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Dietary nutritional profile and phenolic compounds consumption in school children of highlands of Argentine Northwest

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ABSTRACT

The objective of this work was to assess dietary patterns and consumption of phenolic compounds from fruits and vegetables byschoolchildren of high altitude regions from northwest of Argentina. A nutritional survey including food-frequency consumption, 24-h dietary recall and anthropometric measurements was applied to 241 children from 6 to 12 years old. The amounts of the different classes of phenolic compounds were established from Food Composition Tables available in phenol-explorer website. Statistics analyses were performed using IBM SPSS 20.0. Nutritional status assessment showed underweight (2.2%), low weight (12.7%), overweight (12.7%) and obesity (7.4%). Mean intake of phenolic compounds was 412 mg/day. Most consumed foods were infusions and sugar products, consumption of vegetables, fruits and dairy products were low compared to recommendations for this age. Considering that polyphenols have protective health effects, its low consumption could be a risk of development of chronic non communicable diseases.

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1. Introduction

During childhood nutrition plays a key role in growth and development of children. It must provide the nutrients needed to maintain body structures and tissues, and energy for metabolism and physical activity. Also, adopting good eating habits in childhood is essential to achieve a healthy lifestyle in adulthood (Arimond & Ruel, 2004).

The prevalence of childhood overweight and obesity has increased worldwide in recent decades. Prevalence of obesity is higher in developed countries, but is significantly increasing in developing countries, coexisting with undernutrition. In Latin American countries, 5–15% of schoolchildren are overweight and obese. Obesity in childhood has short and long term consequences on health including increasing risk of neurological, pulmonary, gastroenterological, endocrine, hepatic disorders among others. Considering all above mentioned it is important to report dietary characteristics and to assess the nutritional status of the children population (Irizarry & Rivera, 2010).

Using food to provide health benefits beyond prevention of deficiencies is a reasonable change of traditional nutritional intervention. Some food components that are not considered nutrients in the traditional sense can provide health benefits. The exact mechanisms by which fruit and vegetables compounds reduce the risk of these chronic diseases are not precisely known (Rodriguez-Casado, 2016). A combination of antioxidants and phytochemicals found in fruit and vegetables might promote health by combating free radicals, which are linked with early phase development of some chronic diseases (Wang, Ouyang, Liu, & Zhao, 2014).

Number of studies report beneficial health effects of phenolic compounds. Many of the biological effects of polyphenols have been attributed to their high antioxidant potential, since these compounds can protect cell constituents from oxidative damage, limiting the risk of degenerative diseases associated with oxidative stress. However, it is now known that these compounds are more than just antioxidants and are involved in many mechanisms and molecular pathways involved in various physiological functions, resulting generally in a reduced risk of various diseases (Crozier, Jaganath, & Clifford, 2009; Hollman, 2016).

Evidence obtained from animal studies demonstrates association between ingestion of large amounts of polyphenols and diminution of dislypidemia, atherosclerosis and inflammatory process linked to cardiovascular diseases (Khurana, Venkataraman, Hollingsworth, Piche, & Tai, 2013). Polyphenols are secondary metabolites produced by plants, classified as phenolic acids, stilbenes, lignans, flavonoids and tannins. Phenolic compounds are widely distributed in plant foods (Wallace, Blumberg, Johnson, & Shao, 2015). Phenolic acids are structurally characterized by a phenol ring with a carboxylic substituent, resulting hydroxybenzoic, phenylacetic or phenylpropionic acids, in

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particular, hydroxycinnamic acids. Flavonoids can be divided into several subfamilies according to the degree of oxidation of the oxygenated heterocycle which forms part of its structure, being flavanols, flavanones, flavones, flavonols, isoflavones, and anthocyanidins (Kay, 2010).

Among stilbenes, resveratrol distinguishes for its anticarcinogenic properties. This kind of phenolic compound is not widely distributed in foods (Bertelli & Das, 2009).

Lignans are complex phenolic polymer molecules, known as phytoestrogens. Other polyphenols refers to compounds produced by the polymerization of flavonoids and phenolic acids. Finally, tannins have anti-nutritional properties (Santos-Buelga & Scalbert, 2000).

Despite the numerous studies reporting beneficial activities due to diets rich in polyphenols, caution should be taken when it comes to supplementation, since there are no recommendations or upper limits set. This work focuses on the beneficial effects of phenolic compounds, though it must be considered that negative effects cannot be completely disregarded (Fernández & Jiménez, 2012; Fraga, Galleano, Verstraeten, & Oteiza, 2010).

