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Inadequate dietary intake of minerals: prevalence and association with socio-demographic and lifestyle factors

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Abstract

This cross-sectional, population-based study aimed to estimate the prevalence of dietary mineral inadequacies among residents in urban areas of Sao Paulo, to identify foods contributing to mineral intake and to verify possible associations between socio-demographic and lifestyle factors and mineral intake. Data were obtained from the 2008 Health Survey of Sao Paulo (*n* 1511; mean age 43·6 (SD 23·2), range 14–97 years). Dietary intake of minerals was measured using two 24-h dietary recalls. Socio-demographic and lifestyle data were collected. The prevalence of inadequate intake was estimated according to Dietary Reference Intakes methods. Associations between mineral intake and baseline factors were determined using multiple linear regression. Na, Ca and Mg showed the highest dietary inadequacies. Some age/sex groups had lower intakes of P, Zn, Cu and Se. Rice, beans and bread were the main foods contributing towards mineral intake. Female sex was negatively associated with K, Na, P, Mg, Zn and Mn intakes. All age groups were positively associated with the intakes of K, P, Mg and Mn. Family income above one minimum wage was positively associated with Se intake. Living in a household whose head completed ≥10 years of education was positively associated with Ca and negatively associated with Na intake. Former smoker status was negatively associated with Ca intake. Current smoker status was inversely associated with K, Ca, P and Cu intakes. Sufficient physical activity was positively associated with K, Ca and Mg intakes. Overall, the intakes of all major minerals were inadequate and were influenced by socio-demographic and lifestyle factors.

Key words: Diet: Micronutrients: Deficiency: Epidemiological surveys: Nutritional assessment

Brazil, similar to other developing countries, experiences a dual scenario characterised by diseases related to nutritional deficiency and to overweight[1], commonly found in countries undergoing nutritional transition. In this context, micronutrient intake may be affected[1–6], highlighting the importance of micronutrient intake monitoring. The practice of nutritional monitoring is useful to guide public policies focused at preventing deficiency diseases and chronic non-communicable diseases (NCD)[1,2].

The role of minerals for human health is undeniable. However, there is a paucity of knowledge regarding the adequacy of mineral intake within the population. Methods that compare habitual intake with dietary requirements have been used to identify individuals at potential risk[6]. It is also important to identify factors that influence mineral intake, as such knowledge can assist in creating targeted public policies focusing on minerals, whose intake among the population is typically low. Vlismas *et al.*[7] suggest that socio-economic status may influence dietary habits, with education level being a consistent predictor of health, more so than household income or occupation. Other studies suggest that anthropometric status may influence mineral intake adequacy[2,8], which might be explained by the adoption of unhealthier diets, especially by people of low socio-economic status[9].

Given this background, our study aimed to estimate the prevalence of dietary mineral inadequacies in a representative sample of residents from urban areas of Sao Paulo, to identify foods that contribute towards mineral intake and to verify the possible association between socio-demographic and lifestyle factors and mineral intake.

Methods

This survey was approved by the Ethics Committee on Research of the Faculty of Public Health, University of Sao Paulo (Certificate of Presentation for Ethical Appreciation (CAAE) no. 26800414·1·0000·5421). Written informed consent was obtained from all individuals, or from their proxies, before commencement of the study.

Study population

This study examined data from the 2008 Health Survey of Sao Paulo ('Inquérito de Saúde de São Paulo'; ISA-Capital), a cross-sectional,

Abbreviations: 24HR, 24-h dietary recall; NCD, non-communicable disease.

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population-based survey that used a complex, stratified, multistage probability sample design to create a representative sample of non-institutionalised residents from urban areas of Sao Paulo, south-eastern Brazil.

Sample recruitment was performed in two stages. First, seventy census tracts were randomly selected from all urban census tracts in Sao Paulo. Second, 16 607 households within these census tracts were randomly selected and stratified by the following domains: (1) infants (<1 year; both sexes), (2) children (1–11 years; both sexes), (3) male adolescents (12–19 years), (4) female adolescents (12–19 years), (5) male adults (20–59 years), (6) female adults (20–59 years), (7) male elderly (≥60 years) and (8) female elderly (≥60 years). Different sampling fractions were used – based on the proportion of each age/sex group in the population of the urban areas sampled – to preserve the representativeness of each domain. The sample size was calculated on the basis of a prevalence of 0·5 with a sample error of 0·07 at a 5 % significance level and design effect of 1·5.

A total of 3271 individuals participated. Of these, 2691 individuals were aged 12 years and older, and were invited to have a dietary assessment performed. Pregnant or lactating women were excluded. Of those who had their diets assessed, 1511 individuals aged 14 years and older were considered. The cut-off point of 14 years was established to maintain the life stage (age) groups defined in the Dietary Reference Intakes: 9–13 years: puberty; 14–18 years: adolescence; 19–30 years: young adulthood; 30–50 years: middle age; 51–70 years: adulthood; and >70 years: older adults[10]. These age groups, reflecting the life stages, were used for the analysis of data in the present study. The survey response rate was 77 %. The findings presented here are based on the complete case analysis. The low percentage of missing values was likely missing at random or missing completely at random and will likely have minimal impact on associations. No additional information is available on those who refused to respond.

Data entry and databases

Trained interviewers visited the selected households to conduct individual interviews based on a structured questionnaire, assessing the following: socio-demographic (sex, age, education level, income) and lifestyle (smoking status, leisure-time physical activity, BMI, dietary habits) factors.

Sex was classified as male or female. Age at the date of interview was considered in complete years, and was used to group individuals according to the life stages of Dietary Reference Intakes. Educational level of the household head was defined as the number of years of education completed by the head of the family, categorised as <10 years (elementary school or less) or ≥10 years (high school or more). Categories of family income *per capita* were calculated using the arithmetic mean of the sum of all family members' total monetary income – that is, each family member's income averaged out over the number of family members. The prevailing minimum wage established by the Brazilian government at the time of data collection was US$ 258·39 (R$ 415·00), considering the exchange rate on 1 July 2008. Family income was categorised as ≤1 minimum wage *per capita* or >1 minimum wage *per capita*. Smoking behaviour was classified as 'never', 'former' or 'current' smoker, according to the answers provided in the structured questionnaire. Leisure-time physical activity was assessed using relevant questions from the long International Physical Activity Questionnaire[11], and was classified as 'insufficient' or 'sufficient', according to interpretations by Haskell *et al.*[12] and Nelson *et al.*[13]. Sufficient physical activity comprised at least 30 min of moderate-intensity exercise daily, 5 d/week, or at least 20 min of vigorous exercise daily, 3 d/week; otherwise, it was considered as insufficient physical activity. Using self-reported height and weight, BMI was calculated as the quotient of weight (kg) over height squared (m^2) and classified according to their life stage[14–16].

