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

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## Abstract

The proportion of Latin American population > 60 y 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.

**Objective—**To examine the prevalence of MetS and its association with blood micronutrient, homocysteine (tHcy) and CRP concentrations in 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 tHcy concentrations were assessed.

**Subjects—**352 elderly (≥65 y)

**Setting—**Quito, Ecuador.

**Results—**MetS was prevalent (40 %)—considerably more so among women (81%) than men (19%) ($X^2$ = 32.6, P<0.0001). Further, 53 % of those without MetS exhibited two or more of its components. Micronutrient deficiencies were prevalent including those of vitamin C, zinc, B12, and folate. Vitamin C and E concentrations were inversely (OR= 0.78, CI = 0.71 – 0.86; OR=

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0.16, CI =0.03 – 0.81, respectively), and CRP (OR=1.79, CI =1.04 – 3.06) was positively associated with MetS.

**Conclusions—**The co-existence of MetS with micronutrient deficiencies suggests that elderly Ecuadorians suffer from the double burden of diseases that is increasingly observed in less-developed countries. More research is needed to determine 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

## Introduction

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 aging society (2). According to United Nations estimates, the population of Latin American and Caribbean adults aged > 60 y 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 >60 y 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 (PAHO) 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 American countries are likely to have comparatively more diseases, greater disability, and fewer resources for their health care needs. While 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 aging populations. Because older adults face high burdens of disease and disability, this threatens to increase strains on the limited health care resources of their countries.

Metabolic syndrome (MetS) is characterized by disturbed glucose and insulin metabolism, central adiposity, dyslipidemia and high blood pressure, and is associated with type 2 diabetes, cardiovascular disease, and mortality (5). Although the etiology of MetS has not been fully elucidated, available evidence suggests that it is result of a complex interaction between genetic, metabolic and environmental factors (6). Nutritional factors are the most prominent environmental influences, including obesity, dietary glycemic index (7), fruit and vegetables intake (8), total and type of fat intake (9,10), antioxidant nutrients (11), B vitamins, and dairy products (12). Intakes of high glycemic index carbohydrates were positively associated with insulin resistance and prevalence of the metabolic syndrome in subjects of the Framingham Offspring Study (7). Higher intakes of fruit and vegetables were shown to be inversely associated with plasma C-reactive protein (CRP) concentrations, as well as likelihood of having the metabolic syndrome in a cross-sectional study of 486 Iranian females (8). Data from the Third National Health and Nutrition Examination Survey (NHANES III) showed that participants with metabolic syndrome 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, while increased proportions of monounsaturated fatty acid improved insulin sensitivity in adults (9). Higher relative intake of vegetable oils and lower intake of foods containing saturated

fat at age 50 years, were protective against developing sustained hypertension 20 years later (10). In a recent study, Ferritin and transferrin concentrations were shown to be associated with metabolic syndrome 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 high density lipoprotein (HDL) concentration, both components of MetS (14). Energy intake was mainly dependent on high carbohydrate consumption (76.7% of total energy). Furthermore, high prevalence of several micronutrient deficiencies was found (14). Cardiovascular disease (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, though no specific information is available for them. Given that low status of micronutrients such as antioxidants and B vitamins have been suggested to be associated with increased risk for MetS, the current 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 micronutrients concentrations.

In our previous study, 25% of sampled older adults showed blood homocysteine concentration above the upper limit (14). Markers of low-grade inflammation such as CRP (16), and homocysteine (17) have been shown to be associated with cardiovascular disease. Therefore, we also aimed to determine the association of these inflammation markers with micronutrients concentrations and with MetS. This study presents the first report on MetS prevalence in elders living in poor peri-urban communities of Quito, Ecuador, and its relation 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 neighborhoods in northwestern Quito (2800 meters above sea level). The study area had an estimated population of 13,000 and, based on electoral results, 5% were above the age of 65 y. The neighborhoods 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%). Inhabitants were primarily poor immigrants from small cities and rural areas of Ecuador. Their mean monthly income was US$54, which is less than 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 poor urban slums of other Andean countries like Peru and Bolivia.

