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Metabolic syndrome in the elderly living in marginal peri-urban communities in Quito, Ecuador

Fernando Sempértegui[1,9], Bertha Estrella[1], Katherine L Tucker[2,3], Davidson H Hamer[3,4,5], Ximena Narvaez[1], Mercy Sempértegui[1], Jeffrey K Griffiths[3,7,8], Sabrina E Noel[2], Gerard E Dallal[2,3], Jacob Selhub[2,3] and Simin N Meydani[2,3,6,*]

[1]Corporación Ecuatoriana de Biotecnología, Quito, Ecuador: [2]Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, 711 Washington Street, Boston, MA 02111, USA: [3]Tufts University Friedman School of Nutrition Science and Policy, Boston, MA, USA: [4]Center for Global Health and Development, Boston University School of Public Health, Boston, MA, USA: [5]Section of Infectious Diseases, Department of Medicine, Boston University School of Medicine, Boston, MA, USA: [6]Department of Pathology, Sackler School of Graduate Sciences, Tufts University, Boston, MA, USA: [7]Department of Public Health and Family Medicine, Tufts University School of Medicine, Boston MA, USA: [8]Department of Civil and Environmental Engineering, Tufts University School of Engineering, Medford, MA, USA: [9]Medical School, Central University of Ecuador, Ecuador

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Abstract

Objective: The proportion of the Latin American population aged >60 years is expected to double during the next few decades. Metabolic syndrome (MetS) is associated with high morbidity and mortality worldwide. However, little is known about MetS in Latin America in general, and in Ecuador in particular. The present study aimed to examine the prevalence of MetS and its association with blood micronutrient, homocysteine (Hcy) and C-reactive protein (CRP) concentrations in the elderly living in a low-income urban area.

Design: We performed a cross-sectional study. MetS, using the International Diabetes Federation definition, dietary intake and plasma micronutrient, CRP and Hcy concentrations were assessed.

Subjects: A total of 352 elderly (≥65 years) Ecuadorians.

Setting: Quito, Ecuador.

Results: MetS was prevalent (40 %) – considerably more so among women (81 %) than men (19 %; $\chi^2 = 32{\cdot}6$, $P < 0{\cdot}0001$). Further, 53 % of those without MetS exhibited two or more of its components. Micronutrient deficiencies were prevalent, including those of vitamin C, zinc, vitamin B_{12} and folate. Vitamin C and E concentrations were inversely (OR = 0·78, 95 % CI 0·71, 0·86; OR = 0·16, 95 % CI 0·03, 0·81, respectively) and CRP (OR = 1·79, 95 % CI 1·04, 3·06) was positively associated with MetS.

Conclusions: The coexistence of MetS with micronutrient deficiencies suggests that elderly Ecuadorians suffer from the double burden of diseases that are increasingly being observed in less developed countries. More research is needed to determine the causal factors, but results presented suggest that these older adults would benefit from interventions to reduce the risk factors for MetS, in particular higher consumption of micronutrient-rich foods.

Keywords
Elderly
Metabolic syndrome
Ecuador
Micronutrient deficiency
C-reactive protein

The number of older persons is projected to more than double worldwide over the next half century[1]. Most of this elderly population will be living in developing countries, which are the least prepared to deal with the challenges of an ageing society[2]. According to the estimates of the United Nations, the population of Latin American and Caribbean adults aged >60 years will almost double, from about 59 million (10·0 % of the total population) in 2010 to 101 million (15·1 % of the total population) in 2025[3]. Currently, those aged >60 years in Ecuador represent 9·5 % of the population (1 303 000 inhabitants), and this is predicted to rise to 14·1 % (2 262 000 inhabitants) by 2025[3]. A recent report from the Pan American Health Organization and Merck Institute of Aging and Health calls for increased surveillance to identify the extent and causes of morbidity and mortality in older adults[4].

Ecuador, like much of Latin America, has not experienced improvements in living standards to the same degree as most developed nations. Older adults in Latin

**Corresponding author:* Email simin.meydani@tufts.edu

American countries are likely to have comparatively more diseases, greater disability and fewer resources for their health-care needs. Although developed nations have gradually increased their national health resources for older adults, few of the limited health resources of the less developed countries have been devoted to their ageing populations. Since older adults face high burdens of disease and disability, this threatens to increase the strains on the limited health-care resources of their countries.

