Research Article Open Access

The frequency of consumption of selective foods with functionality is related to improved anthropometric obesity indices: A cross-sectional study in Greek and Cypriots adults

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Submission Date: December 22nd, 2023; **Acceptance Date:** April 8th, 2024; **Publication Date:** April 11, 2024

Please cite this article as: Papagianni O., Bountziouka V., Maniati E., Pegkos A., Dimou C., Karantonis H. C., Koutelidakis A. E. The frequency of consumption of selective functional foods with functionality is related to improved anthropometric obesity indices: A cross-sectional study in Greek and Cypriots adults. *Functional Food Science* 2024; 4(4): 134-152. DOI: https://doi.org/10.31989/ffs.v4i4.1274

ABSTRACT

Background: Obesity persists as a significant public health concern. Recent novel strategies advocate for the incorporation of specific foods to better manage adiposity markers and prevent obesity. Numerous epidemiological and clinical studies highlight the potential benefits of including natural functional foods from the Mediterranean Diet, as well as processed foods enhanced with bioactive compounds.

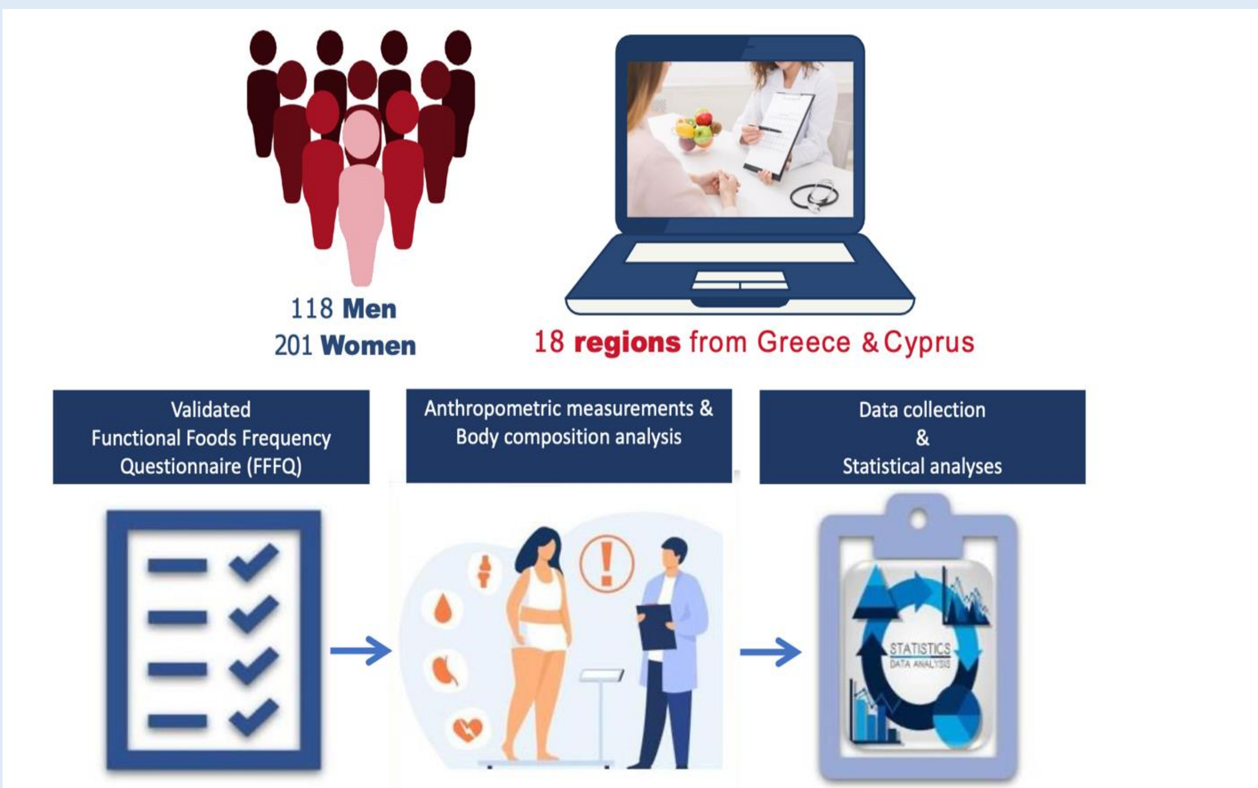
Methods: A validated Functional Food Frequency of Consumption (FFFQ) was administered in 319 Greeks and Cypriots volunteers, aged 18-75. Anthropometric and body composition measures were recorded through established protocols. Linear regression models were used to examine the association between frequency intake of foods and adiposity markers.

Objective: This study was designed to investigate the potential relationship between the frequency of selective foods and obesity markers, among Greek and Cypriot adults.

Results: In this study, 33 natural (i.e., fruits, vegetables, pulses, starchy food items, herbs and spices, beverages, other) and processed (i.e., starchy food items, dairy, fats and oils) functional foods were considered. Most of the foods are consumed weekly/ monthly, whilst participants report daily consumption of olive oil (57%) and coffee (61%). Monthly intake of whole wheat cereals, herbs (thyme/ oregano/ basil), and nuts were associated with greater BMI, at the Bonferroni correction level (p=0.0004). However, results from multiple regression models adjusted for sex, age group, educational level, smoking status, physical activity status, and water intake revealed that only monthly nut intake, compared to daily intake, was associated with greater BMI (2.9 (1.5; 4.4) kg/m2).

Conclusion: The results suggest that the infrequent intake of nuts on Greek and Cypriot participants, is a strong determinant of BMI, and the rare consumption of whole wheat cereals and herbs (thyme/oregano/basil) may weakly affect BMI. Further research is required to safely conclude to these claims, and the implementation of nutritional education programs on functional foods may prove effective in the prevention and management of obesity.

Keywords: Epidemiological study; foods; frequency of consumption; obesity; adiposity markers



BACKGROUND

The obesity pandemic, representing the most critical public health concern of the millennium, underscores a worldwide health threat due to its rapid prevalence and association with chronic diseases such as cardiovascular disease, type 2 diabetes (T2D), and specific cancer types [1, 2]. According to WHO reports in 2022, the prevalence of obesity has increased almost 3-fold worldwide, while 60% of Europeans are either overweight (body mass index (BMI): 25-29.9 kg/m^2) or obese (BMI >30 kg/m^2) [3]. The most recent figures, concerning obesity rates in Greece are discouraging. The Feel4Diabetes study analysis by Siopis et al. (2023) revealed that, among six European countries, Greece has the higher prevalence of family obesity (9.2%) with Hungary being the second highest (8.6%) [2].

According to the World Health Organization (WHO), obesity is "an abnormal or excessive accumulation of fat that can harm health" [4]. The chronic maintenance of a positive energy balance has emerged as the main cause of obesity, as it leads to an excessive body fat accumulation, reflected in an increased BMI [5]. Additionally, the existing epidemiological data indicates that weight gain may result from a combination of an imbalance between energy intake, energy expenditure, and a low level of physical activity [6]. It is noteworthy that, despite the important influence well-known determinants of obesity (i.e., sociodemographic environment, genetic, psychological, and other pathophysiological conditions), modern dietary and lifestyle patterns are also suggested as key factors of obesity [7].

Among dietary patterns, the Mediterranean diet has been highlighted as the most effective, both for the prevention and treatment of obesity [9, 10]. Modern strategies for weight control and obesity prevention, suggest novel nutritional interventions with natural foods with functionality, contained in the Mediterranean diet [5, 6, 8]. Specifically, the frequent consumption of certain natural, functional Mediterranean foods, such as fruits and vegetables, legumes, wild greens, wine, olives, and olive oil, as well as certain herbs and spices (e.g. turmeric, ginger, cinnamon, rosemary, mountain tea etc.) has been associated with health promotion and disease prevention parameters [10]. Furthermore, due to their bioactive constituents, these foods often play a role in regulating hormones implicated in obesity, such as leptin and resistin, potentially aiding in the enhancement of anthropometric indicators like BMI and waist circumference, as well as other markers of obesity. [5, 12].

Research interest around foods with functionality has grown. Given the increased consumer appeal, the most modern strategies for the holistic obesity prevention have highlighted the development of innovative foods with functional role [13]. Numerous processed functional foods like probiotic dietary products and enhanced spreads have gained prominence in the market, with an increasing trend of inclusion in consumer diets due to their perceived health benefits [14].

For the optimal evaluation of obesity in the population, it has been reported that the measurement of body weight and height, waist and hip circumference and the derivation of BMI, the waist-to-hip circumference (WHC) and the waist-to-height ratio (WHtR), are important markers for the diagnosis and prevention of the disease [4]. In an era where medicine demands precision, the newest recommendations command that, when monitoring obesity, and for an optimal understanding of its pathophysiology, a holistic examination of body composition phenotypes is necessary. Under this novel approach, during the body composition analysis, except of body fat distribution, the Fat Free Mass (FFM)/muscle mass should be determined [15].