Data from two non-consecutive, 24-h dietary recalls (24HR) were collected by trained interviewers: one during the interview conducted in the selected households and the other by telephone. The dietary interviews were conducted using the United States Department of Agriculture's (USDA) Multiple-Pass Method and the USDA's Automated Multiple-Pass Method, respectively. These methods guide the individual through five steps: (1) quick list – the interviewee lists, without interruption, all foods and beverages consumed the previous day; (2) forgotten foods list – the interviewer repeats the list of foods and beverages mentioned by the interviewee to identify foods that may have been forgotten; (3) time and occasion – the interviewee elaborates on the time he/she consumed foods and on what he/she considers to be a meal; (4) detail cycle – the interviewee provides descriptions and amounts of each food reported, and the interviewer reviews each occasion and the interval between occasions; and (5) final review probe – the interviewer repeats all information with the intention of collecting data on additional foods not remembered earlier[17]. The 24HR were conducted to include all days of the week and all seasons of the year.

Assessment of dietary mineral intake

The following minerals were considered in this study: K, Na, Ca, P, Mg, Zn, Mn, Cu and Se. Nutrition Data System for Research software, version 2007 (Nutrition Coordinating Centre, University of Minnesota), was used to compute data obtained by the 24HR. After entering data of 24HR, the energy intake values were checked to identify possible mistakes in data collection and entry. Subsequently, foods' mineral values were reviewed using local information from Brazilian food tables[18,19], and, when necessary, the mineral content was corrected to approximate the local reality using the data correction routine of Stata software (version 13.0; StataCorp LP).

Usual dietary intake of minerals was estimated using statistical modelling techniques incorporated in Multiple Source Method programme, a web-based tool used for estimating usual dietary intakes of nutrients and foods consumed by populations and individuals. The usual dietary intake was estimated in a three-step procedure. First, the probability of nutrient intake for each individual was estimated. Second, the usual amount of food intake in days of consumption was estimated. Finally, the above values were multiplied by each other to estimate the usual daily intake for each individual. The programme makes use of covariate information to improve the modelling of consumption probability and intake amount to estimate the distribution of usual intake[20]. Sex and age were the covariates used to adjust the modelling.

The prevalence of individual inadequate dietary intakes of Ca, P, Mg, Zn, Cu and Se was determined using the estimated average requirement (EAR) cut-off point approach, a simplification of the probability method, which estimates the proportion of individuals with usual intakes below the EAR (median requirement). Dietary K and Mn intakes were assessed for comparison with the adequate intake (AI), and the proportion of individuals with usual intakes equal to or greater than the AI value was determined. Na intake was assessed by risk of adverse effects using the tolerable upper intake level, which estimates the proportion of individuals potentially at risk for adverse effects[10]. These processes were conducted for each sex and age group.

A list of foods contributing to mineral intake was obtained, taking into account the sampling design, as suggested by Block *et al.*[21]. In brief, all foods consumed in the first 24HR were classified into food groups according to frequency of consumption and similarity of mineral content. If the food was consumed fewer than five times, it was grouped with other food items according to the similarity of mineral content – for example, smoothies of papaya, banana, apple, avocado and/or strawberry. If consumed at least five times, the food was kept without grouping – for example banana. Once classified, the percentage of minerals contributed was calculated using sample weighting, and the foods were sequenced in rank order of contribution.

Statistical analysis

Statistical analyses were performed using the survey data commands available in Stata software, which consider the sampling weights (probability weights), clustering and stratification of the survey design[22]. A 5 % significance level was considered.

Socio-demographic and health-risk lifestyle factors were expressed as relative frequencies. Mineral intakes are presented as means, standard errors and percentiles stratified by life stage and sex. In order to reduce the errors associated with dietary measurements, the intake of minerals was adjusted according to the total energy intake using the residual method[23]. Multiple linear regression methods were used to verify the relationships between mineral intakes (dependent variables) and socio-demographic and lifestyle factors (independent variables). All regression models were adjusted for BMI and energy intake.

Results

In total, 1511 individuals were assessed. Of these, 58·1 % were women, 63·6 % of household heads completed <10 years of education, 50·7 % earned more than one minimum wage *per capita*, 66·6 % self-reported as never smokers (18·1 % were former smokers), 86·9 % engaged in insufficient leisure-time physical activity and 51·9 % had healthy weight (42·5 % were overweight or obese; Table 1). Their energy intakes are presented in Table 1.

Among the minerals assessed, the prevalence of inadequate intake was highest for Na, Ca and Mg; this was consistent across all life stages (age groups). The prevalence of inadequate intake varied from 50·0 to 95·4 % for Na, 77·9 to 99·8 % for Ca and 82·9 to 99·5 % for Mg. Adolescents had a considerable prevalence of low dietary P intake, especially female adolescents (Tables 2 and 3). Almost none of the individuals had a K intake equal to or above the AI (Table 4).

In some age-/sex-stratified groups, >20 % of individuals had inadequate intakes of Zn, Cu and Se. Men aged >19 years were more susceptible to inadequate Zn intakes than women, and this inadequacy worsened with age. Unlike Zn, Cu intake inadequacy did not worsen with age, and the highest prevalence of inadequate Cu intake was among women. Female adolescents and adults (≥31 years) had lower Se intakes than men, which became more pronounced with age (Tables 2 and 3). A considerable proportion of individuals had Mn intakes equal to or above the AI: 64·3–81·8 % for men and 77·2–90·3 % for women (Table 4).