Knowledge of the contribution of nutrients and bioactive compound of the foods included in the diet is essential to develop food policies and campaigns on nutrition. This also helps to promote the consumption of these beneficial compounds and also for interventions in education and public health.

The objective of this work was to assess dietary patterns and daily consumption of phenolic compounds from fruits and vegetables by schoolchildren of high altitude regions from northwest of Argentina.

2. Material and methods

2.1. Sampling

The sample was composed by schoolchildren from high altitude zone of Tucuman and Jujuy. These provinces are located in Argentinean Northwest and include regions with altitudes between 1500 and 3700 metres above sea level (m.a.s.l). The population of this region is descendant of various ethnic groups including Diaguitas, Aymara, Atacamas. Populations of Jujuy and Tucuman are taken as representative since they have their own and different characteristics to each other, and that social and cultural factors have a big influence on what people eat, how they prepare their food, their food practices and food preferences.

To set the sample size, data of the target populations were taken from National census conducted in 2010 and calculated using a confidence level of 95%. The sample was composed of 241 children from four locations, two per province and represented 1.6% of the scholar population, which was considered to be a representative sample. For this study, it is considered that a valid option is capturing the population under study through educational institutions.

Once schools with the highest concentration of students were selected, a random selection of children from 6 to 12 years old was performed in each one. The inclusion criterion was having permission signed parental consent for each child.

Ethical clearance for the study was obtained from responsible academic of the respective educational institutions. Protocols work with children was properly approved by the scientific committee of CONICET Tucumán.

2.2. Survey

2.2.1. Nutritional survey

A nutritional survey including 48-h dietary recall and anthropometric measurements was conducted by previously trained staff. Younger children (6 to 9 years old) were requested to have a tutor or parent presence for carrying out the survey for reliable information. Photo food models were used as support material to standardize the types and amounts of the main food groups (Cereals, fruits, vegetables, sugar, drinks, spoons, cups, and plates).

2.3. Anthropometric measurements

Weight and height were measured with electronic scales (TEFAL CHARM, SC 2504 Rumilly, Francia; 200 g precision) and mobile rod (KAWE, 44444; Kirchner & Whilhelm GmbH, Asperg, Germany), respectively. Anthropometric measurements were performed according to the recommendation of the World Health Organization guidelines (WHO, 1995).

The nutritional status of schoolchildren was assessed with BMI-for-Age z-score and Height-for-Age z-score, calculated from the mean and standard deviation of the reference population. They were compared with reference standards child growth and reference standards of the World Health Organization (WHO, 2009).

2.4. . Phenolic compounds data analysis

The amounts of the different classes of phenolic compounds were established from Food Composition Tables in phenol-explorer website. It is the first comprehensive database on the polyphenol content in foods. It has more than 35,000 values of 500 different polyphenols contained in more than 400 foods. These data are derived from the systematic collection of more than 60,000 values polyphenol content from more than 13,000 publications critically evaluated before inclusion in the database Phenol-explorer.eu (Rothwell et al., 2013). In the case of regional foods that are not included in the basis above mentioned other published works were used (Anusic, 2012; Cattaneo et al., 2016; Di Paola Naranjo et al., 2016). It is noteworthy that the use of this database is due to the unavailability of regional databases of phenolic compounds.

2.5. Statistical analysis

Categorical variables (anthropometric measurements and physical activity level) were presented as percentages, while continuous variables (age, Energy intake and Basal Metabolism Rate) were expressed as means and standard deviations. Chi-squared test tests were used to evaluate associations between categorical variables, while Student's t-tests were used to compare group means by provinces with confidence level of 95% and the level of significance was set at $p < 0.05$. Statistics analyses were performed using IBM SPSS 20.0.

3. Results and discussion

3.1. Nutritional status and dietary patterns

Prevalence of underweight, overweight and obesity, as well as low height for age (stunting) are shown in Table 1. Anthropometric measurements showed coexistence of undernutrition and obesity. This phenomenon is characteristic of nutritional transition (Bassett, Gimenez, Romaguera, & Samman, 2013; Popkin, Adair, & Ng, 2012).

A particular characteristic of the nutritional transition in Argentina is the great heterogeneity in all the indicative variables between the provinces and regions.