To the best of our knowledge, no previous study has assessed the possible association of the frequency of consumption of foods which present functionality with anthropometric and body composition indices of obesity. Accordingly, this study aims to investigate the potential correlation between the consumption frequency of selective natural-traditional and marketed foods with functionality and markers of obesity among adults in Greece and Cyprus.

METHODS

This cross-sectional study was conducted between July 2020 and July 2023, in several urban and semi-urban areas of Greece and Cyprus, while research basis was established in Lemnos, Greece. Participants completed the questionnaires with the aid of trained field investigators. Participants were informed about the aims of the study and consented to participate in the study. All procedures were performed in accordance with the Declaration of Helsinki.

Study participants: Individuals aged 18 to 60 years, living in Greece or Cyprus for at least one year prior to the study, were voluntarily called to participate in the study. Residents of Lemnos visited the Human Nutrition Unit (HNU, Nutrition & Public Health Lab, University of the Aegean) whilst branches of the HNU were set up in other regions for participants to visit. The visits were performed via personal appointments. After eligibility screening, participants were informed about the aims of the study, data confidentiality, and their voluntarily contribution, as well as providing their written consent.

Assessments: Participants were interviewed privately by personal appointments. The collected data included sociodemographic characteristics, lifestyle, and dietary habits, as well as anthropometric and body composition parameters.

Sociodemographic and lifestyle covariates: Participants' sex (male/ female), educational level (classified as compulsory, higher and post-graduate education), and age group (classified as 18-34- and 35–60-year-old). Participants were asked to self-report whether they engage with low/very low, moderate or high physical activity, according to World Health Organization guidelines [15], and whether they are current or no smokers (i.e. non-smoker or previous-smoker) [17]. Water intake was measured in glasses/ day and classified as 1-6 or 7+ glasses/day.

Frequency of consumption of foods with functionality: Participants were asked whether they were aware of including foods-good candidates for functional foods in their diet. Food frequency consumption was recorded using a 76-item validated FFFQ [18], containing natural and processed foods with functionality and the main categories of foods with no-functionality (e.g., meat, eggs etc.). The FFFQ was administrated by qualified interviewers from the research team. Participants were asked to report the frequency of food intake from a list of 10 potential answers, ranging from never to 6 or more times per day [19]. Potential answers were then grouped to daily (>6 times/day, 4-5 times/day, 2-3 times/day and 1 time/day), weekly (5-6 times/week, 3-4 times/week and 1 time/week) and monthly (2-3 times/month, once/month and never) intake.

Anthropometrics and body composition: Anthropometric measurements and body composition were performed by trained field investigators, following established protocols and procedures [20, 21]. All participants were initially instructed to follow overnight fasting before the examination, and to wear light-weight clothing. Each participant's height and weight were measured barefoot in a standing position, using a stadiometer (Kern MPE 200K-1HEM, Kern & Sohn GmbH, Germany) and BMI (body weight/ height^2, kg/m^2) was calculated [21]. Waist and hip circumferences were measured using an ergonomic circumference measuring tape (Seca 201, Seca GmbH & Co, Germany), according to World Health Organization (WHO) guidelines [20]. Waist-to-hip ratio (WHR), representing fat distribution, was then calculated. Body composition, including body weight and total body fat, was measured *via* bioimpedance, using calibrated, portable body composition analyzers (Tanita SC330 & Tanita BC543, Tanita Corporation, Japan). [21]

Statistical analysis: Categorical data (i.e., sex, age group, educational level, physical activity level, smoking, water intake, frequency of food intake) are shown as frequencies (%), whilst continuous data (i.e., body weight, body mass index, body fat percentage, waist-to-hip ratio) are shown as mean and SD (standard deviation, SD). Normality was tested using the Kolmogorov-Smirnov normality test. Differences (95% confidence interval, CI) in the population proportion estimates for categorical data and the mean values for continuous data between participants who were aware of including functional food in their diets and those who were not aware, were calculated with the asymptotically normally distributed test statistic for proportions and the t-statistic, respectively. One-way ANOVA, with the Bonferroni correction post-hoc test, was used to assess variation in adiposity measurements across the frequency levels of functional food intake. Multiple linear regression models were used to assess whether functional food intake was independently associated with adiposity markers in models additionally adjusted for sex, age, educational level, smoking status, physical activity status, and water intake. Results are shown as coefficient (95% CI). All tests were two-sided, and the statistical level was set at 0.05. The Bonferroni corrected significance level to account for the 132 regression models tested (i.e. 4 outcomes and 33 predictors of interest) was set at 0.0004. Statistical analyses were performed using SPSS software (V.29.0 for Windows, SPSS Inc., Chicago, IL, USA).

RESULTS

Participants: Three hundred forty-eight participants were initially recruited to this epidemiological study. Of them 29 did not provide anthropometric and body composition data because of COVID-19 quarantine restrictions, and therefore were excluded from the analysis. Consequently, complete data exist for 319 volunteers (39% males), of which 84% (n=268) report awareness of inclusion of foods with functionality in their diet. The distribution of socio-demographic and adiposity measures for the overall population and according to awareness levels of including or not foods with functionality in diet, are presented in Table 1. More women, with post-graduate qualifications, non-smokers and participants with high water intake are aware of having foods-good candidates for functional foods in their diet, compared to participants who are not aware, whilst no differences were observed regarding the adiposity markers (Table 1).

Table 1. Distribution of socio-demographic and anthropometric characteristics overall and by awareness of foods with functionality intake

	Overall	Awareness of intake of foods with functionality		Difference (Yes-No)
	(n=319)	Yes (n=268)	No (n=51)	(95% confidence interval)
Male sex, n (%)	125 (39.2)	100 (37.3)	25 (49.0)	-12% (-32%; 8.7%)
Age group, n (%)				
18-34	307 (96.2)	258 (96.3)	49 (96.1)	0.2% (-7.7%; 8.1%)
35-60	12 (3.8)	10 (3.7)	2 (3.9)	-
Education level, n (%)				
Compulsory	3 (0.9)	2 (0.7)	1 (2.0)	-1.3% (-6.9%; 4.3%)
Higher	297 (93.1)	248 (92.5)	49 (96.0)	-3.5% (-12%; 4.8%)
Post-graduate	19 (6.0)	18 (6.8)	1 (2.0)	4.8% (-1.5%; 11%)
Physical activity level, n (%)				
Low	71 (22.3)	59 (22.0)	12 (23.5)	-1.5% (-19%; 16%)
Moderate	195 (61.1)	164 (61.2)	31 (60.8)	0.3% (-20%; 20%)
High	53 (16.6)	45 (16.8)	8 (15.7)	1.1% (-14%; 16%)
Smoking, n (%)				
Yes	102 (32)	79 (29.5)	23 (45.1)	-
No	217 (68)	189 (70.5)	28 (54.9)	16% (-4.7%; 36%)
Water intake, n (%)				
1-6 glasses/day	277 (87.1)	229 (85.8)	48 (94.1)	-
7+ glasses/day	41 (12.9)	38 (14.2)	3 (5.9)	8.3% (-1.8%; 18%)
Body weight, kg	69.2 (16.4)	69.0 (16.7)	70.5 (15.1)	-1.5 (-6.4; 3.4)
Body Mass Index, kg/m^2	24.1 (4.8)	24.0 (4.9)	24.5 (4.3)	-0.50 (-1.9; 0.95)
Body fat percentage, %	22.2 (8.3)	22.0 (8.4)	22.9 (7.6)	-0.90 (-3.4; 1.6)
Waist-to-hip ratio	0.80 (0.34)	0.81 (0.37)	0.79 (0.10)	0.02 (-0.03; 0.07)

Data are shown as mean (SD), unless otherwise indicated

Frequency of consumption of foods with functionality: The distribution of frequency intake of natural and processed foods-good candidates for functional foods is shown in Table 2. The results suggest that yellow/orange fruits and citrus fruits are mostly consumed in a weekly basis (40% and 52%, respectively), whilst berries and pomegranates are consumed monthly (over 70%). About half of the participants consume yellow/orange and red vegetables on a weekly basis. Lentils are consumed weekly in just over half of the sample (52%), whilst the rest of the pulses (i.e., beans, chickpeas, green beans, split peas, as well as soy and its products) are most frequently consumed monthly. About 2/3 of the participants reported weekly to daily intake of whole wheat cereals, whilst the relevant proportion for whole wheat pasta was 4/10. Thyme/oregano/basil were the most frequently used herbs (78% weekly to daily use) followed by cinnamon (52%), whilst turmeric was mostly used monthly. About 8/10 self-reported coffee intake at least weekly, whilst tea and cocoa beverages are mostly consumed monthly (55% and 64%, respectively). About 6/10 self-reported at least weekly intake of nuts and honey, with an equivalent proportion self-reported monthly intake of olives. Processed starchy (e.g. enhanced cereals, gluten free bakeries, etc) and dairy (e.g. probiotics) functional foods and vegan/ enhanced spreads were mostly consumed monthly, whilst most (95%) of the participants self-reported at least weekly intake of olive oil. (Table 2)

Table 2. Distribution of frequency intake of natural and processed food items-good candidates for functional foods.

