxiety levels and sleep quality and suggested the use of telepsychiatry consultation as an important therapeutic strategy [74]. The use of telehealth has been shown to be useful in providing support to patients and is appropriate for the delivery of mental health services [75]. Additionally, the Mediterranean diet does not only have a protective effect on the risk of cardiovascular diseases and certain types of cancer [54,76], but also an increased compliance with it could be associated with lesser mental distress, better sleep quality, and higher scoring for self-perceived health status [77–79].

It is acknowledged that this study has limitations related to the use of self-reported questionnaire, snowball sampling method and the cross-sectional study design. The study information was acquired after lockdown, and although comparisons are critical to be made in order to draw inferences, no conclusive remarks can be drawn. Results stratified by sex should be interpreted with caution, since the majority of the participants were females. Furthermore, in order to minimize selection bias that may arise with snowball sampling (including interrelated-similar individuals), each individual could refer a maximum of three people who were not family members, and only one individual per age group (young adults, older adults, elderly) was enrolled from a household. Moreover, the change in dietary pattern was not assessed in this study, since data on food frequency were only obtained during COVID-19 pandemic, although these can be used as a reference for further studies performed, in these uncertain times. This was done to reduce the probability of including recall bias, since the participants had to respond to multiple questions on food frequency and quantity during COVID-19 lockdown and for a prolonged period prior to that. Also, the presence of obesity and eating disorders were not determined in the study, nor was information on infection with COVID-19 reported. Such analysis would require a longer questionnaire, hence may have decreased the compliance and response rate, but also would have required a larger sample size based on the prevalence of all factors to acquire adequate study power. Another potential limitation of the study was that respondents were mostly females. Although this is usual in online questionnaires [80], it should be considered when generalizing the results. However, using an online survey facilitated data collection during COVID-19 pandemic from all seven emirates. It also guaranteed the anonymity of the participants, thus reducing the social desirability bias. The strengths of this research include data collection timing one month after lockdown which minimizes memory failure for previous habits. In addition, the survey provided was in multiple languages in a multilingual environment like UAE.

The results of the study indicate that individuals in the UAE experienced negative lifestyle changes, unbalanced food choices, a reduction in physical activity, and psychological problems during the COVID-19 pandemic. Although quarantine is an essential measure to protect public health and control the transmission of the virus, these findings should be taken into consideration for future regulations in the UAE.

Supplementary Materials: The following are available online at http://www.mdpi.com/2072-6643/12/11/3314/s1, Eating Habits and Lifestyle during COVID-19 Lockdown in the United Arab Emirates: A Cross-Sectional Study.

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Adherence to Mediterranean Diet and Selected Lifestyle Elements among Young Women with Type 1 Diabetes Mellitus from Northeast Poland: A Case-Control COVID-19 Survey

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Abstract: An appropriate balanced diet and dietary patterns are important at every stage of life, but in the case of young patients with type 1 diabetes mellitus (T1DM), it is especially crucial during the COVID-19 pandemic. The aim of the study was to assess health and nutritional behaviors, mainly adherence to the Mediterranean diet (MD), during the second wave of the COVID-19 pandemic in Poland among women with T1DM, and to compare them with a healthy population. This survey (based on a questionnaire) was conducted in December 2020 and included 219 young women, healthy (n = 106) and with T1DM (n = 113), from northeast Poland. Over 30% of the study group admitted that they did not engage in any physical activity. A large proportion declared that their screen time was 5–7 h a day (48% in control and 40% in T1DM group). High intakes of sweet-beverages, sweets and red meat, but also low intakes of olive oil, fish and nuts were observed. The vast majority of participants (60% vs. 71%) were moderately adherent to the Mediterranean Diet Adherence Screener (MEDAS). The study demonstrated that despite the similarity between the behaviors of healthy people and those with T1DM, negative health and nutritional practices, such as low physical activity, long screen time, medium and high levels of stress and inappropriate eating habits were observed.

Keywords: diabetes mellitus; Mediterranean diet; COVID-19; dietary pattern; metabolic disease; women; nutritional habits; health behaviors; lifestyle; obesity

1. Introduction

Type 1 diabetes mellitus (T1DM) is an insulin-dependent, multifactorial autoimmune disease, which results in degradation of the beta cells of the islets of Langerhans, which causes impaired insulin production and secretion. The treatment method consists of functional intensive insulin therapy delivered by multiple daily injections (MDIs) using an insulin pen, or a device called personal insulin pump, enabling continuous subcutaneous insulin infusion (CSII), which better mimics the physiological rhythm of insulin secretion [1].

COVID-19 (coronavirus disease 2019) is an acute infectious respiratory disease caused by the SARS-CoV-2 virus (severe acute respiratory syndrome coronavirus). It was first recognized and described in November 2019 in central China (Hubei province). It is considered that the origin of this virus was a seafood market where other animals such as snakes, frogs and bats were also sold. The genome of SARS-CoV-2 is known to be similar to the bat coronavirus and one unrecognized coronavirus, probably the pangolin coronavirus [2].

The Mediterranean diet (MD) is a dietary pattern, the benefits of which are supported by a large body of scientific evidence that highlights the potential health benefits of adherence. Nowadays, the MD pattern should be considered not only from a nutritional perspective but also in the light of environmental, economic as well as sociocultural factors. MD is related to a lower risk of developing several chronic diseases, such as type 2 diabetes mellitus (T2DM), heart disease and cancer [3,4]. MD has also been shown to improve cognitive functions [5]. The recently updated MD model highlights the need for a sustainable approach to this diet, with special emphasis on decreased consumption of meat, high fat dairy products and processed foods, and increased intake of locally grown fruits, vegetables, legumes, olive oil, whole grains and nuts. Fish, poultry and red wine should be consumed in moderate amounts. Moreover, the MD may provide considerable amounts of antioxidants, polyphenols, carotenoids (such as lycopene and β-carotene), as well as dietary fiber [3,4,6,7]. Also, because of the high consumption of olive oil, especially extra virgin and nuts, it is rich in monounsaturated and polyunsaturated fatty acids. Many studies have linked their high consumption with an improvement in insulin sensitivity, blood lipid profile, and a reduction in systolic and diastolic blood pressure levels, in line with the standards of medical care established by the American Diabetes Association [7–9].

The aim of the study was to assess health and nutritional behaviors, mainly adherence to MD, during the second wave of the COVID-19 pandemic in Poland among women with T1DM, and to compare them with a healthy population. It was undertaken due to the fact that a number of studies have shown a beneficial effect of the MD in people with diabetes mellitus (DM). This is of particular importance in times of the COVID-19 pandemic. Our research is designed to identify the problem, the solution to which may be inclusion of preventive and educational programs aimed at rectifying possible unhealthy habits. Studies assessing health habits (mainly concerned glycemic management) during the COVID-19 pandemic in healthy people; there are few studies among people with DM, and even fewer among those with T1DM.

2. Materials and Methods

2.1. Participants

This case-control survey was conducted among 219 young Polish women. The study group consisted of 113 persons with T1DM (52% used MDIs and 48% used CSII) and the control group contained 106 healthy individuals. The median ages in T1DM and healthy groups were 22 and 25 years, respectively. The online survey was carried out in December 2020, during the peak of the second wave of the COVID-19 pandemic, through private groups on social media platforms. The main criterion for inclusion in the study group was young age (between 16 and 35 years) and residence in Warmian-Masurian or Podlaskie Voivodeships. Responses from participants residing abroad, a different type of DM than the type 1 and people who had ever tested positive for the new coronavirus have been rejected. At the same time, a survey was conducted among healthy volunteers who expressed their willingness to participate in our study. Each person was informed that the completed questionnaire was anonymous and confidential. The questionnaire could be completed only once and it was possible to withdraw from the survey at any given moment, then the answers were not saved. By completing and sending the questionnaire, respondents confirmed consent to participate in the study. No personal data were required. The study had obtained the consent of the Bioethical Commission of the Medical University of Bialystok No. R-I-002/587/2019.

2.2. Questionnaire

The initial part of the questionnaire included questions that allowed for a reliable selection of study participants, dividing them into groups. The questions concerned the existing diseases, duration of the T1DM and type of treatment, sex, age, place of residence. The body weight and height (self-reported) results were used to calculate the body mass index (BMI), which reflected the general nutritional status of the patient. It was calculated as: weight in kg divided by height in meters squared. In children and adolescents under 18 years of age, it is interpreted according to national standards, and the limits of underweight, overweight and obesity are defined as the 10th, 85th and 97th centiles, respectively [10]. For adults, the values established by the World Health Organization were applied: a person whose BMI is below 18.5 kg/m^2 is considered underweight, the normal value is 18.5–24.9 kg/m^2, whereas in overweight and obese persons the values are 25.0–29.9 kg/m^2 and over 30.0 kg/m^2, respectively [11]. The results of glycated hemoglobin (HbA1c) from the last 3 months (self-reported) were obtained in a laboratory at the request of the attending physician.

The next part of the survey included questions about lifestyle (sleep time, screen time, stress levels), physical activity and eating habits, including the Mediterranean Diet Adherence Screener (MEDAS), which consists of 14 questions about eating behaviors typical of a MD (Table 1). Each question could earn a point; the maximum number of points to be earned was 14. The responses were to refer to the last month preceding the completion of the questionnaire. Based on the total scores, participants were divided into three levels: low (score 0–5), medium (6–9 points) and high (≥10 points) MD adherence.

Table 1. Interpretation of Mediterranean Diet Adherence Screener.

Question	Answer: Yes [Points]	Answer: No [Points]
1. Is olive oil the major dietary fat in your diet?	1	0
2. Do you consume at least 4 tablespoons of vegetable oil every day?	1	0
3. Do you eat at least 2 servings (about 400 g) of vegetables every day?	1	0
4. Do you eat at least 3 servings (about 240 g) of fruit every day?	1	0
5. Do you eat less than 1 serving of red meat/other meat products every day?	1	0
6. Do you eat less than 1 serving of butter, margarine or cream every day?	1	0
7. Do you consume less than 1 serving of sweet or sugar-sweetened fizzy drinks every day?	1	0
8. Do you consume more than 3 glasses (approx. 400 mL) of wine per week per week?	1	0
9. Do you eat at least 3 servings (approx. 450 g) of legume seeds (peas, beans, broad beans, lentils, chickpeas) per week?	1	0
10. Do you eat at least 3 servings (approx. 300 g) of fish or seafood weekly?	1	0
11. Do you consume less than 3 servings of sweets (bought, homemade) weekly?	1	0
12. Do you eat at least 30 g of nuts per week?		
13. Do you choose chicken, turkey or rabbit instead of veal, pork or sausage?	1	0
14. Do you eat pasta, vegetable or rice dishes with garlic, tomatoes, leeks or onions more than twice a week?	1	0
TOTAL	14	0

Category: low (score 0–5), medium (6–9 points) and high (≥10 points) Mediterranean Diet adherence.

The entire questionnaire consisted of questions that had appeared in our previously published study and other authors' work [12,13]. Questions in foreign languages were translated into Polish and assessed by a native speaker of the Polish language in order to exclude any bias in the translation. The translated questionnaire was tested on a small sample of respondents in order to avoid formal and substantive errors.

2.3. Statistical Analysis

Statistical analysis of the results was performed using Statistica software (TIBCO Software Inc., Palo Alto, CA, USA). The Shapiro–Wilk test was applied to check the normal distribution of the variables. According to the test outcomes, Student's *t*-test (parametric variables), the Mann–Whitney U and Kruskal–Wallis ANOVA tests (non-parametric variables) were used. The Chi-square independence test evaluated the relationships between qualitative features. Before the survey, a required minimum sample size was estimated. It was useful for calculating the total participants of our study with a specified confidence interval (95%) and a maximum bias (10%). Values at $p < 0.05$ were considered statistically significant. The supplementary material contains additional characteristics of the most significant results divided according to variables (place of residence, age group).

3. Results

The characteristics of the groups are summarized in Table 2. The distribution of study participants according to insulin therapy was almost equal (52% MDIs vs. 48% CSII users). The majority of patients with T1DM had well-controlled diabetes (glycated hemoglobin —7%). Most of the study respondents (60%) had a normal BMI, 25% and 9%, respectively, were overweight or obese, while 6% were underweight. There were statistically significant differences in body weight and BMI between the healthy and the T1DM groups. People with T1DM had excess body weight and higher BMI more often than healthy persons. The same trend was noticed when the groups were distinguished according to the insulin therapy used. Additionally, in those using pens both parameters were higher compared to users of insulin pumps and healthy persons.

Table 2. Baseline characteristic of study groups.

Studied Parameters	T1DM			Healthy (*n* = 106)
	Total (*n* = 113)	CSII (*n* = 54)	MDIs (*n* = 59)	
Age (years)	25 (20–29)	21 (18–25)	28 (23–32)	22 (21–23)
Body weight (kg) A**, B*, C**	71 (61–79)	68 (61–78)	72 (62–80)	60 (56–68)
Height (cm)	170 (165–174)	170 (165–175)	169 (163–174)	168.5 (163–173)
Body mass index (kg/m^2) A**, C**	24.4 (21.6–27.7)	23.6 (21.7–27.0)	25.4 (22.4–28.4)	21.9 (19.6–24.1)
HbA1c (%) F	7.1 (6.5–8.0)	7.0 (6.6–7.8)	7.3 (6.4–8.2)	-
Place of residence				
Village	15%	15%	15%	24%
City (≤150 k inhabitants)	29%	24%	32%	27%
City (150–250 k inhabitants)	27%	30%	25%	8%
City (≥250 k inhabitants)	29%	31%	27%	42%
Duration of disease E**				
Up to 5 years	18%	28%	8%	-
5–10 years	26%	35%	17%	-
More than 10 years	56%	37%	75%	-
Body Mass Index D**				
Underweight	5%	7%	3%	8%
Normal	50%	56%	45%	72%
Overweight	32%	32%	32%	17%
Obesity	13%	5%	20%	3%

Values are expressed as median, lower, and upper quartile (Me (Q1–Q3)) or percentage of respondents (%). Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), number of respondents (n), type 1 diabetes mellitus (T1DM). A Statistically significant difference between the medians, T1DM vs. Healthy (the Mann–Whitney U test). Statistically significant difference between the medians: B CSII vs. MDIs, C MDIs vs. Healthy (the ANOVA Kruskal–Wallis test). Statistically significant dependence between variables: D T1DM vs. Healthy, E CSII vs. MDIs (the Chi-square test). F Results of the glycated hemoglobin (HbA1c) test were collected from 79% of respondents. * $p < 0.01$ and ** $p < 0.001$.