### Screening and Enrollment

To identify eligible participants, we carried out a census in the three neighborhoods. Eligibility criteria included age ≥65 y, 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 exam (MMSE) that has been used in several countries previously in Spanish, including 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 Ethical 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

Participants were asked to visit one of the three field stations centrally located in each neighborhood (a church, a school or a communitarian house). Two physicians and two nurses collected anthropometric data and blood samples. Prior to the study, all study personnel received training and conducted data collection on the same test subjects to check for inter-observer differences. Two nutritionists performed collection of 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). Participants were asked to wear the least amount of clothing possible. Height was measured to the nearest 0.1 cm, using a steel fiberglass 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 subjects 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 0.1cm using a fiberglass measuring tape. BMI was calculated as weight in Kg divided by the square of height in m (20). The following BMI classifications were used: underweight (BMI: <20), normal weight (BMI: 20–24.9), overweight (BMI: 25–29.9), and obese (BMI: ≥30). Elevated waist circumference was classified using IDF values: men >90 cm, women >80 cm (21).

**Blood Pressure—**Systolic and diastolic blood pressures were measured in mm Hg by detection of Korotkoff sounds, using a conventional certified sphygmomanometer (Riester, CE 0483, Jungingen, Germany). Right arm measurements were obtained while seated, after resting for at least 15 minutes. Subjects with values >130 mm Hg for systolic, or >85 mm Hg for diastolic blood pressures were classified as having high blood pressure (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 de-proteinized 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 (JMUSDA-HNRCA) as described before (23).

Total plasma homocysteine was determined by a method derived from Araki and Sako (24). Controls included pooled plasma samples spiked with different amounts of cysteine and homocysteine. The coefficient of variation for this assay in our laboratory is 7.8%. A cut-off point >15nM/mL (25) was considered as high homocysteine concentration.

C-reactive protein 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 #86083)[(Document: AM-0039 (rev 8.27.90) Protocol: Quantification of Serum Protein with the Cobas Fara II in Conjunction with Atlantic Antibodies Reagents (Atlantic

Antibodies, Inc., Stillwater, MN). A cut-off point >3 mg/L was considered as high CRP concentration (26,27).

Chemical analyses for fasting glucose, triglycerides, low density lipoprotein (LDL), and HDL cholesterol were assessed in Quito, using a conventional autoanalyzer (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 (MetS)—**We used the International Diabetes Federation IDF MetS definition and also report the prevalence of MetS using the Adult Treatment Panel III (ATP III) definition (29). The IDF definition (21) requires subjects 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 triglycerides (>1.7 mmol/L or >150 mg/dL), elevated blood pressure (systolic BP ≥130 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 females) (21). The ATP III definition requires the presence of three or more of the following criteria: 1) elevated waist circumference (>102 cm for men and >88 cm for women); 2) elevated triglycerides (>1.7 mmol/L or ≥150 mg/dL); 3) low HDL cholesterol (<1.03 mmol/L or <40 mg/dL for men and <1.30 mmol/L or <50 mg/dL for females); 4) elevated blood pressure (systolic BP ≥130 or diastolic BP ≥85 mm Hg); 5) elevated fasting glucose (≥6.1 mmol/L or ≥110 mg/dL).

**Definitions of micronutrient deficiencies—**The cut-off points for plasma vitamins inadequacies were defined as follows: Vitamin A ≤ 30 μg /dL (30), PLP ≤ 30 nM/L (14,31,32), B12 ≤ 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 for men ≤ 65 μg/dL and for women ≤ 50 μg/dL (30), and calcium ≤ 8.6 mg/dL (30).

**Dietary intake analysis—**Individual dietary intake was estimated with a modified 24-hour recall/weighing method, (36) as described previously (14). Dietary recall questionnaires were applied two times with each subject, on different working days within a week. Briefly, the interview was carried out in each household, and each subject was given an explanation on the importance of answering as truthfully and accurately as possible. In order to help the subject recall the previous day, we asked her/him about her/his 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 subject 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 thorough review of all recalls to ensure consistency of the data. Two independent data entry staff entered the data into pre-specified excel spreadsheet. These data were sent to Tufts University, where they were linked to the USDA 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 two days of dietary measures were averaged to obtain the most stable measure for each individual. The intra- to inter-person variance for the nutrient intakes were also calculated and utilized in evaluating correlations between nutrient intakes and blood concentrations (see below).

### Statistical Methods

Data entry and management were done with Epi-Info software, version 6.04d (CDC, Atlanta, GA.). Statistical analyses were performed using SPSS, version 11.5 (Lead Technologies Inc. SPSS Inc. Chicago, IL). The prevalence of MetS and of its components was calculated overall and by sex. We also calculated the frequency of MetS components in subjects with and without MetS syndrome. Differences in means and percentages by sex, and between subjects with or without MetS were evaluated by Student's t- and chi-squared tests, respectively.