Metabolic syndrome (MetS) is characterized by disturbed glucose and insulin metabolism, central adiposity, dyslipidaemia and high blood pressure (BP), and is associated with type 2 diabetes, CVD and mortality(5). Although the aetiology of MetS has not been fully elucidated, available evidence suggests that it is the result of a complex interaction between genetic, metabolic and environmental factors(6). Nutritional factors are the most prominent environmental influences, including obesity, dietary glycaemic index (GI)(7), fruit and vegetable intake(8), total and type of fat intake(9,10), antioxidant nutrients(11), B vitamins and dairy products(12). Intake of high-GI carbohydrates was positively associated with insulin resistance and prevalence of the MetS in participants of the Framingham Offspring Study(7). Higher intake of fruit and vegetables was shown to be inversely associated with plasma C-reactive protein (CRP) concentrations, as well as likelihood of having the MetS in a cross-sectional study of 486 Iranian women(8). Data from the Third National Health and Nutrition Examination Survey (NHANES III) showed that participants with MetS had significantly lower circulating concentrations of vitamin C, carotenoids and vitamin E(11). High total fat intake, mainly that of saturated fat, has been linked to lower insulin sensitivity, whereas increased proportions of MUFA improved insulin sensitivity in adults(9). Higher relative intake of vegetable oils and lower intake of foods containing saturated fat at 50 years of age were protective against developing sustained hypertension 20 years later(10). In a recent study, ferritin and transferrin concentrations were shown to be associated with MetS abnormalities(13).

Our previous preliminary work in elderly Ecuadorians living in poor peri-urban communities showed a high prevalence of elevated waist circumference and low HDL cholesterol concentration, both components of MetS(14). Energy intake was mainly dependent on high carbohydrate consumption (76·7 % of total energy). Furthermore, a high prevalence of several micronutrient deficiencies was found(14). CVD is now the primary cause of morbidity and mortality in Ecuadorian elders(15). These findings suggest that the increasing elderly population of Ecuador is at risk for MetS, although no specific information is available for them. Given that the low status of micronutrients such as antioxidants and B vitamins has been suggested to be associated with increased risk for MetS, the present study was conducted using a much larger sample size than that in our preliminary study to determine the prevalence of MetS in elderly Ecuadorians and its association with blood micronutrient concentrations.

In our previous study, 25 % of sampled older adults showed blood homocysteine (Hcy) concentration above the upper limit(14). Markers of low-grade inflammation, such as CRP(16) and Hcy(17), have been shown to be associated with CVD. Therefore, we also aimed to determine the association of these inflammation markers with micronutrient concentrations and with MetS. The present study presents the first report on MetS prevalence in elders living in the poor peri-urban communities of Quito, Ecuador and its relationship to blood micronutrient concentrations and inflammation markers.

Experimental methods

Study site and population

This cross-sectional study was conducted from September 2003 to December 2004 in three adjacent poor peri-urban neighbourhoods in north-western Quito (2800 m above the sea level). The study area had an estimated population of 13 000 and, based on electoral results, 5 % were above the age of 65 years. The neighbourhoods are located on a hillside and are structurally similar, with one main paved road and electricity present in all homes. According to the baseline information collected during the screening phase, just over half of the households had a municipal source of potable water (52 %) and sewerage (62 %). The inhabitants were primarily poor immigrants from small cities and rural areas of Ecuador. Their mean monthly income was US$54, which is <50 % of the basic income in Ecuador, and >40 % of the elderly individuals were illiterate. The living conditions of this population are similar to those of the poor urban slums of other Andean countries such as Peru and Bolivia.

Screening and enrolment

To identify the eligible participants, we carried out a census in the three neighbourhoods. Eligibility criteria included age ≥65 years, mental competence and willingness to provide written informed consent. Age was verified via national identification cards. Mental competence was determined with a variation of the Mini Mental State Examination (MMSE) that has been used in several countries previously, including Spain and Guatemala(18). We identified and provided detailed information about the study to 413 potential participants, who were asked for consent to participate. If the individual was illiterate, the form was read to them in the presence of a literate family member. Of the 413 elderly invited, 352 (85 %) agreed to participate via witnessed informed consent. The Ethics Committees of the Corporación Ecuatoriana de Biotecnología and the Tufts-New England Medical Center Institutional Review Board approved the study protocol and informed consent.

Study procedures

The participants were asked to visit one of the three field stations centrally located in each neighbourhood (a church, a school or a communitarian house). Two physicians and two nurses collected anthropometric data and blood samples. Before the study, all study personnel received training and conducted data collection on the same test participants to check for inter-observer differences. Two nutritionists collected dietary data through household visits. Previously, they also administered the dietary survey jointly to other older adults to close the inter-observer differences.

