Prevalence of Undernutrition and Iron Deficiency in Pre-school Children from Different Socioeconomic Regions in the City of Oaxaca, Oaxaca, Mexico

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Summary Lack of adequate food and in particular high quality protein, is one of the causes of malnutrition in children which could result in retarded growth. Iron deficiency is common in populations where protein sources are of vegetable origin; however in northern Mexico where the bean consumption is high, anemia is not a problem. The primary staples in the Mexican diet are corn tortillas and beans. The objective of this study was to evaluate the anthropometric condition of children 4–6 years old living in the city of Oaxaca, Oaxaca, Mexico and to determine the prevalence of anemia. Mean Z scores for children 4–6 years old living in poor conditions in the city of Oaxaca, Oaxaca, Mexico showed significant differences between socioeconomic groups (p<0.002) for height/age (H/A) and weight/age (W/A) (p<0.001) after adjusting for age and sex. Weight/height (W/H) was not different (p=0.30). By using the Waterlow classification system, 28.8% of the pre-school children of this study were stunted and only 0.9% were classified as wasted. There were no children that presented both stunting and wasting. Iron deficiency was very prevalent in both boys and girls, ranging from 56–79% depending on the indicator used. When classified by the combination of serum ferritin, % transferrin saturation and hemoglobin values, 23.7% of the children were classified as anemic, 11.9% in a state of iron deficiency and 13.6% with low iron reserves.

Key Words malnutrition, iron status, anemia, anthropometry, pre-school children

In developing countries, one of the causes of malnutrition in children is lack of adequate food and in particular high quality protein (1). This protein, energy malnutrition results in retarded growth rate, anemia and other types of nutritional problems (2–4). Due to their rapid growth rate during their growing years, children are most affected. Studies have shown that children who have suboptimal nutrition in their first years of life have cognitive learning disorder, reduced stature and inadequate immune defenses (5). Rarely did these individuals recuperate the growth retardation that occurred in their early childhood even though at some point in later life, their diet improved and was considered adequate (6).

Iron is an essential nutrient not only for normal growth, health and survival of children, but also for normal mental and motor development and cognitive functioning. Iron deficiency is associated with significantly poorer performance on psychomotor and mental development scales and behavioral tests in children (5). The primary staples in the Mexican diet, corn tortillas and beans, contain iron but in the non heme form, which is poorly absorbed (7).

The state of Oaxaca, Mexico is one of the poorest regions in Mexico. In 1996, Curiel et al. (8) in a national survey in Mexico, showed family income available for food in Oaxaca was among the lowest of all the states studied. This same study showed over 20% of the children under 5 years of age to be severely to moderately malnourished. Other studies in Oaxaca (9) showed 85% of the pre-school children to be malnourished. Tenorio et al (10) showed a high prevalence of children under 8 years of age to be of short stature. The objective of this study was to evaluate the anthropometric condition of children 4–6 years old living in the city of Oaxaca, Oaxaca, Mexico and to determine the prevalence of anemia.

MATERIALS AND METHODS

Subjects. The subjects in this study were 124 volunteer children, including 60 boys and 64 girls, ranging in age from 55 to 66 months. The children were recruited from day care centers located in 3 different geographic areas within the city of Oaxaca, Mexico. The areas differed according to economic conditions. The protocol of the study was approved by the Ethnic Review Committee of CIAD, Hermosillo, Sonora, Mexico and prior consent was obtained from the parent or guardian.

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The parents of the children were invited to a seminar where the protocol of the study was explained and if the parents agreed to let their child participate in the study, a consent form was signed. During the first visit, a general health exam was performed by a licensed pediatrician and weight and height of each child were taken. In a follow up visit, blood samples were obtained. At a later date, results of the blood analysis were explained to the parent and information on low cost foods rich in iron was provided.

