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ASSOCIATION BETWEEN TOTAL POLYPHENOL INTAKE AND BODY COMPOSITION MARKERS: A POPULATION-BASED STUDY

ASSOCIAÇÃO ENTRE A INGESTÃO DE POLIFENÓIS TOTAIS E MARCADORES DE COMPOSIÇÃO CORPORAL: UM ESTUDO DE BASE POPULACIONAL

ASOCIACIÓN ENTRE LA INGESTA TOTAL DE POLIFENOLES Y LOS MARCADORES DE COMPOSICIÓN CORPORAL: UN ESTUDIO POBLACIONAL

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ABSTRACT

Objective: This study aimed to evaluate the association between total and class-specific polyphenol intake and body composition markers. Methods: A cross-sectional, population-based household study was conducted with 490 individuals aged ≥ 20 years. Demographic, socioeconomic, lifestyle, dietary (24-hour dietary recall [24HR]), and anthropometric data were collected. Polyphenol intake was estimated based on the 24HR data and the Phenol-Explorer database. The association between tertiles of total and subclass polyphenol intake and body composition markers was assessed using linear regression models adjusted for potential confounders, with a 95% confidence interval. Results: The mean energy-adjusted total polyphenol intake was 873.87 ± 1086.37 mg/day. Higher consumption (2nd and 3rd tertiles) of total polyphenols, flavonoids, flavonols, and other polyphenols was inversely associated with anthropometric markers such as waist-to-height ratio (WHtR; β = –0.01; p = 0.04), triceps skinfold thickness (TSF; β = –2.98; p = 0.02) and subscapular skinfold thickness (SSF; β = –3.11; p < 0.01). Conclusion: These findings suggest that higher polyphenol intake may exert beneficial effects on the reduction of body adiposity, thereby contributing to the prevention and/or treatment of obesity in adults and older adults.

KEYWORDS: *Polyphenols. Body composition. Dietary intake. Adults. Aged.*

RESUMO

Objetivo: Este estudo tem como objetivo avaliar a associação da ingestão de polifenóis totais e de suas classes com marcadores de composição corporal. Métodos: Um estudo transversal, domiciliar e populacional foi conduzido com 490 indivíduos com idade ≥ 20 anos. Foram coletados dados demográficos, socioeconômicos, estilo de vida, consumo alimentar (Recordatório de 24 horas [R24h]) e antropométricos. A estimativa da ingestão de polifenóis foi realizada a partir dos R24h e da base de dados Phenol-Explorer. A associação dos tercis de ingestão de polifenóis totais e de subclasses com os marcadores de composição corporal foi realizada por meio de Regressão Linear, ajustada para potenciais fatores de confusão, com intervalo de confiança de 95%. Resultados: A média de ingestão total de polifenóis ajustada pela energia foi de 873,87 ± 1086,37 mg/dia.

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O maior consumo (2º e 3º tercis) de polifenóis totais, flavonoides, flavonóis e outros polifenóis esteve inversamente associado a marcadores antropométricos, como razão cintura/estatura (RCE; β = –0,01; p = 0,04), dobra cutânea tricipital (DCT; β = –2,98; p = 0,02) e dobra cutânea subescapular (DCSE; β = –3,11; p < 0,01). Conclusão: Esses achados sugerem que o maior consumo de polifenóis pode exercer efeito benéfico na redução da adiposidade corporal, contribuindo para a prevenção e/ou tratamento da obesidade em adultos e idosos.

PALAVRAS-CHAVE: Polifenóis. Composição corporal. Ingestão dietética. Adulto. Idoso.

RESUMEN

Objetivo: Este estudio tiene como objetivo evaluar la asociación de la ingesta de polifenoles totales y de sus clases con marcadores de composición corporal. Métodos: Se realizó un estudio transversal, de hogares y de base poblacional con 490 individuos de ≥ 20 años. Se recopilaron datos demográficos, socioeconómicos, de estilo de vida, de ingesta dietética (recuerdo de 24 horas [24hR]) y antropométricos. La ingesta de polifenoles se estimó a partir del 24hR y la base de datos Phenol-Explorer. La asociación de los terciles de ingesta de polifenoles totales y de subclases con marcadores de composición corporal se realizó utilizando regresión lineal, ajustada por posibles factores de confusión, con un intervalo de confianza del 95%. Resultados: La ingesta media total de polifenoles ajustada por energía fue de 873,87 ± 1086,37 mg/día. El mayor consumo (terciles 2 y 3) de polifenoles totales, flavonoides, flavonoles y otros polifenoles se asoció inversamente con marcadores antropométricos como la relación cintura-estatura (RCE; β = –0,01; p = 0,04), el pliegue cutáneo del tríceps (PCT; β = –2,98; p = 0,02) y el pliegue cutáneo subescapular (PCSE; β = –3,11; p < 0,01). Conclusión: Estos hallazgos sugieren que un mayor consumo de polifenoles puede tener un efecto beneficioso en la reducción de la adiposidad corporal, contribuyendo a la prevención y/o el tratamiento de la obesidad en adultos y ancianos.

