Nutritional Status of Highland and Lowland Children in Ecuador

by Sozina Katuli,1 Zuhair S. Natto,1,2 Lawrence Beeson,1 and Zaida R. Cordero-MacIntyre3,4

1Department of Epidemiology, School of Public Health, Loma Linda University, Loma Linda, CA, USA
2Department of Epidemiology, School of Public Health, King Abdulaziz University, Jeddah, Saudi Arabia
3Center for Health Disparities and Molecular Medicine, School of Medicine, Loma Linda University, Loma Linda, CA, USA
4Department of Nutrition, School of Public Health, Loma Linda University, Loma Linda, CA, USA

Correspondence: Zaida Cordero-MacIntyre Ph.D. Pharm.D., MPH, REHS, MS, RD., Associate Professor. Nutrition Dept. School of Public Health, Center for Health Disparities and Molecular Medicine, School of Medicine. Loma Linda University. Loma Linda, CA 92350. USA. E-mail: <zcordero-macintyre@llu.edu>

Summary

We assessed the nutritional status of children in Ecuador using anthropometric measurements and body composition.

Objectives: To determine whether living in the highlands in Quito was a predisposing factor to poor nutrition in children.

Method: We compared the children in highlands at 2772 m above sea level with their coastal (605 m above sea level) counterparts at Santo Domingo de Los Colorados. By using the WHO standard reference 2007, we distinguished malnourished children from healthy children using $Z$-score of $-2$ as a cut-off point.

Results: Mean $Z$-score indices for both height-for-age (HFA) and weight-for-age (WFA) were found to be significantly lower among urban children than for rural children ($p < 0.001$). Urban children were also four times more likely of becoming mildly stunted (OR = 3.95%, 95% confidence interval (CI): 1.818–8.448) and three times more likely of being mildly underweight (OR = 3.95%, 95% CI: 1.241–7.551).

Conclusion: Living in highland urban areas of Ecuador is a predisposing factor for poor nutrition among children.

Key words: nutritional status, children, elevation, highland, lowland, Ecuador.

Background

The nutritional status of the children in Ecuador may be linked with their family’s socio-economic status, geographical locations and center of origin. The volcanic eruptions in 2006 may also have a bearing on these differences [1, 2]. The indigenous and Afro–Ecuadorian individuals living in the highlands and lowland areas are poor, malnourished and differ in their growth patterns [3–5].

The influence of nutritional status on health has been reported previously. Lehti [6] found increased rate of infant mortality and spontaneous abortion in the population with low-nutritional status. Stunted growth is associated with children who have low-caloric and protein intakes, which is affecting mainly poor communities [7–9]. Nutritional status in children is also associated with infectious diseases [4, 10]. Various studies have shown increased incidences of infections from diarrhea [11], malaria [12], cutaneous leishmaniasis [13], ocular pterygium and respiratory illnesses [14]. The nutritional status of children, therefore, has shown to be an indicator of their overall health status.

Anthropometric indicators, such as weight-for-age (WFA), BMI and height-for-age (HFA), are used to assess underweight, wasting and stunting, respectively, among children aged >5 years [15]. Low HFA scores reflect chronic undernutrition and low BMI scores reflect wasting. WFA is a composite indicator and does not distinguish between chronic and acute undernutrition [16]. WHO recommends the use of $Z$-scores as the method of choice, as they provide a more statistically accurate measure of risk and prevalence of malnutrition [17]. $Z$-scores express a child’s weight or height as a multiple of the SD of the reference population [18]. In developed countries, more efficient equipment such as bioelectrical impedance assessment have been developed to measure body fat, fat mass and fat-free mass. However, there are few studies that have assessed the nutrition disparities in Ecuador.

This study assesses the nutritional status of two subpopulations of Ecuadorian children, representing...
highlands and tropical or coastal groups. The objective is to compare the nutritional status and body composition between school-going children in highlands and lowland areas of Ecuador and to determine the effect of geographical location (highlands vs. lowland) on their nutritional status.

**Methods**

Anthropometric data and bioelectrical impedance assessment measurements were taken and organized at three public schools in Quito and Santo Domingo de Los Colorados (SDDC), among 171 children (aged: 7–15 years). Height and weight measurements were converted to nutritional indices (HFA, WFA and BMI-for-age) using WHO standards [15].

Body composition, fat-free mass and percent body fat were predicted from skinfold thicknesses using equation by Lohman [19]. Arm circumferences and bioelectrical impedance measurements from each child were calculated by following the standard protocols. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer, and weight was measured to the nearest 0.1 kg on the Tanita scale, with children lightly clothed. Skinfolds were taken by a Lange calliper, and circumferences were measured to the nearest 0.1 cm using a flexible tape. A duplicate measurement was collected from each child, and the mean was used for statistical analysis. HFA was used as an index for linear growth. A Z-score of −2 was used as a cut-off point to distinguish healthy from malnourished children. BMI Z-scores greater than +1 were classified as overweight [15].

