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Dietary intake and food contributors of polyphenols in adults and elderly adults of Sao Paulo: a population-based study

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Abstract

A comprehensive estimation of polyphenol intake is needed to gain a better understanding of the association between polyphenol-rich food intake and the potential effects of this intake on chronic diseases. The aim of this study was to estimate the intake of polyphenols and the major dietary contributors in the population of Sao Paulo. Data were obtained from the Health Survey-São Paulo (ISA-Capital 2008) and were reported for 1103 adults and elderly adults. Food intake was estimated by one 24-h dietary recall (24HR). Polyphenol intake was calculated by matching food consumption data from the 24HR with the polyphenol content in foods listed in the Phenol-Explorer database. The mean total intake of polyphenols was 377·5 (SE 15·3) mg/d. The main polyphenol classes were phenolic acids (284·8 (SE 15·9) mg/d) and flavonoids (54·6 (SE 3·5) mg/d). Intakes were higher in the elderly adults than in other adults ($P<0·001$) and higher in individuals with lower educational level ($P=0·01$) and current smokers ($P=0·02$). The main dietary contributors for total polyphenols were coffee (70·5 %), citrus fruits (4·6 %) and tropical fruits (3·4 %). Coffee was the major source of polyphenols, providing 266·2 (SE 16·5) mg/d, and contributed 92·3 % of the phenolic acids and 93·1 % of the alkylmethoxyphenols. These findings will be useful for assessing the potential role on health of polyphenols and specific polyphenol-rich foods, such as coffee, and enable a comparison with people from other countries.

Key words: Polyphenol intakes: Food contributors: Coffee: Representative samples

A high consumption of polyphenols, which are bioactive compounds, has been suggested in several clinical trials and cohort studies to have beneficial effects on human health and to provide protection against several chronic diseases such as CVD, cancers, type II diabetes, neurodegenerative diseases and osteoporosis[1–5].

Polyphenols constitute a very heterogeneous and widespread group of compounds, with more than 500 different molecules[6] found in various amounts in fruits and beverages, such as fruit juice, wine, coffee, tea, cocoa and beer as well as, to a lesser extent, in vegetables, dry legumes and cereals[7,8]. Dietary polyphenols belong to four main classes – flavonoids, phenolic acids, stilbenes and lignans – which are largely present in a glycosidic form (glycosides of flavonoids, lignans and stilbenes) or as esters (phenolic acids esterified to polyols such as quinic acid)[9].

Flavonoids can be divided into six subclasses based on the function of the type of heterocyclic ring involved: flavonols, flavones, isoflavones, flavanones, anthocyanins and flavanols (catechins and proanthocyanidins). In addition, two classes of phenolic acids can be distinguished: derivatives of benzoic acid and derivatives of cinnamic acid[7].

Dietary polyphenols may differ substantially in bioavailability and biological properties, and these aspects should be considered when studying the health effects of these compounds[7,10]. For this reason, it is important to determine the intake of individual polyphenols.

The Phenol-Explorer database (www.phenol-explorer.eu) is the most complete database currently available and freely accessible on the web; this database contains food composition data for 502 polyphenols (flavonoids, phenolic acids, lignans, stilbenes and other minor polyphenols) in 452 foods[8].

The purpose of the present study was to estimate the quantitative intake of polyphenols and the major dietary contributors in the general population of Sao Paulo, using individual food recall and the recently developed database Phenol-Explorer.

Methods

Study population and data collection

Data were retrieved from the 'Health Survey-São Paulo (ISA-Capital 2008)'. The ISA-Capital 2008 is a cross-sectional study designed to assess the health and nutritional status of non-institutionalised civilian residents of São Paulo City in south-eastern Brazil. This survey was a representative, complex, multistage, probability-based study and included participants aged <1 year and over. The survey was conducted in 2008 and combined interviews that collected information on health;

Abbreviation: 24HR, 24-h dietary recall.

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food intake; socio-demographics; lifestyle factors (e.g. smoking, physical activity, alcohol drinking, use of medicines); and physical examinations that included blood collection, anthropometric measurements and blood pressure measurements[11].

A two-stage cluster sampling was used: census tracts and household. In the first stage, the census tracts were drawn using a probability of the number of households. In the second stage, the households were drawn using an inverse probability of the number of households. The drawing was systematic, and eight study domains were defined: <1-year old (both sexes); 1–11 years old (both sexes); and three more age groups for each sex, females and males aged 12–19 years (adolescents), 20–59 years (adults) and 60 years or over (elderly adults). A minimum sample size of 300 in each of the eight domains was estimated to be needed based on a prevalence of 0·5 with a SE of 0·07 at a 5 % significance level and a design effect of 1·5. A total of 3271 individuals participated in the survey. Of these, 2691 individuals, aged 12 years or over, were selected to answer questions about diet, life conditions and socio-demographics. Among those individuals, 2086 subjects were adults and elderly adults. For the present study, only adults and elderly adults (n 1103) who had also completed one 24-h dietary recall (24HR) were included.

Although the proportion of individuals who completed the study was similar by census tract and socio-demographic characteristics compared with the original sample, sampling weights were re-calculated for each individual with consideration of the sample design, non-response and post-stratification adjustment for sex and age group, in order to equalise the socio-demographic features of the sample.