Populations of high altitude areas in the process of nutritional transition are experiencing vulnerability and food insecurity; both could be attributed to limited access and consumption of food. It is

Table 1
Nutritional status of schoolchildren and associated variables.

	Total (n = 241)	Tucumán	Jujuy	p
Age (y)	8.9 ± 2.0	8.7 ± 2.0	9,7 ± 2.1	0.00[#]
Energy intake (kcal/d)	1547 ± 478	1528 ± 511	1590 ± 392	0.37[#]
BMR (kcal/d)	1145 ± 172	1139 ± 179	1159 ± 165	0.02[#]
BMI-for-Age (%)				0.08[##]
Underweight	2.2	3.1	0	
Low weight	12.7	11.3	15.7	
Overweight	12.7	12.6	12.9	
Obesity	7.4	10.1	1.4	
Height-for-Age z score (%)				0.09[##]
<-2 SD (stunting)	4.8	3.7	7.1	
Physical Activity (%)				0.09[##]
Sedentary	97.2	98.8	91.7	
Moderated activity	2.8	1.2	8.3	

BMR: Basal metabolic rate (kcal/d).
Values expresses as mean ± SD or %.
[#] T studen's test.
[##] Chi^2 test.

widely known that most of the large conglomerates, where there are higher levels of urbanization, better income, better access to education and health, better sanitation, among others, are located below 1000 m.a.s.l. on the contrary happens in those cities that are located above 3000 m.a.s.l. These characteristics of quality of life are a reflection of the epidemiological transition generated by demographic and socioeconomic changes. These transitions involve significant changes in the food consumption pattern, physical activity, and body composition which can cause nutrition-related diseases.

In Argentina there are no official nutritional surveys for school children. This subject is particularly important to be approached. Previous studies in provinces that are part of the Argentinean Northwest showed that there have been increasing prevalence of overweight and obesity in recent decades, as well underweight states coexisting with obesity within the same population group and even within the same family (homes dual burden). Between 1995 and 2000 in the province of Jujuy, children between 4 and 16 years old showed a sustained increase in prevalence of overweight and obesity (Lomaglio, 2012).

Although the situation described is multifactorial origin, and any reductionism can lead to partial interpretations, other studies have analyzed the relationship between altitude and nutritional status. In other Latin American countries such as Peru it was found that as the altitude was higher, the prevalence of obesity and overweight was decreasing (Pajuelo Ramírez, Sánchez Abanto, & Arabañil-Huaman, 2010). Altitude is a variable that is not responsible for changes in the prevalence of chronic no communicable diseases by itself; the most important variables are the social, economic and environmental conditions and the quality of life of these populations.

Regarding eating habits, the progressive abandonment of traditional preparations of this high region population (including many agricultural products farmers in the area such as cheeses and goat meat, vegetables and fruits) and its replacement by industrialized foods is remarkable. Food consumption classified according to groups is shown in Fig. 1. Most consumed foods were infusions and sugar products, while other important food groups such as vegetables, fruits and dairy products were low compared to recommendations for this age (MERCOSUR., 2003). All the aforementioned could lead to deficiencies of micronutrients. Also, large quantities of foods rich in energy like sugar, bakery and refined cereal products combined with very low levels of physical activity could be a cause of the high prevalence of overweight and obesity observed in this population. These significant changes in lifestyle and eating pattern could be explained by the many advances in technology and communication systems produced over the last 30 years. Schoolchildren of high altitude of Argentinian Northwest diet can be further classified as monotonous as it not only includes a very small amount of fruits, vegetables and whole grains, but always the same varieties are consumed.

3.2. . Polyphenol intake

Mean intake of phenolic compounds in these schoolchildren was 412 mg/day. The distribution according to classes and subclasses is shown in Fig. 2.

The contribution of phenolic acids was the highest; the mean intake was 310 mg/day representing 76% of the total intake of polyphenols. These compounds were divided into two subclasses in this work (Hydroxybenzoic and hydroxycinnamic acids). This class of compounds was contributed mainly by infusions and in fewer amounts by vegetables consumed for schoolchildren of high altitude of provinces of Jujuy and Tucumán.

Flavonoids contributed 22.9% of total polyphenol intake. Mean intake was 94.1 mg/day. These compounds were analyzed dividing subclasses (flavanols, flavanones, flavones, flavonols, isoflavones, and anthocyanidins). Only some of them were provided by the foods included in the diet of this population. In the studied schoolchildren population, the intake of flavonoids is clearly lower than reported by other authors (Krupp et al., 2016).