**Data analysis**

Independent t-test and multiple linear regression analyses were used to assess the difference and influence of geographic location on nutritional status. Logistic regression was also performed on stunting and underweight children, using Z-scores of −1 as a cut-off point for mildly stunted (HFA less than −1 Z-score) and underweight children (WFA less than −1 Z-score), as none of the children were found below Z-scores of −2 for both the indicators in the costal group. Body fat was also evaluated by Tanita devices, and the prediction equation developed by Lohman was used as follows:

Percent fat for males = \(1.2 (\sum SF) - 0.008 (\sum SF)^2 + I_M\)

Percent fat for females = \(1.33 (\sum SF) - 0.013 (\sum SF)^2 + 2.0\) (females)

where \((\sum SF)\) = sum of triceps and subscapular skinfolds.

\(I_M\) = it is an intercept that varies with maturation level and racial groups in males. In this study, we used a score of −1.7 for white prepubescent boys aged <12 years and −3.4 for white pubescent boys aged ≥12 years [19].

**Results**

Of the 171 children, 66% were in the highlands and 33.3% in the lowland region, with nearly 1:1 male to female ratio (Table 1). All the basic nutritional status indicators were significantly different in the two locations \((p < 0.005)\). The overall prevalence for stunting (less than −2 Z-scores for HFA), underweight (less than −2 Z-score for WFA) and low BMI scores (<−2 Z-score for BMI-for-age) was 7.6, 1.2 and 1.2%, respectively. In the highland region, there were 11.4% children stunted, 1.8% underweight and 1.8% thinner than the healthy children. None of the children were below a Z-score of −2 in the lowland region. However, 35.1% were mildly stunted and 22.8% were mildly underweight (less than −1 Z-score).

In Tables 2 and 3, all indicators except BMI, triceps and biceps were significantly different in the two locations \((p < 0.05)\). There were significantly larger measures for percent body fat, fat mass and fat-free mass observed in the lowland children, but only for the older age groups (≥11 years). The percent body fat calculated using Lohman equation [19] was not significantly different in the two locations. When adjusted for age and gender (Table 4), living in highlands had significant negative influences on HFA (regression coefficient = −0.811, \(p < 0.001)\) and WFA (regression coefficient = −0.431), whereas skinfold triceps only had a slight influence (regression coefficient = 0.47, \(p = 0.041)\).

To determine effects of living in highlands on nutritional status, we used a Z-score of −1 as a cut-off point to distinguish mildly stunting and mildly underweight from healthy children. There were no children with low BMI scores (less than −1 Z-scores) in the lowland areas; therefore, logistic regression was performed only using stunting and underweight as outcome variables, and a model with overweight was added because 15.4% of the children were found overweight (BMI >+1 Z-scores) as follows:

Model 1: Mild stunting \((-1)\) HFA Z-score = age + sex + location [highland (1), lowland (0)] + error.

Model 2: Mild underweight \((-1)\) WFA Z-score = age + sex + location [highland (1), lowland (0)] + error.

Model 3: Overweight (more than +1 BMA Z-score) = age + sex [male (0), female (1)] + location [highland (1), lowland (0)] + error.

Children who lived in the highlands were four times more likely to be stunted (OR = 3.92) and three times likely to be mildly underweight (OR = 3.05) than the children in the lowland areas (Table 5).
Discussion

Triceps, subscapular skinfolds and BMI are recommended for adolescents in addition to HFA and WFA used for children aged <5 years [20, 21]. In the 2007 WHO reference, the appropriate indicators for children aged 5–19 years are HFA, WFA and BMI [15]. The WHO reference 2007 is a reconstruction of the 1977 National Center for Health Statistics (NCHS)/WHO reference. Z-scores use an application of statistical theory to describe how far a child's weight or height is from the average (the median for the NCHS/WHO values) weight or height of a child of the same age in the reference data. The distance (Z-score) is calculated as follows:

$$HFA \text{ Z-score} = \frac{\text{observed height}}{\text{median height}} - \frac{\text{SD}}{\text{median height}}$$

where both the median height and the SD are taken from the normalized growth curves derived from the NCHS/WHO reference values for the given age [20].