	Frequency of intake		
	Daily	Weekly	Monthly
Natural Foods with Functionality, n (%)			
Fruits			
Yellow/orange fruits	83 (26)	129 (40)	107 (34)
Citrus fruits	86 (27)	167 (52)	66 (21)
Red fruits	48 (1.9)	127 (5.0)	144 (5.6)
Berries	24 (7.6)	55 (17)	238 (75)
Pomegranates	18 (5.7)	52 (16)	248 (78)
Vegetables			
Yellow/orange vegetables	62 (20)	148 (47)	106 (34)
Red vegetables	64 (20)	155 (49)	100 (31)
Pulses			
Lentils	22 (6.9)	166 (52)	131 (41)
Beans	19 (6.0)	128 (40)	172 (54)
Chickpeas	17 (5.4)	87 (27)	213 (67)
Green beans	19 (6.0)	114 (36)	184 (58)
Split peas	16 (5.0)	42 (13)	260 (82)
Soya and its products	15 (4.7)	37 (12)	266 (84)
Starchy food items			
Whole wheat pasta	28 (8.8)	99 (31)	192 (60)
Whole wheat cereals	84 (26)	130 (41)	105 (33)
Herbs & spices			
Thyme/Oregano/Basil	82 (26)	165 (52)	71 (22)
Turmeric	28 (8.8)	77 (24)	213 (67)
Cinnamon	48 (15)	119 (37)	151 (48)
Beverages			
Tea	36 (11)	108 (34)	175 (55)
Coffee	194 (61)	68 (21)	57 (18)
Cocoa	22 (6.9)	94 (30)	203 (64)
Other			
Nuts	65 (20)	129 (40)	125 (39)
Olives	34 (11)	98 (31)	187 (59)
Honey	53 (20)	118 (44)	95 (36)
Processed Foods with Functionality, n (%)			
Starchy food items			
Enhanced cereals	29 (9.1)	48 (15.1)	241 (76)
Gluten-free pasta	12 (3.8)	33 (10)	273 (86)
Gluten-free bakeries	10 (3.1)	31 (9.7)	278 (87)
Enhanced bakeries	11 (3.4)	40 (13)	268 (84)
Dairy			
Probiotic/with probiotics dairies	29 (9.1)	57 (18)	233 (73)
Enhanced dairies	22 (6.9)	63 (20)	234 (73)
Fats and oils			
Olive oil	182 (57)	121 (38)	16 (5.0)
Vegan spreads	32 (10)	101 (32)	185 (58)
Enhanced spreads	13 (4.1)	40 (13)	266 (83)

Association between frequency of consumption of selective foods with functionality and obesity indices: The distribution of participants' body weight, BMI, body fat percentage, and WHR across the frequency of consumption levels of foods with functionality, is shown in Table 3. Daily intake of tea, coffee, and olives was associated with greater WHR, body weight, and BMI, whilst weekly intake of pomegranates, split peas, soya and its products, enhanced cereals, gluten-free pasta, gluten-free bakeries, enhanced bakeries, enhanced spreads was associated with greater WHR. Monthly intake of yellow/ orange fruits, whole wheat cereals, herbs, nuts, honey, enhanced cereals and bakeries, olive oil, vegan and enhanced spreads was associated with greater adiposity measures. However, only the association of monthly intake of whole wheat cereals, herbs (thyme/ oregano/ basil), and nuts with greater BMI retained statistical significance at the Bonferroni correction level (Table 3). Particularly, monthly consumers of whole wheat cereals and thyme/oregano/basil presented 2.4-2.8 kg/m^2 greater BMI than weekly and daily consumers. Furthermore, participants who stated to monthly consume nuts had 3 kg/m^2 higher BMI than participants with daily intake reports.

Table 3. Distribution (mean (SD)) of obesity indices according to frequency intake of food groups with functionality.

	Frequency of intake			P-value
	Daily	Weekly	Monthly	
Natural Foods with Functionality				
Pomegranates				
Body weight, kg	67.7 (15.4)	67.8 (16.9)	69.7 (16.4)	0.69
Body mass index, kg/m^2	24.6 (3.7)	23.5 (4.4)	24.2 (4.9)	0.56
Body fat percentage, %	23.2 (8.3)	20.8 (7.3)	22.3 (8.5)	0.41
Waist-to-hip ratio	0.85 (0.13)	0.91 (0.82)	0.78 (0.09)	**0.04**
Split peas				
Body weight, kg	69.5 (18.6)	73.6 (19.5)	68.6 (15.7)	0.18
Body mass index, kg/m^2	23.9 (4.6)	25.2 (5.8)	24.0 (4.6)	0.27
Body fat percentage, %	21.0 (7.3)	22.7 (10.1)	22.2 (8.0)	0.80
Waist-to-hip ratio	0.88 (0.17)	0.96 (0.91)	0.78 (0.09)	**0.004***
Soya and its products				
Body weight, kg	68.9 (15.7)	69.6 (20.8)	69.2 (15.9)	0.98
Body mass index, kg/m^2	23.9 (4.0)	24.0 (6.1)	24.1 (4.7)	0.96
Body fat percentage, %	21.3 (6.9)	23.0 (9.8)	22.1 (8.2)	0.74
Waist-to-hip ratio	0.82 (0.15)	0.95 (0.97)	0.79 (0.09)	**0.02***
Whole wheat cereals				
Body weight, kg	66.8 (13.7)	66.8 (17.5)	74.2 (16.1)	**0.001***
Body mass index, kg/m^2	23.2 (3.9)	23.4 (4.7)	25.8 (5.1)	**<0.001***
Body fat percentage, %	22.0 (7.4)	21.1 (7.8)	23.5 (9.4)	0.09

	Frequency of intake			P-value
	Daily	Weekly	Monthly	
Waist-to-hip ratio	0.78 (0.11)	0.83 (0.52)	0.81 (0.09)	0.62
Thyme/Oregano/Basil				
Body weight, kg	67.7 (14.0)	67.5 (15.6)	75.1 (19.7)	**0.003***
Body mass index, kg/m^2	23.8 (4.7)	23.4 (4.1)	26.2 (5.9)	**<0.001***
Body fat percentage, %	21.5 (8.4)	21.2 (7.4)	25.3 (9.5)	**0.001***
Waist-to-hip ratio	0.79 (0.11)	0.82 (0.47)	0.80 (0.09)	0.73
Tea				
Body weight, kg	69.8 (15.8)	69.9 (17.9)	64.4 (14.4)	0.17
Body mass index, kg/m^2	23.7 (4.3)	24.2 (5.3)	24.1 (4.6)	0.82
Body fat percentage, %	23.8 (8.4)	22.6 (8.2)	21.5 (8.3)	0.22
Waist-to-hip ratio	0.95 (0.99)	0.79 (0.10)	0.79 (0.09)	**0.03***
Coffee				
Body weight, kg	71.4 (15.7)	67.1 (16.9)	64.3 (17.1)	**0.007***
Body mass index, kg/m^2	24.8 (4.7)	23.2 (4.7)	22.8 (4.9)	**0.005***
Body fat percentage, %	22.8 (8.2)	21.3 (8.7)	20.9 (7.9)	0.19
Waist-to-hip ratio	0.80 (0.10)	0.86 (0.72)	0.75 (0.07)	0.19
Nuts				
Body weight, kg	63.7 (10.9)	70.6 (17.3)	70.7 (17.4)	**0.009***
Body mass index, kg/m^2	22.1 (3.2)	24.1 (4.6)	25.1 (5.3)	**<0.001***
Body fat percentage, %	20.9 (6.7)	21.0 (7.7)	24.0 (9.2)	**0.005***
Waist-to-hip ratio	0.78 (0.11)	0.85 (0.52)	0.78 (0.09)	0.27
Olives				
Body weight, kg	66.4 (13.5)	70.4 (17.6)	69.1 (16.3)	0.48
Body mass index, kg/m^2	23.2 (4.4)	24.2 (5.0)	24.2 (4.7)	0.49
Body fat percentage, %	20.7 (7.7)	20.9 (7.6)	23.0 (8.6)	0.07
Waist-to-hip ratio	0.98 (1.02)	0.80 (0.10)	0.78 (0.09)	**0.009***
Honey				
Body weight, kg	68.6 (15.6)	67.6 (16.8)	72.0 (16.3)	0.10
Body mass index, kg/m^2	23.7 (4.5)	23.5 (4.7)	25.2 (4.8)	**0.01***
Body fat percentage, %	20.7 (7.0)	21.5 (7.7)	23.9 (9.4)	**0.02***
Waist-to-hip ratio	0.79 (0.11)	0.83 (0.50)	0.79 (0.09)	0.67
Processed Foods with Functionality				
Enhanced cereals				
Body weight, kg	69.9 (16.1)	67.2 (16.5)	69.5 (16.5)	0.66
Body mass index, kg/m^2	24.2 (5.0)	22.6 (3.9)	24.4 (4.9)	0.06