***PALABRAS CLAVE**: Polifenoles. Composición corporal. Ingesta dietética. Adulto. Anciano.*

1. INTRODUCTION

Obesity is a disease that results from the abnormal or excessive accumulation of adipose tissue, which may be detrimental to health. It is recognized as one of the most important risk factors for the development of chronic noncommunicable diseases (NCDs), such as diabetes mellitus, cardiovascular diseases, and hypertension. The World Health Organization (WHO) classifies obesity as a global epidemic and one of the greatest public health challenges of the 21st century, as it is estimated that more than 1.9 billion adults worldwide are overweight, of whom 650 million are obese. This condition is characterized by low-grade inflammation and represents one of the leading causes of mortality worldwide[1,2].

Body composition can be influenced by multiple factors, including behavioral, environmental, genetic, and lifestyle-related determinants. Among these, diet plays a central role. Diets rich in fruits and vegetables have been consistently associated with favorable health outcomes and may contribute to better body composition profiles. Besides being important sources of essential vitamins, minerals and dietary fiber, fruits and vegetables are also rich in

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bioactive compounds, particularly polyphenols, which have received increasing attention due to their role in maintaining health and preventing noncommunicable diseases (NCDs)[3,4].

Polyphenols are secondary plant metabolites that function as a defense mechanism through the activation of the antioxidant system, promoting the upregulation of various endogenous antioxidants and effectively scavenging excess free radicals. In addition to their antioxidant activity, they also exhibit a range of biological functions, including anti-inflammatory, immunomodulatory, and anticancer properties[5,6].

Polyphenols may influence body composition through multiple biological mechanisms, including modulation of adipogenesis, improvement of mitochondrial function, regulation of lipid metabolism, and reduction of chronic low-grade inflammation. They can inhibit adipocyte differentiation and stimulate lipolysis through pathways involving AMPK activation, reduced oxidative stress, and improved insulin signaling. These mechanisms provide a plausible physiological basis for investigating associations between dietary polyphenol intake and markers of adiposity in population-based studies[5,7,8].

Therefore, the present study aimed to evaluate the association between total and class-specific polyphenol intake and body composition markers in a population of adults and older adults residing in a city in northeastern Brazil.

2. METHODOLOGY

Study design and participants

This was a cross-sectional, population-based study, using data from the *Inquérito de Saúde Domiciliar – Piauí* (Piauí Household Health Survey, ISAD-PI) (2018–2019), which aimed to assess the living conditions and health status of the population through household visits conducted in urban areas of the municipalities of Teresina and Picos, in the state of Piauí, Brazil[9].

The present study included adult participants aged 20–59 years and older adults aged ≥60 years, residing in private households in Teresina, Piauí, who agreed to participate after receiving full information about the study and its ethical procedures. Individuals with any disability or impairment that hindered the completion of the questionnaire or anthropometric assessment were excluded[9].

Data were collected on demographic variables (age and sex), socioeconomic variables (income and education), lifestyle factors (alcohol consumption, smoking, and physical activity), dietary intake, and anthropometric measurements.

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Sample size

Sampling for the ISAD-PI was a complex probabilistic design, using a two-stage cluster sampling method: census tract and household, according to data from the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics, IBGE). Population stratification by age group was considered to ensure adequate representation of adults and older adults[9,10].

Following the same sampling plan, 50% of the households were selected to form a subsample for dietary intake data collection through 24-hour dietary recalls (24HR). The 24HR interviews were conducted in a second data collection stage. For this purpose, 50% of the households randomly selected in each census tract were systematically chosen to form another subsample. After data collection, the final sample comprised 497 households in Teresina, and the subsample used in the present study consisted of 248 households. Adults and older adults residing in these households were invited to participate in the dietary assessment, and a total of 490 individuals agreed to take part and completed the 24HR[9].

For a more detailed description of the sampling procedures, sample size, and variable collection methods used in ISAD-PI, further information is available in the study by Rodrigues *et al.*[9].

Dietary intake assessment

Data on the participants' dietary intake were obtained through the application of 24-hour dietary recalls (24HR), which were conducted following the guidelines of the Multiple Pass Method[11]. A second 24HR was applied to 40% of the population, with a two-month interval, with the objective of correcting the within-person variability[12].

Quantification of the 24HR data was performed to convert household measures of foods and preparations into grams or milliliters[13]. Estimated energy intake was also analyzed[14,15,16] based on the procedures described by Pinheiro *et al.*[13].

Estimated polyphenol intake

The estimation of polyphenol intake was performed using data from the Phenol-Explorer database, available at http://phenol-explorer.eu/, including flavonoids, phenolic acids, stilbenes, lignans, and other polyphenols[17,18]. Data not available in the consulted database were obtained through searches in other scientific databases, including Web of Science and MEDLINE/PubMed, following the method utilized by the Phenol-Explorer.

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Individual polyphenol intake was calculated by multiplying the daily intake of each food item by the polyphenol content corresponding to that food. Finally, the total intake was determined by summing the individual polyphenol intakes.