Multiple logistic regression models, also controlling for age and sex, were fitted to determine whether selected blood micronutrient status, high homocysteine, 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 2 dietary recalls. Day-to-day within person variation in the reference method (mean of the two 24-hour dietary recalls) can attenuate the correlations between nutrient intakes derived from the dietary recalls and serum measures. The intra- to inter-person variance for the nutrient intakes, as estimated by the two 24-hour dietary recalls, were 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-hour dietary recalls, adjusted for energy intake, BMI, smoking, age and sex; $\text{intra}_x$ is the intra-subject variation for the intake variable; $\text{inter}_x$ is the inter-subject variation for the intake variable; and $n_x$ is the number of days of dietary recall, which was two in this study(39).

## Results

Demographic and anthropometric measurements for this population are shown in Table 1. 352 subjects were enrolled in the study, 225 women (64%) and 127 (36%) men. The mean age of the study participants was 74.4 ± 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 one 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 subjects were overweight or obese. A higher percentage of women were overweight than men (Table 1).

Based on the IDF definition, the majority of MetS components were more frequent in women than in men: more women than men had elevated waist circumference ($p<0.05$), elevated triglycerides ($p<0.001$) and low HDL cholesterol ($p<0.0001$) (Table 2). Hypertension and elevated blood glucose concentrations did not differ by sex. Similar results were found using the ATPIII criteria (data not shown).

Based on IDF criteria, 40% of subjects had MetS. Among these subjects, 19 % were men and 81% women ($X^2 = 32.6$, $P < 0.0001$), while 33% (18.3% men and 81.7% women) had MetS based on the ATP III definition. In addition, 52 % (110/210) of the subjects without MetS (defined by IDF) exhibited two or more of its components. In subjects without MetS, a higher percentage of women than men exhibited two or more components of MetS (68/110 vs. 42/110; $X^2 = 9.094$, $P=0.002$).

Based on serum/plasma concentrations, micronutrient inadequacies were common. For men and women, respectively (values in parenthesis are the median and $10^{th}$ and $90^{th}$ percentiles followed by the % of subjects who had low values) vitamin C [0.17 (0.02–0.44), 0.26 (0.09–

0.56) mg/dL; 60% and 33%)], vitamin B6 [39.9 (23–64), 48.1 (27.3–78.3) nM/L; 27% and 16%], vitamin B12 [ 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 subjects. 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/triglyceride ratios, and vitamin C concentrations were inversely associated with MetS (OR=0.78, CI = 0.71 – 0.86; OR= 0.16, 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, CI =1.04 – 3.06) (Table 3). High plasma homocysteine (>15 nM/mL), or low zinc, copper, or B vitamins, were not associated with MetS (Table 3).

After adjusting for age and sex, low plasma vitamin E/triglyceride ratios were associated with high plasma glucose (OR=0.74, CI=0.63–0.86), low HDL (OR=0.84, CI=0.78–0.92), and high waist circumference (OR=0.91, CI=0.85–0.98). Low plasma vitamin C was also associated with hypertension (OR=0.15, CI=0.03–0.67), high waist circumference (OR=0.15, CI=0.03–0.68), and low HDL cholesterol (OR=1.94, CI=1.07–3.50).

Analysis of dietary intake from the subjects is shown in Table 4. In general, the diets were of poor quality—high in carbohydrate and sodium (> 50% had intakes higher than recommended) and low in protein (about 23% had intakes below that recommended), and fat (about 42%), had intakes below that recommended) and in 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. Intake 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%).

Glycemic load 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 subjects was of high glycemic index (GI), using glucose as the reference (40). Ninety-three percent of subjects consumed low linoleic, and alpha linolenic acid, based on the percent of total energy intake, according to AMDR (41). 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, fruit and vegetable and animal product consumption was low, and most likely contributing to low serum micronutrient status, as indicated by positive correlations between intake of fruit and vegetables and plasma vitamin C, B6, and folate concentrations ($P<0.05$, Table 5). A significant correlation between plasma vitamin B12 and animal products in the diet was also observed ($P<0.05$, Table 5). We observed positive correlations between dietary intakes of vitamin C, B6, 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 level 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/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% using the IDF and ATP III definitions, respectively) among poor elderly Ecuadorians living in Quito, Ecuador. This prevalence is comparable to that reported for elderly adults living in the US (40%) (5). Similar to observations in the US, prevalence is higher among women than men. Furthermore, a significant proportion of elderly subjects without MetS had two of the MetS components. Despite their low socioeconomic 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, B6, B12, 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 the nutrition transition in less-developed countries. While, 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 calories", i.e., a diet of poor quality. This diet is low in essential nutrients, resulting in the co-existence of both over- and undernutrition in those living in poverty. The absence of a diversified nutrient-dense diet can lead to caloric 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 subjects in this study supports the contribution of poor quality diet in this population to prevalence of under- and over-nutrition in Ecuadorian elderly (see above and below). Our results demonstrate, for the first time, the existence of this paradoxical condition in elderly Ecuadorians. These findings may be relevant to the 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 cutoff points for waist circumference used in the IDF definition. Among MetS components, low HDL, 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 world-wide 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 for Central and South Americans are presently available. More research is needed to determine the most appropriate cut-off points for this important indicator in different populations.