Anthropometry

Anthropometric measurements were obtained using methods described by Gross[18] and included weight, height, knee height and waist circumference. Weight was recorded to the nearest 0·1 kg using a Detecto scale (Detecto®, Webb City, MO, USA). The participants were asked to wear the least amount of clothing possible. Height was measured to the nearest 0·1 cm, using a steel fibreglass measuring tape affixed to a wooden rod, with a sturdy straight edge used as a headpiece. We also measured knee height to the nearest 0·1 cm, using a knee-height anthropometer[19]. This measurement can be used to estimate standing height for older participants who are unable to stand erect, using published equations[19]. Waist circumference was measured between the border of the right anterior superior iliac crest and the umbilicus, and was recorded to the nearest 0·1 cm using a fibreglass measuring tape. BMI was calculated as weight in kilograms divided by the square of height in metres (kg/m^2)[20]. The following BMI classifications were used: underweight (BMI <20 kg/m^2), normal weight (BMI 20–24·9 kg/m^2), overweight (BMI 25–29·9 kg/m^2) and obese (BMI ≥30 kg/m^2). Elevated waist circumference was classified using the International Diabetes Federation (IDF) values: men >90 cm, women >80 cm[21].

Blood pressure

Systolic and diastolic BP were measured in mm Hg by detection of Korotkoff sounds, using a conventional certified sphygmomanometer (CE 0483; Riester, Jungingen, Germany). Right arm measurements were obtained while seated, after resting for at least 15 min. Participants with values >130 mm Hg for systolic or >85 mm Hg for diastolic BP were classified as having high BP[22].

Laboratory procedures

Blood samples were obtained at the field stations. A 10 ml venous blood sample was drawn after an overnight fast, into an EDTA-treated tube and a tube without anticoagulant. Samples were immediately transported to the laboratory and centrifuged. Plasma samples for vitamin C were promptly deproteinized using perchloric acid and EDTA. Serum or plasma was collected in plastic tubes, frozen at −20°C, and transported to Boston for micronutrient analysis according to standard procedures at the Nutritional Evaluation Laboratory of the Jean Mayer USDA Human Nutrition Research Center on Aging at Tufts University as described previously[23].

Total plasma Hcy was determined by a method derived from Araki and Sako[24]. Controls included pooled plasma samples spiked with different amounts of cysteine and Hcy. The CV for this assay in our laboratory is 7·8 %. A cut-off point of >15 nmol/ml[25] was considered as high Hcy concentration.

CRP was measured in serum, using an immunoturbidimetric reaction in a Cobas Fara II Centrifugal Analyzer with DiaSorin CRP SPQ Test System Antibody Reagent Set II (Item no. 86083, Document AM-0039 (rev 8.27.90); Stillwater, MN, USA). A cut-off point of >3 mg/l was considered as high CRP concentration[26,27].

Chemical analyses for fasting glucose, TAG, LDL and HDL cholesterol were assessed in Quito, using a conventional autoanalyser (HITACHI 911, Roche, Germany). Daily quality control of the precision of the equipment was determined using the Westgard multi-rules[28].

Classification of metabolic syndrome

We used the MetS definition of the IDF and also report the prevalence of MetS using the Adult Treatment Panel III (ATP III) definition[29]. The IDF definition[21] requires participants to have central obesity defined by ethnic and sex-specific waist circumference cut-points (men >90 cm, women >80 cm), plus two of the four other components (elevated TAG (>1·7 mmol/l or >150 mg/dl), elevated BP (systolic BP ≥130 mm Hg or diastolic BP ≥85 mm Hg), elevated fasting blood glucose (≥5·6 mmol/l or ≥100 mg/dl) and low HDL cholesterol (<1·03 mmol/l or <40 mg/dl for men or <1·30 mmol/l or <50 mg/dl for women)[21]. The ATP III definition requires the presence of three or more of the following criteria: (i) elevated waist circumference (>102 cm for men and >88 cm for women); (ii) elevated TAG (>1·7 mmol/l or ≥150 mg/dl); (iii) low HDL cholesterol (<1·03 mmol/l or <40 mg/dl for men and <1·30 mmol/l or <50 mg/dl for women); (iv) elevated BP (systolic BP ≥130 mm Hg or diastolic BP ≥85 mm Hg); and (v) elevated fasting glucose (≥6·1 mmol/l or ≥110 mg/dl).

Definitions of micronutrient deficiencies

The cut-off points for plasma vitamin inadequacies were defined as follows: vitamin A ≤30 μg/dl[30], pyridoxal phosphate (PLP) ≤ 30 nmol/l[14,31,32], vitamin B_{12} ≤ 250 pg/ml[33], folate ≤5 ng/ml[14,34], vitamin C ≤0·2 mg/dl[30], vitamin E ≤500 μg/dl[35] and vitamin D ≤25 ng/ml for mild deficiency and ≤10 ng/ml for severe deficiency[30]. For mineral plasma inadequacies, the cut-off points were: zinc ≤70 μg/dl[30], copper ≤85 μg/dl[30], iron ≤65 μg/dl for men and ≤50 μg/dl for women[30] and calcium ≤8·6 mg/dl[30].