	Frequency of intake			P-value
	Daily	Weekly	Monthly	
Body fat percentage, %	23.0 (9.0)	19.0 (6.0)	24.4 (4.9)	**0.02***
Waist-to-hip ratio	0.82 (0.14)	0.93 (0.86)	0.78 (0.09)	**0.02***
Gluten-free pasta				
Body weight, kg	70.2 (18.9)	69.2 (18.8)	69.1 (16.0)	0.97
Body mass index, kg/m²	24.2 (4.8)	23.4 (4.9)	24.2 (4.8)	0.68
Body fat percentage, %	21.5 (7.6)	21.7 (8.4)	22.2 (8.3)	0.90
Waist-to-hip ratio	0.85 (0.16)	0.97 (1.03)	0.79 (0.09)	**0.01***
Gluten-free bakeries				
Body weight, kg	70.2 (18.9)	69.2 (18.8)	69.1 (16.0)	0.97
Body mass index, kg/m²	24.2 (4.8)	23.4 (4.9)	24.2 (4.8)	0.68
Body fat percentage, %	21.5 (7.6)	21.7 (8.4)	22.2 (8.3)	0.89
Waist-to-hip ratio	0.85 (0.17)	0.98 (1.03)	0.79 (0.10)	**0.01***
Enhanced bakeries				
Body weight, kg	72.2 (18.5)	68.5 (17.8)	69.2 (16.2)	0.80
Body mass index, kg/m²	24.8 (4.6)	23.2 (4.3)	24.2 (4.9)	0.39
Body fat percentage, %	21.9 (7.8)	19.1 (7.1)	22.6 (8.4)	**0.04***
Waist-to-hip ratio	0.86 (0.17)	0.97 (0.93)	0.78 (0.09)	**0.004***
Olive oil				
Body weight, kg	67.1 (13.7)	71.8 (19.3)	73.7 (19.2)	**0.03***
Body mass index, kg/m²	23.7 (4.5)	24.5 (4.7)	26.3 (7.4)	0.06
Body fat percentage, %	21.7 (8.2)	22.3 (7.6)	25.1 (13.0)	0.27
Waist-to-hip ratio	0.78 (0.01)	0.85 (0.54)	0.80 (0.08)	0.23
Vegan spreads				
Body weight, kg	69.5 (13.4)	66.7 (16.6)	70.3 (16.4)	0.20
Body mass index, kg/m²	23.1 (3.8)	23.3 (4.5)	24.7 (5.0)	**0.03***
Body fat percentage, %	20.8 (7.0)	20.8 (7.4)	23.1 (8.8)	0.05
Waist-to-hip ratio	0.80 (0.12)	0.85 (0.60)	0.78 (0.09)	0.25
Enhanced spreads				
Body weight, kg	69.6 (16.1)	67.8 (18.4)	69.4 (16.2)	0.85
Body mass index, kg/m²	23.8 (4.2)	23.0 (4.6)	24.3 (4.8)	0.27
Body fat percentage, %	20.6 (7.4)	19.1 (7.4)	22.7 (8.4)	**0.03***
Waist-to-hip ratio	0.84 (0.17)	0.97 (0.94)	0.78 (0.09)	**0.005***

After adjusting for socio-demographic, lifestyle, and general habits (physical activity, smoking etc.) covariates in multiple linear regression models, only the association between nuts and BMI was retained at Bonferroni correction level, with point estimates for BMI being 2.9 (1.5; 4.4) kg/m² more for the monthly vs the daily intake of nuts (Table 4).

	Body weight, kg			Body mass index, kg/m2			Body fat percentage, %			Waist-to-hip ratio		
	b-coefficient	95% CI	P-value	b-coefficient	95% CI	P-value	b-coefficient	95% CI	P-value	b-coefficient	95% CI	P-value
Natural Foods with Functionality												
Yellow/orange fruits												
Weekly vs daily	3.0	(-1.4; 7.4)	0.18	0.5	('-0.8; 1.8)	0.47	0.8	(-1.3; 3.1)	0.43	0.03	(-0.07; 0.12)	0.59
Monthly vs daily	5.0	(0.4; 9.5)	0.03	1.0	(-0.30; 2.4)	0.12	2.0	(-0.20; 4.3)	0.08	-0.13	(-0.11; 0.09)	0.79
Citrus fruits												
Weekly vs daily	1.6	(-2.5; 5.7)	0.44	-0.20	(-1.4; 1.0)	0.74	-0.6	(-2.7; 1.5)	0.57	0.03	(-0.06; 0.12)	0.49
Monthly vs daily	5.2	(0.13; 10.3)	0.04	1.0	(-0.54; 2.5)	0.20	0.9	(-1.7; 3.5)	0.50	-0.01	(-0.12; 0.10)	0.86
Red fruits												
Weekly vs daily	0.88	(-4.4; 6.2)	0.74	0.10	(-1.5; 1.7)	0.89	1.0	(-1.6; 3.7)	0.43	0.04	(-0.07; 0.15)	0.48
Monthly vs daily	2.2	(-3.1; 7.5)	0.41	0.19	(-1.4; 1.8)	0.82	0.65	(-2.0; 3.3)	0.63	0.005	(-0.11; 0.12)	0.93
Berries												
Weekly vs daily	-0.74	(-8.4; 6.9)	0.85	-0.10	(-2.3; 2.3)	0.99	0.42	(-3.4; 4.3)	0.83	0.08	(-0.81; 0.24	0.31
Monthly vs daily	-0.45	(-7.1; 6.2)	0.89	0.30	(-1.7; 2.3)	0.77	0.32	(-3.0; 3.7)	0.85	-0.15	(-0.16; 0.13)	0.83
Pomegranates												
Weekly vs daily	-1.2	(-9.8; 7.5)	0.79	-1.2	(-3.8; 1.4)	0.37	-1.0	(5.4; 3.3)	0.63	0.07	(-0.11; 0.25)	0.44
Monthly vs daily	0.10	(-7.6; 7.8)	0.97	-0.57	(-2.9; 1.8)	0.63	0.23	(-3.6; 4.1)	0.90	-0.05	(-0.21; 0.12)	0.57
Yellow/orange vegetables												
Weekly vs daily	-2.2	(-6.9; 2.5)	0.36	-0.50	(-1.9; 0.9)	0.49	-1.3	(-3.7; 1.0)	0.27	0.04	(-0.06; 0.14)	0.42
Monthly vs daily	0.78	(-4.2; 5.8)	0.75	0.11	(-1.4; 1.6)	0.88	0.44	(-2.0; 2.9)	0.73	-0.001	(-0.11; 0.10)	0.98
Red vegetables												
Weekly vs daily	-1.3	(-5.9; 3.4)	0.59	-0.34	(-1,7; 1.0)	0.63	-0.94	(-3.3; 1.4)	0.43	0.02	(-0.08; 0.12)	0.69
Monthly vs daily	2.3	(-2.7; 7.3)	0.36	0.79	(-0.73; 2.3)	0.30	0.60	(1.9; 3.1)	0.64	0.03	(-0.08; 0.13)	0.60
Lentils												
Weekly vs daily	-0.14	(-7.2; 6.9)	0.96	-0.51	(-2.7; 1.6)	0.64	-1.2	(-4.8; 2.4)	0.50	0.01	(-0.14; 0.17)	0.85
Monthly vs daily	0.10	(-7.1; 7.3)	0.98	-0.26	(-2.4; 1.9)	0.81	-0.37	(-4.0; 3.3)	0.84	-0.02	(-0.17; 0.13)	0.80
Beans												
Weekly vs daily	-0.04	(-7.7; 7.6)	0.99	-0.24	(-2.6; 2.1)	0.83	-0.43	(-4.3; 3.5)	0.83	0.03	(-0.13; 0.20)	0.70
Monthly vs daily	-3.2	(-10.8; 4.3)	0.40	-1.2	(-3.5; 1.1)	0.31	-0.97	(-4.8; 2.9)	0.62	-0.03	(-0.19; 0.13)	0.71
Chickpeas												
Weekly vs daily	1.5	(-6.8; 9.8)	0.72	0.33	(-2.2; 2.9)	0.80	0.66	(-3.5; 4.9)	0.75	0.04	(-0.14; 0.22)	0.65
Monthly vs daily	-1.1	(-9.0; 6.8)	0.78	-0.50	(-2.9; 1.9)	0.68	-0.08	(-4.1; 3.9)	0.97	-0.03	(-0.20; 0.14)	0.71
Green beans												