The ten foods listed in Table 5 (online Supplementary Tables S5·1 and S5·2) contributed to about 60 % of the total mineral intake. Overall, white rice, brown beans and French bread were the major foods contributing to dietary mineral intake in the sample assessed. Brown beans was among the top five mineral contributors; it was not listed in the top 10 only for Se (general: 132th position; men: 105th position; women: 148th position). White rice and French bread emerged as contributors to all minerals assessed: white rice stayed in the top three foods for most minerals, and French bread was in the top six foods for all minerals. Beef, chicken and milk provided a share of some minerals. Milk was the main contributor of Ca. Meat (beef, chicken, pork and fish) contributed to all minerals except Mn. However, Mn was the only mineral that had among its top 10 food contributors vegetables (lettuce, 8th position (men: 9th; women: 9th)) and whole-grain foods (whole-wheat bread, 5th position (general, men and women)). In addition, banana contributed to Mn (6th (men: 6th; women: 6th)), K (9th (men: 10th; women: 6th)) and Mg (9th (men: 9th; women: 7th)) intakes, and raw tomato contributed to K (8th (men: 8th; women: 7th)) and Cu (10th (men: 14th; women: 12th)), as well as, only for men, Ca (9th) intakes.

In the multiple linear regression model tested (Table 6), significant positive associations were identified between intake of Ca and household head education level ≥10 years and age ≥51 years; intakes of K, P and Mg and all life stages (age groups); intakes of Na and Mn and life stage 31–50 years; intakes of Na, Ca, Mn and Cu and life stage 51–70 years; intakes of Ca and Mn and life stage >70 years; intake of Se and family income more than one minimum wage; and intakes of K, Ca and Mg and sufficient physical activity.

Significant negative associations were identified between female sex and intakes of K, Na, P, Mg, Zn and Mn; household head education level ≥10 years and intake of Na; former smoker status and intake of Ca; and between current smoker status and intakes of K, Ca, P and Cu.

Discussion

Of the minerals assessed in the present study, the only one with probably no likely risk of inadequacy in urban residents of Sao Paulo was Mn. Mn is an essential mineral that functions as

Table 1. Baseline characteristics of urban residents in Sao Paulo: Inquérito de Saúde de São Paulo; ISA-Capital study, 2008
(Numbers, percentages, mean values and standard deviations)

	Men				Women				Total			
Characteristics	*n*	%	Mean	SD	*n*	%	Mean	SD	*n*	%	Mean	SD
Sex	633	41·8	–	–	878	58·1	–	–	1511	100·0	–	–
Age (years)	–	–	40·9	23·4	–	–	45·6	22·9	–	–	43·6	23·2
Household head education												
≤10 years of education	374	59·6	–	–	573	66·6	–	–	947	63·6	–	–
>10 years of education	254	40·4	–	–	287	33·4	–	–	541	36·4	–	–
Family income*												
≤1 minimum wage *per capita*	290	45·8	–	–	455	51·8	–	–	745	49·3	–	–
>1 minimum wage *per capita*	343	54·2	–	–	423	48·2	–	–	766	50·7	–	–
Smoking behaviour												
Non-smoker	382	60·4	–	–	624	71·1	–	–	1006	66·6	–	–
Former smoker	139	22·0	–	–	134	15·3	–	–	273	18·1	–	–
Current smoker	112	17·7	–	–	120	13·7	–	–	232	15·4	–	–
Leisure-time physical activity												
Insufficient physical activity	511	80·9	–	–	801	91·2	–	–	1312	86·9	–	–
Sufficient physical activity†	121	19·2	–	–	77	8·8	–	–	198	13·1	–	–
BMI (kg/m^2)‡												
Underweight	32	5·14	–	–	52	6·0	–	–	84	5·63	–	–
Healthy weight	342	54·9	–	–	433	49·8	–	–	775	51·9	–	–
Overweight and obesity	249	40·0	–	–	385	44·3	–	–	634	42·5	–	–
Energy intake (kJ/d)												
14–18 years	181	28·6	10 741·2	3086·5	176	20·0	8409·8	2857·7	357	23·6	9591·8	3192·8
19–30 years	103	16·3	9937·8	2968·1	118	13·4	7722·8	1901·2	221	14·6	8755·0	2689·5
31–50 years	117	18·5	8943·3	2616·3	191	21·8	6678·1	1738·5	308	20·4	7538·3	2381·1
51–70 years	148	23·4	7500·2	2079·4	235	26·8	5935·0	1456·5	383	25·4	6539·6	1882·8
>70 years	84	13·3	6850·0	1762·3	158	18·0	5360·9	1401·2	242	16·0	5877·7	1689·1
Energy intake (kcal/d)												
14–18 years	181	28·6	2567·2	737·7	176	20·0	2010·0	683·0	357	23·6	2292·5	763·1
19–30 years	103	16·3	2375·2	709·4	118	13·4	1845·8	454·4	221	14·6	2092·5	642·8
31–50 years	117	18·5	2137·5	625·3	191	21·8	1596·1	415·5	308	20·4	1801·7	569·1
51–70 years	148	23·4	1792·6	497·0	235	26·8	1418·5	348·1	383	25·4	1563·0	450·0
>70 years	84	13·3	1637·2	421·2	158	18·0	1281·3	334·9	242	16·0	1404·8	403·7

* Family income *per capita* is the sum of all family members' monetary income averaged out over the number of family members. Minimum wage = US$ 258·39 (R$ 415·00).
† Sufficient physical activity: moderate-intensity exercise for at least 30 min daily on 5 d/week or vigorous-intensity exercise for at least 20 min daily on 3 d/week; otherwise, it was considered as insufficient physical activity[12,13].
‡ BMI classifications: 14–19 years: underweight, BMI < 3rd percentile; healthy weight, BMI > 3rd percentile and <85th percentile; overweight, BMI > 85th percentile and <97th percentile; obese, BMI > 97th percentile[14]; 20–59 years: underweight, BMI < 18·5 kg/m^2; healthy weight, BMI 18·5–24·9 kg/m^2; overweight, BMI 25·0–29·9 kg/m^2; obese, BMI ≥ 30 kg/m^2[15]; and ≥60 years: underweight, BMI < 23 kg/m^2; healthy weight, BMI 23·0–27·9 kg/m^2; overweight, BMI 28–29·9 kg/m^2; obese, BMI ≥ 30 kg/m^2[16].

an antioxidant and plays an important role in amino acid, cholesterol and carbohydrate metabolism[24]. However, a few studies have assessed levels of dietary Mn intake. Hence, the RDA of Mn has not yet been established, making it difficult to assert whether there is, in fact, adequacy of intake[24].