Dietary intake analysis

Individual dietary intake was estimated with a modified 24 h recall or weighing method[36], as described previously[14]. Dietary recall questionnaires were applied two times with each participant, on different working days within a week. Briefly, the interview was carried out in each household, and each participant was given an explanation on the importance of answering as truthfully and accurately as possible. In order to help the participant recall the previous day, we asked him or her about his or her activities, such as the time of awakening, daytime activities and when he or she went to bed. This approach helped the participants to remember the foods ingested. During the interview, the amounts of food consumed were verified by asking the participant the size of the household measures used to prepare the consumed food. More details for this dietary method have been published[14]. The most experienced observer performed quality control with a thorough review of all recalls to ensure consistency of the data. Two independent data entry staff entered the data into a pre-specified Excel spreadsheet. These data were sent to Tufts University, where they were linked to the USDA (US Department of Agriculture) nutrient database, with the addition of food codes for specific Latin American Foods[37]. Foods not included in this file were coded according to the Ecuadorian Table of Foods[38]. The 2 d of dietary measures were averaged to obtain the most stable measure for each individual. The intra- to inter-person variance for the nutrient intakes was also calculated and used in evaluating correlations between nutrient intakes and blood concentrations.

Statistical methods

Data entry and management were carried out using Epi-Info software, version 6·04d (Centres for Disease Control and Prevention, Atlanta, GA, USA). Statistical analyses were performed using the Statistical Package for Social Sciences statistical software package version 11·5 (Lead Technologies Inc., SPSS Inc., Chicago, IL, USA). The prevalence of MetS and of its components was calculated overall and by sex. We also calculated the frequency of MetS components in participants with and without MetS syndrome. Differences in means and percentages by sex, and between participants with or without MetS, were evaluated by the Student's t and χ^2 tests, respectively.

Multiple logistic regression models, also controlling for age and sex, were fitted to determine whether selected blood micronutrient status, high Hcy or high CRP (as binary variables) were associated with the presence of MetS.

Regression analysis was used to assess associations between blood measures and the mean of the two dietary recalls. Day-to-day within-person variation in the reference method (mean of the two 24 h dietary recalls) can attenuate the correlations between nutrient intakes derived from dietary recalls and serum measures. The intra- to inter-person variance for the nutrient intakes, as estimated by the two 24 h dietary recalls, was also calculated and reviewed. The formula used to calculate the de-attenuated regression coefficient is $b_t = b_0(1 + \text{intra}_x/\text{inter}_x/n_x)$, where b_0 is the observed coefficient (slope) of the linear regression of the serum measure on the mean of the two 24 h dietary recalls, adjusted for energy intake, BMI, smoking, age and sex; intra_x is the intra-person variation for the intake variable; inter_x is the inter-person variation for the intake variable; and n_x is the number of days of dietary recall, which was two in the present study[39].

Results

Demographic and anthropometric measurements for this population are shown in Table 1. A total of 352 participants were enrolled in the study, consisting of 225 women (64 %) and 127 (36 %) men. The mean age of the study participants was 74·4 (SD 6·4) years. Male participants were older and most had attended some elementary school. The majority of women were illiterate. Most participants were of rural origin (Table 1). More than 11 % admitted to current tobacco use, and 21 % had previously smoked for more than 1 year. Only 7·7 % acknowledged current alcohol consumption; 50 % used to drink occasionally, 10 % most days and only 4·6 % daily. A considerable percentage of the participants were overweight or obese. A higher percentage of women were overweight than men (Table 1).

On the basis of the IDF definition, the majority of MetS components were more frequent in women than in men; women had elevated waist circumference ($P < 0·05$), elevated TAG ($P < 0·001$) and lower HDL cholesterol than men ($P < 0·0001$; Table 2). Hypertension and elevated blood glucose concentrations did not differ by sex. Similar results were found using the ATP III criteria (data not shown).

On the basis of IDF criteria, 40 % of participants had MetS. Among these participants, 19 % were men and 81 % were women ($\chi^2 = 32·6$, $P < 0·0001$), whereas 33 % (18·3 % men and 81·7 % women) had MetS on the basis of the ATP III definition. In addition, 52 % (110/210) of the participants without MetS (defined by IDF) exhibited two or more of its components. In participants without MetS, a higher percentage of women than men exhibited two or more components of MetS (68/110 *v.* 42/110; $\chi^2 = 9·094$, $P = 0·002$).