The Ethics Committee of the School of Public Health of the University of São Paulo approved the project (CAAE no. 33819114.2.0000.2.0000.5421). An informed consent form was obtained from all the participants.

Assessment of dietary intake

In the study 'Health Survey-São Paulo (ISA-Capital 2008)', dietary intake was measured by two multiple-pass 24HR and a FFQ. The first 24HR was administered in the household by trained interviewers, and the second 24HR was administered by phone. These recalls were representative of all weekdays, weekends and seasons[12] and were made in the households using the Multiple-Pass Method[13]. This method is structured in five steps: (1) the quick list, in which participants list all of the foods and beverages consumed uninterruptedly; (2) the forgotten list, for which participants are asked about commonly forgotten foods consumed, such as candies, coffees and sodas; (3) the time and location of the food and beverage intake; (4) the detailing cycle, which corresponds to the description of the way of preparation and amounts consumed; and (5) the final review, which verifies whether a certain food consumed during the day was not previously recorded[13,14].

The household measures reported in the 24HR were converted into grams and millilitres according to standard Brazilian references, which measured many foods using a precision balance[15,16]. Recipes were broken down into ingredients to estimate the amount of all ingredients in each mixed dish.

Data from the 24HR were entered into the Nutrition Data System for Research (version 5.0, 2007; Nutrition Coordinating Center, University of Minnesota), and were converted into energy and nutrients[17].

For the present study, the dietary intake was estimated from the first 24HR, considering which the methodology is often used for analyses of food contributors[18]. However, we provided as online Supplementary Material data comparing the intake of a single 24HR and two 24HR with a statistical adjustment of the usual intake distribution using a statistical modelling technique Multiple Source Method. Even after using this technique to remove the within-variance, the mean intake did not change, reinforcing our decision that one 24HR is adequate to estimate usual mean and dietary contributors of polyphenol intake.

Correspondence between food items in the dietary recall and those in the Phenol-Explorer database

Data on the polyphenol content in foods were obtained from the Phenol-Explorer database (www.phenol-explorer.eu). The Phenol-Explorer database contains data on the content of 502 polyphenols in 452 foods[6,8]. The Phenol-Explorer has recently been enhanced with data on the effects of food processing on the polyphenol contents of foods. Food processing often causes losses in polyphenol content, usually brought about by oxidation, enzymatic action, removal of skin or seeds and leaching into oil or water, which is then discarded[19].

For accurate measurements of polyphenol intake in this study, an additional coefficient, or retention factor, has been applied to the content value of each polyphenol in raw foods to account for processing. A retention factor is the proportion of a particular polyphenol retained after processing, adjusted for the change in water content[20].

All animal foods that contain no or only traces of plant polyphenols were excluded. Certain food items that may contain polyphenols were present in the dietary recall but not in the Phenol-Explorer database. These food items included some spirits such as tequila, cassava flour, tapioca, sweet potato, coconut and coconut milk, honey, some breakfast cereals and certain minor oils such as rapeseed oil and cottonseed oil. Therefore, these foods were excluded from the database.

For mixed dishes made of polyphenol-containing ingredients and for recipes, polyphenol contents were calculated on the basis of contents of the ingredient or food component and their polyphenol composition.

The correspondence between the food items in the 24HR and the Phenol-Explorer database was assessed according to the following five steps: (1) recipes were separated according to their ingredients; (2) the polyphenol content of each food item was searched in the Phenol-Explorer database as described by Pérez-Jimenez *et al.*[9]; (3) all foods with no or only traces of polyphenols were excluded; (4) weight loss or gain during cooking was corrected using yield and retention factors; and (5) foods were classified according to their polyphenol content, considering the eating habits of this population, the nutritional value of food and literature information. Next, the foods were clustered until attaining ten classes of food, twenty-one groups and thirty-two subgroups. In the present study, of the

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502 phenolic compounds analysed, a total of 317 polyphenols present in these foods were divided into eight classes and twenty subclasses from the 280 food items described in the dietary recalls.

Estimation of polyphenol intake and dietary contributors of polyphenols

In the Phenol-Explorer database, the data used to calculate the polyphenol intake correspond to the HPLC for all phenolic compounds. In the case of lignans and of phenolic acids in certain foods (cereals, olives and beans), data corresponding to the HPLC data after hydrolysis were also collected because these treatments are needed to release phenolic compounds that otherwise cannot be analysed[9,10].

The polyphenol intake was calculated by matching food intake data from the 24HR and the recently developed Phenol-Explorer database on polyphenol content in foods. The individual polyphenol intake from each food was calculated by multiplying the content of each polyphenol by the daily consumption of each food. The total polyphenol intake was calculated as the sum of all individual polyphenol intakes from all food sources reported by the 24HR.

For dietary contributors of polyphenols, a ratio of the daily total or the individual polyphenols provided by the specific food or food group over the total intake of polyphenols from all foods was used to calculate the contribution of each food or food group to the daily total intake of polyphenols.

Statistical analyses

Data regarding socio-demographics and lifestyle characteristics were collected. Educational level was categorised as low (elementary school), medium (middle and high school) and high (university). Monthly household *per capita* income was categorised into two categories: <$135 dollars (450 reais, the equivalent of minimum wage in local money) and >$135 dollars. BMI was calculated and classified as normal weight (<25 kg/m^2) and overweight (≥25 kg/m^2) according to World Health Organization criteria[21]. Physical activity level was categorised as daily low active and active, according to the international physical activity questionnaire, validated in Brazil[22,23]. Smoking status was categorised as non-smoker, former smoker and current smoker. Finally, alcohol consumption was categorised as non-drinker and alcohol drinker.