The WHO Global Database on Child Growth and Malnutrition uses a Z-score cut-off point of less than −2 SD to classify low WFA, low HFA and weight-for-height as moderate and less than −3 SD to define severe undernutrition. The cut-off point of more than +2 SD classifies high weight-for-height as overweight in children. For BMI, the categories are overweight more than +1 SD (equivalent to BMI 25 kg/m² at 19 years, obesity greater than +2 SD equivalent BMI 30 kg/m² at 19 years, thinness less than −2 SD and severe thinness less than −3 SD) [15].
Anthropometric indices differences in highlands and lowland areas

In Table 4, this study showed that children who live in highlands were more stunted than those living in the lowland areas \( (p < 0.001) \). These results concur with that of Leonard et al. [4] who found that highland children were significantly shorter, but not significantly lighter, than their lowland peers. On the contrary, we found the highland children were also lighter than the lowland rural children. Our logistic regression analysis also confirmed these differences. Anthropological studies on the altitudinal differences of body proportions in ancient Andeans also shows that overall body size and limb lengths to body size vary along an altitudinal gradient, with larger individuals from lowland environments and smaller individuals with relatively longer limbs from higher elevations [22]. Although this ecogeographic variation in relation to climate explains the variation in intra-limb proportions [22], the disparity in lifestyle and food security in these two areas may have contributions to the differences observed in this study.

People living in higher elevations are socially and economically exploited; hence, they tend to move to higher elevations where temperatures are even cooler, soils are less fertile and oxygen levels are lower. More calorie energy is required for them to survive in these areas, whereas they often have less to eat [23]. In Ecuador, because of urbanization and many activities in the north, agricultural land productivity is poor. According to the Food and Agriculture Organization, human-induced degradation is higher

### Table 4

**Anthropometric indices differences in highlands and lowland areas**

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in highlands of Ecuador because of high population density. The highlands (Quito) have severely degraded soils than the lowlands of SDDC and Sangolqui [24]. Degraded soils affect agricultural production; hence, there is less food availability that may be reflected in stunting. Quito’s enforcement of policies against land invasions confines a relatively large portion of the poor to rented rooms [25].

### Table 4

**Age- and sex-adjusted differences in nutritional status as indicators in lowland and highland (reference is lowland)**

<table>
<thead>
<tr>
<th>Outcome variable</th>
<th>Independent variables</th>
<th>Beta coefficient</th>
<th>SE</th>
<th>95% CI</th>
<th>p-value</th>
<th>Adjusted R²</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFA Z-scores</td>
<td>Location</td>
<td>-0.811</td>
<td>0.152</td>
<td>-1.111 to -0.511</td>
<td>&lt;0.001**</td>
<td>0.147</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.107</td>
<td>0.034</td>
<td>-0.174 to -0.040</td>
<td>0.043</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.117</td>
<td>0.14</td>
<td>-0.159 to 0.393</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>0.896</td>
<td>0.379</td>
<td>0.149 to 1.644</td>
<td>0.802</td>
<td></td>
</tr>
<tr>
<td>WFA Z-scores</td>
<td>Location (Quito)</td>
<td>0.431</td>
<td>0.178</td>
<td>0.782 to -0.080</td>
<td>0.016*</td>
<td>0.036</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.093</td>
<td>0.04</td>
<td>-0.171 to -0.014</td>
<td>0.021*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>-0.01</td>
<td>0.163</td>
<td>-0.333 to 0.312</td>
<td>0.949</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>0.134</td>
<td>0.493</td>
<td>-0.839 to 1.107</td>
<td>0.786</td>
<td></td>
</tr>
<tr>
<td>MUAC</td>
<td>Location (Quito)</td>
<td>0.897</td>
<td>0.514</td>
<td>-0.119 to 1.912</td>
<td>0.083</td>
<td>0.29</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.883</td>
<td>0.115</td>
<td>0.655 to 1.111</td>
<td>&lt;0.001**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.03</td>
<td>0.473</td>
<td>-0.903 to 0.963</td>
<td>0.949</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>12.153</td>
<td>1.327</td>
<td>9.53 to 14.777</td>
<td>&lt;0.001**</td>
<td></td>
</tr>
<tr>
<td>Skinfold biceps</td>
<td>Location (Quito)</td>
<td>0.323</td>
<td>0.603</td>
<td>0.592 to -0.866</td>
<td>0.592</td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.239</td>
<td>0.135</td>
<td>0.079 to -0.028</td>
<td>0.079</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>2.34</td>
<td>0.553</td>
<td>1.247 to 3.433</td>
<td>&lt;0.001**</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>1.703</td>
<td>1.557</td>
<td>-1.370 to 4.776</td>
<td>0.276</td>
<td></td>
</tr>
<tr>
<td>Skinfold triceps</td>
<td>Location (Quito)</td>
<td>0.497</td>
<td>0.715</td>
<td>-0.914 to 1.908</td>
<td>0.041</td>
<td>0.04</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.331</td>
<td>0.16</td>
<td>0.014 to 0.647</td>
<td>0.488</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>1.49</td>
<td>0.657</td>
<td>0.194 to 2.787</td>
<td>0.025*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>5.5</td>
<td>1.847</td>
<td>1.854 to 9.147</td>
<td>0.003*</td>
<td></td>
</tr>
<tr>
<td>Percent body fat</td>
<td>Location (Quito)</td>
<td>-0.042</td>
<td>1.584</td>
<td>-4.112 to 2.143</td>
<td>0.535</td>
<td>0.276</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.156</td>
<td>0.156</td>
<td>0.124 to 1.527</td>
<td>0.021</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Gender</td>
<td>0.517</td>
<td>1.455</td>
<td>8.571 to 14.316</td>
<td>&lt;0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Intercept</td>
<td>3.944</td>
<td>4.248</td>
<td>19.820</td>
<td>0.003</td>
<td></td>
</tr>
</tbody>
</table>