On the basis of serum or plasma concentrations, micronutrient inadequacies were common for men and women, respectively (values in parenthesis are the median and 10th and 90th percentiles followed by the percentage of participants who had low values): vitamin C (0·17 (0·02–0·44), 0·26 (0·09–0·56) mg/dl; 60 % and 33 %), vitamin B_6 (39·9 (23–64), 48·1 (27·3–78·3) nmol/l; 27 % and

Table 1 Demographic characteristics and anthropometric measurements of elderly Ecuadorians

Variables	Men (*n* 127) Mean	Men SD	Women (*n* 225) Mean	Women SD	*P*
Age (years)†	75·8	6·5	73·7	6·1	<0·001
Education level					
No school (%)	29·4		52·5		<0·0001
Birth place (% rural)	69·0		73·9		NS
Anthropometrics					
Weight (kg)	59·9	9·5	54·0	9·8	<0·0001
Height (cm)	156·0	6·7	144·0	6·0	<0·0001
Height by knee height (cm)‡	158·0	6·4	144·0	5·3	<0·0001
Knee height (cm)	48·0	3·5	44·5	2·8	<0·0001
Waist circumference (cm)	87·5	9·4	87·3	11·6	NS
BMI (kg/m^2)	24·8	3·2	26·1	4·0	<0·001
Underweight (<20 kg/m^2; %)	2·7		4·5		NS
Normal (20·0–24·9 kg/m^2; %)	57·3		39·8		<0·001
Overweight (25·0–29·9 kg/m^2; %)	29·5		41·2		<0·05
Obese (≥30·0 kg/m^2; %)	3·3		14·0		<0·01

†Range is 65–94 years for men; 65–97 years for women.
‡Calculated as described in Blaum *et al.*[19].

Table 2 Distribution of MetS components in elderly Ecuadorians by IDF definition

MetS components	Total (*n* 301–352)† %	Men (*n* 111–127) %	Women (*n* 190–225) %	*P*
High waist circumference (men >90 cm, women >80 cm)	61	37	75	<0·0001
Blood pressure (systolic ≥130 mmHg or diastolic ≥85 mmHg)	51	55	49	NS
Fasting glucose (≥100 mg/dl)	11	9	13	NS
TAG (≥150 mg/dl)	40	28	46	<0·001
HDL cholesterol (men <40 mg/dl, women <50 mg/dl)	73	56	83	<0·0001

IDF, International Diabetic Federation; MetS, metabolic syndrome.
†Total numbers are 352, 301, 351, 351 and 351 for waist circumference, blood pressure, fasting glucose, TAG and HDL cholesterol, respectively.

16 %), vitamin B_{12} (360 (216–676), 390 (208–729) pg/ml; 21 % and 20 %), folate (5·5 (3·4–8·3), 6·2 (3·7–10·5) ng/ml; 37 % and 27 %) and zinc (75 (48–106), 71 (47–108) ug/dl; 41 and 45 %). Deficiencies of vitamins A (54 (39–72), 50 (36–66) μg/dl) and D (severe <10 ng/ml; 22 (14–29), 19 (12–26) ng/ml), iron (123 (79–188), 107 (62–161) μg/dl) and calcium (9·2 (8·6–10·2), 9·3 (8·6–10) mg/dl) were present in <15 % of participants. Mild vitamin D deficiency (<25 ng/ml) was present in 65 % and 87 % of men and women, respectively.

After adjusting for age and sex, plasma vitamin E:TAG ratios and vitamin C concentrations were inversely associated with MetS (OR = 0·78, 95 % CI 0·71, 0·86; OR = 0·16, 95 % CI 0·03, 0·81, respectively; Table 3). High plasma CRP (>3 mg/l) was present in 48·9 % of the participants and was positively associated with MetS (OR = 1·79, 95 % CI 1·04, 3·06; Table 3). High plasma Hcy (>15 nmol/ml), or low zinc, copper or B vitamins, was not associated with MetS (Table 3).

After adjusting for age and sex, low plasma vitamin E:TAG ratios were associated with high plasma glucose (OR = 0·74, 95 % CI 0·63, 0·86), low HDL cholesterol (OR = 0·84, 95 % CI 0·78, 0·92) and high waist circumference (OR = 0·91, 95 % CI 0·85, 0·98). Low plasma vitamin C was also associated with hypertension (OR = 0·15, 95 % CI 0·03, 0·67), high waist circumference (OR = 0·15, 95 % CI 0·03, 0·68) and low HDL cholesterol (OR = 1·94, 95 % CI 1·07, 3·50).

Table 3 Association of age, sex, blood micronutrients, CRP and homocysteine with MetS using the IDF definition

Variables	OR†	95 % CI
Age (years)	0·99	0·95, 1·06
Sex (male)	0·18	0·10, 0·40
Vitamin C (mg/dl)	0·16	0·03, 0·81
PLP (nmol/l)	1·01	1·00, 1·02
Vitamin B_{12} (pg/ml)	1·00	0·99, 1·01
Folate (ng/ml)	1·04	0·94, 1·16
Cu (μg/dl)	0·99	0·98, 1·00
Zn (μg/dl)	1·00	0·99, 1·02
High plasma CRP (>3 mg/l)	1·79	1·04, 3·06
High plasma homocysteine (>15 nmol/ml)	1·73	0·94, 3·18
Vitamin E:TAG ratio	0·78	0·71, 0·86

CRP, C-reactive protein; PLP, pyridoxal phosphate; MetS, metabolic syndrome; IDF, International Diabetic Federation.
†OR is based on a multiple logistic regression model, adjusting for age and sex.