There was a significant dependence ($p < 0.01$) of the frequency of physical activity between the main groups (T1DM vs. healthy). The frequency of physical activity did not affect the type of insulin therapy used—31% of the study group admitted that they did not engage in any physical activity, 38% (39% of CSII and 37% of MDIs users) exercised once or twice a week, 25% (22% and 27%, respectively) exercised three to four times a week, while 6% (7% and 5%, respectively) more than five times a week. Comparing these results to the control group, it was respectively: 15%, 37%, 35% and 13%.

Figure 1 shows the type of physical activity chosen by all the study participants. At that time, the most popular pursuits, in both the healthy and TD1DM groups, were walking (over 80% and 40%, respectively) and home gymnastics (62% in control vs. 35% in T1DM group, $p < 0.001$).

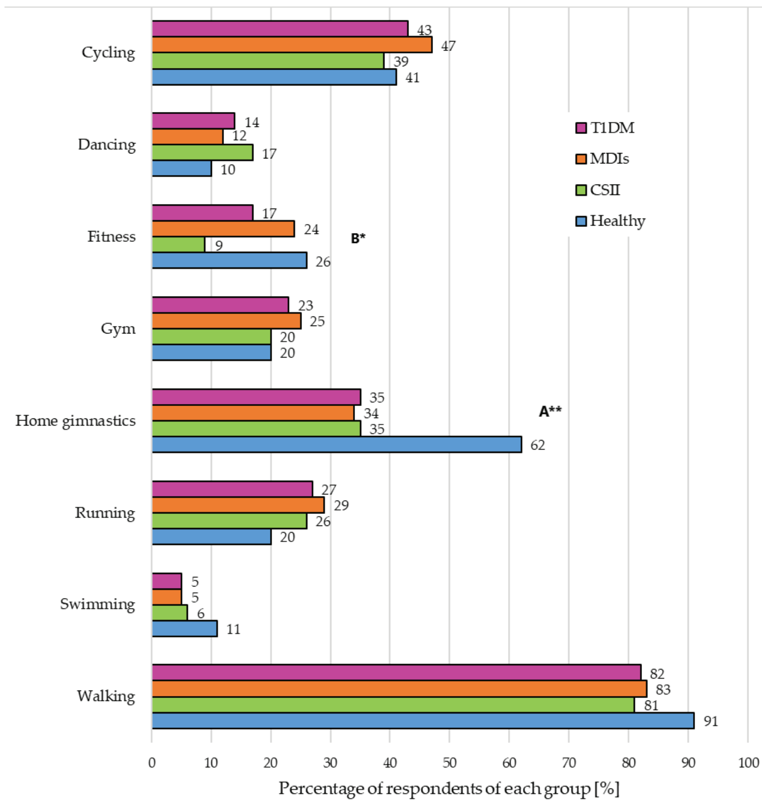

Figure 1. Type of physical activity chosen by study participants during the second wave of the COVID-19 pandemic. Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), type 1 diabetes mellitus (T1DM). Statistically significant dependence between variables: [A] T1DM vs. Healthy, [B] CSI vs. MDIs (the Chi-square test), * $p < 0.05$ and ** $p < 0.001$.

Most respondents devoted 5–8 h per day to sleep: 73% of healthy and 46% T1DM persons (a similar percentage was found in both groups on insulin therapy). Over 8 h of sleep was declared by 23% and 46%, respectively (Table 3).

Almost one-third of the respondents in both groups replied that they spent 2–4 h a day in front of a computer or TV. However, in most cases the declared screen time was 5–7 h a day (48% in control and 40% in T1DM group) (Table 3).

Also, there was a characteristic variation in the number of meals for the T1DM group (Table 3). Statistically significantly ($p < 0.001$), people from this group ate more frequently (41% and 54% ate more than five meals or three to four meals a day, while in the group of healthy people it was 20% and 66%, respectively).

Table 3. Frequency of selected healthy behaviors.

Studied Parameters	T1DM Total (n = 113)	T1DM CSII (n = 54)	T1DM MDIs (n = 59)	Healthy (n = 106)
		Sleep length [A]**		
<5 h	8%	8%	8%	4%
5–8 h	46%	46%	46%	73%
>8 h	46%	46%	46%	23%
		Screen time [B]*		
<2 h	10%	3%	17%	5%
2–4 h	26%	26%	27%	28%
5–7 h	40%	54%	27%	48%
≥8 h	24%	17%	29%	18%
		Number of meals [A]**		
1–2 times/day	5%	8%	3%	14%
3–4 times/day	54%	46%	61%	66%
≥5 times/day	41%	46%	36%	20%

Values are expressed as percentage of respondents (%). Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), number of respondents (n), type 1 diabetes mellitus (T1DM). Statistically significant dependence between variables: [A] T1DM vs. Healthy, [B] CSII vs. MDIs (the Chi-square test), * $p < 0.01$ and ** $p < 0.001$.

Figure 2 shows stress level percentage distribution in the study cohort during the second wave of COVID-19. The vast majority (44%) declared that they experienced medium stress. Slightly fewer (32% of healthy people and 23% of diabetics) said they still felt highly stressed.

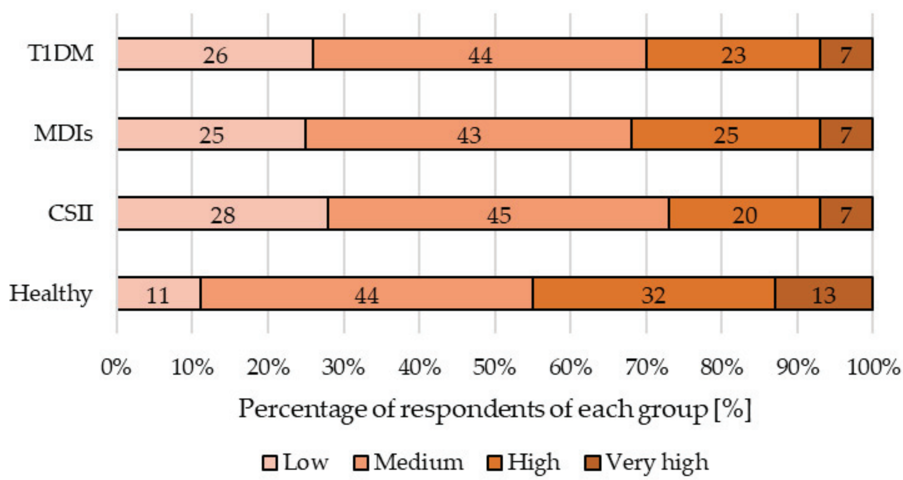

Figure 2. Stress level distribution of study cohort during the second wave of the COVID-19 pandemic. Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), type 1 diabetes mellitus (T1DM). Statistically significant ($p < 0.001$) dependence between T1DM and healthy (the Chi-square test).

The respondents were asked whether they consumed a specific number of servings of a given product or group of products characteristic of the MD according to the MEDAS. Figure 3 presents the percentage of people who declared that they consumed this number of portions of a given food. Statistically significant differences between the responses in the main groups (healthy vs. T1DM) were observed for the servings of vegetables, olive oil, fruits, meat, butter/margarine/cream and fish/seafood consumed. There was also a significant relationship between subgroups using different types of insulin therapy (CSII vs. MDIs) as regards the amount of wine consumed (Figure 3). The vast majority were moderately adherent to MEDAS—60% of healthy and 71% of diabetics (Figure 4).

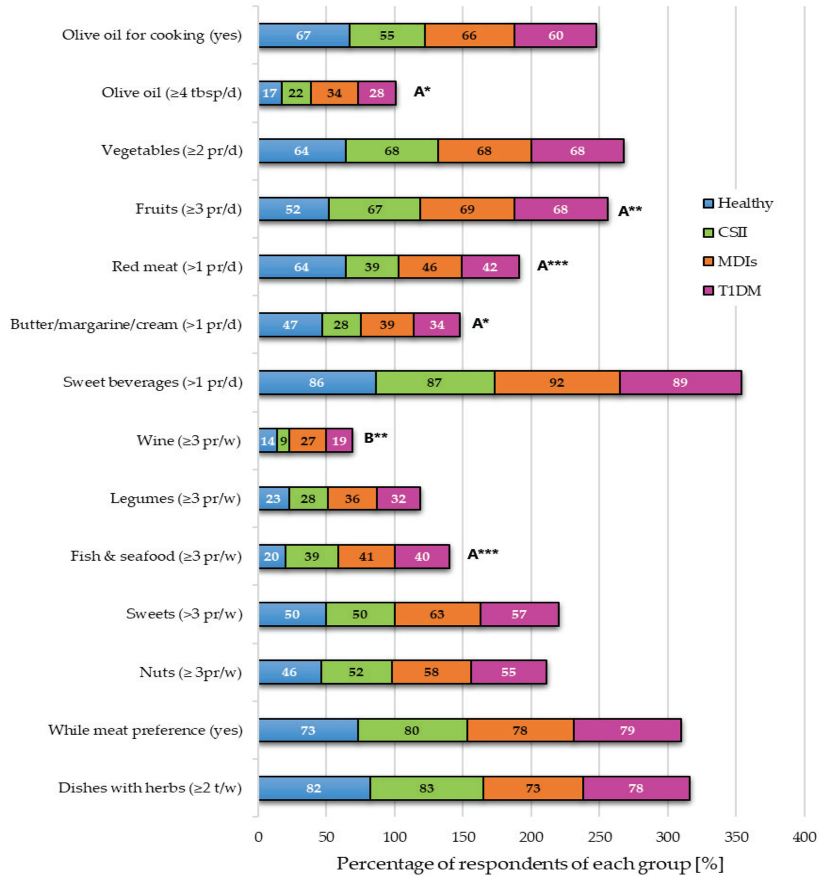

Figure 3. Percentage of respondents consuming certain portion sizes of product groups characteristic of the Mediterranean diet. Values are expressed as percentage of respondents (%). Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), Mediterranean Diet Adherence Screener (MEDAS), Mediterranean Diet (MD), number of respondents (n), daily (d), weekly (w), portion (pr), tablespoon (tbsp), times (t), type 1 diabetes mellitus (T1DM). Statistically significant dependence between variables: ^{A} T1DM vs. Healthy, ^{B} CSII vs. MDIs (the Chi-square test), * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. The size of portion: vegetables 200 g, sweet or beverages 200 mL, meat and fish 100–150 g, legumes 150 g, wine 125 mL, fruits 100 g, nuts 10 g, butter/margarine/cream 12 g.

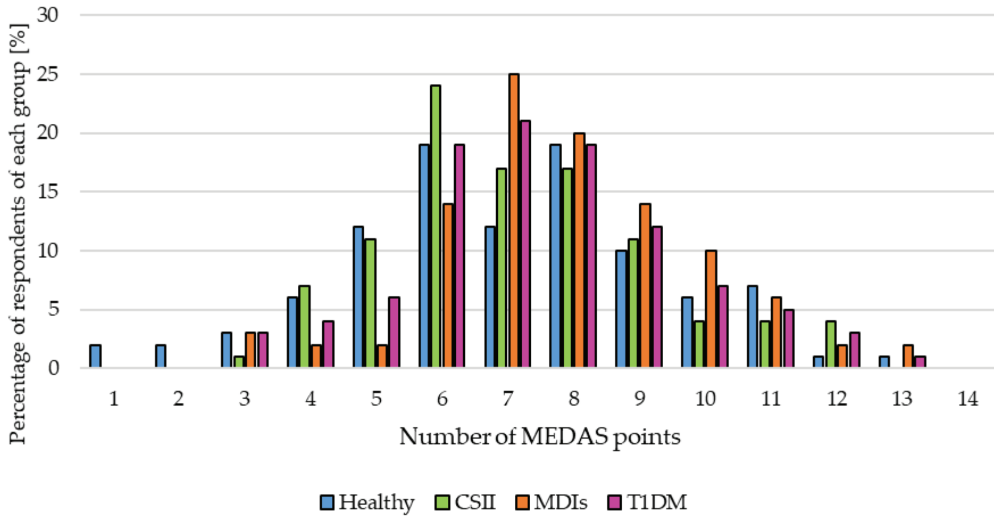

Figure 4. Adherence to the Mediterranean diet in the study cohort. Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), Mediterranean Diet Adherence Screener (MEDAS), type 1 diabetes mellitus (T1DM).

It was observed that diabetic women in the group with high adherence to MEDAS, compared to women with low adherence to MEDAS, more often slept for more than 8 h (50% vs. 40%), spent less time in front of a TV or computer (≥5 h of screen time: 49% vs. 87%) and consumed ≥5 meals a day (44% vs. 27%) (Table 4).

The above results (frequency of physical activity, number of meals, screen and sleep time and stress level) were divided into variables (place of residence, age group) and included in Supplementary Tables S1 and S2.