While the etiologic 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 B vitamin concentrations, and high homocysteine (45,46) and CRP (8,47) have been associated with MetS. We found high prevalences of low blood concentrations of vitamins C, B6, B12, folate, and zinc and elevated CRP and homocysteine 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 blood pressure, 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 blood status seen for several micronutrients. More than 50% of these older adults had hypertension, which may be related to the high daily intake of sodium and/or prevalence of vitamin C deficiency. While we observed a significant association between serum vitamin C concentration and hypertension, the association between dietary Na intake and blood pressure did not reach statistical significance. This may reflect 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 needs to be determined and may differ from those of vitamin C, as they were associated with different sets of MetS components (blood pressure for vitamin C; and HDL, 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 this study had high CRP concentrations. Inflammatory mechanisms may modulate the nutritional, metabolic, and other factors contributing to MetS.

There are limitations to this 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 vitamin C and E, are causally related to the high prevalence of MetS needs to be further determined. Second, the study population included only poor elderly Ecuadorians living in peri-urban, low-income communities. While 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 socioeconomic 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 fruits 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.

## References


1. UN World Population Ageing 1950–2050. Population Division, DESA, United Nations.
2. Hoskins I, K A, Mende S. Toward primary health care adapted to elderly people. Pan American journal of public health. 2005; 17:444–451. [PubMed: 16053655]
3. United Nations. World Population Prospects: The 2008 Revision Population Data Base. 2009. http://esa.un.org/unpp
4. McCarthy M. Boom in Latin American and Caribbean elderly population. Region's health systems have 10 years to prepare for rising number of elderly, report warns. Lancet. 2004; 363:458–459. [PubMed: 14963925]
5. Ford E. Risks for all-cause mortality, cardiovascular disease, and diabetes associated with the metabloic syndrome: a summary of the evidence. Diabetes Care. 2005; 28:1769–1778. [PubMed: 15983333]
6. Lidfeldt J, N P, Nerbrand C, Samsioe G, Schersten B, Agardh CD. Socio-demographic and psychosocial factors are associated with features of the metabolic syndrome. The Women's Health in the Lund Area (WHILA) study. Diabetes, Obesity & Metabolism. 2003; 5:106–112.
7. McKeown NM, M J, Liu S, Saltzman E, Wilson PW, Jacques PF. Carbohydrate nutrition, insulin resistance, and the prevalence of the metabolic syndrome in the Framingham Offspring Cohort. Diabetes Care. 2004; 27:538–546. [PubMed: 14747241]
8. Esmaillzadeh A, Kimiagar M, Mehrabi Y, Azadbakht L, Hu F, Willett W. Fruit and vegetable intakes, C-reactive protein, and the metabolic syndrome. The American Journal of Clinical Nutritoin. 2006; 84:1489–1497.
9. Vessby B, Uusitupa M, Hermansen K, Riccardi G, Rivellese AA, Tapsell LC, Nalsen C, Berglund L, Louheranta A, Rasmussen BM, Calvert GD, Maffetone A, Pedersen E, Gustafsson I-B, Storlien LH. Substituting dietary saturated for monounsaturated fat impairs insulin sensitivity in healthy men and women: The KANWU study. Diabetologia. 2001; 44:312–319. [PubMed: 11317662]
10. Bjorklund K, Lind L, Vessy B, Andrén B, Lithell H. Different metabolic predictors of white-coat and sustained hypertension over 20-year follow-up period: A population-based study of elderly man. Circulation. 2002; 106:63–68. [PubMed: 12093771]
11. Ford ES, M A, Giles WH, Brown DW. The metabolic syndrome and antioxidant concentrations: findings from the Third National Health and Nutrition Examination Survey. Diabetes. 2003; 52:2346–2352. [PubMed: 12941775]
12. Feldeisen SE, T K. Nutritional strategies in the prevention and treatment of metabolic syndrome. Applied physiology, nutrition, and metabolism. 2007; 32:46–60.
13. Vari I, Balkau B, Kettaneh A, Andre P, Tichet J, Fumeron F, Caces E, Marre M, Grandchamp B, et al. Ferritin and transferrin are associated with metabolic syndrome abnormalities and their change over time in a general population: Data from an Epidemiological Study on the Insulin Resistance Syndrome (DESIR). Diabetes Care. 2007; 30:1798–1801.
14. Sempertegui F, E B, Elmieh N, Jordan M, Ahmed T, Rodriquez A, Tucker KL, Hamer DH, Reeves PG, Meydani SN. Nutritional, immunological and health status of the elderly population living in poor neighbourhoods of Quito, Ecuador. The British Journal of Nutrition. 2006; 96:845–853. [PubMed: 17092372]
15. INEC. Censo de población y vivienda de 2001. Quito, Ecuador: 2001. Instituto Nacional de Estadisticas y Censos (INEC).
16. Szmitko PE, Wang C, Weisel RD, de Almeida JR, Anderson TJ, Verma S. New markers of inflammation and endothelial cell activation. Part I. Circulation. 2003; 108:1917–1923.
17. Humphrey LL, Fu R, Rogers K, Freeman M, Helfand M. Homocysteine level and coronary heart disease incidence: a systematic review and meta-analysis. Mayo Clin Proc. 2008; 83:1203–1212. [PubMed: 18990318]
18. Gross, R. CRONOS (Cross-Cultural Research on the Nutrition of Older Subjects). Food Nutr. Bull. 1997; 18:267–303.
19. Blaum CS, Fries BE, Fiatarone MA. Factors associated with low body mass and weight loss in nursing home residents. J. Gerontol. 1995; 50A:M152–M168.