Analysis of the dietary intake from the participants is shown in Table 4. In general, the diets were of poor quality – high in carbohydrate and sodium (>50 % had intake higher than recommended) and low in protein (about 23 % had intake below that recommended), fat

Table 4 Dietary macronutrient and micronutrient intake of elderly Ecuadorians (average of two 24 h recalls)

		Women				Men			
		Intake (*n* 218)				Intake (*n* 124)			
Nutrients	AMDR†, EAR‡ or AI§	Mean	Range	Below ref. (%)	Above ref. or UL (%)	Mean	Range	Below ref. (%)	Above ref. or UL (%)
Energy (kcal)‖		1187	327–2805			1159	166–2428		
Fat (% energy)	20–35†	21·9	5·3–53·6	41·2	5·1	21·9	6·0–40·6	44·4	0·8
Carbohydrate (% energy)	45–65†	65·8	10·3–87·6	2·3	55·5	65·9	36·0–88·8	0·8	55·7
Protein (% energy)	10–35†	13·2	5·3–33·9	20·6	0·0	13·0	5·7–25·9	27·4	0·0
Total vitamin A (μg RAE)	500–6252	396	0·2–3588	74·3	0·0	429	1·7–2696	78·2	0·0
Vitamin D (μg calciferol)	15§	1·35	0·00–7·57	100·0	0·0	1·53	0·00–11·0	100·0	0·0
α-Tocopherol (mg)	12‡	3·10	0·35–8·47	100·0	0·0	3·24	0·21–8·78	100·0	0·0
Vitamin K (μg phylloquinone)	90–120§	29·4	1·0–429	95·4		26·1	1·2–283	97·6	
Vitamin C (mg)	60–75	50·3	0·2–390	74·8	0·0	49·88	1·0–394	84·7	0·0
Riboflavin (mg)	0·9–1·1‡	0·85	0·06–2·61	64·2		0·89	0·13–2·49	70·2	
Folate (μg)	320‡	208	0–646	82·1	0·0	227	18·7–743	76·6	0·0
Vitamin B_6 (mg)	1·3–1·4‡	1·24	0·21–4·59	58·3	0·0	1·25	0·10–2·80	62·9	0·0
Vitamin B_{12} (μg)	2·0‡	2·60	0·00–19·0	56·0		3·02	0·0–18·2	54·8	
Ca (mg)	1200§	247·00	21·3–908	100·0	0·0	248	30–928	100·0	0·0
P (mg)	580‡	575·00	77–1470	58·3	0·0	605	121–1364	52·4	0·0
Mg (mg)	265–350‡	160·00	13–432	93·6	1·4	167	23–415	99·2	0·8
Fe (mg)	5·0–6·0‡	6·29	0·02–17·6	39·5	0·0	6·76	1·37–22·0	50·0	0·0
Zn (mg)	6·8–9·4‡	5·30	0·63–16·8	73·9	0·0	5·59	0·75–13·1	92·7	0·0
Cu (μg)	700‡	862	50–4005	38·1	0·0	886	110–4150	34·7	0·0
Se (μg)	45‡	64·20	7·8–210	28·0	0·0	68·6	12·0–218	27·4	0·0
K (mg)	4700§	1651	134–4036	100·0	0·0	1659	184–3820	100·0	0·0
Na (mg)	1200§ UL 2300	3094	69–20 342	15·6	53·1	3287	200–13 255	13·7	62·1

AMDR, Acceptable Macronutrient Distribution Range; EAR, Estimated Average Requirement; AI, Adequate Intake; ref., reference; UL, Upper Limit; RAE, retinol activity equivalents.
†Adults[50].
‡EAR for women–men aged >70 years[51,52].
§AI for women–men aged >70 years; EAR not available[52–56].
‖1 kcal = 4·184 kJ.