Multiple linear regression analysis of basic indicators adjusted for age and gender.

*significant at $p < 0.05$

**highly significant at $p < 0.001$

### Table 5

**Unconditional logistic regression evaluating HFA, WFA and BMI Z-scores of school children in Quito (highland) and SDDC (lowland)**

<table>
<thead>
<tr>
<th>Measure of nutrition</th>
<th>Model</th>
<th>B</th>
<th>SE</th>
<th>OR (exp B) (95% CI)</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFA Z-score less than −1 (mild stunting) compare with −1 Z-score or more (healthy)</td>
<td>Quito</td>
<td>1.366</td>
<td>0.392</td>
<td>3.919 (1.818–8.448)</td>
<td>&lt;0.001**</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.224</td>
<td>0.083</td>
<td>1.251 (1.063–1.474)</td>
<td>0.007</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>-0.027</td>
<td>0.328</td>
<td>0.974 (0.512–1.850)</td>
<td>0.935</td>
</tr>
<tr>
<td></td>
<td>Error term</td>
<td>3.44</td>
<td>0.973</td>
<td></td>
<td></td>
</tr>
<tr>
<td>WFA Z-score less than −1 (mild underweight) compare with −1 Z-score or more (healthy)</td>
<td>Quito</td>
<td>1.119</td>
<td>0.461</td>
<td>3.062 (1.241–7.551)</td>
<td>0.015**</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>0.122</td>
<td>0.093</td>
<td>1.129 (0.940–1.356)</td>
<td>0.193</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>0.404</td>
<td>0.371</td>
<td>0.668 (0.323–1.383)</td>
<td>0.277</td>
</tr>
<tr>
<td></td>
<td>Error term</td>
<td>-3.165</td>
<td>1.097</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight BMI Z-score greater than +1 (overweight) compare with less than 1 Z-score (healthy)</td>
<td>Quito</td>
<td>-0.263</td>
<td>0.452</td>
<td>0.747 (0.317–1.865)</td>
<td>0.56</td>
</tr>
<tr>
<td></td>
<td>Age</td>
<td>-0.168</td>
<td>0.109</td>
<td>0.846 (0.683–1.047)</td>
<td>0.123</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>-0.413</td>
<td>0.433</td>
<td>0.662 (0.284–1.545)</td>
<td>0.34</td>
</tr>
<tr>
<td></td>
<td>Error term</td>
<td>0.301</td>
<td>1.133</td>
<td>1.352</td>
<td>0.79</td>
</tr>
</tbody>
</table>

*significant at $p < 0.05$

**highly significant at $p < 0.001$

Equation: Logit ($\mu$) = $\beta_1$Quito + $\beta_2$Age + $\beta_3$Sex. $\mu$ = outcome variable; $\beta$ = regression coefficients; $\alpha$ = error term.
Our BMI results concur with that of Leonard et al. [4], who also found that growth rates for body weight are similar in highland and lowland areas. However, BMI systematically underestimates the prevalence of obesity [26], it is therefore possible that mild overweightness detected in lowland children could have been underestimated.

Limitations
Data on food consumption, socio-economic status and physical activity would have brought important insight in evaluating the differences. However, the data available were able to show nutritional disparity between children living in the highlands and those living in the lowland areas.

Conclusions
Living in the urban highlands of Ecuador is a predisposing factor to poor nutritional status in these children. These highlands children are subjected to various factors that may contribute negatively to their nutritional status. Poor quality soils, increased physical activity because of the terrain and effects of urbanization are possible factors that may have influenced our results. Constant man-made soil depletion may have resulted in the long-term food deficit in the highlands, which in turn may have a bearing in the disparity observed. More studies are needed to investigate further on socio-economic aspects that might have influenced the nutrition status in the two geographical locations.

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