Table 4. Health behaviors depending on the Mediterranean Diet Adherence Screener (MEDAS) score category.

Studied Parameters	Low Medas (n = 41)				Medium Medas (n = 144)				High Medas (n = 34)			
	T1DM			Healthy (n = 26)	T1DM			Healthy (n = 64)	T1DM			Healthy (n = 16)
	Total (n = 15)	CSII (n = 11)	MDIs (n = 4)		Total (n = 80)	CSII (n = 37)	MDIs (n = 43)		Total (n = 18)	CSII (n = 6)	MDIs (n = 12)	
Weekly activity												
No activity	40%	46%	25%	35%	25%	24%	26%	9%	50%	50%	50%	6%
1–2 times/week	33%	27%	50%	31%	40%	46%	35%	41%	42%	17%	42%	31%
3–4 times/week	27%	27%	25%	27%	26%	20%	32%	36%	8%	33%	8%	44%
≥5 times/week	-	-	46%	7%	9%	10%	7%	14%	-	-	-	19%
Sleep length												
<5 h	60%	64%	50%	12%	8%	8%	7%	2%	17%	17%	17%	81%
5–8 h	-	-	-	81%	45%	41%	49%	67%	33%	50%	33%	-
>8 h	40%	36%	50%	7%	47%	51%	44%	31%	50%	33%	50%	19%
Screen time												
<2 h	-	-	-	12%	10%	2%	17%	2%	22%	17%	25%	12.5%
2–4 h	13%	9%	25%	15%	26%	22%	30%	34%	39%	83%	17%	25%
5–7 h	47%	55%	25%	58%	45%	62%	30%	44%	11%	-	17%	50%
≥8 h	40%	36%	50%	15%	19%	14%	23%	20%	28%	-	41%	12.5%
Stress level												
Low	47%	37%	75%	12%	25%	30%	21%	10%	39%	37%	75%	13%
Medium	20%	27%	-	42%	44%	49%	4%	45%	17%	27%	-	42%
High	13%	18%	-	19%	25%	16%	32%	34%	27%	18%	-	18%
Very high	20%	18%	25%	27%	6%	5%	7%	11%	17%	18%	25%	27%
Number of meals												
1–2 times/day	20%	18%	25%	19%	39%	5%	67%	14%	28%	67%	8%	6%
3–4 times/day	53%	55%	50%	54%	19%	41%	-	69%	28%	-	42%	75%
≥5 times/day	27%	27%	25%	27%	42%	54%	33%	17%	44%	33%	50%	19%

Values are expressed as percentage of respondents (%). Abbreviations: continuous subcutaneous insulin infusion (CSII), multiple daily injections (MDIs), Mediterranean Diet Adherence Screener (MEDAS), number of respondents (n), type 1 diabetes mellitus (T1DM). Category: low (score 0–5), medium (6–9 points), and high (≥10 points) Mediterranean Diet adherence.

4. Discussion

A properly balanced diet and appropriate dietary patterns are important at every stage of life, but in the case of young patients with T1DM, it is especially crucial since it can prevent or delay the symptoms of many diabetes-related conditions.

The survey was conducted in December 2020, and respondents were asked provide information regarding the previous month. The number of COVID-19 cases recorded in Poland on 1 November was 17,717, and on 23 December—12,358, which was the second peak of the pandemic [14].

Our study showed a high percentage of patients with T1DM who were overweight (32%) or obese (13%). Factors such as increased body weight, low physical activity, long screen time and exposure to stressful situations may lead to diabetic complications. Adherence to the MD has a crucial role in reducing the risk of health consequences.

The restrictions introduced due to the COVID-19 crisis affect various aspects of life. For instance, our research on a group of diabetics, assessing the health consequences of the first wave of the pandemic, showed that the body weight of 31% of respondents had increased by less than 5 kg, while in 11% of the cases—by more than 5 kg [12]. Another study conducted in Poland showed that during the first lockdown, 48.8% of overweight and 55.3% of obese people declared that they ate more, 55.3% and 61.7%, respectively, indicated that they ate more snacks, while 63.3% and 62.6%, respectively, said they cooked more [15]. The research conducted in this study, concerning the period of the second wave, showed BMI above the norm in as many as 45% of respondents with T1DM, which indicates a disturbing trend caused by restrictions on, for example, access to gyms. Research conducted among healthy population, during the first rise in COVID-19 incidence, also showed significant differences in the number of meals consumed. It was shown that during isolation there was an 11.2% increase in the percentage of people who ate five or more meals (from 19.9 to 31.1%) [16]. Being overweight or obese is an increasingly frequent risk factor among people with T1DM, not only in Poland, but also all over the world. It has been demonstrated that in Australia as many as 33% of adolescents under the age of 16 are overweight or obese, and among persons over 18 years of age: 38.3% and 17.2%, respectively [17,18]. Data from Sweden also indicate a large percentage of people over 18 years of age with excess body weight (35.1% of overweight people and 8.9% of obese people) [19]. Our study also showed significant differences in the number of meals consumed by healthy women and those with T1DM. Consumption of five or more meals was declared by 20% and 41%, respectively ($p < 0.001$). At its onset, the pandemic enforced certain social behaviors, such as excessive buying of food and hygiene products for the purpose of creating stocks. The resultant large amounts of products stored at home could be associated with excessive calorie consumption—it has been proven that the number of meals eaten at home increased by 38%. Stressful factors can trigger negative eating behavior, such as snacking between meals, leading to increased caloric value of the diet, and thus obesity [20].

Physical activity is another important element in the prevention of obesity and diabetes complications. Our previous study revealed that during the first wave of the COVID-19 pandemic, the percentage of respondents exercising one to two times a week had increased from 36% (before the pandemic) to 41%. On the other hand, the percentage of people exercising more often had decreased: three to four times a week—from 31% to 19%, more than five times a week—from 12% to 6%. The most common activities were walking and cycling [12]. Our current study found that walking was the physical activity that both people with T1DM (82%) and healthy ones (91%) chose most frequently. Patients with DM also chose cycling (43%) and exercising at home (35%). Regular physical activity improves, among others, sleep quality. There have been reports that during the lockdown period, physical activity, because of its numerous benefits, should be promoted in the same way as other public health related behaviors (including disinfection and distancing). Exercise can be a way to improve both physical and mental health [20,21].

Sleep duration was another factor that was analyzed. We showed that 46% of our respondents slept for more than 8 h—the differences between T1DM and healthy people were statistically significant ($p < 0.001$). Reduction of sleep time has been revealed to play a significant role in the pathogenesis of many chronic diseases. People have more flexibility as regards their sleep hours when they spend more time at home. Usually they fall asleep later and the quality of their sleep is worse: an increase in nocturnal awakenings is observed even when the length of nighttime rest is adequate. Sleep disorders may adversely affect homeostasis, consequently leading to disorders of mood, impaired well-being, worse eating habits, loss of motivation to take up physical activity, eventually resulting in hormonal disorders in obesity and DM [20,22–24].

As regards screen time, we have shown significant differences ($p < 0.01$) between patients with CSII and MDIs. It is a concern that as many as 40% of the diabetics involved in our study spent 5 to 7 h in front of a computer or TV, and 24%—8 h or more.

Stress is another factor that may exacerbate the course of many diseases, including T1DM, and trigger the development of long-term complications. The timing of the pandemic resulted in different patterns of coping with stress. Our previous research aiming to assess changes in social behavior among the DM population found that prior to the pandemic, none of the respondents had described their stress levels as 'very high'. At the beginning of the pandemic, the percentage of people who claimed to be highly stressed was around 32%, while during the study, 4% of respondents rated their stress levels as 'very high' and 17% as 'high' [12]. Our current results have revealed a tendency towards better control of negative emotions and greater capacity to learn to function in a changed reality. The highest percentage of people assessing their stress level as 'very high' was found among healthy people (13%), while among all diabetics, both in the CSII and MDIs groups, the figure was 7%. This may be due to the fact that having been exposed to stress for an extended period of time, they now perceive the new threats differently and are better equipped to face them.

None of the subjects included in our study received the maximum number of points on the MEDAS scale. The most frequent scores were the medium values: from six to nine. The highest percentage of people with MDIs obtained seven points (25%), while the highest percentage of patients with CSII: six points (24%). In the healthy group, 19% of respondents obtained six and eight points each, which proves the need for educational activities that must be carried out in the field of pro-health prophylaxis of patients with T1DM, but also among healthy people.

Metabolic syndrome (MetS) can be another consequence of an improper lifestyle, including inappropriate diet. The impact of cardiovascular disease (CVD) risk factors in adolescents with T1DM is not completely explained. Mayer-Davis et al. conducted a study on a group of 1198 diabetic patients at an average age of 14.83 ± 3.13 years. They showed that CVD risk factors were increased: blood pressure (incidence: 27%), obesity (21%) and high lipid level (18%). The authors concluded that there was little evidence that only a single factor underlay the pattern of CVD risk factors in adolescents with DM [25].

Vidal-Peracho et al. conducted a study to assess compliance with the MD among the inhabitants of Spain—also women with T1DM in the older age group (44.13 ± 12.0 years). The authors, similarly to our study, showed that the average index of the MD among those patients was medium (69%). Interestingly, among the subjects who strictly complied with the recommendations, women constituted a significantly lower percentage than men (22.4% vs. 30.2%). The smallest percentage of women (around 10%) did not follow the recommendation to drink more than seven servings of wine, while the largest proportion complied with the recommendation to use olive oil (around 90%) [26].

The specific components that should be present in the menu of patients following the MD are characterized by multidirectional prophylactic properties and have a positive effect on the parameters of the MetS.

In our study, 46% of healthy people, 52% of CSII and 58% of MDIs patients consumed more than three servings of nuts per week. Although for the majority of diabetic patients oil was the main fat (55% of CSII and 66% of MDIs users), only 22% and 34% of the respondents declared daily consumption of more than four tablespoons. It is worth emphasizing the statistically significant difference (17% vs. 28%, $p < 0.01$) in the frequency of consumption of olive oil between healthy people and those with T1DM. Studies by Grando-Casas et al. showed a positive tendency: patients with T1DM consumed significantly more fatty fish (36.2 vs. 29.2, $p = 0.009$) and nuts (14.7 vs. 9.0, $p = 0.011$) than healthy people [27]. The literature emphasizes the synergistic anti-inflammatory effect of nuts and olive oil, which helps to reduce the health consequences of diabetes. The consumption of fatty acids, including eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), contributes to the reduction of inflammation and has cardioprotective action [28].

The main sources of dietary fiber in the MD are: whole grains, vegetables, fruits and nuts. In our study, consumption of three or more servings of legumes per week was reported by 28% of patients with CSII and 36% of patients with MDIs. Vegetables were consumed twice a day or more often by 68% of patients with CSII and MDIs, while fruit was eaten three or more times a day by a similar number of people: 67% of CSII and 69% of MDIs. In patients with T1DM, adherence to the guidelines of the MD has a beneficial effect on the intestinal microflora. This is an important mechanism because T1DM is an autoimmune disease. Proper microflora decreases the permeability of the intestines and modulates the immune system, whereas low consumption of fiber is related to the development of inflammatory diseases [29].

Products recommended by the MD, such as fruits (e.g., berries) and vegetables, are rich in polyphenolic compounds. Their supporting role is especially emphasized in the context of chronic diseases. Cocoa flavan-3-oils are associated with a reduction in the risk of insulin resistance, systemic inflammation, and DM, as well as improved lipid levels, endothelial blood flow, and blood pressure control. Resveratrol and quercetin also play an important part in cardiometabolic protection. Polyphenols can influence the composition of the intestinal microflora and can also be metabolized to bioactive compounds by intestinal bacteria [30]. The mechanism of action of polyphenols is based on inhibition of intestinal glucose absorption by sodium-dependent glucose transporter 1 (SGLT1), increasing insulin secretion and insulin-dependent glucose uptake, and decreasing hepatic glucose production [31]. There are also reports in the literature that it might be possible to treat DM with polyphenols influencing the AMP-activated protein kinase pathway [32].

We have observed high figures as regards to consumption of sweet beverages of more than one serving per day in 87% of diabetics with CSII and in 92% of diabetics with MDIs. Consuming less than three servings of sweets in a week was reported by 50% of the members of the CSII group and 47% of patients with MDIs. Granado-Casas et al. assessed the compliance with the MD recommendations among patients with T1DM and healthy subjects and showed that diabetic patients consumed significantly fewer sweets (17.4 g vs. 38.5 g, $p < 0.001$) [27]. Patients with insulin resistance and DM are aware of the health consequences of consuming sweet snacks, i.e., excessive body weight and increased insulin resistance, leading to glucotoxicity and accelerated apoptosis of B lymphocytes. Subsequently, immunogenicity is increased, and then symptomatic diabetes develops. In insulin resistance, there is an overload of β cells, which accelerates apoptosis and immune damage [33–36]. It has been shown that obesity and deteriorated self-management that occur in patients with T1DM are significantly associated with the risk of hospitalization for heart failure, as well as retinopathies and macrovascular diseases [17,19,37]. Obese people have three times higher incidence of low-cholesterol high-density lipoprotein (HDL-C) hypolipidemia and four times higher incidence of hypertension compared to normal body weight [38].

The recommendations of the MD include drinking good-quality red wine in moderate amounts. Valerio et al. assessed the relationship between alcohol consumption as well as cigarette smoking and CVD risk factors in adolescents with T1DM. It was shown that 10% of respondents consumed alcohol and smoked cigarettes. Adolescents who drank alcohol and smoked had higher triglyceride levels compared to those who did not (86.9 vs. 63.9 mg/dL, $p = 0.01$) and lower compliance to MD (6 vs. 7) [39].