In spite there are no recommended intakes for any phenolic compounds, results taken from a large prospective cohort of US men and women showed that a greater intake of total flavonoids (512 mg/day) was associated with a lower risk of fatal cardiovascular disease in men and women after several important cardiovascular risk factors were controlled (McCullough et al., 2012). Other works indicate that high consumers (high consumption was defined as ⩾788 mg/day) were at lower risk of all-cause mortality (Feliciano, Pritzel, Heiss, & Rodriguez-Mateos, 2015). Mean intake of total flavonoids in Europe was 428 mg/day (Vogiatzoglou et al., 2015). In Australia the mean consumption of flavonoids is 454 mg/day (Johannot & Somerset, 2006). Although these studies assessed adult population, they can be taken as a trend of consumption. Recent studies prove the effectiveness of components derived from plants, known for their antioxidant and anti-inflammatory properties, these components have proven to be effective in combating the growth of cancer stem cells, metabolism and its microenvironment (Pistollato, Giampieri, & Battino, 2015).

Significantly fewer lignans found, contributing 0.4% of the total, mainly from citrus fruits such as orange and tangerine were consumed by schoolchildren of high altitude region under study.

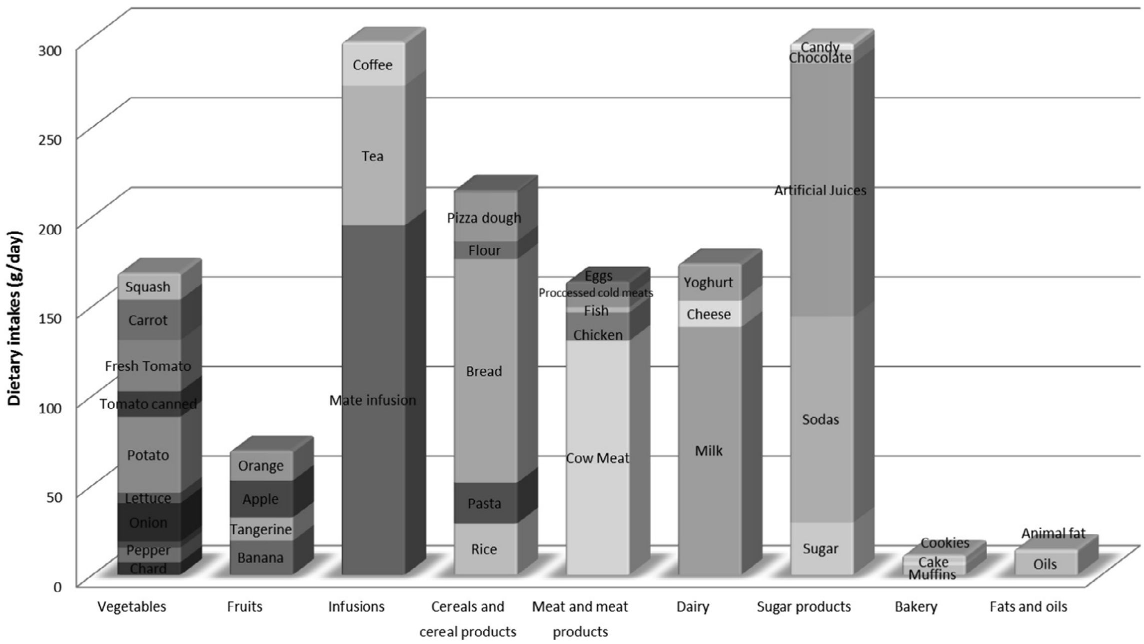
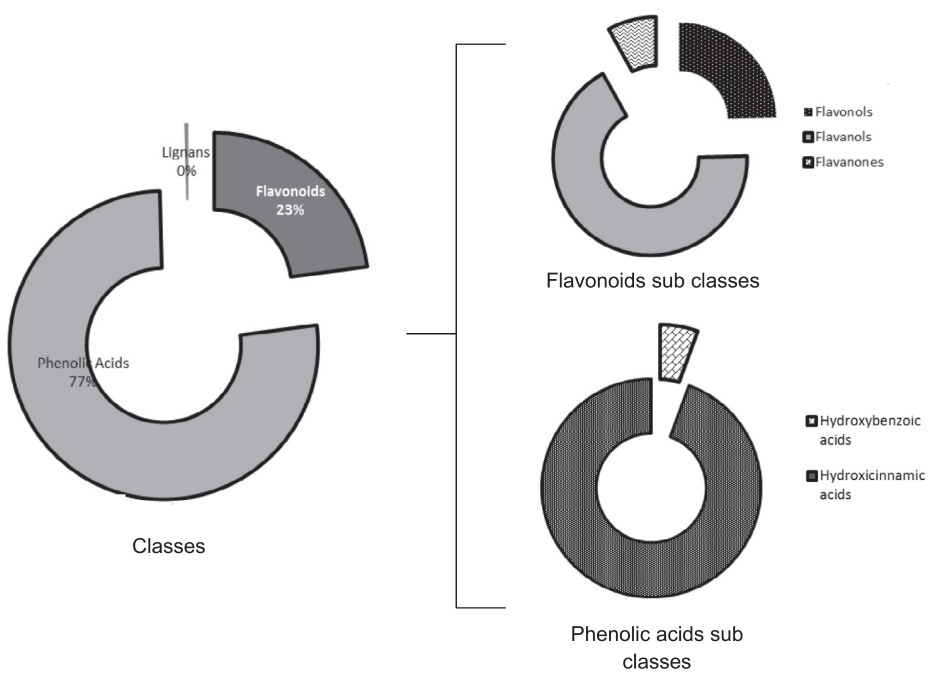