Iron Status. Seven mL of blood was collected from the antecubital vein in heparinized tubes (Becton Dickson VACUTAINER Systems, Rutherford, NJ). Blood samples were centrifuged 15 min at 1500×g (IEC Centra 8R centrifuge, International Equipment Company, a Division of Damon, USA) at 4°C. Hemoglobin was determined by the cyanmethemoglobin method (11) and values below 11 g/dL were considered low (12). Serum ferritin values were measured employing the immunoradiometric assay (13) and values below 10 ng/mL were considered low (12). Transferrin saturation was calculated as the ratio of serum iron to total iron-binding capacity (TIBC) and values below 15% were considered below normal for children (12). Serum iron concentration was determined employing ferrozine as chromogen and measured spectrophotometrically at 560 nm. The TIBC was determined by saturating serum with excess iron and adding magnesium carbonate to remove the iron not bound to serum transferrin. The bound iron remaining in the supernatant after centrifugation was then measured as described above (14). An analysis, using a combination of the 3 indicators, serum ferritin, % transferrin saturation, and hemoglobin values, was made to classify the subjects of this study as % anemic, % in a state of iron deficiency and those with low iron reserves according to Cook et al. (15) and adapted for different age and sex groups (16).

Height and Weight Determination. Height was measured with a portable stadiometer (Holtain LTD, UK) to the nearest 0.1 cm and weight was measured to the nearest 50 g with a balance (A and D Co LTD, Japan) with a capacity of 0-160 kg. The child was lightly clothed and without shoes. Body mass index (Quetelet index) was calculated using the following formula wt(kg)/ht2(m2).

Z Scores. The Z scores (weight/age, height/age, weight/height) were determined by using the software program NCHS (17).

Socioeconomic Status. The socioeconomic level was determined by the method of Mendez (18) taking into consideration living conditions, utility services available, and family income as determined by Camberos (19).

Statistical Analysis. Statistical analysis of the data was by a computer software program SAS (20). Means and standard error of the means were obtained by descriptive statistics. Two way analysis of variance was used to compare differences of treatment means of age, sex, and socioeconomic group. Anthropometric indexes were evaluated by analysis of covariance with the Z score as the dependent variable and the socioeconomic class as the independent or categorical variable. Age and sex were the variables for adjustment (covariance). The number of subjects in the high income group was too small for a statistical analysis, therefore the two groups, medium and high, were combined.

RESULTS

Table 1 presents the physical characteristics of pre-school children age 55 to 66 months, living in 3 different geographic regions classified by economic status in Oaxaca, Oaxaca, Mexico. The average age for these children was 66 mo in the low income group, 62.5 mo in the medium group and 59 mo for the high income group. The global age for the children of this study was 62.5 mo. There was no statistical difference (p=0.05) for age among the different groups or for sex.

Anthropometric indexes were evaluated by socioeconomic group. Mean scores were adjusted for age and sex and the high socioeconomic group of children was eliminated from this analysis due to the low number of subjects in this group. Table 2 presents the mean Z scores for height/age (H/A), weight/age (W/A) and weight/height (W/H) for the low and medium income group, 4-6 y old living in the Oaxaca region. The low income group mean Z scores for H/A was significantly lower (p<0.002) than for the medium income group, as well as the W/A (p<0.001). However there was no difference between the low and medium income group in the mean W/H score (p=0.30), indicating the children of this area have adapted for short stature. If the international standard of H/A deficit is used, with a cutoff point of −2 Z scores with respect to WHO reference standards (21), 35.9% of the children in this study from

Table 1. Physical characteristics of pre-school children in Oaxaca, Oaxaca, Mexico (n=124).