20. Garrow JS, Webster J. Quetelet's Index (W/H2) as a measure of fatness. International Journal of Obesity. 1985; 9:147–153. [PubMed: 4030199]
21. Alberti KG, Z P, Shaw J. Metabloic syndrome -- a new world-wide definition. A Consensus Statement from the International Diabetes Federation. Diabetic medicine. 2006; 23:469–480. [PubMed: 16681555]
22. Grundy, S.; Brewer, H.; Cleeman, J.; Smith, S.; Lenfant, C. AHA & NHLBI. Definition of metabolic syndrome: Report of the National Heart, Lung, and Blood Institute/American Heart Association conference on scientific issues related to definition; Circulation; 2004. p. 433-438.
23. Meydani SN, Meydani M, Rall LC, Morrow F, Blumberg JB, Meydani SN, Meydani M, Rall LC, Morrow F, Blumberg JB. Assessment of the safety of high-dose, short-term supplementation with vitamin E in healthy older adults. American Journal of Clinical Nutrition. 1994; 60:704–709. [PubMed: 7942576]
24. Araki A, Sako Y. Determination of free and total homocysteine in human plasma by high-performance liquid chromatography with fluorescence detection. J. Chromatogr. 1987; 422:43–52. [PubMed: 3437026]
25. Selhub J, Jacques PF, Wilson PW, Rush D, Rosenberg IH. Vitamin status and intake as primary determinants of homocysteinemia in an elderly population. JAMA. 1993; 270:2693–2698. [PubMed: 8133587]
26. Pearson T, Mensah G, Alexander R, Anderson J, Cannon Rr, Criqui M, Fadl Y, Fortmann S, Hong Y, et al. Markers of inflammation and cardiovascular disease: application to clinical and public health practice: A statement for healthcare professionals from the Centers for Disease Control and Prevention and the American Heart Association. Circulation. 2003; 107:499–511. [PubMed: 12551878]
27. Tietz N. Clinical guide to laboratory tests. Harcourt Brace Company. 1995
28. Westgard J, Barry P, Hunt M, Groth T. A multi-rule Shewhart chart for quality control in clinical chemistry. Clin. Chem. 1981; 27:493–501. [PubMed: 7471403]
29. Expert Panel on Detection, E., and Treatment of High Blood Cholesterol in Adults. Executive summary of the second report of the Third Report of the National Cholesterol Education Program (NCEP) Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Journal of the American Medical Association. 2001; 285:2486–2497. [PubMed: 11368702]
30. Tietz, Burtis C, EAshwood E, Bruns D. Tietz Textbook of Clinical Chemistry and Molecular Diagnostics. 2006
31. Driskell JA. Vitamin B6 requirements of humans. Nutrition Research. 1994; 14:293–324.
32. Bailey AL, Maisey S, Southon S, Wright AJ, Finglas PM, Fulcher RA. Relationships between micronutrient intake and biochemical indicators of nutrient adequacy in a "free-living' elderly UK population. Br J Nutr. 1997; 77:225–242. [PubMed: 9135369]
33. Tucker KL, Rich S, Rosenberg I, Jacques P, Dallal G, Wilson PW, Selhub J. Plasma vitamin B-12 concentrations relate to intake source in the Framingham Offspring study. Am J Clin Nutr. 2000; 71:514–522. [PubMed: 10648266]
34. Sauberilich, HE. Evaluation of folate nutrition in population groups. Sauberlich, HE., editor. New York: Wiley and Sons; 1990.
35. Cecil R, Goldman L, Bennett J. Cecil Textbook of Medicine (2-Volume Set). 1999
36. Zamora RM, Valverde V. The dietary score as a simplified methodology in processing and analyzing food consumption data. Arch Latinoam Nutr. 1983; 33:843–860. [PubMed: 6679247]
37. U.S. Department of Agriculture, Agricultural Research Service. 2004. USDA National Nutrient Database for Standard Reference, Release 17. Nutrient Data Laboratory. 2004. http://www.nal.usda.gov/fnic/foodcomp
38. Instituto Nacional de Nutrición. Ministerio de Previsión Social y Sanidad. Tabla de composición de los alimentos ecuatorianos Quito. 1965
39. Willett, W. Nutritional Epidemiology. second edition. Oxford University Press; 1998. p. 306-308.
40. Flood A, Subar AF, Hull SG, Zimmerman TP, Jenkins DJ, Schatzkin A. Methodoloy for Adding Glycemic Load Values to the National Cancer Institute Questionnaire Database. J Am Diet Assoc. 2006; 106:393–402. [PubMed: 16503230]