Similar to Mn, the RDA for K and Na could not be derived[25]. High levels of dietary Na and lower levels of dietary K were observed among both sexes and all life stages (age groups) assessed. Inadequate K and suboptimal Na intake has also been observed globally[1,26–29]. This combination is considered harmful to health because of the high rates of morbidity and mortality related to CVD. On the other hand, high sodium chloride intake results in increased urinary Na excretion, which leads to loss of other minerals, and thus predisposes the body to changes in homoeostasis[30]. According to Powles *et al.*[29], Brazilian adults (≥20 years) have the highest dietary Na intakes (4110 mg/d) in Latin America, and higher than those observed in the USA (3610 mg/d) and Canada (3720 mg/d). These authors also observed higher dietary Na intake in men. A possible explanation is that men generally have higher energy requirements than women. Other reasons include an increased concern with appearance and greater health consciousness among women. As evidenced by Souza *et al.*[31], the present study showed that Na intake was provided by traditional Brazilian foods such as rice and beans and other foods such as bread, meats, pizza and salted margarine, as well as the discretionary addition of salt (especially in the form of sodium chloride) during cooking for seasoning. These foods contributed significantly as a source of Na intake. An increased intake of more K-rich foods such as fruits, leafy green vegetables and root vegetables – combined with a reduced intake of high-salt-content products – especially the addition of salt – could help achieve the physiological requirements for K and Na and could decrease the burden of NCD[25].

To improve this scenario, the World Health Organization[32] set a global target of reducing salt intake by 30 % by 2025, aiming for a salt intake of <5g/d. Several countries have implemented salt reduction strategies. These strategies have included engaging with the food industry to re-formulate products, establish the Na content targets for foods, provide consumer education and ensure front-of-pack labelling; imposing taxes on high-salt foods; and introducing interventions in public institutions[33]. In Brazil, the strategies adopted by the Ministry of Health are promoting healthy eating; providing

Table 2. Dietary intakes of minerals, their distribution and probability of inadequacy in men residing in urban areas of Sao Paulo, according to life stage: Inquérito de Saúde de São Paulo (ISA-Capital) study, 2008
(Numbers, means values and standard deviations)

				Percentiles of minerals intake						
Life stages*	*n*	Mean	SD	10	25	50	75	90	EAR or UL†	Prevalence of inadequate intake (%)
Na (mg/d)										
14–18 years	181	4206·3	1125·1	2732·2	3513·7	4182·7	4892·7	5672·8	1500/2300	95·5†
19–30 years	103	4056·6	1036·7	2652·6	3273·9	4148·0	4966·8	5310·7	1500/2300	95·5†
31–50 years	117	3834·3	1065·3	2445·0	3061·2	3783·5	4651·0	5266·0	1500/2300	92·5†
51–70 years	148	3596·8	1080·1	2390·4	2845·1	3416·4	4162·0	5194·5	1300/2300	88·5†
>70 years	84	3068·3	789·5	2089·3	2514·7	2979·9	3570·6	4039·4	1200/2300	83·4†
Ca (mg/d)										
14–18 years	181	693·7	312·2	374·1	458·1	648·9	841·5	1114·7	1100	90·3
19–30 years	103	594·3	265·6	273·2	393·2	584·4	768·6	916·6	800	77·9
31–50 years	117	563·1	227·7	305·4	396·9	518·2	720·3	906·3	800	85·1
51–70 years	148	556·6	243·6	278·2	382·1	510·6	673·9	934·0	800	84·1
>70 years	84	577·3	239·9	313·2	427·6	562·5	703·1	871·7	1000	96·1
P (mg/d)										
14–18 years	181	1249·2	386·9	804·8	1027·1	1192·6	1428·3	1689·6	1055	30·9
19–30 years	103	1201·1	397·7	772·9	924·6	1138·0	1489·8	1719·9	580	5·9
31–50 years	117	1119·5	302·4	745·2	910·8	1112·5	1325·8	1569·2	580	3·8
51–70 years	148	1079·3	351·2	634·8	825·6	1054·2	1284·9	1546·8	580	7·8
>70 years	84	975·4	264·4	636·3	811·9	973·5	1133·8	1292·4	580	6·7
Mg (mg/d)										
14–18 years	181	263·1	77·6	175·8	208·8	258·5	304·1	345·8	340	83·9
19–30 years	103	255·4	78·2	162·5	202·1	251·8	315·8	353·9	330	82·9
31–50 years	117	241·7	62·7	158·1	199·9	236·1	289·7	334·6	350	95·8
51–70 years	148	237·5	68·5	156·8	191·6	225·6	273·6	345·1	350	95·0
>70 years	84	219·2	51·3	158·5	185·0	220·0	250·8	287·5	350	99·5
Zn (mg/d)										
14–18 years	181	14·8	4·8	9·2	11·7	14·5	18·4	20·5	8·5	9·3
19–30 years	103	14·4	4·4	9·5	11·4	13·6	17·2	20·2	9·4	13·1
31–50 years	117	12·8	4·1	7·8	10·4	12·1	15·1	17·6	9·4	20·1
51–70 years	148	11·5	3·7	7·6	9·1	10·8	13·6	15·4	9·4	28·4
>70 years	84	10·3	2·9	7·0	7·9	10·0	12·3	13·8	9·4	37·8
Cu (mg/d)										
14–18 years	181	1·4	0·4	0·9	1·1	1·3	1·6	1·8	0·69	4·4
19–30 years	103	1·4	0·9	0·9	1·0	1·3	1·5	1·8	0·70	23·3
31–50 years	117	1·2	0·4	0·8	1·0	1·1	1·4	1·7	0·70	10·0
51–70 years	148	1·1	0·5	0·8	0·9	1·1	1·2	1·6	0·70	16·9
>70 years	84	1·0	0·2	0·7	0·9	1·0	1·1	1·2	0·70	9·0
Se (μg/d)										
14–18 years	181	93·0	30·0	59·2	73·7	90·7	107·2	133·2	45	5·5
19–30 years	103	91·4	43·6	55·2	65·8	86·9	100·5	133·9	45	14·5
31–50 years	117	81·0	28·6	48·1	61·4	75·8	97·4	118·0	45	10·4
51–70 years	148	76·0	33·6	44·8	56·1	68·2	88·9	113·9	45	17·9
>70 years	84	62·4	20·8	40·9	50·5	59·6	72·5	83·6	45	20·1

EAR, estimated average requirement; UL, upper limit level.
* 14–18 years: adolescence; 19–30 years: young adulthood; 30–50 years: middle age; 51–70 years: adulthood; >70 years: older adults[10].
† For Na, the results are the proportion of individuals with risk of adverse effects by Na intakes, calculated using the UL.

education and information for healthcare and food handling and manufacturing professionals; and re-formulating processed foods[34].