Other authors who studied adherence to the MD recommendations among people with T1DM also assessed anthropometric and biochemical parameters. Fortin et al. conducted a 6-month nutritional intervention based on the use of an MD and a low-fat diet in patients with T1DM. Changes in anthropometric parameters were observed in the MD group: waist circumference decreased by 1.5 cm and BMI by 0.7 kg/m^2. There was also a reduction in systolic blood pressure (from 137 ± 20 to 134 ± 17 mmHg), diastolic blood pressure (from 79 ± 9 to 77 ± 10 mmHg), LDL-cholesterol (from 1.92 ± 0.67 to 1.81 ± 0.61 mmol/L) and triglycerides (from 1.14 ± 0.069 to 0.93 ± 0.44 mmol/L), but these differences were not statistically significant. The need for long-term use of the above-mentioned diet is emphasized in order to obtain greater improvement in parameters [40].

The study by Zhong et al. was designed to determine the relationship between adherence to the MD and glycemic control in adolescents (<20 years of age) with T1DM. It should be stressed that at the beginning of the study only 3% of the 793 participants obtained a high result (score ≥ 8) regarding the compliance with the MD, 46%—a medium (score from 4 to 7) result, and 51.5%—a low result. People with a high index of the quality of the MD had significantly lower total cholesterol compared to those with a low and medium index (143.6 vs. 161.6 and 157.7 mg/dL) and LDL cholesterol (77.1 vs. 95.5 and 91.8 mg/dL) [41].

One of the consequences of DM is cognitive impairment, especially in terms of verbal memory. Kössler et al. assessed the impact of adherence to the MD in patients with T1DM and T2DM. A beneficial effect on cognitive functions was found in patients with T2DM only, which requires further research [42].

Our study has several limitations. Being retrospective, like many studies from the COVID-19 pandemic period, we left it to the patients to estimate the portions consumed, and they may have been biased. Our survey was conducted only among the inhabitants of northeast Poland; therefore, subsequent studies should be based on a broader population sample from other regions of the country with a large number of cases. The study was conducted among women because they are willing to take part in various types of research far more often than men. Moreover, in Poland the percentage of young women with T1DM is much higher than that of men [43]. However, this can be considered an advantage of this study because we had a group that was homogeneous in terms of age and gender (only women) and resided in neighboring provinces, which provided an overview of a larger region—northeast Poland.

5. Conclusions

Despite the similarities between the behaviors of healthy people and those with T1DM, undesirable nutritional and health habits were observed during the second wave of the COVID-19 pandemic in both groups. The nutritional patterns of those groups were moderately consistent with the MD. Therefore, it is advisable to promote nutritional and health education in order to increase the awareness of the issue among healthy individuals and those with chronic diseases such as DM. The impact of the aforementioned interventions, with particular emphasis on the above results, would have a positive impact on behavior change, but also on improving treatment results. In the times of the COVID-19 pandemic, new guidelines should be developed based on, for example, the MD pyramid combined with local products.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13041173/s1, Table S1. Health behaviors depending on the age group; Table S2. Health behaviors depending on the place of residence.

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MDPI

Systematic Review

Impact of the Level of Adherence to Mediterranean Diet on the Parameters of Metabolic Syndrome: A Systematic Review and Meta-Analysis of Observational Studies

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Abstract: High adherence to the Mediterranean diet (MD) has been associated with a lower prevalence of Metabolic Syndrome (MetS). The present study aimed to investigate the impact of MD adherence on parameters of MetS. A systematic literature search was performed in PubMed, Cochrane Central Registry of Clinical Trials (CENTRAL), Scopus, EMBASE, Web of Science and Google Scholar databases. Observational studies that recorded adherence to MD and components/measures of the MetS, such as waist circumference (WC), blood pressure (BP), fasting blood glucose (FBG), high-density lipoprotein (HDL) cholesterol and triglycerides (TG), were included in this study. A total of 58 studies were included in our study. WC and TG were significantly lower in the high adherence MD group (SMD: −0.20, (95%CI: −0.40, −0.01), SMD: −0.27 (95%CI: −0.27, −0.11), respectively), while HDL cholesterol was significantly higher in the same group (SMD: −0.28 (95%CI: 0.07, 0.50). There was no difference in FBG and SBP among the two groups (SMD: −0.21 (95%CI: −0.54, 0.12) & SMD: −0.15 (95%CI: −0.38, 0.07), respectively). MD may have a positive impact on all parameters of MetS. However, further research is needed in this field.

Keywords: metabolic syndrome; Mediterranean diet adherence; Mediterranean dietary pattern

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1. Introduction

Metabolic Syndrome (MetS), also known as the syndrome X, belongs to the group of non-communicable diseases (NCDs) [1]. The prevalence of MetS has been closely related to socioeconomic factors, as well as lifestyle changes deriving from the impact of westernization on diet and health behavior [1]. Thereby, this transition has led to an increase in morbidity and mortality rates, forcing health systems to introduce more effective strategies so as to prevent the expansion of this epidemic [2]. According to the National Health and Nutrition Examination Survey (NHNES), the prevalence of MetS in US adults reached 34.2% during 2007–2012, with the highest rates observed in non-Hispanic white males and elderly >70 years of age [3]. A large analysis of cohort studies in European countries from 2000 to 2013 revealed that the prevalence of MetS ranged from 42.7%–78.2% for males and 24%–68.4% for females [4].

Metabolic syndrome has been characterized by health professionals and scientists as a cluster of predefined metabolic conditions, namely, hyperglycemia, dyslipidemia, hypertension and central obesity [5]. Chronic low-grade inflammation is considered another important risk factor present in the pathogenesis of MetS [6]. Increased adipose tissue and circulation of inflammatory mediators triggered by excess intake of specific micronutrients comprise the two primary components, which induce proinflammatory responses [6]. Consequently, MetS has been linked to not only the development but also to the progression of other NCDs, such as cardiovascular disease (CVD), type 2 diabetes mellitus (T2DM), chronic respiratory diseases, etc. [7,8]. More specifically, it has been demonstrated that metabolic syndrome can increase the risk of CVD and mortality by 78% [9].

Currently, the most popular criteria used for the diagnosis of the MetS come from three different organizations, the World Health Organization (WHO) [10], the National Cholesterol Education Program in Adult Treatment Panel III (NCEP-ATP III), established slightly different criteria for the identification of MetS, excluding insulin resistance and using waist circumference, which are the most commonly applied criteria in clinical practice [11], and the International Diabetes Federation (IDF) that has also published similar definitions with regards to the MetS, however, diagnosis relies mainly on central obesity [12]. A summary of the diagnostic criteria of MetS can be found in Table 1.

Table 1. Published definitions and criteria for the diagnoses of MetS by the WHO, NCEP-ATP III and IDF.

Organization	Criteria
WHO (1998) [10]	Impaired glucose intolerance or diabetes and insulin resistance *Two or more of the following risk markers:* • BP $\geq$ 160/90 mmHg • Serum TG concentration >150 mg/dL • HDL cholesterol concentration <35 mg/dL (males) and <39 mg/dL (females) • Abdominal obesity: waist to hip ratio >0.90 (males) and >0.85 • (females) and/or BMI > 30 kg/m^2 • Microalbuminuria $\geq$ 20 µg/min
NCEP-ATP III (2002) [11]	*Three or more of the following risk markers:* • Abdominal obesity: WC > 102 cm (males) and >88 cm (females) • Serum TG $\geq$ 150 mg/dL • HDL cholesterol <40 mg/dL (males) and <50 mg/dL (females) • BP $\geq$ 130/85 mmHg • FBG $\geq$ 110 mg/dL
IDF (2006) [12]	Central adiposity [a] *Plus two or more of the following markers* • FBG > 100 mg/dL or diagnosed diabetes • HDL cholesterol <40 mg/dL (males) and <50 mg/dL (females) or treatment for low HDL concentration • Serum TG > 150 mg/dL or treatment for hypertriglyceridemia • BP > 130/85 mmHg or treatment for hypertension

WHO: World Health Organization, NCEP-ATP III: National Cholesterol Education Program in Adult Treatment Panel III, IDF: International Diabetes Federation, HDL: High-Density Lipoprotein, TG: Triglycerides and FBG: Fasting Blood Glucose. [a] Ethnic-specific WC values: Europe $\geq$94 cm for males and $\geq$80 cm for females; South Asia and China $\geq$90 cm for males and $\geq$80 cm for females; Japan $\geq$85 cm for males and $\geq$90 cm for females.

Lifestyle modifications, focusing on dietary patterns and physical activity, may improve markers of MetS and further reduce the risk of development of NCDs [13]. Among various types of dietary treatments, there has been a great deal of evidence with regards to the potential benefits of the Mediterranean diet (MD) in the field of nutritional epidemiology [14]. The traditional MD can be characterized as a plant-based diet containing high amounts of monosaturated fats, omega-3 fatty acids, polyphenols, vitamins and antioxidants, and low amounts of saturated fats and ethanol. With respect to nutrient content, the MD provides approximately 35%–45% fats (of which about 20% derives from monounsaturated fatty acids (MUFAs), 5% from polyunsaturated fatty acids (PUFAs) and 9% from saturated fatty acids (SFAs)), 15% protein and 45% carbohydrates [15]. However, what makes the MD distinct from other dietary patterns is the presence of various food components, including unrefined cereals, legumes, fish, vegetables, fruit, nuts, moderate amounts of wine and, most importantly, olive oil, which is considered the traditional symbol of MD [16].

Over the years, different dietary index scores have been developed for assessing the degree of adherence to the MD [17]. These composite scores aim to measure overall dietary quality with the use of validated food frequency questionnaires (FFQs) [17,18]. Data obtained from FFQs are combined within specific groups, food combinations or nutrients found typically in the MD, in which a specific value is assigned based on a predefined calculation [19]. Ratings resulting from MD scores (MDSs) from all groups are often categorized as low, moderate or high, reflecting the adherence level to MD for each subject [17,18]. As there is no specific rule or consensus as to how the adherence level of different MDSs should be interpreted, low scores indicate poor adherence, whereas higher scores indicate good adherence to MD or otherwise described by the authors. In general, high adherence is the result of frequent consumption in adequate quantities of beneficial components, such as fruits, vegetables, legumes, fish, nuts, whole grain products and olive oil, whereas there is a low intake of alcohol, meat and SFA [20,21].

Several studies have revealed an inverse association between adherence to MD and risk of obesity, CVDs, T2DM as well as all-cause mortality [22–27]. The potential advantages relate to the synergic effect and mechanisms of specific nutrients that have a direct impact on all risk markers of MetS, namely, WC, HDL, TG, FBG, BP, as well as systemic inflammation [28]. Even though the positive impact of MD on risk and occurrence of MetS has been previously confirmed [29,30], there have not been any analyses evaluating how different levels of adherence to MD could favorably impact each parameter of MetS.

Therefore, the purpose of this study was to examine the impact of low and high adherence to MD on the parameters of MetS.

2. Materials and Methods

This study is a systematic review and a meta-analysis which was conducted according to the Meta-analyses Of Observational Studies in Epidemiology (MOOSE) statement (Supplementary File S1). The protocol of this systematic review and meta-analysis was submitted in the OSF platform (https://osf.io/n4ja8/ accessed on 5 March 2021).

2.1. Literature Search

A systematic literature search was conducted in the following electronic databases PubMed, EMBASE, Google Scholar, Scopus, Web of Science and Cochrane Central Registry of Clinical Trials (until 11 January 2021) in all fields option using the following search string: ("Mediterranean diet") AND (Adherence) for the PubMed database, which was modified accordingly for the other search engines (search terms and keywords of our search strategy can be found in Supplementary File S2). Additional relevant studies were searched by references screening of the articles retrieved.

2.2. Study Selection-Eligibility Criteria

Eligible studies for inclusion to systematic review were original observational studies that investigated the impact of MD adherence on three or more parameters of MetS (WC, HDL, TG, SBP and FBG), according to the revised criteria NCEP ATP III [11], in the adult population, using a validated tool or scoring algorithm. MDSs developed by Panagiotakos et al. [31], Sofi et al. [32] and Trichopoulou et al. [21], as well as the PREDIMED MD Adherence Screener (MEDAS) score [33], the short MDS produced by Martinez Gonzalez et al. [34] the serving MDS [35], the Mediterranean-Style Dietary Pattern Score (MSDPS) by Rumawas et al. [36], the MD quality index [37], the relative MD system [38], and modified versions of MDSs [39–49], were used in our included studies. A summary of the diagnostic criteria of MetS can be found in Table 1. Studies that were not published as original papers (e.g., abstracts, conference papers, editorials and commentaries, etc.) were excluded. Additionally, manuscripts that did not provide adequate data regarding low and high adherence to MD were also excluded from this analysis. Only studies in English and Spanish language were part of our review.

2.3. Data Extraction

Records of our search results were imported into a reference management software (Endnote X9 for windows-by Clarivate Analytics USA) and two reviewers (LC, DB), after the removal of duplicates, assessed the studies for eligibility. Any disagreements were solved by a third reviewer (EK). Data extraction was performed independently by the above-mentioned two reviewers using a pre-specified standardized Microsoft® excel form and was checked for accuracy by a third reviewer (EK). In cases of missing data, corresponding authors were contacted by email in order to retrieve any additional data.

The primary outcome of our study was to investigate the impact of high adherence to MD compared to low adherence to MD on the five parameters of MetS according to the NCEP ATP III [11] revised criteria for diagnosis.

2.4. Quality Assessment of Included Studies

The quality of the eligible studies was assessed using the Newcastle Ottawa Scale (NOS) adjusted version for cross-sectional studies by two independent authors (LC and DB) [50]. Any disagreements that arose were solved by consensus and by the involvement of a third author (EK). Sensitivity analysis was further performed after the exclusion of low-quality studies (NOS < 7).