Anthropometric assessment

Researchers were standardized for the assessment of anthropometric measurements through training conducted by the *Laboratório de Avaliação Nutricional de Populações do Departamento de Nutrição da Universidade de São Paulo* (Laboratory of Nutritional Assessment of Populations of the Department of Nutrition at the University of São Paulo) [9,19]. Weight was measured using an electronic scale with a precision of 100 g, and height was measured with a portable stadiometer with a precision of 0.1 cm. Body mass index (BMI) was calculated as weight divided by height squared (kg/m²)[20,21].

Waist circumference (WC) was measured at the mid-axillary line, at the midpoint between the lowest rib and the iliac crest, using a non-extensible measuring tape with a precision of 0.1 cm[19,22]. The waist-to-height ratio (WHtR) was calculated as the ratio of waist circumference (WC), in centimeters, to height, in centimeters[19,23].

Arm circumference (AC) was measured at the midpoint between the acromion and olecranon processes[19,24]. Triceps (TSF) and subscapular (SSF) skinfold thicknesses were measured using a calibrated Lange® caliper with an accuracy of 0.1 mm. SSF was measured only in adults[19,23].

Statistical analysis

For variables with missing values, data imputation was performed using the Predictive Mean Matching method, with the percentage of imputed data not exceeding 20%. Data were not weighted, given that the probability of sample selection was equiprobabilistic.

Analyses were performed using Stata software, version 13.0, employing the survey mode to account for the complex sampling design of the study. Model assumptions were evaluated prior to analysis, including assessment of residual normality by graphical inspection and the Shapiro–Wilk test. The final value was expressed per 1,000 kcal/day to adjust for total dietary energy intake. Continuous variables were expressed as means, and categorical variables as absolute and relative frequencies.

Bivariate comparisons between independent groups were conducted using the Mann–Whitney test (two groups). The association between tertiles of total and subclass polyphenol intake and body composition markers was assessed using linear regression analysis. All variables

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were analyzed in their continuous form, with no categorization applied in the analytical models. Results were expressed as β coefficients and 95% confidence intervals (95% CI), adjusted for age, sex, education level, alcohol consumption, smoking, physical activity, and energy intake (kcal). The level of significance adopted was 5% ($p < 0.05$).

Ethical aspects

This study was reviewed and approved by the Research Ethics Committee of the Federal University of Piauí (UFPI), as well as by the Municipal Health Foundation and the Municipal Health Department of the city of Teresina, Piauí, under protocol number 2.552.426, in accordance with Resolution 466/2012[25].

3. RESULTS

The analyses of the relationship between total polyphenol intake and socioeconomic, demographic, and lifestyle characteristics are presented in Table 1.

Table 1. Total polyphenol intake (mg/day) according to study variables (N = 490)

Variables	N	%	Mean ± SD	Median	IQR	*p*-value
Age (Years)						0.14
20 - 59	362	73.9	787.76 ± 780.12	559.09	170.32-1198.34	
≥ 60	128	26.1	1117.40 ± 1653.30	587.17	287.91-1373.12	
Sex						0.31
Male	163	33.3	934.10±1097.13	583.00	187.77-1325.26	
Female	327	66.7	843.84±1081.40	557.21	188.42-1185.19	
Household income*						0.05
< 2 MW	374	76.3	833.86±995.33	535.51	172.05-1198.34	
> 2 MW	116	23.7	873.87±1086.37	566.91	188.42-1214.35	
Education level						**<0.01**
Illiterate	29	5.9	775.26±754.25[a]	583.54	290.16-962.32	
Primary education	149	30.4	1118.81±1473.60[ab]	824.67	352.85-1401.48	
Secondary education	201	41	850.72±930.02[ac]	575.32	174.55-1240.47	
Higher education	111	22.7	615.19±679.87[ad]	377.07	102.46-923.04	
Alcohol consumption						0.76
No	294	60	918.48±1251.90	560.78	232.68-1198.34	
Yes	196	40	808.67±777.84	575.32	171.32-1310.79	
Smoking						0.22

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No	382	78	821.39±876.05	538.17	172.05-1208.15	
Yes	108	22	1063.97±1624.44	647.39	315.08-1263.49	
Physical activity						0.21
No	96	19.6	1061.89±1489.12	619.08	256.08-1377.36	
Yes	394	80.4	828.06±960.07	559.09	184.07-1196.46	

*Reference minimum wage (MW) equivalent to R$998.00, based on the year 2019. SD: Standard deviation. IQR: Interquartile range. Mann–Whitney test. Equal letters indicate no significant differences; different letters indicate statistically significant differences between means. Data adjusted for 1,000 kcal/day.

A total of 490 individuals participated in the study, of whom 73.9% were aged 20–59 years and 26.1% were aged ≥60 years. The majority were female (66.7%). A significant difference was observed in total polyphenol intake according to education level ($p < 0.01$). Individuals with primary education showed a higher mean intake (1118.81 ± 1473.60 mg/day), whereas those with secondary education (850.72 ± 930.02 mg/day) and higher education (615.19 ± 679.87 mg/day) had lower mean intakes (Table 1).