In Brazil, NCD are the leading cause of all deaths (72 %) and the largest contributor to disease burden. Diabetes and hypertension have become increasingly prevalent, rising in parallel with overweight[35]. In addition to the association between dietary Na and NCD, a causal link between dietary inadequacy of Ca and Mg and NCD has been suggested[36–41]. In the present study, the inadequacy of Ca and Mg intake was more pronounced than that of Na; this could increase NCD. One of the reasons for Mg inadequacy is the low consumption of foods rich in Mg, with most of it being derived from foods that are believed to be intermediate or low sources of this micronutrient. The simple change from white rice (12 mg/100 g of food) to whole rice (43 mg/100 g of food) could have a positive effect on Mg intake, especially if the other cereals were also consumed in their whole form.

Dairy products contributed towards Ca intake in the sample assessed. However, its consumption was insufficient to supply physiological needs. Other foods, which are not particularly rich in Ca, were listed because they were consumed in large quantities. Studies have suggested that consumption of dairy products is associated with a decreased risk of CVD, type 2 diabetes and overweight[42–44].

Intake of P, unlike the other minerals assessed, showed considerable inadequacy among adolescents, and very low to low intake levels in the other age groups. P is found in nature as

Table 3. Dietary intakes of minerals, their distribution and probability of inadequacy in women residing in urban areas of Sao Paulo, according to life stage: Inquérito de Saúde de São Paulo (ISA-Capital) study, 2008
(Numbers, mean values and standard deviations)

				Percentiles of minerals intake						
Life stages*	*n*	Mean	SD	10	25	50	75	90	EAR or UL†	Prevalence of inadequate intake (%)
Na (mg/d)										
14–18 years	176	3147·7	1014·8	1975·6	2531·0	2939·1	3732·0	4286·6	1500/2300	80·0†
19–30 years	118	3046·8	680·6	2284·2	2692·6	2978·0	3498·9	3998·3	1500/2300	86·4†
31–50 years	191	2843·8	747·5	2037·5	2303·3	2768·9	3241·7	3696·4	1500/2300	76·7†
51–70 years	235	2569·2	661·8	1795·3	2210·6	2512·1	2870·5	3275·2	1300/2300	65·5†
>70 years	158	2297·8	721·4	1566·7	1839·5	2160·6	2596·4	2972·2	1200/2300	50·0†
Ca (mg/d)										
14–18 years	176	576·9	231·9	307·8	398·5	565·1	699·6	894·6	1100	98·8
19–30 years	118	555·6	190·0	348·5	424·0	534·6	649·4	822·0	800	90·2
31–50 years	191	484·6	184·0	260·8	328·4	466·0	601·8	756·6	800	95·5
51–70 years	235	492·5	183·0	270·7	356·3	468·4	602·8	734·3	1000	99·7
>70 years	158	502·6	176·9	285·7	382·7	492·3	605·7	721·5	1000	99·8
P (mg/d)										
14–18 years	176	978·6	308·0	625·9	765·4	935·4	1145·5	1342·6	1055	59·9
19–30 years	118	940·0	200·3	693·0	804·5	951·6	1070·6	1193·9	580	3·6
31–50 years	191	876·6	233·8	592·8	708·9	848·2	1010·9	1189·0	580	10·2
51–70 years	235	844·5	221·7	568·0	696·7	833·4	975·1	1143·7	580	11·7
>70 years	158	778·2	222·1	535·3	619·0	752·3	906·6	1025·8	580	18·7
Mg (mg/d)										
14–18 years	176	203·3	60·4	133·6	163·1	197·5	228·0	290·2	300	94·5
19–30 years	118	198·7	46·5	142·9	165·6	195·1	233·8	253·6	255	88·7
31–50 years	191	185·5	46·5	133·2	157·9	174·8	208·2	242·0	265	95·6
51–70 years	235	185·4	45·7	129·5	154·4	177·9	212·1	258·7	265	95·9
>70 years	158	172·1	44·3	124·9	140·6	167·9	198·6	226·1	265	98·2
Zn (mg/d)										
14–18 years	176	11·1	3·8	6·9	8·3	10·9	13·0	15·6	7·3	15·6
19–30 years	118	9·8	2·3	6·8	8·5	9·4	11·1	13·1	6·8	9·7
31–50 years	191	9·4	2·6	6·7	7·7	9·1	10·6	12·3	6·8	15·6
51–70 years	235	8·5	2·5	6·0	7·0	7·7	9·7	11·8	6·8	24·5
>70 years	158	7·5	2·2	5·4	6·1	7·0	8·8	10·4	6·8	37·5
Cu (mg/d)										
14–18 years	176	1·14	0·6	0·7	0·9	1·1	1·3	1·5	0·69	21·5
19–30 years	118	1·13	0·9	0·7	0·9	1·0	1·2	1·4	0·70	30·9
31–50 years	191	0·93	0·3	0·7	0·8	0·9	1·0	1·2	0·70	20·9
51–70 years	235	0·91	0·3	0·7	0·7	0·9	1·0	1·2	0·70	23·6
>70 years	158	0·81	0·3	0·6	0·7	0·8	0·9	1·1	0·70	35·6
Se (μg/d)										
14–18 years	176	74·0	26·2	42·7	57·0	72·5	87·9	104·1	45	13·4
19–30 years	118	69·9	19·9	44·1	59·9	67·2	82·4	93·3	45	10·6
31–50 years	191	62·2	22·1	39·9	48·4	56·5	72·1	91·1	45	21·8
51–70 years	235	59·2	20·7	37·7	45·9	55·7	69·1	77·4	45	24·8
>70 years	158	50·3	17·4	33·3	39·3	48·1	56·2	66·8	45	38·2