<table>
<thead>
<tr>
<th>Socioeconomic</th>
<th>Sex</th>
<th>n</th>
<th>Age (mo)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>BMI (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>M</td>
<td>29</td>
<td>66.5±7.7</td>
<td>17.9±2.0</td>
<td>105.6±4.4</td>
<td>16.1±1.4</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>35</td>
<td>65.5±8.7</td>
<td>16.5±2.3</td>
<td>102.6±5.6</td>
<td>15.3±1.3</td>
</tr>
<tr>
<td>Medium</td>
<td>M</td>
<td>28</td>
<td>62.4±8.4</td>
<td>18.1±2.1</td>
<td>106.4±5.8</td>
<td>16.0±0.8</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>19</td>
<td>62.6±9.8</td>
<td>18.2±2.3</td>
<td>105.4±5.3</td>
<td>16.1±1.5</td>
</tr>
<tr>
<td>High</td>
<td>M</td>
<td>3</td>
<td>63.0±14.0</td>
<td>19.1±2.0</td>
<td>110.2±6.5</td>
<td>15.7±1.6</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>10</td>
<td>55.1±4.7</td>
<td>18.1±4.2</td>
<td>102.9±6.6</td>
<td>16.8±1.8</td>
</tr>
<tr>
<td>Total</td>
<td>M</td>
<td>60</td>
<td>64.0±10.0</td>
<td>18.4±2.0</td>
<td>107.4±3.6</td>
<td>15.9±1.3</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>64</td>
<td>61.0±7.7</td>
<td>17.6±2.9</td>
<td>103.6±3.8</td>
<td>16.1±1.5</td>
</tr>
</tbody>
</table>
Table 2. Mean Z scores for anthropometric indexes by socioeconomic status in Oaxaca, Mexico in pre-school children (n=124) (mean±SE).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Low Income (29 Males; 35 Females)</th>
<th>Medium/High Income (31 Males; 29 Females)</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Height/Age (H/A)</td>
<td>-1.67±0.12</td>
<td>-1.15±0.12</td>
<td>&lt;0.002</td>
</tr>
<tr>
<td>Weight/Age (W/A)</td>
<td>-0.92±0.11</td>
<td>-0.38±0.14</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Weight/Height (W/H)</td>
<td>0.21±0.11</td>
<td>0.45±0.11</td>
<td>&lt;0.300</td>
</tr>
</tbody>
</table>

Means for all variables were adjusted for age and sex by covariance analysis.

Table 3. Percent iron deficiency in pre-school children in Oaxaca, Oaxaca, Mexico (n=124) classified by various indicators.

<table>
<thead>
<tr>
<th>Socioeconomic</th>
<th>Stage 1</th>
<th>Stage 2</th>
<th>Stage 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males</td>
<td>Females</td>
<td>Males</td>
</tr>
<tr>
<td>Low</td>
<td>67</td>
<td>25</td>
<td>77</td>
</tr>
<tr>
<td>Medium</td>
<td>60</td>
<td>64</td>
<td>66</td>
</tr>
<tr>
<td>High</td>
<td>50</td>
<td>80</td>
<td>50</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
<td>56</td>
<td>64</td>
</tr>
</tbody>
</table>

Table 3 reports the percentage of iron deficiency in pre-school children in Oaxaca, Mexico. The data is presented according to socioeconomic level and sex by stage 1 (low serum ferritin values), stage 2 (low % transferrin saturation) and stage 3 (low hemoglobin values). Overall, 59% of the boys and 56% of the girls in this study showed low iron stores according to their serum ferritin (below 10 ng/mL), with the highest deficiency in males of the low income group. For the indicator, % transferrin saturation, (<15%), 64% of the boys and 79% of the girls had below normal values in stage 2, which reflects body stores of iron were completely exhausted which leads to stage 3, anemia. For low hemoglobin values, (<11 g/dL), 51% of the boys and 33% of the girls showed low hemoglobin values with the highest anemia being for low income girls and medium income boys. By using a combination of three indicators, serum ferritin, % transferrin saturation, and hemoglobin, 23.7% of the children were classified as anemic, 11.9% in a state of iron-deficiency, and 13.6% with low iron reserves. These values are higher than what are normally reported for children of this age group.

**DISCUSSION**

Protein and energy malnutrition results in retarded growth rate, anemia and other types of nutritional problems. The state of Oaxaca is one of the poorest regions in Mexico and nutritional problems have been identified in that area. The children in this study, especially those in the low income areas, were shown to be malnourished and of short stature for their age. BMI (kg/m²) for the children in this study compared favorably with Guatemalan children who are also characterized as being short in stature for their age. Martorell et al. (6) showed Guatemalan boys in the same age group as in this study, weighed 13.9-16.9 kg and girls weighed 13.1-16.2 kg. The children of this study weighed more than the Guatemalan children. The BMI for the Guatemalan children was 15.5-16.2 for males and 15.2-15.8 for females. The children of this study had BMI for males of 15.7-16.1 and females 15.3-16.8.

