THE RELATIONSHIP OF BODY WEIGHT TO ALTITUDE IN PRESCHOOL CHILDREN OF SOUTHWESTERN SAUDI ARABIA

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Objectives: To determine the average weight and height and the prevalence of overweight or obesity and thinness in preschool children of the Southwestern highlands of the Kingdom of Saudi Arabia and compare them with their counterparts living at lower altitudes.

Methods: A cross-sectional study of 559 preschool children aged 12-71 months born and living permanently at high altitude, and 463 preschool children of comparable age born and living permanently at low altitude. For each child at high and low altitude, age was recorded and weight and height were measured. Weight for height Z-score with WHO standards was used for an assessment of normal weight, overweight or obesity and thinness.

Results: The highland preschool children were found to be significantly heavier and taller than their counterparts living at low altitude. 92.1% of all highland preschool children and 67.6% of lowland preschool children were found to have normal weight (p < 0.0001). Overweight or obesity was insignificantly greater among preschool children of the highlands (2.3%) compared to the preschool children of the low lying areas (0.9%) (p<0.7). Thinness was significantly more prevalent among preschool children of the lowlands (31.5%) than preschool children of the highlands (5.5%) (p < 0.0001). At both high and low altitude, there were no significant differences in the prevalence of overweight or obesity or thinness between boys and girls.

Conclusion: The findings of this study indicate that thinness is a major nutritional problem among lowland preschool children. This may be attributed to the prevailing tropical environmental conditions on the health of children at low altitude.

Key Words: Body weight, Altitude, Saudi Arabia

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INTRODUCTION
The composition of air stays the same but the total barometric pressure falls with increasing altitude. As a result, the partial pressure of oxygen falls and a state of hypoxia is said to occur.1 Certain biochemical, physiological and microanatomical responses occur during acclimatization and adaptation to chronic hypoxia of high altitude.2 Among these responses are changes in body build.2 Several studies on the relationship between high altitude and body build have been carried out in different parts of the world including the Andes,3 the Simen mountains4 and the Sarawat mountains.5, 6 However, to our knowledge no study on preschool children specific to the Southwestern highlands of Kingdom of Saudi Arabia has been reported. Furthermore, no attempts have been made to determine the prevalence of overweight or obesity in preschool children at high altitude.

Many reports have shown that children's overweight or obesity is frequently associated with metabolic and psychological complications as well as hypertension.7 Of greater concern is the persistence of childhood obesity into adulthood along with its numerous associated health risks.7 On the other extreme, thinness poses an equally important health problem. In addition to its serious effects on physical health, it may also have adverse effects on child's cognitive and behavioral development.8 The present study was, therefore, undertaken to determine the average weight and height and the prevalence of overweight or obesity and thinness in preschool children of the Southwestern highlands of the Kingdom of Saudi Arabia and compare them with their counterparts living at low altitude.

METHOD
This study was carried out in high and low altitude areas of Aseer Province in the Southwestern part of the Kingdom of Saudi Arabia. Alsoda village and the villages around Sabit Allia city were selected at high altitude (2800-3150 m) and the villages around Mohyel city were selected at low altitude (500 m). Environmental data on these areas are shown in Table 1.9 Alsoda is approximately 600 km, and Sabit Allia approximately 520 km south of Jeddah (the second city in the Kingdom). Moyhel city lies in Tihama valley, approximately 550 km south of Jeddah. Health services for the two areas are provided by health centers run by qualified physicians who use two referral hospitals that are easily accessed by good roads. Potable water and electricity are available in these areas. Meat, chicken and rice constitute the major dietary items for people living in both areas.

Table 1: Environmental data on high and lowland of the study

| Variables                  | Highland       | Lowland       |
|----------------------------|----------------|---------------|
| Altitude (meter)           | 2800-3150      | 500           |
| Barometric pressure (mmHg) | 550-590        | 720           |
| Atmospheric O2 tension (mmHg) | 110-120     | 145           |
| Relative humidity (%)      | 20-30          | 50-90         |
| Summer temperature (shade) (°C) | 16-28       | 30-45         |
| Winter temperature (shade) (°C) | 5-15        | 25-35         |

The data presented in this paper were obtained from 559 preschool children aged between 12-71 months, born and living permanently at high (about 89.2 % of the total preschool children registered in health centres at high altitude study area) and 463 preschool children of comparable age born and living permanently at low altitude (about 90.3% of all preschool children registered in the health centres at low altitude study area). Each child was first subjected to detailed clinical examination. Children in whom pathology was detected by clinical examination, as well as children who were not born and who did not live permanently in the designated study areas were excluded from this study. Of a total of 1046 children seen, 24 were excluded because they did not fulfill the criteria for inclusion in this study. All subjects were Arab and of Saudi nationality. All measurements were taken in the health centers. This study was carried out in 2002.