Weekly vs daily	-1.5	(-9.2; 6.3)	0.70	-0.72	(-3.1; 1.6)	0.55	-1.3	(-5.2; 2.6)	0.52	0.02	(-0.14; 0.19)	0.79
Monthly vs daily	-2.6	(-10.1; 4.9)	0.50	-0.99	(-3.3; 1.3)	0.40	-1.3	(-5.1; 2.5)	0.50	-0.05	(-0.21; 0.11)	0.55
Split peas												
Weekly vs daily	4.4	(-4.7; 13.6)	0.34	1.6	(-1.1; 4.5)	0.24	2.8	(-1.9; 7.4)	0.24	0.13	(-0.07; 0.32)	0.20
Monthly vs daily	0.05	(-8.0; 8.1)	0.99	0.40	(-2.0; 2.9)	0.74	1.6	(-2.5; 5.7)	0.45	-0.04	(-0.21; 0.14)	0.66
Soya and its products												
Weekly vs daily	0.29	(-9.4; 9.9)	0.95	0.02	(-2.9; 2.9)	0.99	1.5	(-3.4; 6.4)	0.54	0.17	(-0.04; 0.37)	0.11
Monthly vs daily	-0.18	(-8.5; 8.2)	0.97	0.16	(-2.4; 2.7)	0.90	0.80	(-3.4; 5.0)	0.70	0.003	(-0.18; 0.18)	0.97
Whole wheat pasta												
Weekly vs daily	-0.71	(-7.4; 6.0)	0.83	-0.30	(-2.3; 1.7)	0.77	-0.59	(-3.4; 3.3)	0.97	0.03	(-0.12; 0.17)	0.72
Monthly vs daily	0.34	(-5.9; 6.6)	0.91	0.41	(-1.5; 2.3)	0.67	0.46	(-2.7; 3.6)	0.77	-0.01	(-0.15; 0.12)	0.86
Whole wheat cereals												
Weekly vs daily	-1.1	(-5.4; 3.2)	0.62	0.08	(-1.2; 1.3)	0.90	-0.48	(-2.7; 1.7)	0.66	0.04	(-0.05; 0.14)	0.36
Monthly vs daily	5.0	(0.41; 9.6)	0.03	2.2	(0.86; 3.6)	0.002	1.9	(-0.47; 4.2)	0.11	0.02	(-0.09; 0.11)	0.75
Thyme/Oregano/Basil												
Weekly vs daily	-0.55	(-4.7; 3.6)	0.79	-0.50	(-1.7; 0.74)	0.42	-0.50	(-2.6; 1.6)	0.63	0.03	(-0.06; 0.11)	0.55
Monthly vs daily	6.9	(-1.9; 11.8)	0.007	2.2	(0.74; 3.7)	0.003	3.3	(0.75; 5.8)	0.01	0.006	(-0.10; 0.11)	0.91
Turmeric												
Weekly vs daily	-3.2	(-10.1; 3.7)	0.36	-1.9	(-4.0; 0.15)	0.07	-1.3	(-4.8; 2.2)	0.45	0.07	(-0.07; 0.22)	0.33
Monthly vs daily	-1.0	(-7.3; 5.2)	0.75	-1.6	(-3.5; 0.28)	0.09	-1.6	(-4.8; 1.5)	0.31	-0.01	(-0.15; 0.12)	0.85
Cinnamon												
Weekly vs daily	-1.4	(-6.8; 3.9)	0.60	-0.59	(-2.2; 1.0)	0.48	-0.77	(-3.5; 2.0)	0.60	0.05	(-0.07; 0.16)	0.43
Monthly vs daily	-0.56	(-5.7; 4.6)	0.83	-0.50	(-2.1; 1.1)	0.53	-0.28	(-2.9; 2.3)	0.83	-0.03	(-0.14; 0.09)	0.65
Tea												
Weekly vs daily	2.3	(-3.8; 8.5)	0.45	0.33	(-1.5; 2.2)	0.73	0.007	(-3.1; 3.1)	0.99	-0.15	(-0.28; -0.02)	0.02
Monthly vs daily	1.3	(-4.6; 7.3)	0.65	0.04	(-1.7; 1.8)	0.96	-0.93	(-3.9; 2.1)	0.54	-0.15	(-0.28; -0.03)	0.02
Coffee												
Weekly vs daily	-4.3	(-8.6; 0.09)	0.05	-1.6	(-2.9; -0.32)	0.01	-1.2	(-3.5; 0.97)	0.27	0.05	(-0.04; 0.15)	0.28
Monthly vs daily	-5.7	(-10.5; -0.91)	0.02	-2.0	(-3.5; -0.60)	0.006	-2.9	(-5.3; -0.43)	0.02	-0.05	(-0.15; 0.06)	0.35)
Cocoa												
Weekly vs daily	0.90	(-6.6; 8.4)	0.81	0.78	(-1.5; 3.1)	0.50	1.8	(-2.0; 5.6)	0.35	0.10	(-0.06; 0.26)	0.21
Monthly vs daily	1.2	(-5.9; 8.3)	0.75	1.0	(-1.1; 3.2)	0.35	2.1	(-1.5; 5.7)	0.25	0.05	(-0.10; 0.20)	0.53
Nuts												
Weekly vs daily	5.6	(0.92; 10.3)	0.02	1.7	(0.27; 3.1)	0.02	0.33	(-2.0; 2.7)	0.78	0.05	(-0.53; 0.15)	0.33
Monthly vs daily	7.4	(2.6; 12.2)	0.003	2.9	(1.5; 4.4)	**0.0006**	2.9	(0.48; 5.4)	0.02	0.0003	(-0.10; 0.10)	0.99

Olives												
Weekly vs daily	3.6	(-2.7; 9.8)	0.26	1.1	(-0.83; 2.9)	0.27	0.36	(-2.8; 3.5)	0.82	-0.15	(-0.28; -0.01)	0.03
Monthly vs daily	2.8	(-3.0; 8.6)	0.35	0.95	(-0.81; 2.7)	0.29	2.0	(-0.89; 5.0)	0.17	-0.18	(-0.30; -0.05)	0.006
Honey												
Weekly vs daily	-2.1	(-6.7; 2.5)	0.36	-0.40	(-1.8; 0.98)	0.56	0.37	(-1.9; 2.7)	0.76	0.03	(-0.07; 0.13)	0.52
Monthly vs daily	2.3	(-2.5; 7.3)	0.34	1.4	(-0.11; 2.8)	0.07	2.6	(0.12; 5.1)	0.04	0.01	(-0.10; 0.11)	0.85
Processed Foods with Functionality												
Enhanced cereals												
Weekly vs daily	-4.8	(-12.1; 2.5)	0.20	-1.7	(-3.9; 0.43)	0.11	-2.5	(-6.2; 1.2)	0.18	0.10	(-0.06; 0.25)	0.23
Monthly vs daily	-2.5	(-8.7; 3.6)	0.41	-0.08	(-1.9; 1.8)	0.93	0.61	(-2.5; 3.7)	0.70	-0.03	(-0.16; 0.10)	0.66
Gluten-free pasta												
Weekly vs daily	-1.8	(-12.4; 8.8)	0.74	-0.54	(-3.8; 2.7)	0.74	2.0	(-3.4; 7.4)	0.47	0.17	(-0.06; 0.40)	0.14
Monthly vs daily	-1.7	(-10.9; 7.5)	0.72	0.14	(-2.7; 3.0)	0.92	1.9	(-2.8; 6.6)	0.43	-0.005	(-0.20; 0.20)	0.96
Gluten-free bakeries												
Weekly vs daily	-5.5	(-16.9; 6.0)	0.35	-1.8	(-5.2; 1.7)	0.31	-0.90	(-6.7; 4.9)	0.76	0.18	(-0.06; 0.43)	0.15
Monthly vs daily	-1.5	(-11.7; 8.7)	0.78	0.07	(-3.0; 3.2)	0.96	1.6	(-3.6; 6.7)	0.55	-0.01	(-0.23; 0.21)	0.93
Enhanced bakeries												
Weekly vs daily	-5.0	(-15.7; 5.7)	0.36	-1.4	(-4.7; 1.8)	0.39	-1.1	(-6.5; 4.3)	0.68	0.15	(-0.08; 0.38)	0.19
Monthly vs daily	-3.2	(-12.9; 6.5)	0.52	-0.31	(-3.3; 2.6)	0.83	1.5	(-3.4; 6.4)	0.54	-0.02	(-0.23; 0.19)	0.85
Probiotic/with probiotics dairies												
Weekly vs daily	-6.4	(-13.5; 0.69)	0.08	-1.5	(-3.6; 0.67)	0.18	-1.2	(-4.8; 2.4)	0.50	0.10	(-0.05; 0.26)	0.18
Monthly vs daily	-5.6	(-11.8; 0.52)	0.07	-0.98	(-2.8; 0.90)	0.30	0.36	(-2.8; 3.5)	0.82	0.01	(-0.13; 0.14)	0.90
Enhanced dairies												
Weekly vs daily	-6.5	(-14.3; 1.2)	0.10	-2.2	(-4.5; 0.18)	0.07	-2.1	(-6.0; 1.9)	0.30	0.07	(-0.10; 0.24)	0.43
Monthly vs daily	-7.6	(-14.6; -0.55)	0.03	-1.7	(-3.9; 0.43)	0.12	-0.93	(-4.5; 2.6)	0.60	-0.004	(-0.16; 0.15)	0.96
Olive oil												
Weekly vs daily	3.8	(0.22; 7.5)	0.04	0.67	(-0.43; 1.8)	0.23	0.83	(-1.0; 2.7)	0.38	0.06	(-0.02; 0.14)	0.13
Monthly vs daily	6.5	(-1.5; 14.5)	0.11	2.5	(0.04; 4.9)	0.05	2.9	(-1.1; 7.0)	0.15	0.01	(-0.16; 0.19)	0.87
Vegan spreads												
Weekly vs daily	-3.3	(-9.5; 2.9)	0.30	0.06	(-1.8; 1.9)	0.95	-0.10	(-3.3; 3.1)	0.95	0.05	(-0.09; 0.19)	0.47
Monthly vs daily	1.02	(-4.8; 6.9)	0.73	1.5	(-0.26; 3.3)	0.09	2.0	(-0.99; 5.0)	0.19	-0.02	(-0.15; 0.11)	0.76
Enhanced spreads												
Weekly vs daily	-4.2	(-14.1; 5.7)	0.40	-1.0	(-4.1; 1.9)	0.48	-1.0	(-6.0; 3.9)	0.67	0.13	(-0.09; 0.34)	0.25
Monthly vs daily	-1.5	(-10.4; 7.3)	0.73	0.43	(-2.2; 3.1)	0.75	2.2	(-2.2; 6.6)	0.33	-0.03	(-0.22; 0.16)	0.77