Data are presented as means and standard errors, medians and interquartile ranges for continuous variables and frequencies and percentages for categorical variables. The mean and median intakes of total polyphenols were determined for the total study population as well as according to different socio-demographic and lifestyle characteristics, such as sex, age class, race, educational level, family income, BMI, physical activity groups, smoking status and alcohol consumption.

The polyphenol intake distribution was analysed by the Kolmogorov–Smirnov test and did not follow a normal distribution. Thus, we also reported median values to compare differences in intakes between groups using the Mann–Whitney *U* test and the Kruskal–Wallis test, as appropriate. Mean intakes (mg/d per person) of all individual polyphenols, polyphenol groups (phenolic acids, flavonoids, alkylphenols, alkylmethoxyphenols, stilbenes, tyrosols, lignans and other polyphenol groups) and major food contributors (% contribution to polyphenol class) were determined.

All the analyses were carried out using the appropriate sample weights to account for the complex survey design. For all the analyses, STATA® statistical software package version 12 was used, and a $P<0{\cdot}05$ was considered to be statistically significant.

Results

Total polyphenol intake

A total of 1103 individuals were available for the final analyses. The sample comprised forty-six men and 54 % women, mostly white (59 %), with a medium educational level (69 %). Participants were divided into two groups based on their age – that is, adults and elderly adults – and the frequencies and percentages of general characteristics of the studied population are shown in Table 1.

The mean and median polyphenol intake values for the whole population were 377·5 and 300·3 mg polyphenols/d, respectively (Table 2). The total polyphenol intake is presented according to socio-demographic and lifestyle characteristics in Table 2. Intakes were higher in elderly adults than in other adults ($P<0{\cdot}001$), 414·9 (SE 12·7) and 370·2 (SE 18·3) mg/d, respectively; therefore, we decided to stratify the results according to age: adults and elderly adults. Adults with a lower educational level (elementary school) showed a significantly higher total polyphenol intake ($P=0{\cdot}01$) compared with subjects with medium (middle and high school) and higher (university) educational levels (453·3 (SE 0·0) compared with 374·7 (SE 17·7) and 331·6 (SE 39·1) mg/d). Differences were also observed in the elderly adults ($P=0{\cdot}03$), but in this group individuals with a higher educational level had the highest intake of polyphenols. Furthermore, higher intakes were detected among current smokers than in former smokers and non-smokers. However, significant differences existed only in adults ($P=0{\cdot}02$). Higher mean polyphenol intakes were also found among men, who were white, in the higher physical activity groups and of normal weight, but no significant influence on polyphenol intake was observed in either age group.

Intake of polyphenols and main food contributors

Among the 348 food items considered in the 24HR, 280 contained polyphenols according to the Phenol-Explorer database. In all, 317 polyphenols from eight polyphenol classes and twenty polyphenol subclasses were described in these foods. The intakes of the total, the different classes and the subclasses of polyphenols according to the different food groups and main food contributors are shown in Table 3. The mean total intake of polyphenols was 377·5 (SE 15·3) mg/d. The main polyphenol classes were phenolic acids (284·8 (SE 15·9) mg/d, 75·5 % of total intake of polyphenols) and flavonoids (54·6 (SE 3·5) mg/d, 14·5 % of total intake of polyphenols), whereas other

Table 1. General characteristics of the studied population (ISA-Capital 08), Sao Paulo, Brazil (Numbers and percentages)*

	Age groups					
	Adults (20–59 years)		Elderly adults (≥60 years)		Total population	
Characteristics	*n*	%	*n*	%	*n*	%
Sex						
Male	252	47·0	193	40·5	425	46·0
Female	354	53·0	324	59·5	678	54·0
Race						
White	323	57·0	348	68·2	671	58·8
Others	263	43·0	169	31·8	432	41·2
Educational level						
Low	49	06·5	189	33·9	238	11·0
Medium	431	71·1	299	57·7	730	68·9
High	106	22·4	29	08·4	135	20·1
Household *per capita* income						
<1 MW	254	39·6	243	44·7	497	40·5
≥1 MW	332	60·4	274	55·3	606	59·5
BMI (kg/m^2)†						
Normal weight	322	54·8	207	39·9	529	52·4
Overweight	264	45·2	310	60·1	574	47·6
Physical activity						
Low active	224	37·3	316	59·4	540	40·9
Active	360	62·7	201	40·6	561	59·1
Smoking status						
Never	338	59·4	297	56·6	635	58·9
Former smoker	94	15·5	166	33·2	260	18·4
Current smoker	154	25·1	54	10·2	208	22·7
Alcohol drinking						
No	430	72·0	417	79·3	847	73·2
Yes	156	28·0	100	20·7	256	26·8

MW, minimum wage.
* The sample weight was considered for statistical analysis.
† Weight and height related.

polyphenols such as alkylphenols, alkylmethoxyphenols, stilbenes, tyrosols and lignans accounted for lower proportions (each one <1 %). The mean daily intakes of hydroxycinnamic acids (281·2 mg/d) in the phenolic acid group and flavanones (16·1 mg/d) in the flavonoid group were higher compared with other groups. Flavonols (14·6 mg/d) were the third most consumed polyphenol subgroup. The remaining polyphenols were grouped into a wide class of 'other polyphenols', including furanocoumarins, hydroxybenzaldehydes, hydroxybenzoketones, hydroxycinnamaldehydes, hydroxycoumarins, naphthoquinones, among others, representing 0·5 % of the total polyphenol intake.