For each child, age in months was calculated and recorded from birth certificates at the time of examination. For children under two years, the body weight was measured on a baby scale and the supine length was taken with a measuring board (Harpenden). For children over two years, the body weight was measured with an Avery beam weighing scale and the standing height was measured with a stadiometer (SECA). The weights of the children in minimal clothing were taken to the nearest 0.1 kg, and the heights and supine lengths were taken without shoes to the nearest 0.5 cm.

Normal weight, overweight or obesity and thinness were assessed using the following WHO criteria:10
### Table 2: Prevalence of thinness, normal weight and overweight or obesity among high altitude preschool Saudi children based on weight for height Z-score data by age and gender

| Age group (months) / Gender | Number | <2 SD Thinness N (%) | 2 SD Normal weight N (%) | >2 SD Obesity N (%) | Mean Z-score | SD Z-score |
|-----------------------------|--------|---------------------|--------------------------|-------------------|-------------|-----------|
| 12-23                       | Male   | 36                  | 2 (5.6)                  | 34 (94.4)         | 0           | -0.04     | 1.0       |
|                             | Female | 36                  | 2 (5.6)                  | 34 (94.4)         | 0           | -0.2      | 1.1       |
| 24-35                       | Male   | 55                  | 5 (9.1)                  | 49 (89.1)         | 1 (1.8)     | -0.4      | 1.1       |
|                             | Female | 49                  | 0                        | 47 (95.9)         | 2 (4.1)     | -0.1      | 1.0       |
| 36-47                       | Male   | 59                  | 1 (1.7)                  | 57 (96.6)         | 1 (1.7)     | -0.5      | 0.8       |
|                             | Female | 47                  | 4 (8.5)                  | 41 (87.2)         | 2 (4.3)     | -0.4      | 1.1       |
| 48-59                       | Male   | 68                  | 5 (7.4)                  | 61 (89.7)         | 2 (2.9)     | -0.6      | 1.1       |
|                             | Female | 83                  | 4 (4.8)                  | 77 (92.8)         | 2 (2.4)     | -0.3      | 1.1       |
| 60-71                       | Male   | 65                  | 6 (9.2)                  | 57 (87.7)         | 2 (3.1)     | -0.7      | 1.1       |
|                             | Female | 61                  | 2 (3.3)                  | 58 (95.1)         | 1 (1.6)     | -0.5      | 1.0       |
| **Total**                   | Male   | 283                 | 19 (6.7)                 | 258 (91.2)        | 6 (2.1)     | -0.5      | 1.0       |
|                             | Female | 276                 | 12 (4.3)                 | 257 (93.1)        | 7 (2.5)     | -0.3      | 1.1       |

### Table 3: Prevalence of thinness, normal weight and overweight or obesity among low altitude preschool Saudi children based on weight for height Z-score data by age and gender

| Age group (months) / Gender | Number | <2 SD Thinness N (%) | 2 SD Normal weight N (%) | >2 SD Obesity N (%) | Mean Z-score | SD Z-score |
|-----------------------------|--------|---------------------|--------------------------|-------------------|-------------|-----------|
| 12-23                       | Male   | 32                  | 12 (37.5)                | 20 (62.5)         | 0           | -1.5      | 1.0       |
|                             | Female | 32                  | 8 (25.0)                 | 24 (75.0)         | 0           | -1.2      | 1.1       |
| 24-35                       | Male   | 47                  | 23 (48.9)                | 24 (51.1)         | 0           | -1.9      | 1.0       |
|                             | Female | 40                  | 10 (25.0)                | 29 (72.5)         | 1 (2.5)     | -1.3      | 1.1       |
| 36-47                       | Male   | 59                  | 26 (44.1)                | 33 (55.9)         | 0           | -1.8      | 0.9       |
|                             | Female | 35                  | 9 (25.7)                 | 26 (74.3)         | 0           | -1.5      | 0.8       |
| 48-59                       | Male   | 48                  | 13 (27.1)                | 34 (70.8)         | 1 (2.1)     | -1.5      | 1.2       |
|                             | Female | 49                  | 18 (36.7)                | 31 (63.3)         | 0           | -1.6      | 1.0       |
| 60-71                       | Male   | 62                  | 14 (22.6)                | 46 (74.2)         | 2 (3.2)     | -1.3      | 1.2       |
|                             | Female | 59                  | 13 (22.0)                | 46 (78.0)         | 0           | -1.3      | 0.9       |
| **Total**                   | Male   | 248                 | 88 (35.5)                | 157 (63.3)        | 3 (1.2)     | -1.6      | 1.1       |
|                             | Female | 215                 | 58 (27.0)                | 156 (72.6)        | 1 (0.5)     | -1.4      | 1.0       |