When total polyphenol intake was analyzed according to food groups and age group, a significant difference was found only for fruit consumption ($p = 0.02$), with higher intake among older adults (128.05 ± 235.42 mg/day) compared with adults (80.16 ± 182.63 mg/day) (**Table 2**).

Table 2. Total polyphenol intake (mg/day) according to age group and food groups.

Variables	**Total Polyphenol Intake**			
	Adults (N = 362)	**Older adults (N= 128)**	**Total (N=490)**	
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	***p*-value**
Alcoholic beverages	3.75±30.96	0.57±6.44	2.93±26.85	0.37
Non-alcoholic beverages	19.32±125.54	6.64±44.95	16.01±110.41	0.61
Fruits	80.16±182.63[a]	128.05±235.42[b]	92.67±198.65	**0.02**
Vegetables	22.51±67.31	31.65±81.23	24.89±71.24	0.49
Cereals	224.32±423.82	287.95±589.73	240.94±472.98	0.62
Cocoa and Chocolate	3.66±32.07	0.00±0.00	2.71±27.60	0.09

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Seeds	430.99±648.98	661.49±1585.82	491.20±987.08	0.38
Oils and seasonings	3.04±31.56	1.05±8.21	2.52±27.45	0.31

SD: Standard Deviation. Mann-Whitney test. Equal letters do not differ statistically. Different letters indicate a significant difference between means. Analysis adjusted for 1,000 kcal/day.

The intake of total polyphenols and subclasses among adults and older adults is shown in Table 3. The total polyphenol intake, after energy adjustment, was 873.87 ± 1086.37 mg/day. The flavonol intake was significantly higher among older adults compared with adults (10.00 ± 22.06 mg/day vs. 8.81 ± 26.87 mg/day; p = 0.03, respectively).

Table 3. Intake of total polyphenols, flavonoids, flavonols, flavones, flavanones, flavanols, and other polyphenols (mg/day) by age group

Variables	**Total Polyphenol Intake**			
	Adults (N = 362)	**Older adults (N= 128)**	**Total (N=490)**	
	Mean ± SD	**Mean ± SD**	**Mean ± SD**	***p*-value**
Total polyphenols	787.76± 780.12	1117.40± 1653.30	873.87± 1086.37	0.14
Flavonoids	70.08±94.34	82.59± 133.11	73.35± 105.84	0.22
Flavonols	53.39±76.62	63.99± 122.30	56.16±90.78	0.68
Flavones	0.82±5.39	0.71±1.90	0.79± 4.73	0.65
Flavanones	7.06± 28.52	7.89± 27.67	7.28± 28.27	0.73
Flavanols	8.81± 26.87	10.00± 22.06	9.12±25.69	**0.03**
Other polyphenols	240.52±324.08	269.90±522.38	248.20±385.45	0.98

SD: Standard Deviation. Mann-Whitney test. Equal letters do not differ statistically. Different letters indicate a significant difference between means. Analysis adjusted for 1,000 kcal/day.

Table 4 presents the association between tertiles of total polyphenol and subclass intake with body composition markers in adults and older adults. In the linear regression analysis, total polyphenol intake showed no significant association (p > 0.05) with BMI, WC, or WHtR, both in the crude and adjusted analyses for potential confounding factors.

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However, when evaluating subclasses, specific associations were observed. In the crude analysis, other polyphenols showed an inverse association with waist circumference in the second tertile (β = –3.20; 95% CI: –6.35; –0.15; p = 0.04). In addition, still in the crude model, individuals in the second tertile of flavone (β = –0.02; 95% CI: –0.04; 0.00; p = 0.05) and flavanone intake (β = –0.03; 95% CI: –0.05; 0.01; p = 0.01) presented an inverse association with WHtR. Nevertheless, flavonoid intake showed an inverse association with WHtR in the second tertile (β = –0.01; 95% CI: –0.02; 0.00; p = 0.04) after adjustment (Table 4).

Table 5 describes the association between tertiles of total polyphenol and subclass intake with AC, TSF, and SSF in adults and older adults. Regarding TSF, for total polyphenol intake, the crude analysis revealed a significant inverse association between the highest tertile of intake and TSF (β = –2.47; 95% CI: –4.57; –0.37; p = 0.02). For flavonoid intake, an inverse association with TSF was observed in the second tertile in adjusted analyses (β = –2.57; 95% CI: –4.86; –0.28; p = 0.03), and similarly, in the third tertile (β = –2.98; 95% CI: –5.42; –0.54; p = 0.02). It was also observed that flavonol intake showed an inverse association with TSF in the third tertile after adjustment (β = –3.11; 95% CI: –5.98; –0.25; p = 0.03). Regarding the intake of other polyphenols, a significant inverse association was found in the third tertile (β = –2.72; 95% CI: –5.24; –0.19; p = 0.03) with TSF (Table 5).