Fig. 1. Mean daily intake of foods by schoolchildren.



	Flavonoids			Phenolic acids		
	Flavonols	Flavanols	Flavanones	Hydroxybenzoic acids	Hydroxicinnamic acids	Ligans
Jujuy	22.8	56.3	21.0	23.1	195.6	3.4
Tucum	22.1	64.5	3.1	15.9	332.5	1.2
Total	22.9	62.5	7.5	17.7	298.3	1.7

Values expressed in mg

Fig. 2. Phenolic compounds intake: classes and sub classes distribution.

The list of main sources of phenolic compounds and the relative contribution of different foods is described in the Table 2.

Importantly, in the region under study food sources of phenolic compounds are grown, but they are poorly consumed by this population since they are not part of their dietary pattern. Their polyphenol composition is described in Table 3.

Low consumption of polyphenols cannot be analyzed independently of the eating pattern. Low consumption of fruits and vegetables can be defined as a trend observed in terms of schoolchildren of the region under study, but also repeated in other regions of the world, including those culturally different (Boeing et al., 2012).

Table 2
Contribution of different foods to the polyphenol content in the diets of school children.

Food	Mean intake (g/d)	Polyphenols content (mg/100 g)	Polyphenols contributed by mean intake (mg)	Relative contribution (%)
Mate	195.0	127.0	247.6	60.0
Tea	78.0	100.5	78.1	18.9
Coffee	24.0	89.0	21.0	5.1
Onion	21.4	62.3	13.1	3.2
Potato	42.5	28.35	12.0	2.9
Apple	20.6	56.32	11.7	2.8
Orange	16.6	48.84	8.2	2.0
Chard	7.04	121.4	7.2	1.7
Carrot	22.6	20.0	4.5	1.1
Tangerine	13.0	7.9	1.0	0.2

Table 3
Data of phenolic compounds contents in regional foods.

