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Association of Mean Daily Polyphenols Intake with Mediterranean Diet Adherence and Anthropometric Indices in Healthy Greek Adults: A Retrospective Study

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Abstract: Research data indicate the possible effect of both polyphenols consumption and Mediterranean diet adherence on metabolic diseases' prevalence. The present retrospective study investigated the possible association of polyphenols mean daily intake with Mediterranean diet adherence and anthropometric indices in a sample of the Greek population. A total of 250 healthy volunteers, aged between 18 and 65 years, were randomly recruited from central and northern Greece. Total daily polyphenols intake was estimated using a semi-quantitative food frequency questionnaire (FFQ) based on the NHANES study, while Med Diet Score was used for the degree of Mediterranean diet adoption. Daily polyphenols intake was identified by the Phenol Explorer database, and anthropometric measurements (BMI, waist-to-hip circumference, and body composition) were performed. The mean daily polyphenols intake was determined to be 1905 mg, while most of the participants had moderate or high mean consumption last year (67.5% of the sample were consuming more than 1000 mg/d). Moderate adherence to the Mediterranean diet (higher Med Diet Score) was associated with increased mean daily polyphenols intake ($p = 0.016$). Increased polyphenols intake and higher Med Diet Score were associated with decreased waist-to-hip circumference ($p = 0.027, 0.004$, respectively). Specific functional foods rich in polyphenols, such as sour cherry, tomatoes, black tea, and cocoa were associated with improved body composition indices. Larger epidemiological studies need to be performed for safer conclusions about whole population polyphenols intake and its association with metabolic disease biomarkers.

Keywords: phenolic compounds; Mediterranean diet adoption; traditional functional foods; body composition; waist-to-hip circumference

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1. Introduction

Polyphenols have been studied as bioactive compounds of high importance, with a possible role in human health promotion [1–3]. Dietary models rich in fruits, vegetables, cereals, legumes, nuts, and a plethora of natural functional foods and beverages, are linked with high intake of polyphenols [4–9]. Their structure, with hydroxyl groups, promotes their possible antioxidant activity in human organisms, while antibacterial, anti-inflammatory, cardioprotective, antidiabetic, and anticancer activities have also been studied due to either antioxidative properties or possible effects on gene expression, by modulating protein synthesis and specific metabolic pathways related to diseases' pathophysiology [2,3,8–14].

Regular dietary intake of polyphenols, approximately 1–2 g per day, has been associated with chronic disease prevention [1]. Nonetheless, human response to phytochemicals appears to be highly variable, and there is little evidence to suggest a definite influence of polyphenols on human health [2]. Polyphenols' bioaccessibility and bioavailability depend on various parameters, including food structure, genetic variations, and interactions with meal components [15,16]. In addition, the final bioaccessible polyphenol amount in the small intestine is estimated to be below 50% [17]. Hence, the establishment of dietary reference intake for polyphenols is difficult and has not yet performed [2]. However, several studies have investigated polyphenols intake in different populations, by using 24-recalls or semi-quantitative food frequency questionnaires and polyphenols databases [16–19]. For example, the average daily intake of polyphenols in the Spanish diet is around 3000 mg/person/day [16], although the PREDIMED research of 7000 Spanish people found total phenols intake to be 820 ± 323 mg per day, with flavonoids and phenolic acids being the most abundant components [18]. In France, the total polyphenol intake in 4000 adults is estimated at 1193 ± 510 mg/d [17], and in Poland at 1756.5 ± 695.8 mg/d [19]. In Greece, there is not adequate data about polyphenols consumption, and the present study is one of the few studies that investigate the mean polyphenols intake in a subgroup of the population. In addition, investigation of possible correlations between a variety of natural functional foods from the Mediterranean diet with mean polyphenols intake is of high importance for the further understanding of the possible bioactivity of polyphenols in a balanced diet.