Table 4. Association of intake of foods with functionality with markers of obesity.

All models were adjusted for sex, age group, educational level, smoking status, physical activity status and water intake.

DISCUSSION:

This cross-sectional, epidemiological study aimed to investigate the potential relationship between the frequency of consuming natural and processed foods with functionality and adiposity markers. The main findings suggest that there is a small but noteworthy proportion who were not aware of consuming foods with functionality. Most of the study participants seem to adhere to a diet rich in carotenoids, including weekly intake of fruits (especially citrus) and vegetables (especially red), although quaintly berries and pomegranates are consumed less frequently. However, it was only the association of greater BMI with monthly intake whole wheat cereals, herbs (thyme/ oregano/ basil), and nuts that retained significance at the Bonferroni correction level. Moreover, adjusting for sex, age group, educational level, smoking status, physical activity status, and water intake, monthly nut intake was associated with greater BMI, at the Bonferroni correction level.

Reports highlight the protective role of functional food intake against chronic diseases (e.g. cardiovascular, metabolic syndrome, cancer, etc.). Adhering to the Mediterranean Diet, including natural foods-good candidates for functional foods, such as fruits, vegetables, and legumes may contribute to controlling obesity, measured through adiposity markers such as BMI and body fat [22]. This study provides some evidence, albeit weak, that infrequent (i.e., weekly/ monthly) intake of yellow/orange fruits, pomegranates, split peas, soya and its products, whole wheat cereals, thyme/oregano/basil, nuts, honey, enhanced cereals, gluten-free pasta, gluten-free bakeries, enhanced bakeries, olive oil, vegan spreads, and enhanced spreads was positively associated with adiposity markers. Therefore, increasing frequency of intake of these foods with functionality might provide a potential of controlling adiposity.

Olive oil, berries, pomegranates, and honey are essential components of the Mediterranean Diet due to their rich nutritional, phytochemical, and antioxidant profile, which are also recognized for their protected role in cardiovascular disease and cancer [23]. Ntrigiou et al. [24], in results from another Greek sample, also highlighted the rare intake of pomegranates and berries, although, in contrast to this study, they observed a negative association between higher intake of these food groups, BMI, and WHR.

High intake of whole grains has been associated with reduced BMI, through effects on appetite and energy expenditure, due to their bioactive compounds (e.g. dietary fibers, lignans, phytosterols, etc.) [25]. These factors may have a beneficial effect on the maintenance of energy balance and body composition [25]. Moreover, the inclusion of specific aromatic herbs in diet, such as thyme, oregano, and basil, have been reported to contribute to fat peroxidation, due to their bioactive compounds (thymol, carvacrol, rosmarinate, etc.), presenting a positive effect on body composition variables [26]. It is well known that caffeine, presented in coffee, may possess a beneficial role on obesity indices, via mechanisms such as lipid peroxidation, the rise of energy expenditure, thermogenesis, and the reduction of energy intake [27]. Although, Costa et al. demonstrate that higher coffee intake is associated with reduced BMI and WHR, this claim remains unstable due to study design heterogeneity and variation in the general population habits [27].

The frequent incorporation of tea into the habitual diet has also been suggested for the control of the diposity markers, mainly due to a gradual reduction in caloric intake, as a result of reduced absorption of lipids and proteins, or due to the activation of AMP-activated protein kinase, by tea polyphenols [6]. Furthermore, the anti-obesity effect of pomegranates has been extensively studied and their main mechanisms of action are related to reduced fat absorption and appetite suppression through regulation of adiponectin and leptin secretion [28]. Examining our findings on the effect of split peas and soya products on waist/hip circumference, albeit at the nominal significance level, it is enough to consider that several legumes, are energy-rich components of the diet [23]. Nevertheless, Cubas-Basterrechea et al. emphasized that the nutritional value of legumes has been linked to the prevention and control of both obesity, diabetes markers, and the Mediterranean Diet (MetS), not to mention the fact that their consumption should be enhanced, drawing attention to socio-demographic characteristics [28]. Honey has been previously reported to contribute to obesity management, but due to its high sugar content, this statement should be extensively examined [30]. Considering that the underlying mechanisms of action are still not well-known, it has been reported that the entire dietary pattern, which is followed, and the dose, received per day may lead to different effects of honey intake on obesity parameters [30, 31].

As an integral part of the Mediterranean diet, olive oil proved to be probably beneficial on body weight management. The inhibitory effect of extra virgin olive oil (EVOO) against the hydrolytic enzymes α-glucosidase and α-amylase has been previously reported [23]. In addition, it has been suggested as a powerful fat oxidation enhancer, while regulating myocardial metabolic enzymes, leading to the optimization of cardiac energy metabolism [23].

Regarding our weak, primary findings, extracted for the effect of several processed, healthy foods on adiposity markers, it is noteworthy that higher intake of ultra-processed foods has been associated with increased body weight, BMI, and depression prevalence, but with lower incidence of diabetes [32]. In parallel, the frequent consumption of processed food groups is related to unhealthy lifestyle and dietary habits, while sex was reported to affect these associations [32]. Recent studies have marked gluten-free products, such as bakeries and pasta as contributors of BMI increase [33]. In fact, Valetta et al. observed that the establishment of a gluten-free diet in their study population led to a doubling of the percentage of obese people [34]. Dietary habits formed due to the high price, as well as the availability of high-fat, gluten-free products appear to be determining factors in these outcomes [33]. However, it has been reported that the frequent consumption of enhanced bakeries may contribute to better management of factors such as excessive blood glucose, insulin resistance, cardiovascular parameters, etc. Considering the high energy load, as well as the effect of several psychological and sociodemographic characteristics, it is necessary to further investigate the effect of their daily intake on obesity indicators [35].

The present study highlighted only one strong relationship between the frequency of the selected healthy foods and adiposity markers. Specifically, daily intake of nuts found to be related with lower BMI than rare consumption, considering several sociodemographic, dietary, and lifestyle characteristics. Previously, large cohort studies confirmed that the frequency of nut intake is inversely related to BMI [36]. Findings from the Physician's Health study indicated that men who ate nuts two or more times a week had a lower BMI than those who ate nuts less often [36]. After understanding the complex mechanisms of the nuts' effectiveness against adiposity, it has been reported that nuts provide unsaturated fats, proteins, and other bioactive compounds, through which they may increase thermogenesis, and due to their energy density through dietary fibers, they may increase satiety [37]. Due to fiber presence in a nuts structure and the incomplete mastication, the gastric emptying may be delayed, which may lead to lower fat absorption and hunger suppression [37]. It is worth mentioning that the frequent intake of nuts has been linked to the adoption of a healthy lifestyle, in the context of a balanced diet, rich in antioxidants and poor in processed foods [38]. In addition, it has been observed that the most frequent nut consumers refrain from smoking and are physically active

[38].