The main food contributors to the intake of total polyphenols and each polyphenol class or subclass are also shown in Table 3. The main dietary sources for total polyphenols were coffee (70·5 %) and fruits, especially citrus fruits (4·6 %) and tropical fruits (3·4 %), whereas vegetables accounted for a lower percentage of the total amount of polyphenols in the diet (1·3 %). In the citrus fruit group, the main contributor was tangerine with 49·3 %, and in the tropical fruits group papaya was the largest contributor (59·9 %). Coffee was the primary food item contributing to phenolic acid intake (92·3 %), mainly hydroxycinnamic acids (93·5 %). Beer was the main source of hydroxybenzoic acids, with a contribution of 51·0 %. Major contributors of intakes of flavonoids were citrus fruits, mainly oranges (17·0 %), and beans (14·3 %). In addition, important contributors to the intake of flavanones were fruits (especially oranges and orange juice). Flavonols were found in onions and beans, and flavanols were found in beans and apples. Tyrosols were derived from fruit vegetables (tomato and olives) and olive oil, lignans were derived from vegetable oil and seeds, alkylphenols were provided in bread and refined wheat flour, stilbenes were present in wine and berries (mostly grapes) and alkylmethoxyphenols and other polyphenols came mostly from coffee and beer. Flour products, especially refined wheat flour, were the major sources of flavones; berries (mostly grapes) were the major sources of anthocyanins; and soya milk was the major source of isoflavones.

Table 4 shows the stratification by age of the percentage contribution by the polyphenol class. Differences between adults and the elderly adults were observed regarding the same food items and their amounts. The largest differences were verified in the following classes of flavonoids and tyrosols. With regard to the total polyphenol intake, the food items were the same, but the elderly adults consumed a larger amount of fruits.

Polyphenols from coffee: the main dietary contributor

The specific contribution of coffee to the total polyphenol intake in this population was estimated. Coffee provided 266·2 (SE 16·5) mg/d of polyphenols, which represented approximately 70·5 % of the total intake, being the major polyphenol

Table 2. Total polyphenol intake according to socio-demographic and lifestyle characteristics of the studied population (ISA-Capital 08) Sao Paulo, Brazil (Mean values with their standard errors; medians and interquartile ranges (IQR))

	Polyphenol intake (mg/d)											
	Adults (20–59 years)				Elderly adults (≥60 years)				Total population			
Characteristics	Mean	SE	Median	IQR	Mean	SE	Median	IQR	Mean	SE	Median	IQR
Total population	370·2	18·2	292·2	136·8–473·8	414·9	12·7	348·6	215·0–544·1	377·5	15·3	300·3	154·1–486·9
Sex												
Male	384·5	26·5	297·2	125·0–481·0	437·5	25·4	367·4	220·9–544·1	392·1	23·9	306·0	134·0–491·7
Female	357·4	20·6	287·2	161·3–453·7	399·6	16·2	345·3	214·5–545·2	365·0	16·7	297·1	167·9–481·8
*P**			0·85				0·21				0·77	
Race												
White	378·5	23·0	294·8	148·3–491·7	421·3	15·5	360·1	219·5–559·6	386·6	18·8	299·0	163·8–506·7
Others	359·1	20·6	286·7	129·7–466·1	401·2	26·7	322·6	207·9–501·4	364·4	20·8	300·3	141·4–466·1
P			0·66				0·16				0·38	
Educational level												
Low	453·3	0·0	306·0	161·6–638·6	397·4	23·8	319·4	214·5–520·9	425·3	28·7	313·5	184·0–583·7
Medium	374·6	17·7	305·2	151·8–486·0	415·2	19·3	352·1	207·0–529·7	380·2	15·6	311·2	169·4–498·8
High	331·6	39·1	261·8	111·0–381·9	483·1	0·0	441·4	322·6–598·9	341·9	36·9	271·1	118·6–403·9
P			0·01				0·03				<0·01	
Household *per capita* income												
<1 MW	407·0	35·7	304·2	136·8–518·3	411·2	20·2	349·3	229·0–520·9	407·8	29·9	321·7	154·1–518·3
≥1 MW	345·9	22·3	283·2	138·7–463·1	417·9	16·8	347·2	206·0–565·5	356·8	19·7	288·2	157·5–479·2
P			0·30				0·85				0·26	
BMI (kg/m^2)*												
Normal weight	385·4	31·9	294·8	151·8–483·4	437·2	22·2	352·1	228·4–538·9	391·8	28·6	298·6	158·6–496·4
Overweight	351·7	19·6	286·7	129·7–446·6	400·1	18·7	346·7	207·9–544·1	361·6	16·9	300·9	144·1–481·0
P			0·58				0·37				0·67	
Physical activity												
Low active	341·0	27·4	265·3	122·2–463·1	401·8	16·1	347·2	226·9–511·7	355·4	20·9	283·1	148·3–484·6
Active	387·3	23·4	306·2	161·3–477·4	434·1	24·8	348·6	193·3–587·7	392·5	21·3	311·8	163·3–491·7
P			0·13				0·62				0·28	
Smoking status												
Never	349·2	19·8	271·9	120·4–453·0	402·1	14·8	338·0	214·5–532·9	357·5	16·8	283·1	127·0–466·1
Former smoker	367·3	30·6	321·7	191·3–498·8	414·3	27·0	356·2	214·5–523·6	381·1	23·3	324·4	194·3–500·6
Current smoker	421·5	34·5	327·0	184·0–535·6	488·5	52·5	385·5	248·4–589·0	426·4	32·4	327·0	185·8–538·4
P			0·02				0·37				0·02	
Alcohol drinking												
No	357·4	21·1	285·8	128·4–465·2	421·4	14·4	353·4	221·3–557·3	368·7	17·1	302·3	152·1–486·0
Yes	403·1	36·6	297·1	167·9–503·9	390·1	35·5	311·8	185·3–456·4	401·4	33·5	297·1	168·5–503·9
P			0·24				0·07				0·49	