2.5. Statistical Analysis

Means and standard deviations (SD) from eligible studies reported high and low MD adherence for each parameter of MetS were used. Wherever it was necessary, and data were presented as median, minimum or maximum values or 95% confidence intervals (CI), conversion to mean and SD was performed [51–54]. When values of FBG, TG and HDL cholesterol were presented as mmol/L, conversion to mg/dL was employed using the Omni calculator [55]. The inverse variance method was used in order to estimate the weight of each study. The random effects model was used due to higher methodological heterogeneity among the included studies [56,57]. Moreover, Hedge's g was used as effect size and standardized mean difference (SMD) as a summary statistic model due to the heterogenous scores using in included studies for the definition of low and high adherence to MD [56]. Estimation of heterogeneity was performed with Cochrane Q test ($p < 0.1$: existence of heterogeneity) and I^2 statistic [56,57]. I^2 values >50% indicated substantial heterogeneity across studies. Publication bias was assessed with funnel plots and Egger's test [53]. All statistical analyses were performed using the R software developed at Bell Laboratories (formerly AT&T, now Lucent Technologies version 4.0.2).

3. Results

3.1. Search Results

A total of 9933 studies were identified through the literature search. After removing 3654 duplicates, 6279 studies were detailed screened for eligibility. The process of eligibility of our included studies can be found in the flow diagram in Figure 1. Not relevant to the topic examined studies, studies including population <18 years old, studies in which validated tool for assessment of MD were not used and in which the level of adherence was not clearly described were excluded. Overall, 58 studies were characterized as acceptable for the systematic review [39,40,43–47,49,58–107] and 41 for the meta-analysis [45–47,49,58–88,90–94]. Authors of studies in which data were not adequate for our systematic review or/and meta-analysis were contacted by email requesting supplemental data without any response received.

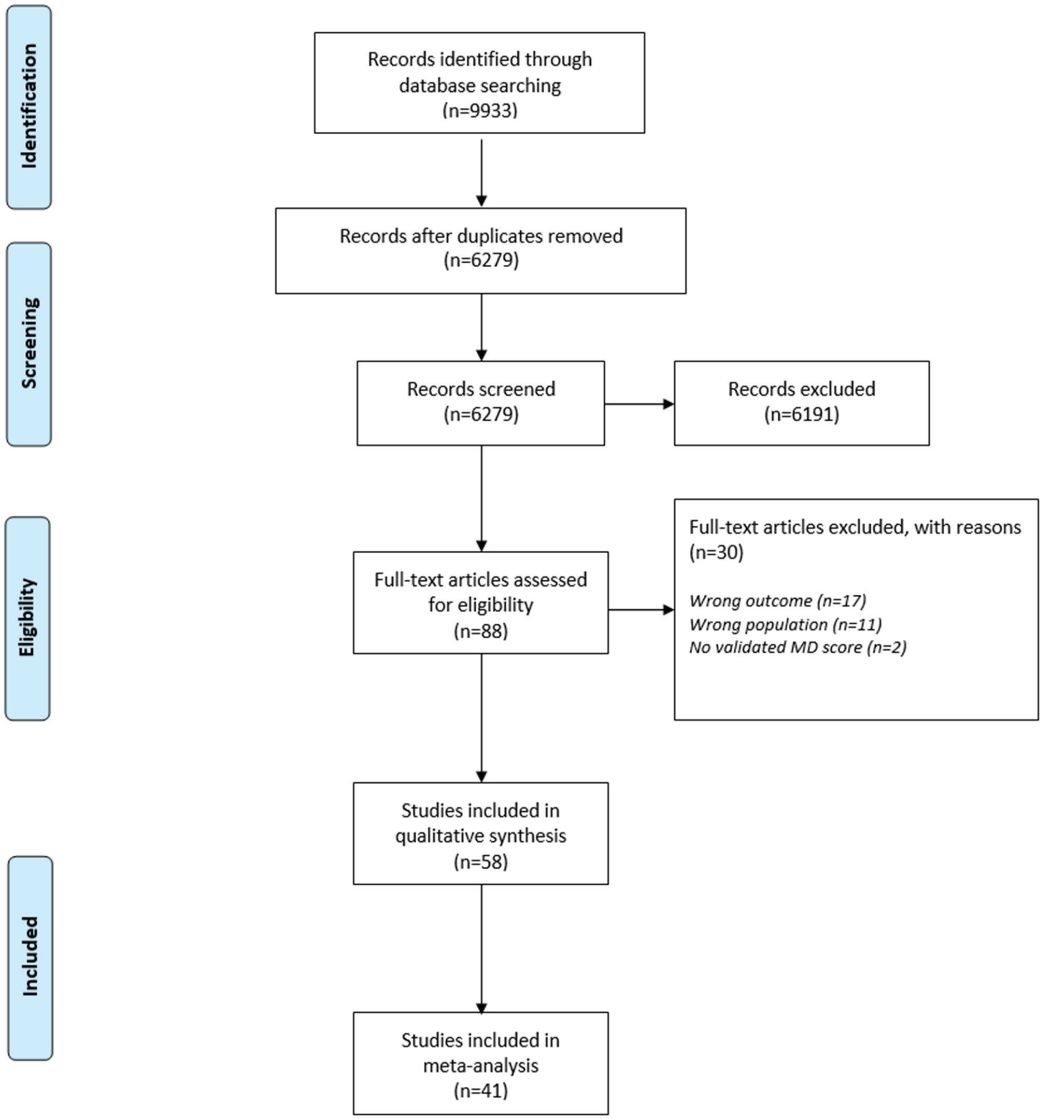

Figure 1. Flow diagram of the eligibility process of included studies.

3.2. Quality Assessment

The quality of the 58 included studies was examined according to the NOS [50]. Five studies were characterized as unsatisfactory due to their ratings (2–4 stars) [43,67,75,80,107], whereas for 17 studies the quality was only satisfactory (5–6 stars) [39,49,61,63,71,86,92–94,96,97,100,104,105]. The majority of the included studies (*n* = 28) [40,44,45,47,58–60,62,65,68–70,72,74,76,77,79,81–85,87,88,95,101,103,106] were good quality studies (7–8 stars), and eight studies were at the top of quality studies scoring 9 stars [46,64,66,73,91,98,99,102]. More information regarding the assessment of quality according to the NOS can be found in Supplementary File S3.

3.3. Publication Bias

Funnel plots of studies included in our meta-analysis regarding each parameter of MetS can be found in Supplementary Figure S1a–e. Both the symmetry of funnel plots and Egger's test results confirm the absence of publication bias in all parameters of MetS except TG. Eggers's test results were $p = 0.8325$ referred to WC, $p = 0.2177$ referred to HDL, $p = 0.04598$ referred to TG, $p = 0.8533$ referred to SBP, and $p = 0.4677$ referred to FGL.

3.4. Study Characteristics

Characteristics of the included studies can be found in Table 2 for studies included in the systematic review and Table 3 for studies included in the meta-analysis, in which the country origin, the number, the mean age as well as the specific group of participants, and the MD assessment tool are included. In total, 74,058 adult subjects from all over the world (Australia, Chile, Finland, France, Greece, Iran, Italy, Korea, Morocco, The Netherlands, Poland, Spain, Sweden, Taiwan, Turkey, UK and USA) who followed an MD were examined.

3.5. Result on Components of MetS

3.5.1. Waist Circumference (WC)

In three studies in which OR of the prevalence of WC >102 cm for males and >88 cm for females was used as a measure of the effect, low odds for this outcome were observed in the groups of high adherence to MD [39,99,104]. Moreover, in the study by Mirmiran et al. [103], in which the incidence of abnormalities during 3 years follow-up was examined and expressed as OR, a lower incidence was found in the high adherence group, but this was not significant ($p > 0.05$). In Aridi et al. [95] and Mattei et al. [101], a significantly lower mean WC was found in the high adherence groups, as well as in 3 more studies [98,102,107] in which follow-up results were obtained. In Rumavas et al. [106], a significantly lower geometric mean of WC in the high adherence group was reported ($p < 0.001$), and in Steffen et al., the prevalence of subjects reporting an unhealthy WC was significantly lower in the high adherence group [44]. Only in one study, WC did not differ between the low and the high adherence group [40].

The meta-analysis results showed a lower WC in the low adherence group [SMD: −0.20, (95%CI: −0.40, −0.01)] with a high heterogeneity among studies ($I^2 = 95\%$) as presented in Figure 2. In order to explore the heterogeneity, a subgroup analysis of higher quality (NOS > 7) and lower quality (NOS < 7) studies was performed, which led to not significant results (SMD: −0.19 (95%CI: −0.48, 0.10)) and $I^2 = 96\%$ as can be seen in Supplementary Figure S2.

Table 2. Characteristics of studies included only in the systematic review.

Study ID (Country)	No of Participants (F/M)	Mean Age (Years)	Population	MD Assessment Tool	WC (cm)	HDL Cholesterol (mg/dL)	TG (mg/dL)	FBG (mg/dL)	SBP (mmHg)	Measure of Effect
Alvarez-Leon 2006 (Canary Islands) [39]	578 (329/249)	≥18 [1]	General population	Semi-quant FFQ 81 to calculate Specific food item score (10-item) [39]	L = 1 H = 0.77 [0.38–1.56]	L = 1 H = 0.90 [0.56–1.42]	L = 1 H = 1.05 [0.63–1.75]	L = 1 H = 2.46 [1.13–5.37] *	L = 1 H = 0.58 [0.34–0.99] *	OR [95%CI]
Aridi 2020 (Australia) [95]	3245 (1753/1492)	48.6 (17.6)	General population	Trichopoulou MDS [21]	L = 94.5 (14.7) H = 90.7 (13.3) *	L = 88.7% H= 89.9%	L = 83.1% H = 85.8%	L = 6.1% H = 5.7%	L = 123.6 (18.8) H = 122.1 (18.4)	Mean (SD)/ %Prevalence
Barnaba 2020 (Italy) [96]	349 (228/121)	18–86 [1]	General population	MD serving score [35]	No info	L + M = 52.2 (11.1) H = 52.2 (13.4)	L + M = 107.5 (54.4) H = 110 (43.42)	L + M = 98.1 (12.2) H = 103.5 (11.76)	No info	Mean (SD)
Huang 2013 (Sweden) [40]	187 (0/187)	70	Elderly population with CKD	Modified Trichopoulou MDS 14-item [21]	L = 97 (10) H = 97 (11)	L = 47 (14) H = 48 (14)	L = 127.8 (59.9) H = 122.2 (70.8)	L = 103 (20) H = 106 (28)	L = 149 (19) H = 148 (19)	Mean (SD)
Karayiannis 2017 (Greece) [97]	142 (0/142)	37.8 (5.4)	Subjects without systemic diseases, cryptorchidism or varicocele, microorchidism, vasectomy or hormonal treatment in the last six months	MDS by Panagiotakos 0–55 points [31]	No info	L = 49.4 (11.3) H = 50.4 (10.6)	L = 107.9 (39.3) H = 84.3 (27.1)	L = 89.6 (9.1) H = 86.4 (8.3)	No info	Mean (SD)
Kesse-Geyot 2013 (France) [98]	1881 (668/1213)	49.7 (6.2)	General population	Trichopoulou MDS—9 points [21]	L = 84.21 (0.9) H = 82.8 (0.96)	L = 58 (1.19) H = 58.8 (1.2)	L = 88.5 (35.4) H = 84.07 (2.65)	L = 90.7 (0.4) H = 90.4 (0.7)	L = 128.7 (1.4) H = 127.67 (1.42)	Mean (SD)
Kim 2018 (Korea) [99]	2349 (1159/1190)	19–65 [1]	General population	Modified MDS -9 points [41]	L = 1 H = 0.45 [0.31–0.66] *	L = 1 H = 0.89 [0.70–1.13] *	L = 1 H = 0.72 [0.55–0.94] *	L = 1 H = 0.83 [0.63–1.10] *	L = 1 H = 0.99 [0.74–1.34] *	OR
Mahdavi-Roshnan 2017 (Iran) [100]	344 (154/190)	L = 59.0 (8.30) H = 58.0 (9.36)	Subjects with CVD risk factors	PREDIMED MEDAS score -14 points [33]	No info	L = 42.81 (8.34) H = 43.3 (8.23)	L = 209.61 (399.33) H = 155.83 (87.63)	L = 116.4 (66.9) H = 105.9 (66.1)	No info	OR/ Mean (SD)
Mattei 2017 (US) [101]	1194 (No info)	L = 56.6 (7.9) H = 57.2 (7.7)	Subjects with no severe health conditions or cognitive impairments	Trichopoulou MDS—9 points [21]	L = 103 (14) H = 102 (13) *	L = 46.3 (12.5) H = 45.96 (12.3)	L = 163 (93) H = 165 (127)	L = 115 (53) H = 112 (36) *	L = 135 (19) H = 137 (20)	Mean (SD)
Mayr 2019 (Australia) [102]	37 (No info)	No info	Patients with coronary heart disease	PREDIMED MEDAS score 14—item [33]	L = 103.5 (3.4) H = 100.7 (3.3) *	L = 48.7 (6.5) H = 46.02 (6.1)	L = 102.75 (33.9) H = 115.15 (36.8)	L = 91.6 (13.40) H = 99 (13.30)	L = 136.5 (10.4) H = 133.4 (10.2)	Mean (SD)
Mirmiran 2015 (Iran) [103]	1683 (927/756)	L = 36.3 (13.3) H = 41.3 (13.8)	General population	Trichopoulou MDS—8 points [21]	L = 1 H = 0.74 [0.48–1.13]	L = 1 H = 0.82 [0.48–1.40] *	L = 1 H = 0.81 [0.56–1.17] *	L = 1 H = 1.01 [0.73–1.39]	L = 1 H = 0.86 [0.64–1.22]	OR
Mziwira 2015 (Morocco) [104]	90 (90/0)	39.9 (0.66)	General non-pregnant population	Specific MDS- 0%–100% [42]	L = 1 H = 0.54 [0.13–2.27]	L = 1 H = 0.29 [0.02–3.02]	L = 1 H = 0.47 [0.04–4.94]	L = 1 H = 0.27 [0.05–1.49]	L = 1 H = 0.77 [0.19–3.15]	OR