In Mediterranean countries, the main dietary sources of polyphenols are olives, olive oils, fruits, vegetables, and coffee [18]. The Mediterranean diet has been studied as a possible protective parameter for chronic disease prevention. Many studies have concluded that a lot of natural functional foods from the Mediterranean diet, containing polyphenols and other phytochemicals, may have protective effects against atherosclerotic processes, obesity, gastrointestinal diseases, cancer, and other pathologies [20–25]. Mediterranean foods such as olive oil, honey, tomatoes, cauliflower, broccoli, citrus fruits, pomegranate, grapes, fennel, radish, oregano, mint, dittany, salvia and other fruits, vegetables, wild greens, and herbs may contribute to specific diseases' prevention due to their bio-functional compounds, including oleuropein, resveratrol, sulforaphane, anthocyanins, quercetin, tannins, and others. The studied possible mechanisms of their bioactivity include effects on the lipid profile, endothelial and thrombotic factors, postprandial glycemia and lipemia, effects on gene expression, and metabolic pathways [3,19–23,26–28]. In the PREDIMED study, the increase in polyphenols intake from the Mediterranean diet was associated with decreased inflammatory biomarkers and improvement in cardiovascular risk biomarkers [29]. Furthermore, mean polyphenols intake was higher in Italians who adhered to the Mediterranean diet than those who did not [30]. The correlation of Mediterranean diet adherence with total polyphenols consumption is of high importance in the direction of establishing nutritional policies to prevent metabolic diseases, such as obesity, diabetes mellitus, and metabolic syndrome, that appear to have increased prevalence in the Greek population.

Obesity and metabolic syndrome are metabolic conditions that have been correlated with significant fat deposition in intra-abdominal spaces, insulin resistance, hypertension, hyperlipidemia, increased risk for diabetes mellitus, cardiovascular diseases, and high mortality and morbidity risk [31–33]. In recent decades, human nutritional attitudes have turned to the Westernized lifestyle, which is characterized by increased sugars, saturated fat, increased total calories, and decreased physical activity [34,35]. Scientific evidence strongly supports that Mediterranean diet adherence might protect from metabolic disorders due to its beneficial impact on metabolic biomarkers, such as serum lipids, inflammation, and oxidative stress [36–38]. In Greece, the lower adherence to the Mediterranean diet has been correlated with increased incidence of obesity and cardiovascular disease in children and adults [36,37], so the need for diet improvement should be the aim of the national nutritional policies. Fruits, vegetables, olive oil, nuts, legumes, grapes, berries, pomegranate, herbs, and greens, all high in total phenolics and other bioactive compounds, have been researched for their prospective role in weight management and metabolic biomarker improvement (lipidemic profile, glucose levels, and thrombotic status). Effects on lipid absorption, increased thermogenesis and fat oxidation, and appetite control are among the proposed mechanisms of their action [3,21]. In a recent study in Greek adults, the increased consumption of specific functional foods rich in polyphenols, such as cocoa and pomegranate, correlated with decreased BMI, while several anthropometric indices, such as body fat content and waist-to-hip ratio, were also evaluated [39]. The examination of a subgroup of the Greek population's mean daily polyphenols intake, particularly in younger adults, is of particular interest to support nutritional education programs that promote increased consumption of functional foods and beverages rich in polyphenols, possibly with high bioactivity.

The scope of the present retrospective study was the investigation of mean polyphenols intake and consumption of specific foods rich in polyphenols in healthy, mainly young Greek adults, and its association with Mediterranean diet adherence and anthropometric parameters. The present study aims to investigate the hypothesis of if polyphenols intake is adequate in a sample of the Greek population and whether polyphenols intake and consumption of foods rich in polyphenols are correlated with Mediterranean diet adherence and anthropometric indices. This is of high importance to the Greek population, which appears to have increased incidence of obesity, in order for nutritional policies to be promoted to improve the overall health of the Greek population.

2. Materials and Methods

2.1. Subjects

The study protocol was approved by the Ethics Committee of the University of the Aegean (January 2019) and carried out according to the Declaration of Helsinki of 1975, as revised in 2013. All volunteers signed an informed consent form and were fully informed about the aim of the study, and the confidentiality of the data.

A total of 250 volunteers, 99 men and 145 women, aged 18–65 years old, were randomly recruited from three different regions of Greece: Athens, Chalkida (central Greece), and Lemnos Island (northern Greece). The participants' selection was performed randomly through social media, announcements, and e-mails. Inclusion criteria included healthy adults, who had never suffered from chronic diseases (cardiovascular diseases, diabetes mellitus, cancer, psychological diseases, etc.). Age over 65 and under the age of 18 were both factors for exclusion. All participants completed a medical screening questionnaire containing basic demographic and medical history information, as well as smoking habits, nutritional supplements consumption, and physical activity. After the first screening interview of 260 people, 250 participants were recruited based on the inclusion and exclusion criteria of the study, and 244 of them finally completed the study. The selection of the participants and the collection of the data were carried out by collaborating nutritionists.