In a national nutritional study in Mexico, Curiel et al. (8) showed 33.9% of the children in Mexico under 5 years of age to be malnourished and 48% in the state of Oaxaca. These values were not broken into groups according to socioeconomic levels but do compare well with the 35.9% malnourished children in the low income group, which is the predominant socioeconomic group in the Oaxaca area. Using the Waterlow classification system, 28.8% of the children in this study were stunted. The last national height census in Mexico (24) showed 35.3% of the children in the state of Oaxaca to have low H/A Z scores (Z = -1.56).

Iron deficiency is generally acknowledged to be the...
most common, single nutritional deficiency in both developing and developed countries. Three stages of iron deficiency may be recognized. The first is a substantial reduction in the normal iron stores (25). Plasma or serum ferritin has proved to be a useful assay of storage iron in normal subjects. When iron stores are depleted and before anemia may be identified by a decrease in hemoglobin below the normal limits, the second stage of iron deficiency exists. This moderate degree of iron deficiency may be recognized by assay of plasma iron supply to erythropoietic cells (reflected by decreases in transferrin saturation) and of iron availability for hemoglobin synthesis (reflected by increases in erythrocyte protoporphyrin). The third and most severe degree of iron deficiency involves overt microcytic anemia. This latter stage may be identified by a decrease in hemoglobin concentration (or hematocrit) and a decrease in MCV. No single biochemical indicator is consistently diagnostic of iron deficiency. The use of several indicators of iron status provides a much better assessment (12, 26). By using a combination the indicators, serum ferritin, % transferrin saturation, and hemoglobin, 23.7% of the children in this study were classified as anemic, 11.9% iron deficient and 13.6% with low iron reserves. The children in this study showed a more severe state of iron problems than what are normally reported for children of this age group.

Mild iron deficiency in children is probably the result of the combination of high requirements and a diet deficient in bioavailable iron. Important consequences of tissue iron deficiency on mental performance, physical capacity and cellular immunity has been described (27–29). Wyatt and Triana (30), a study of the dietary intake for the children of this study, reported the children in all income groups exceeded the recommended iron intake of 10 mg/d, however, the intake of heme iron was very low. Particularly in the low income group, the dietary iron comes from non-animal protein sources such as beans and tortillas.

In a study between the relationship between iron deficiency and anemia in Venezuelan children, Taylor et al. (31) using the following criteria: hemoglobin concentrations below 11.5 g/dL, serum ferritin concentration below 10 ng/mL, and transferrin saturation below 14%, for children 4–7 years old, showed a certain proportion of the children with apparently normal hemoglobin concentrations were iron deficient. Although the effects of milder iron deficiency without anemia are not clear, cellular immunity may be affected by iron deficiency before the overt symptoms of anemia appear (28). Salas et al. (32) showed 8.2% iron deficiency in children between 2 and 5 years old from a good socioeconomic class in Spain. Subjects were considered to have iron deficiency if they had abnormal values in two or more parameters such as serum ferritin, and % transferrin saturation. In a similar population, Fernández-Ballart et al. (33) reported 11.4% of the 3–8 years old children had below normal serum ferritin values, and 22.7% below normal % transferrin saturation, and 6.8% low hemoglobin values. Very few reports have been published on iron deficiency of children living under the poor economic conditions of this study. Lower incidences of anemia, using hemoglobin values alone are usually reported and this same trend was observed in this study as in the others. Of the low income group which represents the highest proportion of the population, 28.8% of the children studied were stunted, 35.9% malnourished, and 23.7% anemic. Data presented here indicates that at least a third of the preschool children living in Oaxaca, Mexico are at risk due to depleted iron body stores and subsequent anemia, and malnutrition which is reflected in their short stature.

CONCLUSIONS

Mean Z scores for children 4–6 years old living in poor conditions in the city of Oaxaca, Oaxaca, Mexico showed significant differences between socioeconomic groups (p<0.002) for H/A and W/A (p<0.001). However W/H was not different (p=0.30). By using the Waterlow classification system, 28.8% of the pre-school children of this study were stunted and only 0.9% were classified as wasted. There were no children that presented both stunting and wasting. Iron deficiency was very prevalent in both boys and girls, ranging from 56–79% depending on the indicator used. When classified by the combination of serum ferritin, % transferrin saturation, and hemoglobin values, 23.7% of the children were classified as anemic, 11.9% in a state of iron deficiency, and 13.6% with low iron reserves.

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