Food	Scientific name	Polyphenol content mg GAE/100g)	Main Class of compounds	References
Huckleberry	Vaccinium	154.2	Flavonoids	Van de Velde, Grace, Esposito, Pirovani, & Lila, 2016
Lettuce	Lactuca sativa	36.39	NA	Viacava, Roura, & Agüero, 2015
Oca pulp	Oxalis tuberosa	149.2	Phenolic acids	Jiménez and Sammán (2014)
Oca Skin	Oxalis tuberosa	200.6	Phenolic acids	Jiménez and Sammán (2014)
Yacón Pulp	Smallanthus sonchifolius	54.4	Phenolic acids	Jiménez and Sammán (2014)
Yacón Skin	Smallanthus sonchifolius	22.7	Phenolic acids	Jiménez and Sammán (2014)
Peaches	Prunus persica	68	Flavonoids	Rodrigo-García, Álvarez Parrilla, de la Rosa, Mercado Mercado, Herrera Duenez (2006)
Honeys	–	92.3	Flavonoids	Aloisi (2014)
Propolis	–	590	Flavonoids	Bedascarrasbure, Maldonado, Álvarez, and Rodriguez (2004)
Pollen		87.17	Flavonoids	Aloisi (2014)
Pears	Pyrus communis	0.03	Flavonoids	Barda, INTA
Purple corn	Zea mayz	31.01	Flavonoids	Mayorga Gavilanes (2010)
Red corn	Zea mayz	16.15	Flavonoids	Mayorga Gavilanes (2010)
Yellow corn	Zea mayz	1.84	Flavonoids	Mayorga Gavilanes (2010)
Aromatic species		175.05	NA	Saluzzo, Cabana, and Viturro (2014)
Oregano essentials Oils	Origanum vulgare	10.0	Phenolic acids	Olmedo, Asensio, and Grosso (2015)
Rosemary essentials oils	Rosmarinus officinalis	8.0	Flavonoids	Olmedo, Asensio, and Grosso (2015)
Laurel essentials oils	Laurus nobilis	10.5	Flavonoids	Olmedo, Asensio, and Grosso (2015)
Chañar Flour	Geoffroea decorticans	1240	Flavonoids	Costamagna, Ordoñez, Zampini, Sayago, and Isla (2013)
Chañar arrope with sugar	Geoffroea decorticans	153	Flavonoids	Costamagna et al. (2013)
Chañar arrope without sugar	Geoffroea decorticans	220	Flavonoids	Costamagna et al. (2013)
Algarrobo blanco	Prosopis Alba cotyledons	1150	Flavonoids	Cattaneo et al. (2016)
Syrah grape	Vitis vinifera	10.62	Flavonoids	Lingua, Fabani, Wunderlin, and Baroni (2016)
Merlot grape	Vitis vinifera	14.58	Flavonoids	Lingua et al. (2016)
Cabernet sauvignon grape	Vitis vinifera	19.86	Flavonoids	Lingua et al. (2016)
Tomato	Solanum lycopersicum	92.0	Phenolic acids	Di Paola Naranjo et al. (2016)
Blackberry	Rubus ulmifolius	161.8*	Flavonoids	Fredes (2009)
Yerba Mate	Ilex paraguariensis	127*	Phenolic acids	Anusic, 2012

* Values were measured by HPLC and expressed in mg/100 g. All others values were measured by Folin-Ciocalteu and expressed in mg gallic acid (GA) per 100 g.

However, in some regions of the world despite modernization, healthy eating patterns are maintained. Mediterranean diet includes foods rich in polyphenols daily. This can be observed in its updated dietary guidelines, where herbal teas and fruits and vegetables are at the base. But it also proposes educational strategies for successful implementation of these recommendations (Bach-Faig et al., 2011).

In this regard the actions of nutritional education should be directed to the incorporation of food resulting in a benefit for the population, especially in the studied population, considering the very high percentage of overweight and obesity observed.

Despite the different studies on the intake of polyphenols made in other countries, in Argentina there are no previous works of this kind. This study is a first step towards generating data intake of phenolic compounds for this population.

Although the database is not typical of the region, it is important to note that when comparing the data of some phenolic compounds thrown by different databases, there were no significant variations in their food contents. Composition tables used also allow comparing the results of this work with others made in other regions of the world. Data collection of phenolic compounds composition in food produced in the region is currently being developed. Initial results are shown in Table 3.

4. Conclusion

The scholar population of high region of the northwest Argentine presented inadequate dietary patterns, as well as undernutrition and obesity. Consumption of energy-dense foods could lead to perpetuate this anthropometric profile, marked by the growth of overweight and obesity. In addition, consumption of fruits and vegetables was very low, which determines the non-fulfillment of nutritional requirements, both of micronutrients and bioactive compounds.

The data provided by this work suggest that habitual intake of most compounds is likely too low to reduce risk of cardiovascular diseases in this population. Further research is required to investigate the potential health benefits of phenolic compounds, in particular the primary prevention of chronic diseases in the general public. The study of intakes in different populations may be one of the steps towards the establishment of recommendations and further study.

Conflict of interest

All the authors declare no conflict of interest; also we certify that we have participated sufficiently in the work to take public responsibility for the content, including participation in the concept, design, analysis, writing, or revision of the manuscript. We have seen and approved the final version of the manuscript being submitted. Furthermore, each author certifies that this material or similar material has not been and will not be submitted to or published in any other publication.

All authors whose names are listed in publication certify that they have no affiliations with or involvement in any organization or entity with any financial interest.

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