2.2. Study Design

This was a retrospective, cross-sectional, observational study started on 1 March 2019 and finished on 10 September 2019. The participants visited the University Nutritional Unit, and completed two questionnaires, one semi-quantitive food frequency questionnaire (FFQ) for assessing their nutritional patterns regarding foods that contain polyphenols [40], and one for assessing the degree of adherence to the Mediterranean diet [41]. The participants were asked to recall their nutritional habits in the last year. Anthropometric measurements were also performed (weight, height, waist-to-hip ratio, body fat, body water content, muscle mass, and bone mass).

2.3. Questionnaires

The frequency and quantity of consumption of foods containing polyphenols and Mediterranean diet adoption was investigated by two validated questionnaires. The first was a semi-quantitive food frequency questionnaire (FFQ), based on the NHANES study FFQ [40] after some modifications. Changes were made in particular with the goal of including more natural foods high in polyphenols, without changing the type of questions, based on previously published studies on natural functional food consumption in the Greek population [23,39]. The questionnaire included four parts. The first contained questions about gender, age, occupation, and other demographic characteristics. The second part contained questions about the nutritional background of the participants, smoking, water consumption, use of medication, and supplements. In the third part, the frequency and the quantity of foods that contain polyphenols were investigated. A total of 109 foods and food groups were evaluated and included fruits, vegetables, legumes, cereals, nuts, herbs, spices, olive oil, wild greens, wine, especially tomatoes, grapes, raisins, red wine, black chocolate, broccoli, lentils, etc. The possible answers were "every day", "4–5 times per day", "2–3 times per day", "1 time per day", "5–6 times per week", "3–4 times per week", "1–2 times per week", "3–4 times per month", "1–2 times per month", and "never" [23,39,40]. The filling of the questionnaires took place with assistance by the researchers, using pictures with food portions, and aimed to identify the frequency of each item consumption, the number of items, and the quantity consumed each time. For seasonal fruits and vegetables, the volunteers were informed to fill the consumption only for the season that the foods consumed.

The second questionnaire was the Mediterranean Diet Score that was proposed by Panagiotakos et al. (2006) [41], and consisted of 11 main components of the Mediterranean diet (non-refined cereals, fruits, vegetables, potatoes, legumes, olive oil, fish, red meat, poultry, full-fat dairy products, and alcohol). For the consumption of items closer to the Mediterranean diet, scores of 0, 1, 2, 3, 4, and 5 were assigned when a participant reported no consumption, rare, frequent, very frequent, weekly, and daily, respectively. For the consumption of foods away from this pattern, the same scores were assigned on the reverse scale. Then, the total Med Diet Score from 0 to 55 was calculated. A high Med diet score indicates high Mediterranean diet adherence, while a low Med diet score indicates low Mediterranean diet adherence [41]. The Med Diet Score was also grouped into three categories (low 1–17, moderate 18–36, and high adherence 37–55).

2.4. Phenol Explorer Database

The calculation of mean polyphenols intake per day from each food was determined based on the frequency and the quantity consumed each time, by using the Phenol Explorer Database on polyphenol content in foods (http://phenol-explorer.eu, accessed on 1 March 2019). The data from total polyphenols in the database was expressed as total phenolics, which was determined by using the Folin–Cioacalteau assay. Phenol Explorer is a comprehensive database for natural polyphenols including food synthesis, processing, and humans' polyphenol metabolites. The database contains a total of 459 foods, which are classified into 9 categories and 67 sub-categories. During the calculation of the total polyphenol content from each food, the seasonality of the fruits and vegetables was considered, as they are consumed in a specific season in the year, so the participants declared the consumption only for this specific period.