41. Dietary reference Intakes for Energy, Carbohydrate, Fiber, fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). Washington, D.C: The National Academies Press; p. 769-770.

42. Tanumihardjo S, Anderson C, Kaufer-Horwitz M, Bode L, Emenaker N, Haqq A, Satia J, Silver H, Stadler D. Poverty, obesity, and malnutrition: an international perspective recognizing the paradox. JADA. 2007; 107:1966–1972.

43. Olson C. Nutrition and health outcomes associated with food insecurity and hunger. J. Nutr. 1999; 129(2S Suppl):521S–524S. [PubMed: 10064322]

44. Ford. Intake and circulating concentrations of antioxidants in metabolic syndrome. Current atherosclerosis reports. 2006; 8:448–452. [PubMed: 17045069]

45. Cankurtaran M, Kay T, Yavuz B, Shorbaqi A, Halil M, Coskun T, Arslan S. Serum vitamin-E levels and its relation to clinical features in nonalcoholic fatty liver disease with elevated ALT levels. Acta gastro-enterologica Belgica. 2006; 69:5–11. [PubMed: 16673555]

46. Meigs J, Jacques P, Selhub J, Singer D, Nathan D, Rifai N, D'Agostino R, Wilson P, Study FO. Fasting plasma homocysteine levels in the insulin resistance syndrome: the Framingham offspring study. Diabetes Care. 2001; 24:1403–1410. [PubMed: 11473077]

47. Yudkin J, Stehouwer C, Emeis J, Coppack S. C-reactive protein in healthy subjects: associations with obesity, insulin resistance, and endothelial dysfunction: a potential role for cytokines originating from adipose tissue? Arterioscler Thromb Vasc Biol. 1999; 19:972–978. [PubMed: 10195925]

48. Nicolson G. Metabolic syndrome and mitochondrial function: molecular replacement and antioxidant supplements to prevent membrane peroxidation and restore mitochondrial function. J Cell biochem. 2007; 100:1352–1369. [PubMed: 17243117]

49. Yoo S, N T, Baranowski T, Zakeri IF, Yang SJ, Srinivasan SR, Berenson GS. Comparison of dietary intakes associated with metabolic syndrome risk factors in young adults: the Bogalusa Heart Study. The American Journal of Clinical Nutritoin. 2004; 80:841–848.