Table 5 presents the results for SSF. After adjustment, a reduction of 3.11 mm in SSF was observed in the second tertile of total polyphenol intake (95% CI: –4.98; –1.24; p < 0.01), and a decrease of 2.17 mm in the third tertile of flavonoid intake (95% CI: –4.29; –0.05; p = 0.04). Regarding the intake of other polyphenols, after adjustment, decreases of –2.45 mm (95% CI: –4.85; –0.59; p = 0.04) and –3.16 mm (95% CI: –5.61; –0.72; p = 0.01) were found in the second and third tertiles, respectively.

Table 4. Association between tertiles of total polyphenol and subclass intake with BMI, WC, and WHtR in adults and older adults (N = 490)

	Total Polyphenol and Subclass Intake											
	BMI				WC				WHtR			
	Crude Analysis		Adjusted Analysis		Crude Analysis		Adjusted Analysis		Crude Analysis		Adjusted Analysis	
Variables	β (95% CI)	-value	β (95% CI)*	-value *	β (95% CI)	-value	β (95% CI)*	-value *	β (95% CI)	*p*-value	β (95% CI)*	-value *
Total polyphenols												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.83(-2.32-0.66)	.26	1.19(-2.62-0.24)	.10	-0.29(-3.26-2.68)	.84	-1.19(-3.86-1.46)	0.36	0.01(-0.01-0.03)	.39	-0.00(-0.02-0.01)	.60
3st Tertile	-0.31(-1.59-0.99)	.63	0.87(-2.22-0.48)	.20	1.08(-1.03-3.20)	.30	-0.97(-3.16-1.21)	0.37	0.01(-0.00-0.02)	.14	-0.00(-0.02-0.01)	.62

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Flavonoids												
1st Tertile	REF		REF		REF		REF	-	REF		REF	
2st Tertile	-0.97(-2.18-0.23)	.11	0.86(-1.94-0.21)	.11	-1.36(-3.74-1.03)	.25	-2.06(-4.44-0.32)	0.09	-0.01(-0.28-0.01)	.07	-0.01(-0.03-0.00)	**.04**
3st Tertile	-0.51(-1.80-0.77)	.42	0.81(-2.10-0.47)	.20	0.11(-2.10-2.33)	.92	-1.55(-4.03-0.94)	0.21	-0.00(-0.02-0.14)	.74	-0.01(0.02-0.00)	.20
Flavonols												
1st Tertile	REF		REF		REF		REF	-	REF		REF	
2st Tertile	-0.82(-2.49-0.84)	.32	0.49(-2.10-1.12)	.54	-2.39(-5.87-1.09)	.17	-1.92(-5.38-1.54)	0.26	-0.02(-0.04-0.00)	.08	-0.01(-0.02-0.01)	.24
3st Tertile	-1.12(-2.67-0.43)	.15	1.29(-2.86-0.29)	.10	-1.33(-4.17-1.50)	.34	-2.89(-6.05-0.26)	0.07	-0.01(-0.03-0.00)	.12	-0.02(-0.04-0.00)	.06
Flavones												
1st Tertile	REF		REF		REF		REF	-	REF		REF	
2st Tertile	-0.65(-2.18-0.87)	.39	0.31(-1.80-1.18)	.67	-3.16(6.40-0.08)	.05	-1.43(-4.64-1.78)	0.37	-0.02(-0.04-0.00)	.05	-0.01(-0.03-0.01)	.31
3st Tertile	-0.27(-1.43-0.88)	.63	0.21(-1.31-0.89)	.70	-2.21(-4.80-0.37)	.09	-1.47(-3.75-0.82)	0.20	-0.01(-0.03-0.00)	.14	-0.01(-0.02-0.00)	.06
Flavanones												
1st Tertile	REF		REF		REF		REF	-	REF		REF	
2st Tertile	-1.74(-3.67-0.19)	.07	1.06(-3.24-1.13)	.33	-2.46(-6.46-1.53)	.22	-0.85(-5.87-4.16)	0.73	-0.03(-0.05-0.01)	**.01**	-0.01(-0.03-0.02)	.53
3st Tertile	-0.03(-1.15-1.08)	.95	0.09(-1.07-1.13)	.99	-0.65(-3.26-1.95)	.61	0.20(-1.84-2.24)	0.84	-0.00(-0.02-0.01)	.68	-0.00(-0.01-0.01)	.63
Flavanols												
1st Tertile	REF		REF		REF		REF	-	REF		REF	
2st Tertile	-0.78(-2.15-0.59)	.25	0.67(-2.01-0.67)	.31	0.38(-1.97-2.75)	.74	-0.38(-3.95-2.73)	0.80	0.00(-0.01-0.08)	.77	-0.00(-0.02-0.01)	.73
3st Tertile	0.00(-1.36-1.36)	.99	0.11(-1.46-1.23)	.86	1.930.45-4.32)	.11	0.05(-2.71-2.80)	0.97	0.01(-0.01-0.03)	.18	-0.00(-0.02-0.01)	.96
Other polyphenols												
1st Tertile	REF		REF						REF		REF	
2st Tertile	-0.88(-2.40-0.64)	.24	0.71(-2.24-0.81)	.34	-3.20(-6.25- -0.15)	**.04**	-2.16(-4.87-0.54)	0.11	-0.17(-0.03-0.00)	.05	-0.01(-0.03-0.00)	.07
3st Tertile	-0.81(-2.26-0.64)	.26	1.14(-2.63-0.35)	.13	-1.24(-3.89-1.40)	.34	-2.33(-5.25-0.58)	0.11	-0.01(-0.03-0.06)	.19	-0.01(-0.03-0.00)	.09