MW, minimum wage.
*Comparisons across categories were performed by using the Mann–Whitney *U* test or the Kruskal–Wallis test.

Table 3. Total, classes and subclasses of polyphenol intake, according to food group sources and main food contributors, Sao Paulo, Brazil (Mean values with their standard errors)

Polyphenol class and subclass	Food group (mg/day per person)																						Main food contributors (% contribution to polyphenol class)
	Alcoholic beverages		Non-alcoholic beverages		Fruits and natural juices		Vegetables		Cereals and tubers		Beans		Seeds and nuts		Seasonings		Cocoa and chocolate		Oils		Total foods		
	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	
Phenolic acids	2·8	0·4	263·0	16·3	3·2	0·4	4·7	0·4	9·6	1·0	<0·1		0·4	0·2	<0·1		<0·1		0·5	<0·1	284·8	15·9	Coffee (92·3) Potatoes (3·0) Beer (0·9)
Hydroxycinnamic acids	0·8	0·1	262·9	16·3	2·8	0·3	3·9	0·3	9·5	1·0	<0·1		0·3	0·2	<0·1		0·132	<0·1	0·5	<0·1	281·2	15·9	Coffee (93·5) Potatoes (3·0) Apples (0·7)
Hydroxybenzoic acids	1·8	0·3	0·1	<0·1	0·4	<0·1	0·7	0·2	0·1	<0·1	<0·1		<0·1		<0·1		–		<0·1		3·4	0·4	Beer (51·0) Leaf vegetables (10·2) Fruit vegetables (7·2)
Flavonoids	2·3	0·6	1·1	0·5	27·3	2·6	10·3	0·9	2·4	0·2	7·8	0·4	1·3	0·5	<0·1		1·7	0·4	<0·1		54·6	3·5	Citrus fruits (17·0) Citrus juices (14·5) Beans (14·3)
Flavanones	<0·1		–		15·9	1·9	<0·1		–		–		<0·1		–		–		–		16·1	1·9	Citrus fruits (57·5) Citrus juices (41·9) Beer (0·3)
Flavonols	0·2	<0·1	<0·1		1·0	0·1	9·4	0·9	–		3·7	0·2	<0·1		<0·1		<0·1		–		14·6	0·9	Onion (51·8) Beans (25·2) Leaf vegetables (7·6)
Flavanols	1·5	0·3	1·0	0·4	3·4	0·4	–		<0·1		3·6	0·2	<0·1		<0·1		1·6	0·4	–		11·4	0·8	Beans (31·8) Apples (21·4) Cocoa and chocolate (14·6)
Anthocyanins	0·4	0·1	–		5·3	1·0	0·6	0·0	–		0·4	0·1	–		–		–		–		6·8	1·1	Berries (75·1) Wine (6·5) Beans (5·9)
Flavones	<0·1		–		1·0	0·1	0·1	<0·1	2·3	0·2	<0·1		–		<0·1		–		<0·1		3·6	0·3	Flours (65·1) Citrus juices (27·2) Fruit vegetables (3·2)
Isoflavonoids	<0·1		–		–		–		–		0·1	<0·1	1·3	0·5	<0·1		–		–		1·5	0·5	Soya (91·3) Beans (8·2) Seasonings (0·3)
Tirosols	0·3	<0·1	–		–		1·7	0·3	–		–		–		<0·1		–		0·9	0·1	3·1	0·4	Fruit vegetables (56·0) Olive oil (30·2) Beer (9·9)
Lignans	–		–		<0·1		<0·1		<0·1		–		0·5	0·3	–		–		1·6	0·5	2·3	0·7	Cereal oils (71·3) Nuts (25·6) Olive oil (2·0)
Alkylmethoxyphenols	0·1	<0·1	1·9	0·1	–		–		–		–		<0·1		–		<0·1		<0·1		2·1	0·1	Coffee (93·1) Beer (6·8) Cereal oils (0·1)
Others	0·1	<0·1	1·3	<0·1	0·4	<0·1	<0·1		–		–		–		<0·1		<0·1		<0·1		1·9	0·1	Coffee (68·1) Citrus juices (21·6) Beer (6·9)
Alkylphenols	<0·1		–		–		–		0·9	0·1	–		–		–		–		–		1·0	0·2	Bread (66·8) Flours (28·0) Breakfast cereals (4·7)
Stilbenes	<0·1		–		<0·1		–		–		<0·1		<0·1		<0·1		<0·1		<0·1		<0·1		Wine (80·4) Berries (18·4) Cocoa and chocolate (0·5)
Total polyphenols	5·9	1·0	267·5	16·5	55·9	4·4	19·2	1·5	13·3	1·2	7·9	0·5	2·4	0·7	0·4	<0·1	1·9	0·5	3·1	0·6	377·5	15·3	Coffee (70·5) Citrus fruits (4·6) Tropical fruits (3·4)

–, omitted values.