Table 2. *Cont.*

Study ID (Country)	No of Participants (F/M)	Mean Age (Years)	Population	MD Assessment Tool	WC (cm)	HDL Cholesterol (mg/dL)	TG (mg/dL)	FBG (mg/dL)	SBP (mmHg)	Measure of Effect
Roldan 2019 (Spain) [105]	107 (58/49)	61.16 (23)	Overweight/Obese T2DM patients with poor glycemic control	PREDIMED MEDAS score—14 points [33]	No info	L = 48.29 H = 52.45 *	L = 223.56 H = 171.23 **	L = 201.14 H = 132.88 *	No info	Mean
Rumawas 2009 (US) [106]	1069 (608/461)	L = 52.4 (9.9) H = 54.8 (9.6)	Non-diabetic general population	The MSDPS—100 points [36]	L = 98.5 H = 97.1 **	L = 53.3 H = 54 *	L = 114 H = 103 **	L= 98.5 H = 97.1 *	L = 122 H = 121	Geometric mean
Steffen 2014 (US) [44]	865 (511/354)	L = 24.3 H = 25.7	General population	Modified Trichopoulou MDS—22 points [21]	L = 59.4% H = 41.9% **	L = 68.4% H = 59.3% *	L = 37.3% H = 21.6% **	L= 21.3% H = 19.1% *	L= 49.2% H = 40.4% *	%Prevalence
Tortosa 2007 (Spain) [107]	1040 (No info)	No info	Graduate students	Trichopoulou MDS—9 points [21]	L = 82.5 (12) H = 82 (12) *	L = 63.8 (15) H = 64.1 (19) *	L = 80.0 (38) H = 78 (40)	L = 86.1 (11) H = 87.3 (17)	L = 112.5 (14) H = 113.3 (13)	Mean (SD)
Yang 2014 (US) [43]	395 (0/395)	L = 38.2 (8.6) H = 37.1 (8.4)	General population	Study Specific MDS—42 points [43]	No info	L = 41.7 (1.3) H = 46.6 (1.3)	L = 140.4 (1.8) H = 115.8 (1.8)	L = 93.2 (1.2) H = 91.1 (1.2)	L = 122.4 (12.6) H = 122.8 (13.3)	Geometric mean (SD)

* $p < 0.05$, ** $p < 0.001$. [1]: Age range. Variables are displayed as mean (SD), OR [95% Confidence Interval]. CKD: Chronic Kidney Disease, F: Female, FBG: Fasting Blood Glucose, FFQ: Food Frequency Questionnaire, H: High Adherence, HDL: High-Density Lipoprotein, L: Low Adherence, M: Male, M: Moderate Adherence, MD: Mediterranean Diet, MEDAS: Mediterranean Diet Adherence Screener, MDS: Mediterranean Diet Score, MSDPS: Mediterranean-Style Dietary Pattern Score, OR: Odds Ratio, SBP: Systolic Blood Pressure, SD: Standard Deviation, T2DM: Type 2 Diabetes Mellitus, TG: Triglycerides and WC: Waist circumference.

Table 3. Characteristics of studies included in the meta-analysis.

Study ID (Country)	No Participants (F/M)	Age (Years)	Population	MD Assessment Tool
Abiemo 2013 (US) [45]	2440 (1305/1135)	L = 60.0 (10.3) H = 63.0 (10.3)	General population	Study Specific Alternate MDS—10 points [45]
Ahmad 2018 (US) [58]	16,623 (16,623/0)	L = 52.6 (6.7) H = 54.9 (8.1)	General population	Trichopoulou MDS—9 points [21]
Ahmed 2020 (US) [59]	224 (133/91)	L = 56.2 (12.6) H = 66.7 (11.6)	Community-dweling adults	Sofi MDS—12 points [32]
Asghari 2016 (Iran) [60]	622 (308/314)	L = 43.0 (9.1) H = 43.7 (9.7)	Subjects without CKD	Trichopoulou MDS—8 points [108]
Baratta 2017 (Italy) [61]	148 (47/101)	L = 51.7 (11.3) H = 57.7 (11.9)	Outpatients presenting with T2DM, HBP, Overweight/Obese, Dyslipedemia or MetS	Short MDS—9 points [34]
Bondia-Pons 2009 (Spain) [62]	70 (41/29)	47 (15.3)	General population	MD Quality Index—14 point % adherence [37]
Campanella 2020 (Italy) [63]	2387 (1183/1204)	L = 45.5(15.5) H = 54.6 (15.5)	General population	Relative MD system—18 points [38]
Dai 2008 (US) [64]	194 (0/194)	L = 53.8 (0.3) H = 54.8 (0.3)	Middle aged twins who have served in the Vietman War	Trichopoulou MDS—9 points [21]
Esposito 2009 (Italy) [65]	475 (232/243)	L = 58.0 (7.0) H = 58.3 (7.0)	T2DM patients	Trichopoulou MDS—9 points [21]
Gardener 2015 (US) [66]	543 (308/235)	L = 69.0 (8.0) H = 65.0 (9.0)	Population never diagnosed with stroke	Trichopoulou MDS—9 points [21]
Giraldi 2020 (Italy) [67]	209 (61/148)	L = 41.7 (13.3) H = 49.9 (16.4)	Patients with NAFLD	Sofi MDS—12 points [32]
Giugliano 2010a (Italy) [69]	315 (315/0)	L = 57.7 (6.7) H = 58.0 (6.8)	T2DM patients	Trichopoulou MDS—9 points [21]
Giugliano 2010b (Italy) [68]	288 (0/288)	L = 54.7 (6.9) H = 58.7 (7.0)	T2DM patients	Trichopoulou MDS- 9 points [21]
Granado-Casas 2020 (Spain) [70]	92 (52/40)	L = 41.9 (10.6) H = 45.1 (10.9)	T1DM patients	Trichopoulou MDS—9 points [21]

Table 3. *Cont.*

Study ID (Country)	No Participants (F/M)	Age (Years)	Population	MD Assessment Tool
Grosso 2015 (Poland) [46]	4678 (2408/2270)	45–69 *	General population	Modified Panagiotakos MDS—60 points [31]
Hu 2013 (Spain) [71]	7305 (4188/3117)	L = 67.2 (6.2) H = 67.0 (6.2)	Adults with high risk of CVD, with T2DM or at least 3/6 CVD risk factors	PREDIMED MEDAS Score—14 points [33]
Izadi 2016 (Iran) [72]	325 (325/0)	L = 28.0 (6.2) H = 27.2 (5.2)	Pregnant carrying singleton fetuses with/without GDM	Trichopoulou MDS—9 points [21]
Jalilpiran 2020 (Iran) [73]	357 (0/357)	L = 66.5 (6.7) H = 63.3 (5.8)	General population	Trichopoulou MDS—9 points [21]
Jayedi 2019 (Iran) [74]	131 (131/0)	L = 54.7 (6.8) H = 54.9 (7.5)	Females with prevalent T2DM or with history of 3–10 yrs T2DM and with/without DN	Trichopoulou MDS—9 points [21]
Köroğlu 2020 (Turkey) [75]	25 (0/25)	18–65 *	Patients with lower limb amputation	PREDIMED MEDAS Score—14 points [33]
Kwon 2020 (Korea) [76]	148 (84/64)	L = 43.6 (9.1) H = 53.3 (8.3)	General Population	PREDIMED MEDAS Score—14 points [33]
Lavados 2020 (Leu) [77]	368 (158/210)	L = 67.2 (18.7) H = 69.9 (16.9)	Patients with acute ischemic stroke	PREDIMED MEDAS Score—14 points [33]
Leu 2019 (Taiwan) [78]	1400 (807/593)	L = 48.4 (12.7) H = 50.6 (11.4)	General Population	Trichopoulou MDS—9 points [21]
Mateo-Gallego 2017 (Spain) [79]	1016 (54/962)	L = 50.9 (4.0) H = 51.7 (3.7)	Employees of car assembly plant	Trichopoulou MDS—9 points [21]
Molina-Leyva 2018 (Spain) [80]	25 (No info)	L = 43.7 (10.9) H = 50.8 (13.5)	Patients with psoriasis	PREDIMED MEDAS Score—14 points [33]
Moradi 2020 (Iran) [81]	153 (95/58)	L = 64.7 (9.3) H = 67.2 (9.8)	Diabetic patients with nephropathy	Trichopoulou MDS—9 points [21]
Mosconi 2014 (US) [82]	52 (37/15)	L = 53.0 (13) H = 55.0 (12)	Cognitive-normal individuals	Study Specific MDS—9 points [82]

Table 3. *Cont.*

Study ID (Country)	No Participants (F/M)	Age (Years)	Population	MD Assessment Tool
Park 2016 (US) [83]	1034 (572/462)	L = 40.8 (0.9) H = 40.8 (1.3)	Metabolicaly healthy and unhealthy obese population	Panagiotakos MDS—55 points [31]
Peñalvo 2015 (Spain) [84]	516 (18/498)	L = 50.8 (3.8) H = 51.5 (3.4)	General population	MEDAS Score [33] Alternative MD index [41]
Pocovi-Gerardino 2020 (Spain) [85]	159 (143/16)	L = 38.6 (9.7) H = 28.3 (12.8)	Patients with SLE	PREDIMED MEDAS Score—14 points [33]
Ruiz-Cabello 2016 (Spain) [86]	118 (118/0)	L = 52.0 (4.8) H = 52.9 (4.1)	Peri- and menopausal females	Panagiotakos MDS—55 points [31]
Salas-Huetos 2019 (Spain) [87]	57 (0/57)	L = 24.1 (4.5) H = 26.3 (4.8)	Healthy subjects	Trichopoulou MDS—9 points [21]
Sotos-Prieto 2014 (UK) [88]	10,359 (5593/4766)	L = 59.0 (9.4) H = 59.3 (9.3)	General population	Trichopoulou MDS—9 points [21]
Tuttolomondo 2015 (Italy) [89]	288 (162/126)	L = 72.9 (14.8) H = 72.4 (13.2)	Patients with ischemic heart disease	Trichopoulou MDS—9 points [21]
Tuttolomondo 2020 (Italy) [90]	409 (250/159)	L = 70.2 (12.6) H = 72.0 (10.4)	Patients with congestive heart failure	Trichopoulou MDS—9 points [21]
Tzima 2007 (Greece) [91]	1040 (333/707)	L = 55.0 (13) H = 35.0 (10)	Obese and Overweight population	Panagiotakos MDS—55 points [31]
Veglia 2019 (Finland, Sweden, Netherlands, France, Italy) [47]	1835 (980/855)	L = 64.8 (5.4) H = 63.9 (5.7)	Patients with >3 vascular risk factors	Study Specific MDS—7 points [47]
Veissi 2016 (Iran) [92]	157 (104/53)	L = 54.3 (9.9) H = 54.6 (8.9)	T2DM patients	Study Specific MDS—4 points [92]
Viscogliosi 2013 (Italy) [93]	55 (33/22)	L = 59.6 (10.2) H = 60.0 (9.4)	High CVD risk population	PREDIMED MEDAS Score—14 points [33]
Vitale 2018 (Italy) [49]	1539 (606/933)	No info	T2DM patients with HbA1c 7%–9%	Modified Trichopoulou MDS—18 points [21]
Zupo 2020 (Italy) [94]	324 (228/96)	L = 38.0 (13.1) H = 42.5 (13.1)	General population	PREDIMED MEDAS Score—14 points [33]

* Age range. Variables are displayed as mean (SD). CKD: Chronic Kidney Disease, CVD: Cardiovascular Diseases, DN: Diabetic Nephropathy, F: Female, GDM: Gestational Diabetes Mellitus, H: High Adherence, HBP: High Blood Pressure, L: Low Adherence: M: Male, MDS: Mediterranean Diet Score, MEDAS: Mediterranean Diet Adherence Screener, MetS: Metabolic Syndrome, NAFLD: Non-Alcoholic Fatty Liver Disease, SLE: Systemic Lupus Erythematosus, T1DM: Type 1 Diabetes Mellitus and T2DM: Type 2 Diabetes Mellitus.