2.5. Anthropometric Characteristics

Body Mass Index (BMI), body fat and water content, muscle mass, and bone mass were measured with body analyzers, TANITA BC-545 N and TANITA SC-330 P. The analyzers are based on Bioelectrical Impendence Analysis (BIA). The electrode sites were cleaned with an alcohol swab, participants removed their shoes and their socks, and they had not consumed large amounts of water or food for at least two hours before the measurements. Furthermore, they had not exercised vigorously before the procedure. Height was evaluated using an audiometer (Gima Tape Height Measure), while the waist-to-hip ratio was measured using a measuring tape. BMI classification was carried out according to WHO [42]. Specifically, participants were considered underweight when BMI < 18.5, overweight when BMI ≥ 25, and obese when BMI ≥ 30. Participants' body composition was classified as follows: body water 45–65 and 50–65%, body fat 22–34 and 8–22%, bone mass 2.5–4 and 3–5%, and muscle mass 63–75.5 and 75–89%, for women and men, respectively [43].

2.6. Statistical Analysis

Statistical analysis was performed by using the SPPS VER. 22 Statistical Package. This program provides information about both the intensity and the nature of the relationship between specific variables. Initially, data grouping was performed and then frequency distribution (frequencies) was carried out by using descriptive statistics. The continuous variables (BMI, body fat, body water, muscle tissue, bone mass, and waist-to-hip ratio) were tested for normality using the Kolmogorov–Smirnov test and were following a normal distribution. Analysis of variance (one-way ANOVA, Bonferroni post hoc analysis) was performed to evaluate the possible relationship between categorical variables (frequency of consumption of foods rich in polyphenols, grouped polyphenols intake, and grouped Med Diet Score) and continuous variables (BMI, body fat, muscle tissue, etc.). Differences were considered significant at $p < 0.05$ and F > 1, coefficient interval 95%.

3. Results

Table 1 presents the general socio-demographic characteristics of the participants. A total of 250 participants were recruited to the study, while 244 completed the study, specifically 145 women (59.43%) and 99 men (40.57%). Of the participants, 75.41% were aged between 18–35 years old, 54.30% came from Lemnos Island (Northern Greece), while 44.70% were from central Greece (Athens, Chalkida). No statistically significant difference was observed in mean polyphenol intake between the two genders (p = 0.324) and between different ages (p = 0.965).

Table 1. General socio-demographic characteristics of the participants.

Sample Characteristics		Participants' Percent
Age	18–35	75.41%
	36–46	11.07%
	47–57	9.84%
	58–70	3.69%
Living Area	Athens	14.49%
	Chalkida	31.26%
	Lemnos island	54.32%

The mean daily intake of polyphenols is estimated at 1905 mg. Table 2 presents the percentage of mean daily polyphenol intake in mg per day. Most of the participants (40.63%) were consuming 1000–2000 mg polyphenols per day, while 33.93% > 2000 mg and 25.45% below 1000 mg.

Table 2. Mean daily polyphenols intake and Mediterranean diet adherence of the participants.

Polyphenols' Consumption and Med Diet Score		Participants' Percent
Polyphenol Consumption Per Day	<1000 mg (low)	25.45%
	1000–2000 mg (moderate)	40.63%
	>2000 mg (high)	33.93%
Adherence to the Mediterranean Diet (Med Diet Score)	(0–20) Low	4.17%
	(21–35) Medium	82.00%
	(36–55) High	14.00%

Table 2 also presents the degree of Mediterranean diet adherence. Only 14.00% of the participants had high adherence to the Mediterranean diet, while most of them (82.00%) appeared moderate, and 4.17% had low adherence.

Table 3 present the association of anthropometric indices with low, moderate, or high polyphenol intake. Participants who were consuming low intakes of polyphenols (<1000 mg) appeared to have significantly increased body water content, in comparison with participants with high intakes (>2000 mg) (p = 0.024). Moderate polyphenols' intake (1000–2000 mg) was associated with significantly reduced waist-to-hip circumference, compared with low polyphenols' intake (p = 0.027). Furthermore, moderate adherence to the Mediterranean diet, correlated with significantly higher polyphenols intake in comparison with low adherence (p = 0.016).

Table 3. Association between polyphenols intake and Med Diet Score and body composition.

Body Composition	Categorized Polyphenols Low/Moderate/High Consumption *	Med Diet Score Low/Moderate/High Adherence **
Body Fat	-	-
Muscle Mass	-	-
Body Water	Low–High: p = 0.024	-
BMI	-	Low–Moderate: 0.021 High–Low: 0.017
BMR	-	Low–Moderate: 0.003 High–Low: 0.005
Bone Mass	-	-
Body Weight	-	-
Waist Circumference	-	Low–Moderate: 0.019 High–Low: 0.020
Hip Circumference	-	-
Waist/Hip Ratio	Low–Moderate: p = 0.027	Low–Moderate: 0.032 High–Low: 0.004
Med Diet Score	Low–Moderate: p = 0.016	-

* Polyphenol consumption per day: Low < 1000 mg, Moderate 1000–2000 mg, High > 2000 mg; ** adherence to the Mediterranean diet: 0–20 Low, 21–35 Medium, 36–55 High.