ISAD-PI-CAPITAL: Health Survey of Piauí – Capital. CI: Confidence Interval. BMI: Body Mass Index; WC: Waist Circumference; WHtR: Waist-to-Height Ratio. Linear Regression Model. *Adjusted for age, sex, education level, alcohol consumption, smoking and physical activity. Analysis adjusted for 1,000 kcal/day.

Table 5. Association between tertiles of total polyphenol and subclass intake with AC, TSF, and SSF in adults and older adults (N = 490)

	Total Polyphenol and Subclass Intake											
	AC				**TSF**				**SSF**			
	Crude Analysis		**Adjusted Analysis**		**Crude Analysis**		**Adjusted Analysis**		**Crude Analysis**		**Adjusted Analysis**	
Variables	**β (95% CI)**	***p*-value**	**β (95% CI)***	***p*-value ***	**β (95% CI)**	***p*-value**	**β (95% CI)***	***p*-value ***	**β (95% CI)**	***p*-value**	**β (95% CI)***	***p*-value ***
Total polyphenols												
1st Tertile	REF		REF		REF		REF		REF		REF	

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2st Tertile	-0.84(-2.19- 0.51)	0.21	-0.90(-2.15-0.34)	0.15	-1.77(-4.00-0.46)	0.11	-2.18(-4.53-0.16)	0.07	-2.55(-4.55- -0.55)	**0.01**	-3.11(-4.98- -1.24)	**<0.01**
3st Tertile	0.00(-1.07-1.08)	0.99	-0.33(-1.37-0.72)	0.53	-2.47(-4.57- -0.37)	**0.02**	-2.04(-4.06- -0.03)	0.05	-1.57(-3.77-0.58)	0.14	-2.03(-4.32-0.25)	0.08
Flavonoids												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.91(-1.88-0.58)	0.06	-0.97(-1.88- -0.64)	**0.04**	-3.50(-6.09- -0.91)	**0.01**	-2.57(-4.86- -0.28)	**0.03**	-2.42(-5.01-0.16)	0.06	-2.18(-4.69-0.32)	0.08
3st Tertile	-0.42(-1.39-0.55)	0.38	-0.74(-1.79-0.30)	0.15	-3.88(-6.75- -1.02)	**0.01**	-2.98(-5.42- -0.54)	**0.02**	-2.19(-4.46-0.08)	0.06	-2.17(-4.29- -0.05)	0.04
Flavonols												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.09(-2.23-0.39)	0.16	-0.87(-2.16-0.42)	0.18	-2.84(-5.56- -0.12)	**0.04**	-2.29(-4.92-0.34)	0.08	-1.07(-3.87-1.71)	0.43	-0.80(-3.43-1.83)	0.54
3st Tertile	-0.97(-2.18-0.23)	0.11	-1.30(-2.59- -0.00)	**0.05**	-4.47(-7.73- -1.21)	**<0.01**	-3.11(-5.98- -0.25)	**0.03**	-2.13(-4.62-0.35)	0.09	-1.94(-4.34- 0.45)	0.11
Flavones												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.09(-1.51-1.33)	0.90	0.07(-1.47-1.62)	0.92	-0.49(-3.39-2.41)	0.73	-1.39(-4.43-1.65)	0.36	-0.54(-3.97-2.87)	0.75	-0.75(-4.17-2.66)	0.65
3st Tertile	-0.32(-1.37-0.72)	0.53	-0.13(-1.12-0.86)	0.79	-0.90(-3.25-1.44)	0.44	-1.86(-3.92-0.21)	0.08	-0.85(-2.63-0.93)	0.33	-1.25(-3.01-0.51)	0.15
Flavanones												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	0.09(-1.69-1.89)	0.92	0.22(-1.66-2.09)	0.81	-2.69(-5.56-0.19)	0.07	-2.13(-5.03-0.77)	0.14	-2.83(-5.78-0.11)	0.06	-1.96(-4.96-1.04)	0.19
3st Tertile	0.12(-0.79-1.04)	0.78	0.31(0.55-1.17)	0.46	-0.07(-2.18-2.04)	0.95	-1.15(-3.22-0.91)	0.26	-0.14(-2.08-1.80)	0.88	-0.61(-2.83-1.60)	0.58
Flavanols												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.52(-1.74-0.70)	0.39	-0.47(-1.66-0.72)	0.43	-2.50(-5.81-0.80)	0.13	-1.65(-4.35-1.05)	0.22	-1.91(-4.98-1.16)	0.21	-1.88(-4.91-1.15)	0.21
3st Tertile	0.28(-0.79-1.36)	0.59	0.23(-0.88-1.35)	0.67	-2.46(-5.32-0.39)	0.09	-1.30(-3.86-1.26)	0.31	-1.92(-4.34-0.49)	0.11	-2.02(-4.52-0.47)	0.11
Other polyphenols												
1st Tertile	REF		REF		REF		REF		REF		REF	
2st Tertile	-0.61(-1.82-0.61)	0.31	-0.97(-1.88- -0.06)	**0.04**	-1.67(-4.27-0.92)	0.20	-2.54(-5.08-0.00)	**0.05**	-2.12(-4.58-0.34)	0.09	-2.45(-4.85- -0.59)	**0.04**
3st Tertile	-0.55(-1.69-0.59)	0.33	-0.74(-1.79-0.30)	0.15	-3.23(-6.30- -0.27)	**0.04**	-2.72(-5.24- -0.19)	**0.03**	-2.93(-5.48- -0.39)	**0.02**	-3.16(-5.61- -0.72)	**0.01**