Table 5 Correlation between dietary and blood nutrient concentrations

Dietary variable	Serum variable	Observed regression coefficient	Corrected regression coefficient†
Vitamin C (mg)	Vitamin C (mg/dl)	0·0005*	0·001
Vitamin B_6 (mg)	PLP (nmol/l)	5·6	11·10
Vitamin B_{12} (μg)	Vitamin B_{12} (pg/ml)	9·0	21·70
Zn (mg)	Zn (μg/dl)	0·19	0·40
FV servings	Folate (ng/ml)	0·18*	0·39
FV servings	Vitamin B_{12} (pg/ml)	3·3	7·00
FV servings	PLP (nmol/l)	1·6*	3·40
FV servings	Vitamin C (μg/dl)	0·02*	0·04
Animal protein (g)	Zn (μg/dl)	0·01	0·02
Animal protein (g)	Vitamin B_{12} (pg/ml)	2·4*	5·70

PLP, pyridoxal phosphate; FV, fruit and vegetables.
*$P<0·05$ adjusted for age, sex, smoking, BMI and energy intake.
†Also adjusted for intra- or inter-individual variation in dietary intake.

(about 42 % had intake below that recommended) and several micronutrients (see Table 4), consistent with the low blood micronutrient status exhibited.

The main sources of energy were white rice (16 %), potatoes (13 %), sugar (8 %) and bread (7·5 %). Milk, eggs, cheese, beef, chicken giblet and chicken breast contributed 4·5 %, 1 %, 0·6 %, 3·7 % and 2·6 %, respectively. Intakes of grains other than rice and wheat (barley, oats, 2·3 % of energy), legumes (mainly black beans, 0·7 %), vegetables other than potato (corn, onions, cassava, plantains, total 4·5 %) and of fruit (mainly banana, 0·6 %) were low. Protein consumption was low and was derived mainly from beef (11 %), rice (9 %), chicken giblet (9 %), milk (7 %) and potatoes (7 %). Fish provided 3 % of the protein. The main source of fat was from palm oil (16 %); the main sources of carbohydrate were rice (20 %), potatoes (16 %) and white sugar (13 %).

Glycaemic load (GL) was mainly from white rice (25 %), potatoes (21 %), white granulated sugar (12·5 %), bread (9·7 %) and pasta (2·7 %). The diet of 20 % of participants was of high GI, using glucose as the reference[40]. Based on the percentage of total energy intake, according to the Acceptable Macronutrient Distribution Range[41], 93 % of the participants consumed low linoleic and α-linolenic acid. However, there was no correlation between high GI, GL or low unsaturated fat with MetS (data not shown) in this population. Sodium intake was mainly from regular salt (76 %), boiled potato (4·4 %) and bread (4·3 %). The average intake of dietary salt was 3·2 g. As indicated above, the consumption of fruit and vegetables and animal products was low, and most likely contributing to low serum micronutrient status, as indicated by positive correlations between the intake of fruit and vegetables and plasma vitamin C, vitamin B_6 and folate concentrations ($P<0·05$; Table 5). A significant correlation between plasma vitamin B_{12} and animal products in the diet was also observed ($P<0·05$; Table 5). We observed positive correlations between dietary intakes of vitamin C, vitamin B_6, PLP and zinc with respective plasma concentrations, but these reached statistical significance for vitamin C only ($P<0·05$; Table 5). The lack of statistically significant association between the dietary and blood levels of these nutrients could be due to high day-to-day variation in dietary intake, as indicated by substantially higher regression coefficients after adjustment for intra- or inter-individual variation (Table 5). A larger number of dietary recalls might be needed to obtain accurate dietary intake for these nutrients.

Discussion

We report that MetS, a constellation of conditions associated with substantial morbidity and mortality worldwide, is prevalent (40 % and 33 %, respectively, using the IDF and ATP III definitions) among the poor elderly Ecuadorians living in Quito, Ecuador. This prevalence is comparable to that reported for elderly adults living in the USA (40 %)[5]. Similar to observations in the USA, prevalence is higher among women than men. Furthermore, a significant proportion of elderly participants without MetS had two of the MetS components. Despite their low socio-economic status, 33 % of elderly men and 55 % of elderly women were overweight. A significant proportion of these adults exhibited low concentrations of blood micronutrients (15 %, 82 %, 15 %, 20 %, 29 % and 37 % had vitamins D, C, B_6, B_{12}, folate and zinc inadequacy, respectively, and 88 % exhibited at least one vitamin or mineral deficiency), indicating that they suffer from the increasingly common double burden of malnutrition and chronic disease associated with food insecurity and nutrition transition in less developed countries. Although historically malnutrition was defined as undernutrition, in recent years a situation has been described that links poverty, food insecurity and malnutrition to obesity and associated diseases[42]. This paradoxical condition has been attributed to the fact that the diet of most of the world's poor consists of 'empty energy', i.e. a diet of poor quality. This diet is low in essential nutrients, resulting in the coexistence of both over- and undernutrition in those living in poverty. The absence of a diversified nutrient-dense diet can lead to energy overnutrition and obesity as well as micronutrient deficiencies. Related to this, households characterized as food-insecure have been shown to have the highest BMI[43]. In fact, the analysis of dietary intake of the participants in the present study supports the contribution of poor-quality diet in this population to the prevalence of under- and overnutrition in the Ecuadorian elderly. Our results show, for the first time, the existence of this paradoxical condition in elderly Ecuadorians. These findings may be relevant to 30 % of the elderly in Ecuador who live in the Andean region, and to the elderly of other developing Latin American countries living in similar conditions.