Table 3 also presents the association of anthropometric indices with low, moderate, or high Mediterranean diet adherence. Participants who had moderate or high adherence to the Mediterranean diet appeared to have a significantly decreased ratio of waist circumference and hip circumference (p = 0.032, p = 0.004). Higher Med Diet Score was also significantly correlated with reduced Body Mass Index (Low- Moderate: p = 0.021 High-Low: p = 0.017) and Basal Metabolic Rate (Low- Moderate: p = 0.003, High-Low: p = 0.005).

Table 4 presents associations between the consumption of specific foods rich in polyphenols with anthropometric indices. Specifically, increased tomato and sour cherry consumption was correlated with decreased body fat (p = 0.0222, p = 0.024). Increased red wine and sour cherry consumption were associated with decreased BMI (p = 0.003, p = 0.018). Waist circumference was significantly decreased after higher consumption of carrot, dark chocolate, and cocoa powder (p = 0.022, p = 0.003, p = 0.022), rather than lower consumption. Hip circumference was significantly decreased after higher consumption of red wine, strawberry, carrot, red pepper, and black tea (p = 0.03, p = 0.011, p = 0.015, p = 0.02, p = 0.009), rather than lower consumption. Other foods and beverages evaluated, totaling 109, showed no statistically significant differences, including a variety of fruits, vegetables, herbs, wild greens, olive oil, oils, coffee, and many others.

Table 4. Association among the consumption foods rich in polyphenols with anthropometric indices.

Food Rich in Polyphenols/Body Composition	Body Fat	Muscle Mass	Body Water	BMI	BMR	Waist Circumference	Hip Circumference	Bone Mass
Red wine	-	-	-	0.003	-	-	0.030	-
Tomato	0.022	-	-	-	-	-	-	-
Sour cherry	0.024	-	-	0.018	-	-	-	-
Strawberry	-	-	-	-	-	-	0.011	
Carrot	-	-	-	-	-	0.022	0.015	-
Red pepper	-	-	-	-	-	-	0.020	-
Dark chocolate	-	-	-	-	-	0.003	-	-
Cocoa powder	-	-	-	-	-	0.022	-	-
Black tea	-	-	-	_	-	-	0.009	-

The values in the cells represent pv < 0.05 from ANOVA Bonferroni analysis, from associations with F > 1. The table presents negative associations in anthropometric indicators with statistically significant differences between higher and lower consumption of each food.

4. Discussion

Dietary polyphenols have been studied for their potential beneficial effect on human health and disease prevention [2,3,8–14,44–47]. Nevertheless, their bioactivity is dependent on their bioavailability, which differs in the various polyphenol subcategories [15–17]. For this reason, recommendations for polyphenol intake have not yet been established [2,44]. According to epidemiological studies which aimed to investigate polyphenols intake, an approximate mean intake of about 900 mg/day has been proposed. However, further investigation is strongly recommended for improved dietary polyphenols assessment methods, standardized and validated analytical procedures, implementation of food databases containing polyphenol subcategories, and validation of specific biomarkers that are affected by polyphenols [44].

The first result of the present study was that the mean daily polyphenols intake of the Greek participants was 1905 mg, while most of the participants had moderate or high polyphenols intake (1000–2000 or > 2000 mg/day). Our study is one of the first that could contribute to progress in the investigation of polyphenols consumption in the Greek population. Nevertheless, the results cannot be representative of the Greek population due to the small sample size (n = 244) and given the fact that 75% of the subjects belong to the age group 18–35. These results are in accordance with other studies that investigated the mean polyphenols intake in different countries, using FFQ or 24 h-recall and polyphenols databases, such as Phenol Explorer [16–19]. However, we must emphasize that in other studies, results are obtained with a much larger number of subjects involved. Perez-Jimenez et al. estimated the mean polyphenols consumption in 4492 men and women in France to be 1193 ± 510 mg/d, with hydroxycinnamic acid esters and proanthocyanidins being the most consumed polyphenols [17]. In Poland, Grosso et al. estimated in 10,447 participants of the HAPPIE study an average of 1756.5 ± 695.8 mg polyphenols consumption per day, with an increased amount of coffee, cocoa, and tea polyphenols [19]. Nevertheless, in the PREDIMED study, a multicenter, randomized, and controlled trial, the mean total polyphenols in 7200 Spanish participants were estimated to have lower values, specifically 820 ± 323 mg per day, with hydroxycinnamic acids having the highest consumption and 5-caffeoylquinic acid being the highest ingested individual polyphenol [18].