50. Dietary Reference Intakes for Energy, Carbohydrate, Fiber, Fat, Fatty Acids, Cholesterol, Protein, and Amino Acids (Macronutrients). 2002. http://www.nap.edu/catalog/10490.html

51. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. 2000. http://www.nap.edu/catalog/10026.html

52. Dietary Reference Intakes: Applications in Dietary Assessment. 2000. http://books.nap.edu/catalog/9956.html

53. Dietary Reference Intakes for Water, Potassium, Sodium, Chloride, and Sulfate. 2004. 2004. http://www.nap.edu/catalog/10925.html

54. Dietary Reference Intakes for Calcium, Phosphorus, Magnesium, Vitamin D, and Fluoride. Institute of Medicine (IOM). 1997. http://www.nap.edu/books/0309063507/html/

55. Dietary Reference Intakes for Thiamin, Riboflavin, Niacin, Vitamin B6, Folate, Vitamin B12, Pantothenic Acid, Biotin, and Choline. 1998. http://www.nap.edu/catalog/6015.html

56. Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids. 2000

## Table 1

Demographic Characteristics and Anthropometric Measurements of Elderly Ecuadorians

| Variable | Men (n=127) | Women (n=225) | P |
|---|---|---|---|
| Age (y) [mean ± SD (range)] | 75.8 ± 6.5 (65 – 94) | 73.7 ± 6.1 (65 – 97) | < 0.001 |
| Education level | | | |
| No school (%) | 29.4 | 52.5 | < 0.0001 |
| Birth place (% rural) | 69.0 | 73.9 | NS |
| Anthropometrics (mean +SD) | | | |
| Weight (kg) | 59.9 ± 9.5 | 54.0 ± 9.8 | < 0.0001 |
| Height (cm) | 156 ± 6.7 | 144 ± 6.0 | < 0.0001 |
| Height by knee-height (cm)* | 158 ± 6.4 | 144 ± 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 (BMI < 20) (%) | 2.7 | 4.5 | NS |
| Normal (BMI 20–24.9) (%) | 57.3 | 39.8 | < 0.001 |
| Overweight (BMI 25–29.9 (%) | 29.5 | 41.2 | < 0.05 |
| Obese (BMI ≥ 30) (%) | 3.3 | 14.0 | < 0.01 |

* calculated as described (19)

## Table 2

Distribution of Metabolic Syndrome 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 or diastolic ≥85) | 51 | 55 | 49 | NS |
| Fasting glucose (≥100 mg/dL) | 11 | 9 | 13 | NS |
| Triglycerides (≥150 mg/dL) | 40 | 28 | 46 | < 0.001 |
| HDL (men <40 mg/dL, women <50 mg/dL) | 73 | 56 | 83 | < 0.0001 |

* International Diabetic Federation.

† n= 352, 301, 351, 351, and 351 for waist circumference, blood pressure, fasting glucose, triglycerides and HDL, respectively.

## Table 3

Association of age, sex, blood micronutrients, CRP, and Homocysteine with Metabolic Syndrome using the IDF definition

| Variable | OR[†] | 95% CI[‡] |
|---|---|---|
| Age (y) | 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 (nM/L)[*] | 1.01 | 1.00 – 1.02 |
| Vitamin B12 (pg/mL) | 1.00 | 0.99 – 1.01 |
| Folate (ng/mL) | 1.04 | 0.94 – 1.16 |
| Copper (μg/dL) | 0.99 | 0.98 – 1.00 |
| Zinc (μg/dL) | 1.00 | 0.99 – 1.02 |
| High plasma CRP (>3 mg/L) | 1.79 | 1.04 – 3.06 |
| High plasma Homocysteine (>15 nM/mL) | 1.73 | 0.94 – 3.18 |
| Ratio vitamin E / Triglycerides | 0.78 | 0.71 – 0.86 |

[*] PLP= Pyridoxal phosphate.

[†] OR (odds ratio) are based on a multiple logistic regression model, adjusting for age and sex.

[‡] CI=confidence interval

**Table 4**

Dietary macronutrient and micronutrient intake of elderly Ecuadorians[1]