EAR, estimated average requirement; UL, upper limit level.
* 14–18 years: adolescence; 19–30 years: young adulthood; 30–50 years: middle age; 51–70 years: adulthood; >70 years: older adults[10].
† For Na, the results are the proportion of individuals with risk of adverse effects by Na intakes, calculated using the UL.

inorganic phosphate. In the body, it is regulated by the kidneys and has an important structural role[30]. The inadequacies observed among adolescents can be explained by the higher requirements needed to support their intense period of growth[30]. Phosphate salts are commonly used by industries as additives, making processed foods good sources when ingested in significant amounts[30]. In the present study, the main contributors of P were meat, milk and Brazilian traditional foods. It is important to emphasise that, although most food sources have good P bioavailability, beans and whole-grain cereals contain a non-protoplasmic phytic acid that the human digestive system cannot hydrolyse; hence, this P is not directly available[30].

In terms of Zn intake, in the present study, men were more susceptible to inadequate Zn intake than women. This difference may be reflective of the lower intake of Zn-rich foods, combined with the higher sex-specific recommended requirements[45]. In addition, the highest inadequacy observed was among older adults, consistent with the findings of the Brazilian National Dietary Survey[6]. This age-related inadequacy of intake may be explained by the commonly observed monotony of the diet and difficulties older people experience with chewing, which impairs the consumption of foods such as meat. Foods that contributed towards Zn intake in the present sample varied from sources that are rich in Zn (red meat) to sources that have moderate (beans and milk) or poor (bread and white rice) Zn content. Consumption of whole grains could help achieve the recommended Zn intake. Inadequacies in dietary Zn can lead to impairment of the immune system, changes in oxidative stress and other alterations that can raise the risk of developing NCD[45].

Table 4. Dietary intakes of minerals with adequate intake (AI), their distribution and probability of adequacy in men and women residing in urban areas of Sao Paulo, according to life stage: Inquérito de Saúde de São Paulo (ISA-Capital) study, 2008
(Numbers, mean values and standard deviations)

				Percentiles of minerals intake						
Life stages*	*n*	Mean	SD	10	25	50	75	90	AI	Probability of adequate intake (%)
For men										
K (mg/d)										
14–18 years	181	2438·7	757·6	1517·4	1959·4	2338·3	2908·1	3212·4	4700	1·1
19–30 years	103	2418·0	811·4	1454·1	1811·6	2314·0	2831·8	3456·4	4700	1·0
31–50 years	117	2254·4	585·7	1550·6	1913·0	2187·7	2563·1	3014·0	4700	0·0
51–70 years	148	2290·4	729·2	1442·1	1860·3	2187·9	2577·3	3235·0	4700	0·7
>70 years	84	2195·2	585·2	1530·2	1828·1	2122·8	2533·0	2926·3	4700	0·0
Mn (mg/d)										
14–18 years	181	3·2	1·0	2·0	2·5	3·1	3·8	4·6	2·2/9·0	81·8
19–30 years	103	3·0	0·9	1·8	2·3	2·9	3·6	4·3	2·3/11·0	68·9
31–50 years	117	3·0	0·9	1·8	2·4	2·9	3·7	4·1	2·3/11·0	76·9
51–70 years	148	2·9	0·9	1·9	2·2	2·8	3·4	4·3	2·3/11·0	68·9
>70 years	84	2·7	0·7	1·8	2·2	2·7	3·1	3·6	2·3/11·0	64·3
For women										
K (mg/d)										
14–18 years	176	1911·1	568·2	1252·7	1508·7	1856·0	2206·1	2621·3	4700	0·0
19–30 years	118	1875·6	468·8	1285·2	1563·5	1848·1	2206·4	2438·7	4700	0·0
31–50 years	191	1802·9	460·9	1260·3	1507·0	1719·9	2005·2	2348·7	4700	0·0
51–70 years	235	1834·7	458·8	1283·9	1483·5	1782·0	2160·1	2466·4	4700	0·0
>70 years	158	1786·0	525·2	1287·1	1432·1	1681·0	2045·4	2506·4	4700	0·0
Mn (mg/d)										
14–18 years	176	2·5	0·7	1·6	2·0	2·4	2·9	3·5	1·6/9·0	90·3
19–30 years	118	2·5	0·7	1·6	2·0	2·5	2·9	3·3	1·8/11·0	83·1
31–50 years	191	2·3	0·6	1·6	1·8	2·2	2·6	3·2	1·8/11·0	79·1
51–70 years	235	2·3	0·6	1·5	1·9	2·2	2·7	3·1	1·8/11·0	83·8
>70 years	158	2·1	0·6	1·4	1·7	2·0	2·2	2·7	1·8/11·0	77·2

* 14–18 years: adolescence; 19–30 years: young adulthood; 30–50 years: middle age; 51–70 years: adulthood; >70 years: older adults[10].

Inadequacies in the intake of Cu and Se have also been implicated as factors that may contribute to the increased risk of developing NCD; the role of both minerals as antioxidants would be one reason for this[45,46]. Se, when ingested in large amounts, can also increase the risk of diabetes, thus taking on an uncertain role[46]. In the present study, Cu and Se, similar to Zn, showed moderate-to-low inadequacies, and women had lower intakes. These findings can probably be explained by the lower amount of foods consumed by women, which consequently reduces the intake quantity of these minerals, which have the same dietary reference intake for both sexes.

Although liver, one of the most Cu-rich foods, has been listed among the contributors of this mineral, the other foods listed are considered to have moderate levels of Cu, supporting the observed inadequacy. For Se, in addition to meat and rice, foods containing wheat contributed to the consumption of this mineral. Beans did not appear to contribute because the variety widely consumed in Sao Paulo – brown beans or 'carioquinha' beans – have the lowest Se concentrations (0·1 μg/100 g) compared with other varieties such as black beans, 11·9 μg/100 g; red beans, 3·2 μg/100 g; and white beans, 2·6 μg/100 g[19].