The second finding of the present study was that increased polyphenols intake was associated with higher adherence to the Mediterranean diet (increased Med Diet Score). This represents an expected and predictable result, given the fact that several studies have shown that the Mediterranean diet is correlated with an increase in polyphenols intake [29,30,45,46]. The Mediterranean diet is proposed as a balanced, nutritional model with a possible protective effect on human health, and is characterized by increased consumption of fruits, vegetables, olive oil, cereals, and fish and decreased consumption of meat, sugar, and saturated fatty acids. The possible effect of this diet on disease pathophysiology has been studied by evaluating the whole nutrients and phytochemicals, that contain polyphenols, and are attributed to their synergistic actions [20–28,48,49]. Polyphenols are basic phytochemicals of fruits, vegetables, herbs, greens, coffee, olive oil, nuts, wine, and a plethora of Mediterranean diets' traditional functional foods [3,23–25]. Several studies have also correlated polyphenols intake with Mediterranean diet adoption. In the PREDIMED study, the increase in polyphenols intake from a Mediterranean diet was associated with decreased inflammatory biomarkers and improved cardiovascular risk factors [29]. Godos et al., in 1937 adults from southern Italy, observed that the intake of polyphenols was higher in individuals more adherent to the Mediterranean diet. Specific subclasses, such as lignans, anthocyanins, and flavanones, had a linear positive association with higher adherence to the Mediterranean diet, while others had a non-linear association [30]. Sera-Majem et al. concluded that the possible effect of the Mediterranean diet on human health depends on multifactorial procedures, including human genetic variations and food composition differences [29]; so, the exact correlation of polyphenols intake from the Mediterranean diet with human health is difficult to be determined.

An important result of the present study was that high adherence to the Mediterranean diet was correlated with decreased BMI, waist circumference, and waist-to-hip ratio, and in parallel, high polyphenols intake was correlated with decreased waist-to-hip ratio. These results are highly underlined due to the lack of enough data from similar studies. In last few years, there has been a need to develop nutritional policies aimed at prevention of obesity and metabolic syndrome. Polyphenols, as major bioactive compounds of the Mediterranean diet, have been studied as possible factors that may positively affect plasma lipids, insulin resistance, diabetes mellitus, inflammatory progress, weight gain, and body mass index, as well as waist-to-hip ratio [8,29,46,47]. The Mediterranean diet is emerging as a key strategy for improving metabolic biomarkers, as several studies have concluded that Mediterranean diet adherence is related to a decreased risk of obesity, cardiovascular diseases, diabetes mellitus, osteoporosis, and hypertension [36,38,41,48–53]. The results of the present study indicate a possible synergistic effect of Mediterranean diets' bioactive compounds, including polyphenols, on body composition. The possible studied mechanisms of Mediterranean diet bioactive compounds and especially polyphenols for the prevention of metabolic diseases include free radicals scavenging and oxidative stress reduction, decrease in LDL and total cholesterol, postprandial control of glucose levels, attenuation of insulin resistance, enhancement of saturation, stimulation of thermogenesis and fatty acids oxidation, etc. [21,52,53].

Another result of high importance, due to the lack of relevant studies with similar correlations, was that specific foods from the Mediterranean diet, such as red wine, tomato, sour cherry, strawberry, carrot, and red pepper, as well as cocoa and black tea, were correlated with improved anthropometric characteristics (BMI, body fat, and circumferences). A plethora of traditional functional foods from the Mediterranean diet have been studied for their potential effect on body composition, BMI, and circumferences, as well as biochemical biomarkers [39,50,51]. In a recent pilot interventional study, fortification of a spread cheese with polyphenols from mountain tea increased the postprandial total antioxidant capacity in healthy adults [52]. In another retrospective study, the daily consumption of fiber-rich foods from 301 young Greek adults was correlated with reduced BMI, body fat, and waist-to-hip ratio, while low-fat foods showed a negative association with body fat and body water. Furthermore, participants who consumed pomegranate, a common Mediterranean fruit, had a lower BMI than those who did not, whereas oat eating was linked to lower body fat and higher body water, and chocolate consumption was linked to lower BMI and increased body water [39]. This study is in accordance with the present study, in which cocoa and dark chocolate consumption was associated with reduced waist circumference.