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Table 4. Main food contributors for adults and elderly adults, according to total and classes of polyphenol intake, Sao Paulo, Brazil

	Main food contributors (%)	
Polyphenol class	Adults (20–59 years)	Elderly adults (≥60 years)
Phenolic acids	Coffee (92·1)	Coffee (93·3)
	Potatoes (3·1)	Potatoes (2·6)
	Beer (1·0)	Apples (1·1)
Flavonoids	Citrus juices (15·7)	Citrus fruits (30·3)
	Beans (15·4)	Beans (11·9)
	Onion (15·0)	Berries (11·3)
Stilbenes	Wine (80·0)	Wine (82·0)
	Berries (18·8)	Berries (17·1)
	Cocoa and chocolate (0·7)	Beans (0·5)
Lignans	Cereal oils (78·6)	Nuts (72·6)
	Nuts (18·4)	Cereal oils (23·8)
	Olive oil (1·9)	Olive oil (2·5)
Tirosols	Fruit vegetables (58·3)	Olive oil (56·8)
	Olive oil (27·7)	Fruit vegetables (31·7)
	Beer (10·5)	Wine (6·2)
Alkylphenols	Bread (60·7)	Bread (86·8)
	Flours (33·1)	Flours (11·2)
	Breakfast cereals (5·6)	Breakfast cereals (1·9)
Alkylmethoxyphenols	Coffee (92·0)	Coffee (98·7)
	Beer (7·9)	Cereal oils (1·2)
	Cereal oils (0·1)	Beer (0·03)
Others	Coffee (73·4)	Coffee (80·4)
	Citrus juices (25·4)	Citrus juices (14·9)
	Beer (0·4)	Herbs (1·4)
Total polyphenols	Coffee (70·8)	Coffee (68·9)
	Citrus fruits (3·7)	Citrus fruits (9·0)
	Tropical fruits (3·0)	Tropical fruits (5·6)

Table 5. Polyphenol intake from coffee by individuals in Sao Paulo, Brazil (Mean values with their standard errors; percentages)

Individual and class of polyphenols ingested from coffee	Total intake from (mg/d)				Intake derived from coffee
	Coffee		Full diet		
	Mean	SE	Mean	SE	%
Phenolic acids	262·9	16·3	284·8	15·9	92·3
Hydroxycinnamic acids	262·9	16·3	281·2	15·9	93·5
5-Caffeoylquinic acid	86·8	5·4	98·7	5·2	87·9
4-Caffeoylquinic acid	73·9	4·6	74·2	4·6	99·5
3-Caffeoylquinic acid	64·2	3·9	64·6	3·8	99·4
5-Feruloylquinic acid	14·5	0·9	14·5	0·9	99·8
4-Feruloylquinic acid	10·6	0·7	10·6	0·6	99·9
3,4-Dicaffeoylquinic acid	3·3	0·2	3·4	0·2	96·4
4,5-Dicaffeoylquinic acid	2·5	0·1	2·5	0·1	100·0
Caffeic acid	<0·1	<0·1	0·5	<0·1	7·5
Alkylmethoxyphenols	1·9	0·1	2·1	0·1	93·1
4-Ethylguaiacol	0·8	<0·1	0·8	<0·1	100·0
4-Vinylguaiacol	0·6	<0·1	0·7	<0·1	79·9
Guaiacol	0·2	<0·1	0·2	<0·1	100·0
4-Ethylcatechol	0·2	<0·1	0·2	<0·1	100·0
3-Methylcatechol	0·1	<0·1	0·1	<0·1	100·0
Others	1·3	0·1	1·9	0·1	68·1
Pyrogallol	0·7	<0·1	0·7	<0·1	99·3
Catechol	0·5	<0·1	0·5	<0·1	99·8
Phenol	0·1	<0·1	0·1	<0·1	100·0
Total polyphenols	266·2	16·5	377·5	15·3	70·5

contributor in the diet of this population. Table 5 shows the contribution of coffee to the intake of different classes and subclasses of polyphenols, which was more than 92·0 % of phenolic acids, especially hydroxycinnamic acids (93·5 %) such as 5-caffeoylquinic acid, alkylmethoxyphenols (93·1 %) and other polyphenols (68·1 %). Table 5 also presents individual polyphenols ingested only from coffee according to the class (e.g. 4,5-dicaffeoylquinic acid, guaiacol, catechol and phenol). This does not mean that these polyphenols are found only in coffee, but rather that other sources are scarcely consumed or not consumed by the adults and elderly adults of Sao Paulo.

Discussion

The present study describes the estimation of dietary polyphenol intakes in Sao Paulo, and it shows that coffee is the main dietary contributor of polyphenol intake.