Strengths and limitations: Our study can be characterized by several strengths. According to our knowledge, this is the first epidemiological study that aimed to examine the possible association between the frequency of intake of natural Mediterranean foods and processed, healthy foods, with body composition and anthropometric parameters of adiposity. Moreover, the participants' origin covered several regions of Greece and Cyprus, making our results quite representative. This study was performed in a wide range of ages (18- to 75-years-old), both with normal-weight and obese participants, and investigated several dietary and lifestyle covariates.

Our study presents limitations. Due to its cross-sectional design, the current study cannot address causality, whilst the possibility of reverse association between adiposity markers and functional food intake is present. Different types of exposure (e.g. lifestyle and dietary parameters, biomarkers etc.) in a larger sample of the Greek and Cyprian population, should be recorded in more detail, to fully clarify whether the frequency of consumption of the selected foods with functionality is a unique influencing factor on the outcome of obesity markers. The failure of registration of key bioactive compounds, abundant in these foods-good candidates for functional foods, such as polyphenols, unsaturated fats etc. is another challenge of our study. Furthermore, bias of over- or under-estimation by the use of the Frequency of Functional Foods Questionnaire should be acknowledged. Although portion size was included during data collection, the exact determination of the received dose of each functional food group may contribute to more accurate processing of the data. Finally, Greek and Cypriots was examined as a united population, and the study did not investigate possible differences between the two countries, regarding the relationship of frequency of consumption of foods with functionality with the tested obesity indicators.

As food groups are highly correlated to each other by including them in the model it would produce an unstable model due to the high degree of collinearity. We appreciate that the most ideal approach should have been a data mining approach such as principal component analysis, however the assumptions for doing so were not valid. Moreover, models should have been additionally adjusted for overall energy intake, but we don't have this information in the current data.

CONCLUSION

Results of this epidemiological study on Greek and Cypriot volunteers suggested that infrequent intake of whole wheat cereals, herbs (in particular thyme/oregano/basil), and principally nuts were determinants of BMI. Moreover, nutrition education is essential for people to be aware of the presence of functional foods in their diet. The organization and implementation of nutritional education programs could be an effective strategy to increase public health awareness regarding the potential health benefits of frequent intake of functional foods, combating obesity.

Author Contributions: [O.P.]: [Research Design], [Epidemiological study implementation], [Statistical analysis], and [First draft writing]; [V.B.]: [Guidance and Supervision of the statistical analysis], and [Intellectual input in the first draft writing]; [C.D.]: [Research Design]; [H.K]: [Research Design]; [E.M]: [Epidemiological study implementation]; [A.P]: [Epidemiological study implementation]; [A.K]: [Research Design], [Supervision of the study], and [Approval of the final ms draft]. All authors read and approved the final version of the manuscript.

Competing Interests: There are no conflicts of interest to declare.

Acknowledgements and Funding: The research received no funding. We would like to thank all the participants for their voluntary contribution to the study.

Ethics: The study was carried out according to the guidelines of the Declaration of Helsinki. All participants were informed about the aim of the study and provided their written consent.

REFERENCES

1. Boccellino, M.; D'Angelo, S. Anti-Obesity Effects of Polyphenol Intake: Current Status and Future Possibilities. *International Journal of Molecular Sciences*. MDPI AG August 2, 2020, pp 1–24. DOI: https://doi.org/10.3390/ijms21165642 .
2. Siopis, G.; Moschonis, G.; Reppas, K.; Iotova, V.; Bazdarska, Y.; Chakurova, N.; Rurik, I.; Radó, A. S.; Cardon, G.; Craemer, M. De; et al. The Emerging Prevalence of Obesity within Families in Europe and Its Associations with Family Socio-Demographic Characteristics and Lifestyle Factors; A Cross-Sectional Analysis of Baseline Data from the Feel4Diabetes Study. *Nutrients*, 2023, *15* (5). DOI: https://doi.org/10.3390/nu15051283 .
3. Boutari, C.; Mantzoros, C. S. A 2022 Update on the Epidemiology of Obesity and a Call to Action: As Its Twin COVID-19 Pandemic Appears to Be Receding, the Obesity and Dysmetabolism Pandemic Continues to Rage On. *Metabolism: Clinical and Experimental*. W.B. Saunders August 1, 2022. DOI: https://doi.org/10.1016/j.metabol.2022.155217 .
4. Sommer, I.; Teufer, B.; Szelag, M.; Nussbaumer-Streit, B.; Titscher, V.; Klerings, I.; Gartlehner, G. The Performance of Anthropometric Tools to Determine Obesity: A Systematic Review and Meta-Analysis. *Sci Rep*, 2020, *10* (1), 1–12. DOI: https://doi.org/10.1038/s41598-020-69498-7 .
5. Venkatakrishnan, K.; Chiu, H. F.; Wang, C. K. Extensive Review of Popular Functional Foods and Nutraceuticals against Obesity and Its Related Complications with a Special Focus on Randomized Clinical Trials. *Food and Function*. Royal Society of Chemistry May 1, 2019, pp 2313–2329. DOI: https://doi.org/10.1039/c9fo00293f .
6. Konstantinidi, M.; Koutelidakis, A. E. Functional Foods and Bioactive Compounds: A Review of Its Possible Role on Weight Management and Obesity's Metabolic Consequences. *Medicines*, 2019, *6* (3), 94. DOI: https://doi.org/10.3390/medicines6030094 .
7. Coats, R., & Martirosyan, D. The effects of bioactive compounds on biomarkers of obesity. *Functional Foods in Health and Disease*, 2015, 5 (11), DOI: https://doi.org/10.31989/ffhd.v5i11.219 .
8. Apalowo, O., Adegoye, G., & Obuotor, T. (2024). Exploring the Functional Roles of Sustainable Dietary Patterns on Gut Microbiota Composition and Optimal Health. Bioactive Compounds in Health and Disease, 7(2), 110–130. DOI: https://doi.org/10.31989/bchd.v7i2.1279
9. Dominguez, L. J.; Veronese, N.; Di Bella, G.; Cusumano, C.; Parisi, A.; Tagliaferri, F.; Ciriminna, S.; Barbagallo, M. Mediterranean Diet in the Management and Prevention of Obesity. *Exp Gerontol*, 2023, *174*. DOI: https://doi.org/10.1016/j.exger.2023.112121 .
10. Mohammadi, S.; Lotfi, K.; Mirzaei, S.; Asadi, A.; Akhlaghi, M.; Saneei, P. Adherence to Mediterranean Diet and Its Association with Metabolic Health Status in Overweight and Obese Adolescents. *Int J Clin Pract*, 2022, *2022*. DOI: https://doi.org/10.1155/2022/9925267 .
11. Kandyliari, A.; Elmaliklis, I. N.; Kontopoulou, O.; Tsafkopoulou, M.; Komninos, G.; Ntzatha, C.; Petsas, A.; Karantonis, H. C.; Koutelidakis, A. E. An Epidemiological Study Report on the Antioxidant and Phenolic Content of Selected Mediterranean Functional Foods, Their Consumption Association with the Body Mass Index, and Consumers Purchasing Behavior in a Sample of Healthy Greek Adults. *Applied Sciences (Switzerland)*, 2021, *11* (17), 1–14. DOI: https://doi.org/10.3390/app11177818 .
12. Rodríguez-Pérez, C.; Segura-Carretero, A.; del Mar Contreras, M. Phenolic Compounds as Natural and Multifunctional Anti-Obesity Agents: A Review. *Crit Rev Food Sci Nutr*, 2019, *59* (8), 1212–1229. DOI: https://doi.org/10.1080/10408398.2017.1399859 .
13. Alongi, M.; Anese, M. Re-Thinking Functional Food Development through a Holistic Approach. *J Funct Foods*, 2021, *81* (April), 104466. DOI: https://doi.org/10.1016/j.jff.2021.104466 .
14. Gupta, E.; Mishra, P. Functional Food with Some Health Benefits, So Called Superfood: A Review. *Curr Nutr Food Sci*, 2020, *17* (2), 144–166. DOI: https://doi.org/10.2174/1573401316999200717171048 .
15. Bosy-Westphal, A.; Müller, M. J. Diagnosis of Obesity Based

on Body Composition-Associated Health Risks—Time for a Change in Paradigm. *Obesity Reviews*, 2021, *22* (S2). DOI: https://doi.org/10.1111/obr.13190 .