In parallel, our study observed that black tea consumption was correlated with decreased hip circumference. Tea, both green and black, is one of the richest beverages in polyphenols and appears to have strong antioxidant activity [8,10]. Several studies have shown that tea may affect anthropometric indices. Bohn et al. concluded in a randomized controlled, double-blind study with 111 participants that regular ingestion of black tea over 3 months inhibited weight gain and reduced waist circumference and waist-to-hip ratio [54]. Tea polyphenols may have a positive effect on obesity attenuation, due to their involvement in specific mechanisms, such as inhibition of digestion, absorption, and uptake of lipids and sugars, thus reducing calorie intake, promotion of lipid metabolism by activating AMP-activated protein kinase, attenuation of lipogenesis and enhancement of lipolysis, and reduction in lipid accumulation by inhibiting lipids differentiation and proliferation, as well as reduction in oxidative stress [21]. In the present study, sour cherry was correlated with reduced BMI and body fat, while strawberries were correlated with waist circumference. Several studies have shown the possible effect of berries on metabolic biomarkers. However, the studies about their effect on weight control are limited. More interventional and prospective studies are required on a larger number of individuals to get definite results about the effect of berries on weight management [21]. In a recent review study, the authors proposed a positive relationship between anthocyanin supplementation and anti-obesity effects [55]. Besides, anthocyanins from berries, red wine, and other Mediterranean fruits have been correlated with a possible protective effect on cardiovascular biomarkers [3]. Our study also showed that tomatoes correlated with decreased body fat, while carrots and red peppers were correlated with reduced circumferences. Specific carotenoids, such as lycopene of tomatoes and beta carotene of carrots, may restrain adipogenesis and adipocyte hypertrophy, while enhancing fat oxidation and energy expenditure in adipocytes, attenuating obesity in both animal and human studies. Nevertheless, more clinical, interventional studies should be conducted for clearer conclusions [56]. Furthermore, polyphenols and capsaicin from red pepper may induce thermogenesis and promote fat oxidation [21]. Finally, we should underline that other foods of the Mediterranean diet, rich in polyphenols, that have been correlated with improved metabolic biomarkers, such as olive oil, olives, nuts, herbs, and greens [3,21], were not associated with anthropometric indices in the present study. Further research is required for the investigation of the involvement of a variety of traditional Mediterranean foods on body composition.

It should be noted that the present study shows some limitations and has several weaknesses in specific points. Initially, the range of the participants' age is wide, as most of the participants are aged between 18 and 35 years old. In addition, this is a retrospective study, so the results should be confirmed by larger epidemiological prospective studies. An extra limitation is the limited sample number and the requirement of participants only from the Northern and central regions of Greece. Additionally, the semi-quantitative questionnaire used may lead to sub- or over-estimation of mean polyphenols intake. To draw more secure and reliable conclusions on polyphenols intake and its relationship with Mediterranean diet adherence and anthropometric indices in the Greek population, larger epidemiological and interventional studies with a wider population sample from various Greek locales, both urban and rural, should be performed.

5. Conclusions

The present study was performed on the Greek population and estimated the mean polyphenols intake in a subgroup of mainly young adults at 1905 mg, while most of the participants appeared to have moderate polyphenols consumption last year. In parallel, the higher adoption of the Mediterranean diet was associated with increased polyphenols intake, while increased polyphenols intake and Mediterranean diet adherence were correlated with reduced waist-to-hip ratio. Correlations were observed among some traditional functional foods rich in polyphenols and specific anthropometric indices, increasing the importance of further investigating the possible beneficial effect of these foods on metabolic diseases. However, further research should be performed in a larger sample of the Greek population, and especially more interventional and epidemiological studies, to draw clearer conclusions and to investigate the exact mechanisms by which polyphenols may affect the pathophysiology of metabolic diseases.

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