ISAD-PI-CAPITAL: Health Survey of Piauí – Capital. CI: Confidence Interval. AC: Arm Circumference; TSF: Triceps Skinfold; SSF: Subscapular Skinfold. Linear Regression Model. *Adjusted for age, sex, education level, alcohol consumption, smoking and physical activity. Analysis adjusted for 1,000 kcal/day.

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4. DISCUSSION

The present study investigated the association between total polyphenol intake and body composition markers in adults and older adults from the municipality of Teresina, Piauí, using anthropometric methodologies that are useful in population-based studies and in clinical practice, as they include low-cost and noninvasive body fat indicators.

Participants with lower education levels tended to have higher values of total polyphenol intake compared to those with higher education levels. This finding suggests that education level may be associated with dietary choices, access to, and intake of bioactive compounds such as polyphenols. On the other hand, it is also evident that a higher level of education was not directly related to appropriate nutritional education knowledge.

In contrast to the findings of this study, Jardim *et al*.[26] observed that higher education level was associated with the NOVA food groups, showing greater likelihood of increased consumption of unprocessed foods and culinary ingredients, and a reduction in the consumption of processed foods. In the study by Louzada *et al*.[27], among the Brazilian population, as well as in findings among Americans and Canadians, it was evidenced that education level was related to the consumption of ultra-processed foods (UPFs). The longer the duration of formal education, the greater the likelihood of reducing UPF consumption (such as hamburgers and pizza) and increasing the intake of healthier foods such as olive oil and brown rice, highlighting the importance of formal education as a key factor in acquiring nutrition-related knowledge.

It was also observed that participants with higher income showed a greater mean intake of total polyphenols compared to those with lower income. In addition, when analyzing total polyphenol intake by food groups, a higher consumption of fruits was found among older adults compared to younger adults. In the other food groups, the analyzed trends suggest that the population shows distinct dietary choices, such as lower consumption of cocoa and chocolate and higher intake of seeds among older adults. These choices may be related to food preferences and/or dietary restrictions and/or nutritional recommendations aimed at the prevention, treatment, and/or health recovery[28,29].

Results from other studies suggest that higher consumption of unhealthy foods was associated with male sex, younger age, lower education level, and higher income[27,30]. Thus, regarding dietary aspects, in general, greater nutritional knowledge, income conditions, and age seem to be associated with healthier food choices and eating practices[26].

However, although these may be potential factors influencing eating behavior, they are not the only determinants. For instance, the study by Montero Bravo *et al*.[31], which evaluated a

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sample of 105 university students from health-related programs (including nutrition), showed that even when students believed they had good nutritional knowledge, this was not necessarily compatible with their eating habits. The intake of healthy foods rich in bioactive compounds, such as polyphenols, may be influenced by intrinsic factors, such as geographical area, population characteristics, sociocultural factors, access to specific foods typical of the local diet, and, above all, eating habits[5,31].

In this study, total polyphenol intake, after energy adjustment, was 873.87 ± 1086.37 mg/day. Compared to other countries, this value was lower than the total polyphenol intake reported in Japan (approximately 1500 mg/day), but similar to the results observed in European countries and in North and South America (approximately 900 mg/day and 800 mg/day, respectively). In Europe, a wide variability in intake was observed among countries. Poland and France had the highest total polyphenol intake (over 1000 mg/day), followed by Italy (approximately 650 mg/day) and Spain (approximately 300 mg/day)[30,32].

One of the findings of this study was that there was no significant difference in total polyphenol intake between adults and older adults, indicating similar consumption across the evaluated age groups. On the other hand, flavonol intake was considerably higher among the older population, suggesting greater consumption of flavonol-rich foods (e.g., fruits, vegetables, and seeds). Therefore, the higher intake of these foods may represent a positive aspect, particularly considering the role of flavonols in the prevention of NCDs associated with the aging process. Increasing evidence suggests that a healthy dietary pattern emphasizing fruits and vegetables rich in phenolic compounds exerts a protective effect capable of reducing the risk of chronic diseases[7,8,33].