This present study confirms that socio-demographic and lifestyle factors influence the intakes of minerals differently. Sex and age were the main factors influencing mineral intake, showing that, although it is suggested that high cost and low access to foods might explain low mineral intake – because most mineral-rich foods are usually more expensive[2,7,47,48] – other personal factors, including lifestyle, may influence mineral intake to an equal or greater extent. Being female, for example, in the present study showed one interesting aspect: decreased Na intake. The decreased Na intake among women was also observed in the Thai National Health Examination Survey IV, specifically in women ≥30 years[49]. On the other hand, except for Na, Zn, Cu and Se, older age was associated with increased mineral intake. This observation may reflect a better diet quality in older people as a response to minimise the diseases common of age, as described by Andrade[50].

In the present study, the level of education of the household head and family income *per capita* were associated with intakes of different minerals. This highlights that these two factors impact the intake of minerals differently and independently, as has been suggested by some authors[7,51,52]. Although the education level of the household head was shown to influence Na and Ca intake, family income *per capita* was shown to influence only the intake of Se. Education may be a potential means of improving micronutrient intake; this information can be considered while developing public policies.

The adoption of healthier habits by participants engaging in sufficient physical activity was reflected by the increased intakes of K, Ca and Mg. Smoking, even in those categorised as former smokers, was negatively associated with mineral intake. The negative effects of smoking may lead to the development of unhealthier habits and by possible changes in gustatory capacity.

Doubtless, the global decline observed in the intake of whole grains[53] directly affects the inadequacy of mineral intake, as

Table 5. Main food contributors to dietary intake of minerals in residents of urban areas of Sao Paulo: Inquérito de Saúde de São Paulo (ISA-Capital) study, 2008
(Percentages of contribution)

	K		Na		Ca		P		Mg		Zn		Mn		Cu		Se	
Rank	Foods	%	Foods	%	Foods	%	Foods	%	Foods	%	Foods	%	Foods	%	Foods	%	Foods	%
1	Brown beans	12·9	White rice	19·5	Milk	23·7	Beef meat	11·5	Brown beans	13·9	Beef meat	28·9	White rice	30·5	Beef liver	23·8	French bread	16·5
2	Beef meat	8·8	French bread	8·8	Brown beans	7·9	Milk	10·3	White rice	9·3	White rice	7·4	Brown beans	11·7	Brown beans	10·8	White rice	9·3
3	Milk	7·9	Beef meat	7·8	Mozzarella cheese	5·6	White rice	7·2	French bread	5·8	Brown beans	5·9	French bread	8·9	White rice	9·1	Whitefish	8·4
4	Chicken	4·2	Brown beans	7·7	Pizza*	4·3	Chicken	7·2	Beef meat	5·6	Chicken	5·6	Wheat crackers	4·1	French bread	4·9	Chicken	4·9
5	White rice	2·8	Chicken	4·8	French bread	3·6	Brown beans	5·4	Milk	5·3	Milk	4·1	Whole-wheat bread	1·9	Beef meat	4·2	Pizza*	3·4
6	French bread	2·7	Pizza*	2·6	Process cheese	3·6	French bread	5·0	Chicken	4·3	French bread	3·7	Banana	1·6	Chicken	1·9	Milk	3·2
7	Coffee	2·7	Salt	2·4	White rice	3·1	Whitefish	3·0	Whitefish	2·7	Hamburger or ground beef	2·1	Lettuce, green leaf	1·2	French fries	1·7	Spaghetti noodles with tomato sauce	2·9
8	Tomato, raw	2·6	Sausage†	2·3	Yogurt‡	2·2	Process cheese	2·8	Beer	2·6	Pork meat	1·9	Spaghetti with tomato sauce	1·2	Cocoa or chocolate, dry mix	1·6	Esfiha with cheese, meat or vegetables	2·7
9	Banana	2·6	Process cheese	1·8	Cocoa or chocolate, dry mix	1·9	Pizza*	2·7	Banana	1·9	Esfiha with cheese, meat or vegetables	1·8	Pizza*	1·2	Spaghetti noodles with tomato sauce	1·2	Beef meat	2·4
10	Whitefish	2·1	Salted margarine	1·8	Ice cream	1·6	Mozzarella cheese	2·2	Coffee	1·6	Pizza*	1·7	Tea‡	1·1	Tomato, raw	1·1	Sausage†	1·9
% Total		49·4		59·5		57·6		57·4		53·0		63·2		63·4		60·2		55·6

* Varied salted flavours.
† Mixed meats.
‡ Varied flavours.

Table 6. Multiple linear regression analysis of dietary intake of minerals* with socio-demographic and lifestyle factors in residents from urban areas of Sao Paulo: Inquérito de Saúde de São Paulo (ISA-Capital) study, 2008
(*β* Non-standard regression coefficients and 95 % confidence intervals)