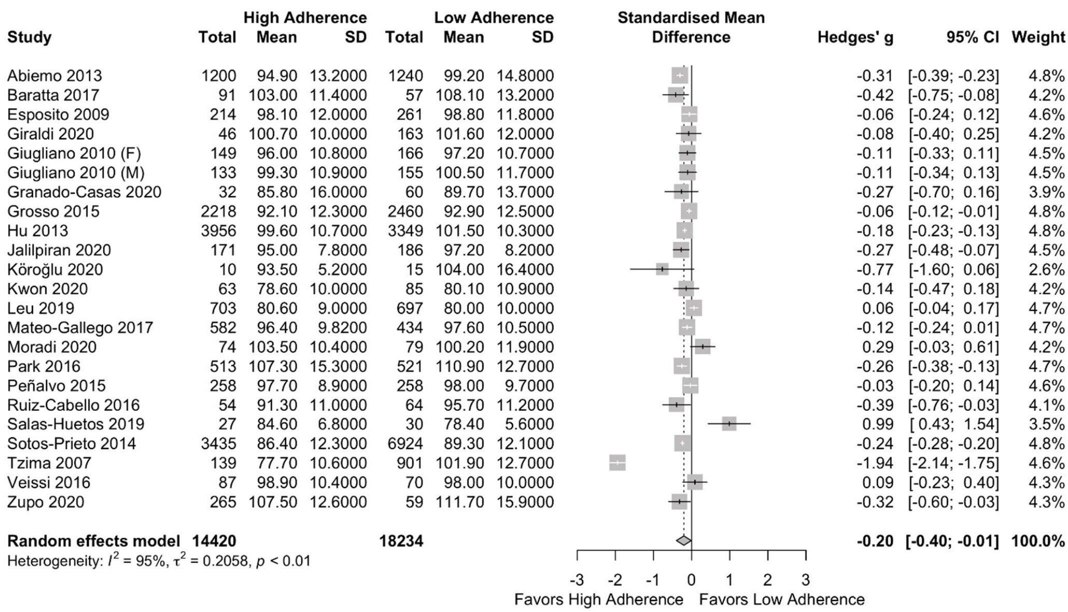

Figure 2. Forest plot of the impact of level of adherence to MD on WC (cm).

3.5.2. HDL Cholesterol

In subjects reporting high adherence to MD, the ORs of HDL cholesterol <40 mg/dL for males and <50 mg/dL for females were lower, compared to low adherers but not significantly [39,99,104], even after three years of follow-up [103]. Mean and geometric mean HDL cholesterol concentrations were increased in the high adherence groups [40,97,98,100,105–107]. A significantly increased (p = 0.0258) HDL cholesterol concentration in the high adherence group was reported by Yang et al. [43]. In Aridi et al. [95] and Steffen et al. [44], the percentage of subjects with increased HDL cholesterol was higher in the high MD adherence group compared to the low adherence group. On the contrary, in two studies, the mean HDL cholesterol concentration was higher in low adherence compared to high adherence groups [101,102]. Only in Barnaba et al., no difference regarding the mean HDL concentration was found between the moderate-high adherence group and the low adherence to MD group [96].

Results of our meta-analysis can be found in the forest plot of Figure 3. Significant higher HDL cholesterol concentration in the high adherence to MD group was observed (SMD: 0.28 (95%CI: 0.07, 0.50)) with high heterogeneity among the included studies I^2 = 96%.

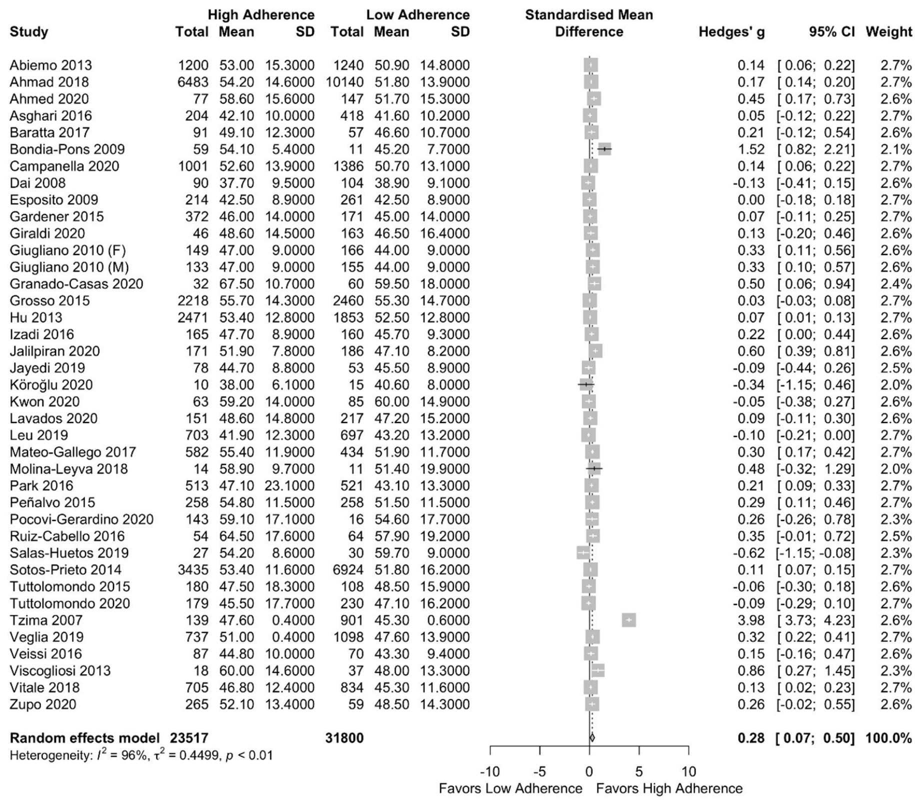

Figure 3. Forest plot of the impact of level of adherence to the MD on HDL cholesterol (mg/dL).

In the subgroup analysis (based on the quality of studies per NOS), the significantly increased HDL cholesterol concentration was remained after excluding the low-quality studies (SMD: 0.36 (95% CI: 0.03, 0.68)) with I^2 = 98% as can be seen in Supplementary Figure S3.

3.5.3. Serum Triglycerides

Regarding the studies which used OR as a measure of effect, in three studies [99,103,104], the ORs of having TG concentration above 150 mg/dL were lower for the high adherence group, and in only one study, the OR was higher [39]. Means and geometric means TG concentration were observed to be lower in high adherence groups [40,43,98,100,102,105–107] compared to the low adherence groups. Similarly, in Steffen et al. [44], a significantly lower percentage was reported for increased TG concentration in the high adherence to MD group compared to the low adherence group. In contrast, in two studies led by Barnaba and by Matei, a higher concentration of TG was reported in the high-moderate adherence group and in the high adherence group, respectively, compared to the low adherence group [96,101]. Additionally, in the study led by Aridi, a higher, but not significant, percentage reported increased TG concentration in the high adherence to MD group compared to the low adherence group [95].

After performing the meta-analysis, TG concentration was found to be lower in the high adherence to MD group compared to the low adherence group (SMD: −0.27 (95%CI: −0.44, −0.11)) with a high heterogeneity among the studies I^2 = 95% as is presented in Figure 4. In the subgroup analysis of low- and high-quality studies, the same results also remained after excluding the low-quality studies (SMD: −0.29 (95% CI: −0.52, −0.05)) with I^2 = 97% (Supplementary Figure S4).

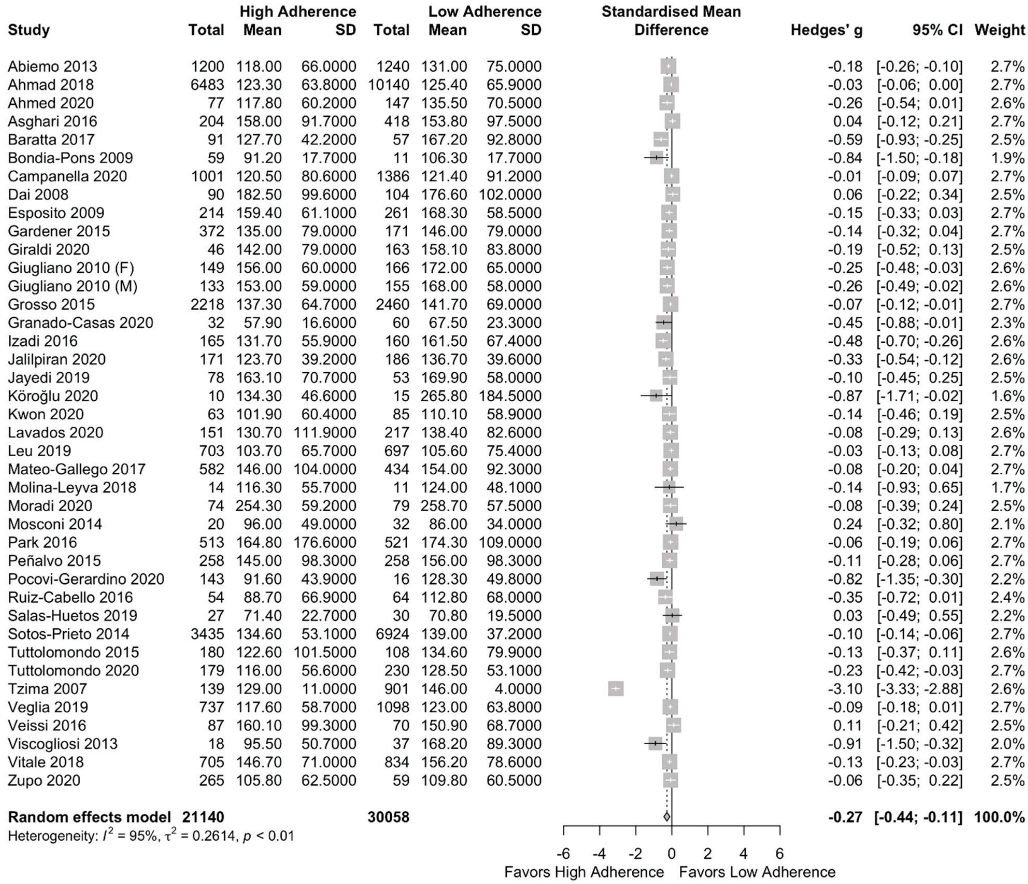

Figure 4. Forest plot of the impact of level of adherence to the MD on serum TG (mg/dL).

3.5.4. Fasting Blood Glucose

In 2 studies by Alvarez-Leon et al. [39] and Mirmiran et al. [103], ORs of having FBG >180 mg/dL were higher in the high adherence group to MD in comparison to the low adherence group, whereas in 2 other studies were opposite (ORs were lower regarding in the high adherence group) [99,104]. Means and geometric means concentration of FBG were lower in high adherers compared to low MD adherers [43,97,98,100,105,106]. According to Aridi et al. and Steffen et al. studies, a lower percentage of subjects presented FBG concentration >110 mg/dL in the high adherence group compared to the low adherence to MD group [44,95]. However, the mean concentration of FBG was increased in high adherers compared to low adherers [40,102,107] and low-moderate adherers [96].

The meta-analysis results can be found in Figure 5. There was no difference in FBG between the two groups (SMD: −0.21 (95%CI: −0.54, 0.12)). The above did not change after performing a subgroup analysis per the NOS classification (SMD: −0.24 (95%CI: −0.70, 0.22) for the high-quality studies) as can be seen in Supplementary Figure S5.

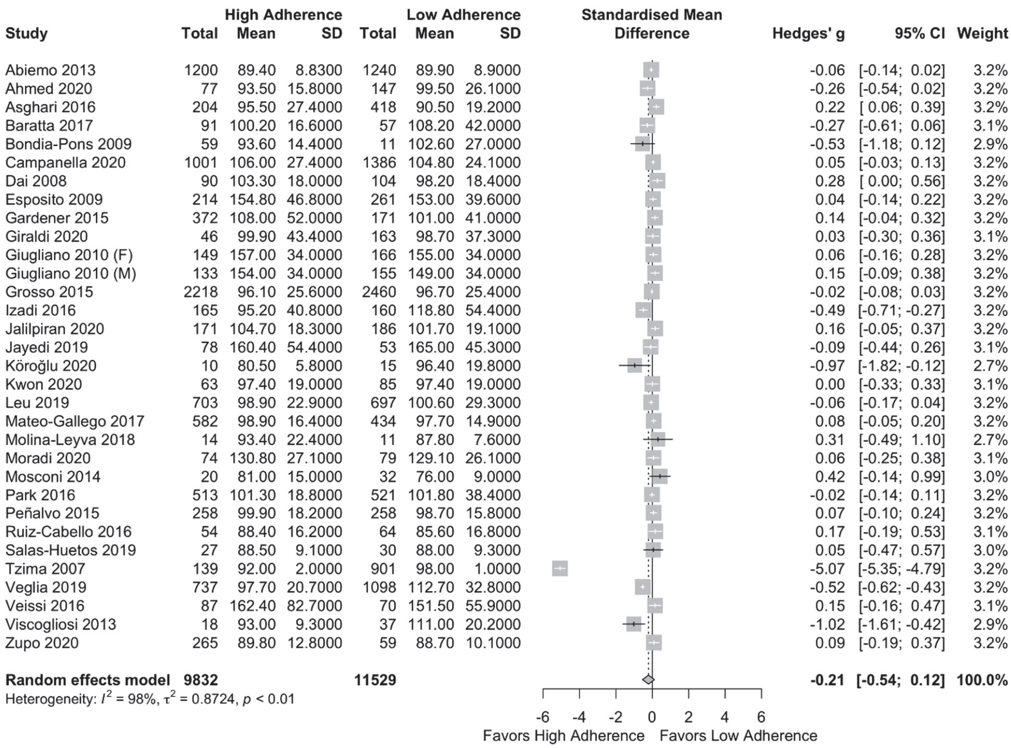

Figure 5. Forest plot of the impact of level of adherence to MD on FBG (mg/dL).

3.5.5. Systolic Blood Pressure (SBP)

Regarding the SBP, in four studies, the ORs of a measuring SBP >130 mmHg were lower in subjects reporting high adherence to MD compared to low adherers [39,99,103,104]. Moreover, means and geometric means of SBP were lower in the high adherence group compared to the low adherence group [40,98,102,106]. According to Aridi et al. [95] and Steffen et al. [44], lower percentages of subjects presented SBP >130 mmHg from the high adherence to MD group compared to the low adherence group. Three studies reported the opposite (higher SBP was observed in higher adherence to MD) [43,101,107].

Meta-analysis results can be found in Figure 6. Lower SBP was observed in the high adherence group but not significant (SMD:−0.15 (95% CI: −0.38, 0.07)) with high heterogeneity across the included studies (I^2 = 97%). This result did not change after the performance of a subgroup analysis based on the quality of studies (SMD: −0.25 (95%CI: −0.60, 0.10), I^2 = 98%) as can be seen in Supplementary Figure S6.