16. Bull, F. C.; Al-Ansari, S. S.; Biddle, S.; Borodulin, K.; Buman, M. P.; Cardon, G.; Carty, C.; Chaput, J. P.; Chastin, S.; Chou, R.; et al. World Health Organization 2020 Guidelines on Physical Activity and Sedentary Behaviour. *British Journal of Sports Medicine*. BMJ Publishing Group December 1, 2020, pp 1451–1462. DOI: https://doi.org/10.1136/bjsports-2020-102955 .
17. Troisi, R. J.; Heinold, J. W.; Vokonas, P. S.; Weiss, S. T. *Cigarette Smoking, Dietary Intake, and Physical Activity: Effects on Body Fat Distribution-the Normative Aging Study13*; 1991; Vol. 53. DOI: https://doi.org/10.1093/ajcn/53.5.1104 .
18. Papagianni, O.; Staramou, A.; Rigopoulos, N.; Dimou, C.; Koutelidakis, E. A. Development and Validation of a Functional Foods Frequency Questionnaire for Greek Adults. *Curr Top Nutraceutical Res*, 2021, *19* (3), 373–381. DOI: https://doi.org/10.37290/ctnr2641-452X.19:373-381 .
19. Willett, W. *Nutritional Epidemiology*, 3d ed.; Oxford University Press: Oxford, 2013. DOI: https://doi.org/10.1093/acprof:oso/9780199754038.001.0001
20. Astrup, A. Healthy Lifestyles in Europe: Prevention of Obesity and Type II Diabetes by Diet and Physical Activity. *Public Health Nutr*, 2001, *4* (2b), 499–515. DOI: https://doi.org/10.1079/phn2001136 .
21. Merrigan, J. J., Stute, N. L., Eckerle, J. J., Mackowski, N. S., Walters, J. R., O'connor, M. L., Barrett, K. N., Briggs, R. A., Strang, A. J., & Hagen, J. A. (n.d.). Issue 4): 18 OPEN ACCESS Journal of Exercise and Nutrition (Vol. 5). DOI: https://doi.org/10.53520/jen2022.103133
22. Alkhatib, A.; Tsang, C.; Tiss, A.; Bahorun, T.; Arefanian, H.; Barake, R.; Khadir, A.; Tuomilehto, J. Functional Foods and Lifestyle Approaches for Diabetes Prevention and Management. *Nutrients*. MDPI AG December 1, 2017. DOI: https://doi.org/10.3390/nu9121310 .
23. Battino, M.; Forbes-Hernández, T. Y.; Gasparrini, M.; Afrin, S.; Cianciosi, D.; Zhang, J.; Manna, P. P.; Reboredo-Rodríguez, P.; Varela Lopez, A.; Quiles, J. L.; et al. Relevance of Functional Foods in the Mediterranean Diet: The Role of Olive Oil, Berries and Honey in the Prevention of Cancer and Cardiovascular Diseases. *Crit Rev Food Sci Nutr*, 2019, *59* (6), 893–920. DOI: https://doi.org/10.1080/10408398.2018.1526165 .
24. Ntrigiou, V.; Ntrigios, I.; Rigopoulos, N.; Dimou, C.; Koutelidakis, A. E. Functional Food Consumption Correlates With Anthropometric Characteristics and Body Composition in Healthy Adults. *Curr Top Nutraceutical Res*, 2018, *16* (4), 279–288.
25. Maki, K. C.; Palacios, O. M.; Koecher, K.; Sawicki, C. M.; Livingston, K. A.; Bell, M.; Cortes, H. N.; McKeown, N. M. The Relationship between Whole Grain Intake and Body Weight: Results of Meta-Analyses of Observational Studies and Randomized Controlled Trials. *Nutrients*, 2019, *11* (6).
26. Vázquez-Fresno, R.; Rosana, A. R. R.; Sajed, T.; Onookome-Okome, T.; Wishart, N. A.; Wishart, D. S. Herbs and Spices-Biomarkers of Intake Based on Human Intervention Studies - A Systematic Review. *Genes and Nutrition*. BioMed Central Ltd. May 22, 2019. DOI: https://doi.org/10.1186/s12263-019-0636-8 .
27. Costa, M. S. da; Pontes, K. S. da S.; Guedes, M. R.; Barreto Silva, M. I.; Klein, M. R. S. T. Association of Habitual Coffee Consumption with Obesity, Sarcopenia, Bone Mineral Density and Cardiovascular Risk Factors: A Two-Year Follow-up Study in Kidney Transplant Recipients. *Clinical Nutrition*, 2023, *42* (10), 1889–1900. DOI: https://doi.org/10.1016/j.clnu.2023.08.004.
28. Gheflati, A.; Mohammadi, M.; Ramezani-Jolfaie, N.; Heidari, Z.; Salehi-Abargouei, A.; Nadjarzadeh, A. Does Pomegranate Consumption Affect Weight and Body Composition? A Systematic Review and Meta-Analysis of Randomized Controlled Clinical Trials. *Phytotherapy Research*. John Wiley and Sons Ltd May 1, 2019, pp 1277–1288. DOI: https://doi.org/10.1002/ptr.6322.
29. Cubas-Basterrechea, G.; Elío, I.; Alonso, G.; Otero, L.; Gutiérrez-Bardeci, L.; Puente, J.; Muñoz-Cacho, P. Adherence to the Mediterranean Diet Is Inversely Associated with the Prevalence of Metabolic Syndrome in Older People from the North of Spain. *Nutrients*, 2022, *14* (21). DOI: https://doi.org/10.3390/nu14214536.
30. Terzo, S.; Mulè, F.; Amato, A. Honey and Obesity-Related Dysfunctions: A Summary on Health Benefits. *Journal of Nutritional Biochemistry*. Elsevier Inc. August 1, 2020. DOI: https://doi.org/10.1016/j.jnutbio.2020.108401 .
31. Ramli, N. Z.; Chin, K. Y.; Zarkasi, K. A.; Ahmad, F. A Review on the Protective Effects of Honey against Metabolic Syndrome. *Nutrients*. MDPI AG August 2, 2018. DOI: https://doi.org/10.3390/nu10081009 .
32. Konieczna, J.; Morey, M.; Abete, I.; Bes-Rastrollo, M.; Ruiz-Canela, M.; Vioque, J.; Gonzalez-Palacios, S.; Daimiel, L.; Salas-Salvadó, J.; Fiol, M.; et al. Contribution of Ultra-

Processed Foods in Visceral Fat Deposition and Other Adiposity Indicators: Prospective Analysis Nested in the PREDIMED-Plus Trial. *Clinical Nutrition*, 2021, *40* (6), 4290–4300. DOI: https://doi.org/10.1016/j.clnu.2021.01.019 .

33. Theethira, T. G.; Dennis, M. Celiac Disease and the Gluten-Free Diet: Consequences and Recommendations for Improvement. *Digestive Diseases*, 2015, *33* (2), 175–182. DOI: https://doi.org/10.1159/000369504 .
34. Valletta, E.; Fornaro, M.; Cipolli, M.; Conte, S.; Bissolo, F.; Danchielli, C. Celiac Disease and Obesity: Need for Nutritional Follow-up after Diagnosis. *Eur J Clin Nutr*, 2010, *64* (11), 1371–1372. DOI: https://doi.org/10.1038/ejcn.2010.161 .
35. Raffaele Zanchini, G. D. V. F. B. Lifestyle, Psychological and Socio-Demographic Drivers in Functional Food Choice: A Systematic Literature Review Based on Bibliometric and Network Analysis. *Int J Food Sci Nutr*, 2022, *73* (6), 709–725.
36. Vadivel, V.; Kunyanga, C. N.; Biesalski, H. K. Health Benefits of Nut Consumption with Special Reference to Body Weight Control. *Nutrition*. November 2012, pp 1089–1097. DOI: https://doi.org/10.1016/j.nut.2012.01.004 .
37. Baer, D. J.; Dalton, M.; Blundell, J.; Finlayson, G.; Hu, F. B. Nuts, Energy Balance and Body Weight. *Nutrients*. Multidisciplinary Digital Publishing Institute (MDPI) March 1, 2023. DOI: https://doi.org/10.3390/nu15051162.
38. Witkowska, A. M.; Wàskiewicz, A.; Zujko, M. E.; Szcześniewska, D.; Śmigielski, W.; Stepaniak, U.; Pająk, A.; Drygas, W. The Consumption of Nuts Is Associated with Better Dietary and Lifestyle Patterns in Polish Adults: Results of WOBASZ and WOBASZ II Surveys. *Nutrients*, 2019, *11* (6). DOI: https://doi.org/10.3390/nu11061410 .