Regarding the association between total polyphenol and subclass intake with body composition markers, the findings of this study indicate that total polyphenol intake was not associated with general (BMI) or central adiposity markers (WC and WHtR).

In the meta-analysis by Arisi *et al.*[34], which evaluated the effect of consuming a flavonoid-rich food on anthropometric measures such as BMI, no improvements in this parameter were identified, a finding similar to that of the present study.

In contrast, a meta-analysis evaluating changes in anthropometric measures through dietary polyphenol consumption in individuals with obesity reported a reduction in BMI[4]. Furthermore, Turan-Demirci *et al.*[35] investigated total polyphenol and flavonoid intake in overweight/obese adults and observed that the consumption of these compounds was inversely associated with BMI.

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In the present study, when considering specific subclasses, higher flavonoid intake was associated with lower WHtR values, suggesting a potential protective effect against central obesity. Flavonoids are bioactive compounds capable of modulating inflammatory and oxidative processes, in addition to exerting positive effects on lipid and carbohydrate metabolism[6].

In this study, the intake of antioxidant compounds showed an inverse association with TSF and SSF values in the population. Consequently, this may exert a beneficial effect in obesity. Flavonoid intake, derived from a variety of fruits, vegetables, seeds, nuts, stems, and flowers, as well as from their processed products such as wine and juices, represents an important regulatory factor capable of modulating food intake, adipogenesis, adipocyte life cycle, thermogenesis, energy expenditure, and gut microbiota regulation, among other effects[36].

Furthermore, dietary polyphenols may act on multiple bodily processes to exert anti-obesity effects, including the inhibition of adipogenesis. This process involves several stages, such as growth arrest, mitotic clonal expansion, early differentiation, and terminal differentiation. Polyphenols can inhibit adipogenesis through the regulation of signaling pathways and transcription factors[37].

Thus, due to their antioxidant, anti-obesogenic, and chemoprotective properties, polyphenols appear to improve mechanisms related to chronic diseases such as obesity by modulating proteins, genes, and transcription factors involved in the reduction of lipogenesis, increase in lipolysis, energy expenditure, stimulation of fatty acid β-oxidation, carbohydrate metabolism, and attenuation of oxidative stress[38,39].

The low level of nutritional knowledge observed among the evaluated target population is concerning. In this context, it is crucial to implement educational actions aimed at raising awareness regarding healthy eating practices. These initiatives are effective in expanding information about healthy lifestyle habits and food choices, thereby promoting important changes related to dietary behavior[26,27].

It is important to highlight that the estimation of polyphenol intake was performed based on searches in the Phenol-Explorer database[32,36]. Nevertheless, some limitations must be considered in the interpretation of the results of this study. As this is a cross-sectional study, without longitudinal follow-up, it is not possible to establish causal relationships. Additionally, the 24HR method relies essentially on the memory of the respondents. Although the interview was conducted by trained interviewers, it is known that there may be underreporting or recall bias on the part of the participants.

It is also important to highlight that, when interpreting these results, the wide data variation due to individual differences in consumption, as well as the small number of participants

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in some age groups, must be considered. In addition, individual variability in how the body metabolizes and absorbs polyphenols may affect their bioavailability, even after repeated consumption of the same food.

Therefore, these factors may limit the interpretation of the results, highlighting the need for additional studies with larger sample sizes. Moreover, part of the observed association may reflect broader dietary patterns rather than the isolated effect of polyphenols. Future analyses incorporating diet quality indices and detailed macronutrient adjustments may help clarify these relationships.

One of the main strengths of this study is its innovative approach, which considers anthropometric parameters beyond BMI in relation to polyphenol intake. The combination of these body composition markers allows for the assessment of fat distribution and provides an alternative, non-invasive, easily accessible, and low-cost measure[40].

It is also worth emphasizing that the data presented here reflect the important impact of a diet rich in bioactive compounds, such as polyphenols, found in fruits, vegetables, seeds, teas, cocoa, and chocolate, on the prevention, recovery, and/or treatment of obesity and overall health across different stages of life, thereby supporting the development of nutritional education initiatives and public health policies.

5. FINAL REMARKS

Overall, the results of this study indicate that higher consumption (2nd and 3rd tertiles) of polyphenols, particularly total polyphenols, flavonoids, flavonols, and other polyphenols, was inversely associated with anthropometric markers such as waist-to-height ratio (WHtR), triceps skinfold thickness (TSF) and subscapular skinfold thickness (SSF). These findings suggest that greater consumption of polyphenols positively impacts body composition, being a promising strategy for preventing and managing obesity in adults and the elderly. This supports the development of public health actions and policies that may include the implementation of interventions involving dietary polyphenols to promote positive changes in eating behavior and lifestyle. Further longitudinal studies are warranted to confirm these associations.

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