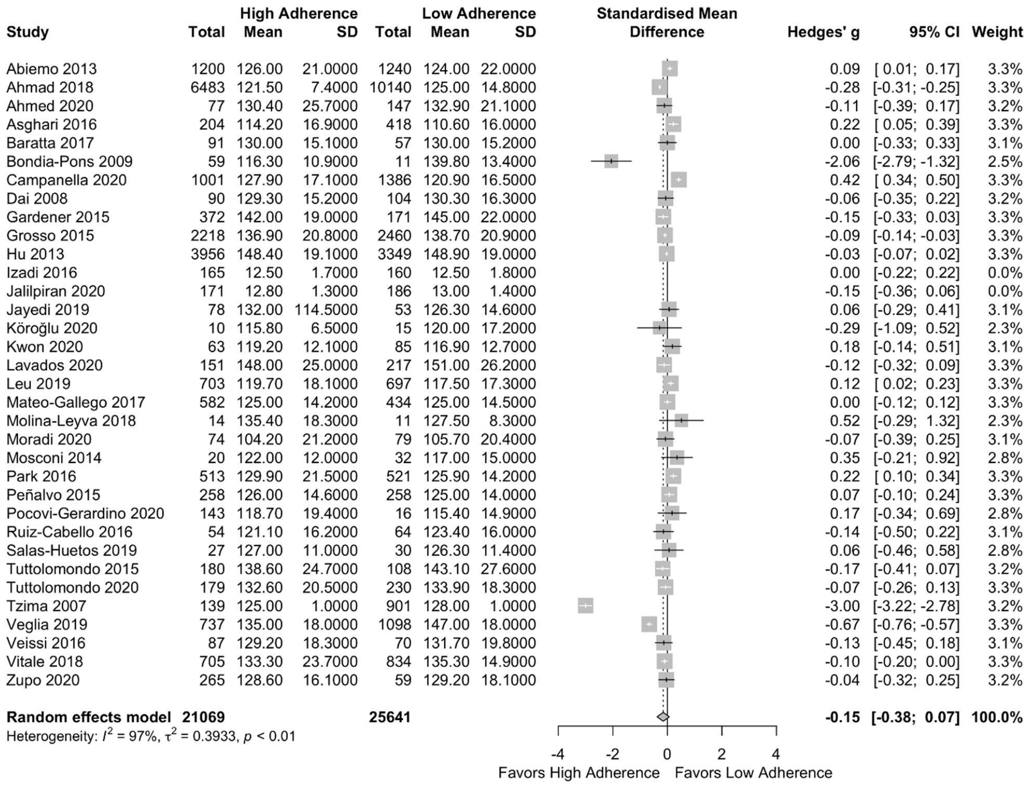

Figure 6. Forest plot of the impact of level of adherence to the MD on SBP (mg/dL)—n = 25,641.

4. Discussion

Our systematic review and meta-analysis aimed to investigate the association between a low and high level of adherence to MD and risk parameters of MetS, according to the NCEP-ATP III criteria. The present study, examining 41 observational studies, revealed a positive impact of MD on the five components of MetS, including WC, HDL, TG, FG and BP. Although a previous meta-analysis conducted by Kastorini et al. [30] explored the effect of MD on MetS prevalence, including its components, this is the first meta-analysis estimating the impact of the level of adherence to MD on each parameter of MetS according to evidence obtained by MD adherence scores.

With regards to abdominal obesity, our results showed a significant inverse association between WC and adherence to MD. Only one study [40] did not find any statistical difference in WC between the different levels of adherence to MD groups, which could be attributed to the underlying health condition of participants (CKD patients). Increased WC, which was detected in the low adherence to MD subjects, along with the accumulation of visceral fat, have been linked to the presence of low-grade systemic inflammation, increased oxidative stress and overexpression of pro-inflammatory cytokines, including CRP, IL-6 and TNF-a [109,110]. These metabolic abnormalities have a direct impact on other biochemical risk markers of MetS, and more specifically HDL, TG and FG, which consequently stimulate atherogenesis and mediate insulin resistance [111]. The high content of antioxidants, polyphenols and fiber found in MD have been previously associated with decreased systemic inflammation and central obesity, which could explain its beneficial effect [112,113]. Moreover, an enhanced with nuts MD was found to be helpful regarding the maintenance of body weight status [114,115].

A significantly positive correlation was also found between high adherence to MD and HDL cholesterol concentration. Our findings are consistent with previously reported data from randomized controlled trials (RCTs), in which a Mediterranean dietary pattern improved HDL cholesterol concentration and the overall lipid profile [116–118]. Increased intake of olive oil, polyphenols, antioxidants as well as an optimal ratio of MUFA:SFA, through the adherence to MD, seemed to have a synergistic effect on various mechanisms of lipid metabolism by promoting changes on the overall composition of HDL cholesterol particles, increased antioxidant and cholesterol efflux capacity [117,119]. Furthermore, a higher HDL concentration observed in high MD adherers could potentially be a secondary effect closely related to lower mean values of central obesity, as aforementioned, and improved cardiometabolic risk markers.

According to our results, an inverse significant association was observed between TGs concentration and adherence to MD. In a large network meta-analysis performed by Tsartsou et al. [108], the protective effect of MD on the overall lipid profile, including TGs, was also demonstrated. These findings were mainly attributed to the high content of olive oil polyphenols and oleic acid as part of the MD [108]. Another meta-analysis of RCTs, investigating the effect of plant oils on blood lipids, had also reported a decrease in TG concentration from the use of diets rich in olive oil [120]. Notwithstanding, it was demonstrated that oils rich in omega-3-fatty acids (n-3 FAs) caused a greater decrease in TGs than olive oil [120]. The metabolic mechanisms responsible for these changes are related to the types of fatty acids, i.e., MUFAS and n-3 FAs, which have the ability to suppress postprandial TGs, enhance TG clearance, decrease the activity of TG lipase and the overall TG synthesis [121–123].

Taking the above into consideration, where the mean values of WC, HDL cholesterol and serum TG concentration were significantly closer to normal in the high adherence to MD groups compared to the low adherence group, we conclude that the level of adherence to MD could play an important role to ameliorate the obesity level and the impaired lipid profile, in combination or not with appropriate pharmacological treatment.

With respect to FBG, an inverse correlation was demonstrated between MD levels of adherence and FBG, which, however, was not statistically significant. A possible explanation for that could be the high number of individuals diagnosed with diabetes or at diabetic risk who participated in the studies [49,61,65,68–71,74,81,92], along with other confounding factors (e.g., age, BMI, medication, etc.). However, the fact that mean values of FBG in both high and low adherers were within the normal range led us to the conclusion that MD adherence can have a positive impact on glycemic control regardless of the level of adherence. Sufficient evidence exists supporting the positive effect of adherence to MD so as to improve glycemic control and decrease the overall risk of T2DM [124]. A systematic review of 17 studies assessing the effect of MD on the incidence of T2DM revealed that high adherence to MD was significantly correlated with improved FBG concentration and HbA1c in diabetic patients [125]. Additionally, both RCTs and prospective cohort studies have also confirmed the benefits of MD on glycemic control over other diets among different subgroups of the population, including healthy individuals, individuals with high CVD/T2DM risk or diabetic patients [65,126,127]. These outcomes have been closely related to the composition of MD, which is rich in anti-inflammatory compounds, as well as to its enhanced activity of glucagon-like peptide (GLP-1) hormone and to changes in gut microbiome caused by MD [48]. Notwithstanding, a meta-analysis by Ajala et al. on 20 RCTs demonstrated that not only MD but also low-carbohydrate, low-glycemic-index and high protein diets could enhance the cardiometabolic profile [128].

Regarding SBP and adherence to MD level, we have also found an inverse but non-statistically significant association. Hypertension is considered a major risk factor for endothelial dysfunction and the development of CVDs [129]. It has been previously demonstrated that prolonged adherence to MD can decrease both SBP and DBP [130].

According to our included studies, in a vast majority, the mean SBP was <130 mmHg in both low and high adherence to MD groups. Consequently, we can conclude that even a poor adherence to MD can positively influence SBP. This conclusion is in accordance with existing data from previously published studies that have reported a significant inverse correlation between adherence of MD and BP [131,132]. Moreover, two recent meta-analyses showed that MD could significantly reduce BP when compared to control diets [133,134]. In addition, a greater decrease in BP was recorded for subjects presented with higher BP at baseline and in studies with a longer duration of the intervention [133]. Various nutrients included in MD exerted beneficial effects through improved vasodilation and endothelial function such as nitric oxides, flavonoids and minerals [135].

The benefits of MD adherence are not limited to the five parameters of MetS [136]. MiRNAs were found to be better regulated in obese patients following an MD [137]. Recent studies have shown that an MD reduces serum inflammatory markers as well as the incidence of stroke, CVD and breast cancer [138,139]. Moreover, MD was recommended as a diet that can help women with menopause-related symptoms and needs [140].

Our study can be characterized by several strengths. According to our knowledge, this is the first systematic review and meta-analysis that aimed to examine the impact of the level of adherence to an MD on the parameters of MetS. Moreover, the great number of the studies included and the subjects examined (n = 74,058), whose origin covered a significant part of the world, made our results quite representative. Furthermore, publication biases were not detected in our study, except from the studies included for the TG parameter in which the p-value of Egger's test was not rounded up 0.04598. In addition, the fact that we have included studies that used validated MD adherence scores in order to assess the level of adherence to MD increased the accuracy of our conclusions. The limitations of our study mainly concerned the heterogeneity in the included studies. High heterogeneity was detected for all parameters of MetS, which was potentially due to the different types of population (i.e., ethnicity) and health status (i.e., healthy, obese/overweight and diagnosed conditions) across all included studies, as well as to the difference between sample sizes and the use of a variety of MDS. The presence of high heterogeneity in population samples and the fact that subjects under pharmacological treatment were not excluded do not allow for inference of our results regarding the role of MD. Over and above, the variety of MDSs used to assess adherence among studies introduces biases due to the different ways of classification and quantification of food components. Furthermore, levels of adherence to MD may be perceived differently, depending on the geographical location and, thus, produce additional bias. For example, high adherers living in Mediterranean regions might have a greater intake of specific foods when compared to high adherers residing in non-Mediterranean regions. Moreover, the conversion of data whenever necessary for unification of the quantitative analysis adds to our study's limitations. Moreover, we have included studies published in English and Spanish; therefore, studies published in a different language were not a part of this study.

5. Conclusions

High adherence to MD can have a positive impact on all parameters of MetS. In addition, there is sufficient evidence suggesting that long-term consumption of MD can protect from obesity and improve cardiometabolic risk markers, including the markers used for the diagnosis of MetS. Although high heterogeneity was identified across the included studies, our results support previous findings and point to the potential biases that may derive from the use of MDSs. Furthermore, it remains still unclear whether MD exerts the same beneficial effect on both unhealthy and healthy populations; therefore, further research is needed in this field.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/nu13051514/s1, Supplementary File S1: MOOSE checklist, Supplementary File S2: Search Strategy, Supplementary File S3: Quality of Studies according to the New Castle Ottawa Scale, Supplementary Figure S1a–e: Funnel plots of studies included in our meta-analysis regarding each parameter of MetS, Supplementary Figure S2: Subgroup analysis based on the quality of studies regarding WC, Supplementary Figure S3: Subgroup analysis based on the quality of studies regarding HDL cholesterol, Supplementary Figure S4: Subgroup analysis based on the quality of studies regarding serum TG, Supplementary Figure S5: Subgroup analysis based on the quality of studies regarding FBG Supplementary Figure S6: Subgroup analysis based on the quality of studies regarding SBP.

Author Contributions: Conceptualization: L.C., D.R.B., E.K. and M.C.; methodology: X.T.; software: X.T.; validation: L.C., D.R.B. and E.K.; formal analysis: X.T.; investigation: L.C., D.R.B. and E.K.; data curation: L.C., D.R.B. and E.K.; writing—original draft preparation: L.C., D.R.B. and E.K.; writing—review and editing: L.C., D.R.B., E.K., X.T. and M.C.; visualization: X.T.; supervision, M.C.; project administration, M.C.; All authors have read and agreed to the published version of the manuscript.

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Abbreviations

BP	Blood Pressure
CI	Confidence Interval
CVD	Cardiovascular Disease
DBP	Diastolic Blood Pressure
FFQs	Food Frequency Questionnaires
FG	Fasting Glucose
GLP-1	Glucagon-Like Peptide-1
HbA1c	Glycohemoglobin
HDL	High-Density Lipoprotein
IDF	International Diabetes Federation
MD	Mediterranean Diet
MDS	Mediterranean Diet Score
MEDAS	Mediterranean Diet Adherence Screener
MetS	Metabolic Syndrome
MSDPS	Mediterranean-Style Dietary Pattern Score
MOOSE	Meta-analyses Of Observational Studies in Epidemiology
N-3 FAs	Omga-3-Fatty Acids
NAFLD	Non-Alcoholic Fatty Liver Disease
NCDs	Non-Communicable Diseases
NCEP ATP III	National Cholesterol Program in Adult Treatment Panel III
NHNES	National Health and Nutrition Examination Survey
NOS	New Castle Ottawa Scale
OR	Odds Ration
RCT	Randomized Controlled Trial
SD	Standard Deviation
SBP	Systolic Blood Pressure
SMD	Standardized Mean Difference
T2DM	Type 2 Diabetes Mellitus
TG	Triglycerides
UK	United Kingdom
US	United States
WC	Waist Circumference
WHO	World Health Organization

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