Owing to the large heterogeneity of food composition data[5,9,24–27], comparisons of polyphenol intake between populations are difficult. Thus, the use of the same food composition database or of harmonised food composition data is highly desirable to facilitate a comparison of polyphenol intake data in different studies[9]. All food composition data used in the present study were available on the Phenol-Explorer web site (www.phenol-explorer.eu).

Most of the studies found in the literature search used similar methodology for polyphenol assessment[9,10,28], and thus their data allow comparisons with the present study. The estimated mean of the total intake of polyphenols in the present study was 377·5 (SE 15·3) mg/d, which was lower than the 1193·0 (SD 510·0) mg/d found by Pérez-Jiménez *et al.*[9] in the SUpplémentation en VItamines et Minéraux AntioXydants (SU.VI.MAX) cohort, as well as the values reported by other studies with regard to the Polish (1757·0 (SD 696·0))[28], Finnish (863·0 (SD 415·0))[27] and Spanish (820·0 (SD 323·0)) populations[10]; however, this is only a comparison among different countries, with different dietary patterns, which reflect the different amounts consumed. If we consider the total polyphenol intake to be approximately 1 g/d throughout the world, as reported by Scalbert & Williamson[29], our study suggests a daily polyphenol intake of almost three times lower than the estimated value.

Differences were also observed in phenolic acids and flavonoid intakes in comparison with the aforementioned studies. The flavonoid intake of 54·6 (SE 3·5) mg/d was much lower than what was reported for the USA (189·7 mg/d)[26], slightly lower than the estimated daily mean of flavonoid intake in the Brazilian population, which ranged from 60·0 to 106·0 mg/d[30], but higher than that reported in Japan 16·7 (SD 9·2) mg/d[31], in the Netherlands (23 mg/d)[32] and in Finland (0·4 mg/d, ranging from 0 to 41·4 mg/d)[33], although in these last two studies only the intake of subclasses of flavonoids (i.e. flavonols and flavones) was estimated. Higher differences were also observed regarding the intake of phenolic acids (284·8 (SE 15·9) mg/d) compared with those reported for French, Finnish and Polish populations[9,27,28], but these contents were similar to that observed in the Spanish cohort[10].

The above-mentioned large differences can be explained by the individual food preferences and various dietary habits among the different populations, which are often dictated by culture; thus, they affect the intake of subgroups and amount of polyphenols. Furthermore, retention factors were not examined in one study[27],

which may overestimate the mean content of polyphenols, because many processes such as storing, cooking and peeling can cause variable losses in the concentrations of polyphenols.

Hydroxycinnamic acids were the most abundant phenolic acids consumed in all cohorts and in the present study. Flavanones were the most abundant flavonoids consumed by these subjects and by the Spanish population[10], whereas isoflavones were less consumed because of the low consumption of their main dietary sources. Stilbenes had the lowest consumption rate, accounting for approximately 0·1 mg/d per person because of their low contents in foods.

Previous studies among the French, Finnish and Polish populations[9,27,28] reported that polyphenol intake was influenced by sex, with men having a higher absolute intake of total polyphenols, suggesting that polyphenol intake in men is influenced by the quantity of food. In this study, a slightly higher intake of polyphenols in men was reported, but no significant influence on polyphenol intakes was observed. Significant differences in polyphenol intake were due to age, education level and smoking (higher intakes in elderly participants, in participants with low education level and current smokers).

In an epidemiological study conducted in Brazil, Jaime *et al.*[34] observed a positive association between age and the consumption of fruits and vegetables: elderly adults were the highest consumers of fruits and vegetables according to WHO recommendations, which explained a higher intake of polyphenols among elderly participants. It was also observed that elderly subjects with a university educational level showed a significantly higher total polyphenol intake than subjects with low (elementary school) and medium (middle and high school) educational levels. It may be speculated that higher education might mediate healthier lifestyles and eating behaviours, such as the consumption of fruits and vegetables, which are rich in polyphenols. However, the results regarding adults were the opposite when compared with those shown for the aforementioned elderly adults. This can be explained because adults with a lower educational level (primary school) consume larger amounts of coffee, which is a great source of polyphenols, compared with subjects with a higher educational level.

Similarly, smoking was associated with a higher intake of polyphenols in adults. This may be explained because smokers were more likely to drink coffee, which was the major contributor to polyphenol intake.

In this study, the main food contributors to polyphenol intake were mostly represented by coffee, which accounted for 70·5 % of the total polyphenol intake, followed by fruits (citrus and tropical) and potatoes, which accounted for 4·6, 3·4 and 2·2 %, respectively, of the total polyphenol intake. On the other hand, vegetables accounted for a lower percentage of the total amount of polyphenols in the diet of the citizens of Sao Paulo (1·3 %). The aforementioned cohorts[9,10,28] reported a higher contribution of polyphenol intake from coffee (18·0–44·0 %) but also from vegetables (>12·0 %), and a significantly higher intake from alcoholic beverages, due to a higher consumption of red wine, which was not observed in the present study. A possible explanation for these differences is that the daily intake of fruits and vegetables is below the levels recommended by the FAO of 400 g[35] for >90 % of the Brazilian population[36]. According to Faller & Fialho[37], the intake of fruit and vegetables was only 66·8 g/d, well below the recommendation. In accordance with Jaime & Monteiro[38], fewer than half (41·0 %) of the adults in Brazil consume vegetables daily, whereas fewer than a third (30·0 %) report daily consumption of fruits. Even fewer Brazilians (only one in eight) meet the recommendation of consuming five or more servings a day of these foods.