| | | Female | | | Male | | |
|---|---|---|---|---|---|---|---|
| **Nutrient** | **AMDR*, EAR† or AI‡** | **Intake[mean (range)] n=218** | **Below ref (%)** | **Above ref or UL(%)** | **Intake [mean (range)] n=124** | **Below ref (%)** | **Above ref or UL(%)** |
| Energy (Kcal) | | 1187 (327–2805) | | | 1159 (166–2428) | | |
| Fat (% energy) | 20–35[1] | 21.9 (5.3–53.6) | 41.2 | 5.1 | 21.9 (6.0–40.6) | 44.4 | 0.8 |
| Carbohydrate (% energy) | 45–65[1] | 65.8 (10.3–87.6) | 2.3 | 55.5 | 65.9 (36.0–88.8) | 0.8 | 55.7 |
| Protein (% energy) | 10–35[1] | 13.2 (5.3–33.9) | 20.6 | 0 | 13.0 (5.7–25.9) | 27.4 | 0 |
| Total vitamin A (μg RAE) | 500–6252 | 396 (0.2 – 3588) | 74.3 | 0 | 429 (1.7 – 2696) | 78.2 | 0 |
| Vitamin D (μg calciferol) | 15[3] | 1.35 (0.00 – 7.57) | 100 | 0 | 1.53 (0.00 – 11.0) | 100 | 0 |
| Alpha tocopherol (mg) | 12[2] | 3.10 (0.35 –8.47) | 100 | 0 | 3.24 (0.21 – 8.78) | 100 | 0 |
| Vitamin K (μg phylloquinone) | 90–120[3] | 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 | 49.88 (1.0 – 394) | 84.7 | 0 |
| Riboflavin (mg) | 0.9–1.1[2] | 0.85 (0.06 –2.61) | 64.2 | | 0.89 (0.13 – 2.49) | 70.2 | |
| Folate (μg) | 320[2] | 208 (0 – 646) | 82.1 | 0 | 227 (18.7 – 743) | 76.6 | 0 |
| Vitamin B-6 (mg) | 1.3–1.4[2] | 1.24 (0.21 –4.59) | 58.3 | 0 | 1.25 (0.10 – 2.80) | 62.9 | 0 |
| Vitamin B12 (μg) | 2.0[2] | 2.60 (0.00 –19.0) | 56.0 | | 3.02 (0.0 – 18.2) | 54.8 | |
| Calcium (mg) | 1200[3] | 247 (21.3 – 908) | 100 | 0 | 248 (30– 928) | 100 | 0 |
| Phosphorus (mg) | 580[2] | 575 (77 – 1470) | 58.3 | 0 | 605 (121 – 1364) | 52.4 | 0 |
| Magnesium (mg) | 265–350[2] | 160 (13 – 432) | 93.6 | 1.4 | 167 (23– 415) | 99.2 | 0.8 |
| Iron (mg) | 5.0–6.0[2] | 6.29 (0.02 –17.6) | 39.5 | 0 | 6.76 (1.37 – 22.0) | 50.0 | 0 |
| Zinc (mg) | 6.8–9.4[2] | 5.30 (0.63 –16.8) | 73.9 | 0 | 5.59 (0.75 – 13.1) | 92.7 | 0 |
| Copper (μg) | 700[2] | 862 (50 –4005) | 38.1 | 0 | 886 (110 – 4150) | 34.7 | 0 |
| Selenium (μg) | 45[2] | 64.2 (7.8 – 210) | 28.0 | 0 | 68.6 (12.0 – 218) | 27.4 | 0 |
| Potassium (mg) | 4700[3] | 1651 (134 –4036) | 100 | 0 | 1659 (184 –3820) | 100 | 0 |
| Sodium (mg) | 1200[3] UL 2300 | 3094 (69 –20342) | 15.6 | 53.1 | 3287 (200 – 13255) | 13.7 | 62.1 |

[1] Average of two 24 hour recalls

* AMDR (Acceptable Macronutrient Distribution Range, adults) (50)

† EAR (Estimated Average Requirement, women-men, aged >70 y) (51,52)

‡ AI (Adequate Intake, women-men, aged >70 y); EAR not available (52–56)

**Table 5**

Correlation between dietary and blood nutrient concentrations

| Diet variable | Serum variable | Observed regression coefficient | Corrected regression coefficient** |
|---|---|---|---|
| Vitamin C (mg) | Vitamin C (mg/dL) | 0.0005* | 0.001 |
| Vitamin B6 (mg) | PLP (nM/L) | 5.6 | 11.1 |
| Vitamin B12 (μg) | Vitamin B12 (pg/mL) | 9.0 | 21.7 |
| Zinc (mg) | Zinc (μg/dL) | 0.19 | 0.40 |
| FV-servings | Folate (ng/mL) | 0.18* | 0.39 |
| FV-servings | Vitamin B12 (pg/mL) | 3.3 | 7.0 |
| FV-servings | PLP (nM/L) | 1.6* | 3.4 |
| FV-servings | Vitamin C μg/dL) | 0.02* | 0.04 |
| Animal protein (g) | Zinc (μg/dL) | 0.01 | 0.02 |
| Animal protein (g) | Vitamin B12 (pg/mL) | 2.4* | 5.7 |

* P<0.05 adjusted for age, sex, smoking, BMI and energy intake

** also adjusted for intra/inter individual variation in dietary intake

PLP, Pyridoxal phosphate

FV, fruit and vegetable