There was a 12 % difference in MetS prevalence using the IDF or ATP III definitions. This appears to be due to the lower cut-off points for waist circumference used in the IDF definition. Among MetS components, low HDL cholesterol, high waist circumference and hypertension were present in >50 % of the participants, while high fasting glucose concentrations were only observed in 11 %. We present most of our results using the worldwide IDF MetS consensus statement definition[23]. This definition uses South Asian recommendations for waist circumference, which may be more appropriate for this population than those used in APT III. No cut-off points are presently available for Central and South Americans. More research is needed to determine the most appropriate cut-off points for this important indicator in different populations.

Although the aetiological pathways that lead to MetS have not been fully determined[6], it is clear that nutritional status and intake are important contributors[12]. Limited evidence suggests that circulating concentrations of antioxidants may be lower among people with MetS than those without this condition[44]. Furthermore, low vitamin B concentrations and high Hcy[45,46] and CRP[8,47] have been associated with MetS. We found high prevalences of low blood concentrations of vitamins C, B_6, B_{12}, folate and zinc and elevated CRP and Hcy concentrations in this population. However, only plasma vitamin C, vitamin E and CRP were significantly associated with MetS in this relatively small sample. As MetS appears to be linked to oxidative stress[48], it is plausible that deficiencies of micronutrients with antioxidant properties, including vitamins C and E, could be related to MetS, although, given the cross-sectional design of the study, it is not possible to draw conclusions on the potential pathogenic mechanisms of those deficiencies. Vitamin C deficiency was the most commonly identified deficiency in our participants. Low plasma vitamin C may reflect low fruit and vegetable intake, which has been shown to increase the risk of MetS[8,49]. In support of this, fruit and vegetable servings correlated negatively with high systolic BP, although this did not reach statistical significance.

Dietary analysis showed that, as a group, these elderly individuals consumed diets of poor quality, with the majority consuming higher than recommended levels of carbohydrates, mostly of high or intermediate GI, and lower than recommended levels of fat, especially polyunsaturated fat, and micronutrients, consistent with the observed low BP status seen for several micronutrients. More than 50 % of these older adults had hypertension, which may be related to the high daily sodium intake and/or prevalence of vitamin C deficiency. Although we observed a significant association between serum vitamin C concentration and hypertension, the association between dietary sodium intake and BP did not reach statistical significance. This may reflect the difficulty in obtaining accurate dietary sodium intake. We found a strong inverse correlation between vitamin E concentrations and risk of MetS. The underlying mechanisms for the apparent protective effect of vitamin E need to be determined and may differ from those of vitamin C, as they were associated with different sets of MetS components (BP for vitamin C; and HDL cholesterol, waist circumference and glucose for vitamin E).

Inflammation, and in particular high CRP concentration, has been implicated in MetS[47]. More than 48 % of the elderly in the present study had high CRP concentrations. Inflammatory mechanisms may modulate the nutritional, metabolic and other factors contributing to MetS.

There are limitations to the present study that should be noted. First, this was a cross-sectional study, and as such cannot determine causality. Whether the micronutrient status, particularly that of vitamins C and E, is causally related to the high prevalence of MetS needs to be further determined. Second, the study population included only the poor elderly Ecuadorians living in peri-urban, low-income communities. Although this population may be representative of the elderly in other Andean countries such as Bolivia and Peru, the results may not be generalizable to those in coastal areas or those who live in better socio-economic conditions.

In conclusion, MetS is highly prevalent in these poor peri-urban elderly Ecuadorians. Our findings suggest that poor nutritional status is an important contributor to the high prevalence of MetS in this population. As MetS is highly correlated with morbidity and mortality from chronic diseases such as diabetes and CVD, and relatively few resources are available for the health care of elders in Latin American countries, measures to prevent MetS may reduce the burden of these diseases and improve the quality of life in this growing segment of the population. Given the high prevalence of micronutrient deficiencies in the presence of obesity, nutrition interventions could have a significant impact on health outcomes in this population. More research is needed to determine causal factors, but these data suggest that elderly Ecuadorians would benefit from dietary interventions to normalize blood lipids, reduce hypertension and weight gain and improve micronutrient status. Given that the diet of these elderly appeared to be high in salt and low in fruit and vegetables, good-quality protein and essential fatty acids, this population is likely to benefit from reduced salt intake, higher consumption of fruit and vegetables, foods with better-quality protein and fatty acid profiles such as fish, chicken, low-fat dairy and legumes.

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