Likewise, wine consumption in Brazil is very low (1·9 l/person per year)[39], whereas beer is the most consumed alcoholic beverage in this country, with an average consumption of 62·0 l/person per year in 2012[40]. For this reason, in the group of alcoholic beverages, beer was the major drink contributing to the total of polyphenol intake (63·1 %), and wine contributed only 36·5 %, which reinforces the previous hypothesis.

Another remarkable difference between the polyphenol intake in European countries and the population of Sao Paulo was the relevant contribution of tropical fruits to the amount of polyphenols, especially papaya, guava and banana. Furthermore, beans contributed to approximately 7·8 mg/d of flavonoids per person (14·3 %), and they were the main food item contributing to flavanols intake. Consequently, the low intake of polyphenols of these compounds in the PREvención con DIeta MEDiterránea (PREDIMED) cohort[10] and the SU.VI.MAX[9] could reflect a low consumption of beans. In the present study, beer was the main dietary source of hydroxybenzoic acids (1·7 mg/d, corresponding to 51·0 %), whereas in other cohort studies this item is not mentioned. In those studies, the main food sources of hydroxybenzoic acids were tea, red wine and olives[9,10].

As we have mentioned above, these differences in polyphenol intake may depend on country-specific food preferences and, consequently, on preferences for main dietary contributors, specifically coffee contribution. Coffee is one of the most polyphenol-rich beverages consumed worldwide, containing 214·0 mg of total polyphenols per 100 ml[41]; therefore, the health implications of these polyphenols are of high interest. In this study, coffee was the main food source of hydroxycinnamic acids (262·9 (SE 16·3) mg/d), thus enhancing the total phenolic acid intake (284·8 (SE 15·9) mg/d), which is consistent with other studies[9,10,28]. Moreover, 80 % of adults and elderly adults were coffee drinkers, and the mean intake was 168 ml/d (equivalent 1·5 cups/d). This result is very similar to that found by Sousa & da Costa[42] in the Brazilian population. In the Polish population, 83·0 % were consumers of coffee, with a mean intake of 237·0 ml/d[28], and in French adults 92·0 % of the total population were coffee drinkers[9]. Mediterranean populations have a relatively low consumption of coffee (equivalent to 100 ml/d), perhaps because of the mean age of 67 years of their participants[10]. The main characteristic of the Sao Paulo population was the high consumption of coffee and the presence of polyphenols provided by coffee. It provided 266·2 mg of polyphenols daily, constituting 70·5 % of the total intake.

The results of this study should be interpreted based on the same limitations. First, although the Phenol-Explorer is the most complete database currently available, information about some regional foods consumed in Brazil is still scarce because they have not been characterised or have been only poorly characterised (e.g. cassava flour, tapioca, sweet potato and coconut or coconut milk). However, despite the database not having

information about these foods, their consumption was low or non-existent, and thus biasing of the data is unlikely. Besides, although Brazil provides a wide variety of regional foods, Sao Paulo is a cosmopolitan and less traditional city and is less prone to consume these regional foods.

Furthermore, for some major polyphenol dietary contributors, composition data are still scarce. This was particularly evident for coffee for which only two types of coffee (decaffeinated or caffeinated, both filter) have been used to calculate intakes of phenolic acids, and these calculations did not take into account the different brewing recipes – for example, boiling, steeping, filtration or pressure.

A further point to note is that in our study and in the French cohort the tool used was the 24HR, but in other studies FFQ were used. Although, on average, these recalls were collected across all weekdays, weekends and seasons, the 24HR method, like other methods used to assess dietary intake (e.g. FFQ and records), has been shown to be prone to systematic and random measurement error. However, if the interest is in estimating the mean intake, recall data for 1 d will be adequate, because with random error the mean is unbiased.

An essential step towards understanding the potential protective effects of polyphenols against chronic disease risk is to estimate the consumption of polyphenols with a FFQ or other instruments such as the 24HR in order to identify the compounds most likely to provide the greatest protective effects[7,10,26]. Even now, however, despite the reported importance of the health effects of polyphenols, a limited number of studies on the estimation of polyphenol intake have been documented around the world, and very few comprehensive assessments of polyphenol intake in different populations have been performed.

In conclusion, the present study gives a comprehensive description of the total polyphenol intake and main food contributors of dietary polyphenols in adults and elderly adults of Sao Paulo. To our knowledge, this study provides the first estimation of dietary polyphenol intakes in this population. The application of this methodology will facilitate the investigation of polyphenol intake and its relation with the incidence of CVD in epidemiological observational studies such as the ISA-Capital study and will also be useful for future dietary recommendations for individuals and population groups. In addition, the detailed data obtained on dietary polyphenol intake will be useful to assess the potential role on health of specific foods with high polyphenol content, such as coffee. Further research would clarify whether high consumption of coffee and, consequently, the increased intake of polyphenols in the population of Sao Paulo could be translated to improve health or provide protection against CVD.

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Supplementary material

For supplementary material/s referred to in this article, please visit http://dx.doi.org/doi:10.1017/S0007114515005061

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