	K (mg/d)		Na (mg/d)		Ca (mg/d)		P (mg/d)		Mg (mg/d)		Zn (mg/d)		Mn (mg/d)		Cu (mg/d)†		Se (μg/d)	
Factors	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI	*β*	95 % CI
Sex (ref. male)																		
Female	−124·2	−191·7, −56·8	−279·8	−363·4, −196·2	26·2	−0·3, 52·8	−35·6	−64·0, −7·3	−13·6	−18·7, −8·4	−1·1	−1·5, −0·7	−0·2	−0·3, −0·1	−0·0	−0·1, 0·0	−1·4	−4·7, 1·9
Life stage (ref. 14–18 years)																		
19–30 years	152·4	35·8, 269·0	113·0	−27·8, 253·8	−9·7	−58·4, 39·0	45·3	1·1, 89·6	13·1	3·6, 22·6	0·0	−0·6, 0·6	0·1	−0·1, 0·2	0·1	−0·0, 0·1	2·6	−2·1, 7·3
31–50 years	171·4	95·8, 247·1	179·2	50·1, 308·3	−11·4	−43·0, 20·2	44·7	12·7, 76·7	16·4	9·4, 23·4	−0·2	−0·7, 0·3	0·2	0·1, 0·3	0·0	−0·0, 0·1	−0·1	−3·8, 3·5
51–70 years	373·1	264·8, 481·3	168·9	35·0, 302·8	44·6	4·6, 84·6	95·5	54·9, 136·1	32·6	23·9, 41·3	−0·3	−0·8, 0·2	0·3	0·2, 0·5	0·1	0·0, 0·1	2·2	−2·9, 7·3
>70 years	425·9	327·4, 524·5	51·4	−67·5, 170·3	87·7	49·6, 125·7	90·5	57·0, 124·0	31·6	23·2, 40·1	−0·4	−0·9, 0·1	0·3	0·1, 0·4	0·0	−0·0, 0·1	−2·0	−5·7, 1·7
Household head education (ref. <10 years)																		
≥10 years	38·0	−24·6, 100·7	−87·0	−167·8, −7·3	57·7	25·5, 89·8	14·5	−20·1, 49·1	1·4	−5·1, 7·9	−0·2	−0·7, 0·2	−0·0	−0·1, 0·1	−0·0	−0·1, 0·0	1·1	−2·6, 4·9
Family income *per capita* (ref. ≤1 minimum wage)‡																		
>1 minimum wage	7·5	−49·8, 64·8	−6·9	−94·1, 80·3	16·8	−13·7, 47·3	17·3	−10·7, 45·2	0·5	−4·4, 5·4	−0·2	−0·6, 0·3	−0·0	−0·1, 0·1	−0·0	−0·1, 0·0	4·1	1·6, 6·6
Smoking behaviour (ref. non-smoker)																		
Former smoker	−15·9	−92·4, 60·3	91·2	−14·6, 197·0	−52·0	−90·6, −13·5	2·7	−27·1, 32·6	0·1	−6·8, 7·1	0·2	−0·2, 0·5	−0·0	−0·2, 0·1	−0·0	−0·0, 0·0	2·8	−1·0, 6·6
Current smoker	−93·7	−173, −14·4	−73·2	−181·7, 35·3	−64·0	−106·4, −21·7	−46·6	−77·9, −15·3	−7·8	−15·7, 0·2	0·1	−0·4, 0·7	−0·1	−0·3, 0·0	−0·1	−0·1, −0·0	−2·4	−6·1, 1·4
Leisure-time physical activity (ref. insufficient physical activity)																		
Sufficient physical activity§	133·0	44·6, 221·3	−84·8	−205·0, 35·5	62·8	9·1, 116·4	41·2	−2·5, 84·8	10·3	2·2, 18·4	0·0	−0·6, 0·6	−0·1	−0·2, 0·1	−0·0	−0·1, 0·0	3·1	−2·0, 8·1
BMI (kg/m^2)	−3·0	−8·8, 2·9	1·7	−9·2, 12·6	0·1	−3·1, 3·2	2·0	−0·7, 4·6	−0·5	−1·1, 0·2	0·0	−0·0, 0·1	−0·0	−0·0, 0·0	−0·0	−0·0, 0·0	0·3	−0·1, 0·6
Constant	1943·5	1816·6, 2070·3	3254·2	3003·5, 3504·9	487·6	403·2, 572·0	888·3	828·7, 948·0	210·7	197·9, 223·5	11·0	10·2, 11·9	2·8	2·6, 3·0	0·1	0·0, 0·2	61·0	51·8, 70·2

Ref. reference.
* Mineral intakes were adjusted according to the individual energy intake[23] and intra-individual variability[20].
† Cu intakes (mg/d) were log transformed to obtain normal distribution.
‡ Family income *per capita* is the sum of all family members' monetary income averaged out over the number of family members. Minimum wage = US$ 258·39 (R$ 415·00).
§ Sufficient physical activity: moderate-intensity exercise for at least 30 min daily on 5 d/week or vigorous-intensity exercise for at least 20 min daily on 3 d/week; otherwise, it was considered as insufficient physical activity[12,13].

does the lower consumption of fruits and vegetables. Urgent consideration needs to be given to the question of how to approach the population in order to make individuals and the food industry aware of the necessity of adopting healthy lifestyle habits, in order to prevent diseases. From this perspective, dietary guidelines are important tools for health promotion. Such guidelines can encourage healthy eating habits that take into account changes in population eating habits, health conditions and advances in scientific knowledge[54].

Globally, public policies for minerals have been more focused on Fe, I and Na[33,55–57]. Some countries have also focused on Zn and Ca, encouraging Zn and Ca fortification of foods[56,57]. Other minerals, whose intakes are frequently inadequate, such as Mg, are not contemplated in these actions. This may be due to a paucity of data regarding the population intake of these minerals. New public policies that include the monitoring of more minerals are necessary to avoid mineral deficiencies and the consequences thereof.

A critical appraisal of the present study must to be taken into consideration. Evaluation of dietary intake is susceptible to both random and systematic errors. To minimise this bias, 24HR was conducted by a trained interviewer using standardised methods, as multiple-pass methods minimise the omission of possibly forgotten foods and standardise the level of detail for describing foods. Moreover, the interviewers were trained to communicate directly with the participants to minimise the influence of psychological determinants of misreporting[58]. In addition, the intra-individual variation was removed, and the effect of energy was considered for the associations tested. Finally, Se content in foods, especially in plants, can vary according to the availability of this mineral in the soil where the plant is grown; this may also influence the Se content in meats, depending on the animal feedstuff[46]. Therefore, it is important to recognise that, despite the corrections made in the database with data analysis of Brazilian foods[19], the values obtained for all minerals may contain inaccuracies.

In conclusion, residents from urban areas of Sao Paulo have significantly inadequate intakes of most of the minerals assessed, taking all ages/life stages and both sexes into account. The high prevalence of inadequate intake raises concerns because of the association with impairments in vital functions and development of NCD. Moreover, the major foods contributing towards dietary intake of minerals were not the most mineral-rich food sources, but reflected the Brazilian cultural dietary pattern. Socio-demographic and lifestyle factors may influence the ability to reach the dietary reference intake of minerals. These findings may contribute to identification of population subgroups that are vulnerable to inadequate intake of minerals, to better target public health policies and to assist in monitoring established policies.

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Supplementary material

For supplementary material/s referred to in this article, please visit https://doi.org/10.1017/S0007114516004633

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