**Normal weight:** proportion of preschool children between -2 standard deviation (SD) and +2 SD from the median weight for height of the National Center for Health Statistics and the Centers for Disease Control and Prevention (NCHS/CDC).  
**Overweight or obese:** proportion of preschool children above +2 SD from the median weight for height of the NCHS/CDC reference population.  
**Thinness:** proportion of preschool children below -2 SD from the median weight for height of the NCHS/CDC reference population.

At different stages of the study, the collected data were compiled and fed into a computer. SPSS package version 10 was used for statistical analysis. Student T-test, Chi-square test and Crude odd ratios (cOR) with 95% confidence interval (CI) were used where appropriate to determine statistical significance. P value < 0.05 was considered statistically significant.

**RESULTS**

The total number of preschool children recruited for this study at high and low altitudes was 559...
and 463 respectively, giving response rates of 89.2% and 90.3%. The boys to girls ratio at high altitude was nearly 1:1 while that at low altitude was 1.3:1. The mean ages ± standard deviations (SDs) in months of boys and girls at high altitude were 42.3 ± 15.5 and 43.4 ± 15.4 respectively (p<0.4). The respective values in the sample from low altitude were 44.6 ± 16.6 and 44.4 ± 17.1 (p<0.9). There were no significant differences in the mean ages between boys and girls at high altitude and their peers at low altitude (p<0.1 for boys and 0.5 for girls).

The highland preschool children were found to be significantly heavier and taller than their counterparts living at low altitude. This was true for both boys and girls. The average height and weight of the highland boys were 96.1 ± 12.6 cm and 14.4 ± 3.4 Kg respectively while the average height and weight of the lowland boys were 91.9 ± 11.9 cm and 11.9 ± 3.0 kg respectively (p<0.0001 for both height and weight). At high altitude the average height and weight of the girls were 95.0 ± 11.9 cm and 13.9 ± 3.2 kg respectively compared with an average height of 91.0 ± 12.6 cm, and average weight of 11.6 ± 2.7 kg in lowland girls (p<0.0001 for height and weight).

Weight for height Z-score was used for the assessment of normal weight, overweight or obesity and thinness in the two localities. Ninety two percent of all highland preschool children and 67.6% of all lowland preschool children were found to have normal weight (cOR 5.6, 95% CI [3.9-8.1], p<0.0001). Table 2 and 3 show the prevalence of normal weight, overweight or obese and thinness by age and gender. Although the overall prevalence of overweight or obese was greater among highland children (2.3%) compared to lowland children (0.9%) the differences was not statistically significant (p<0.7). At both high and low altitude, there were no significant differences in the prevalence of overweight or obesity between boys and girls (p<0.8 for highland children and p<0.6 for lowland children). Similar trends were observed when the same sexes were compared at different altitudes (p<0.6 for boys and p<0.2 for girls).

Thinness was significantly more prevalent among lowland children (31.5%) than their counterparts living at highland (5.5%) (cOR 7.8, 95% CI [5.2-11.8], p<0.0001). This was true for both boys (cOR 7.6, 95% CI [4.5-13.1], p<0.0001) and girls (cOR 8.1, 95% CI [4.2-15.6], p<0.0001). At both high and low altitude, thinness was more prevalent among boys than girls although the differences were not statistically significant (p<0.3 for highland children and p<0.06 for lowland children).

**DISCUSSION**

The results presented in this paper have shown that preschool children of the southwestern highlands of the Kingdom of Saudi Arabia are significantly taller and heavier than their counterparts of comparable age living in the low lying areas. It also showed that thinness was significantly more prevalent among lowland preschool children than preschool children living at high altitude while no significant difference in the prevalence of overweight or obesity was observed between the two groups of preschool children.

In this study, age was calculated in months from birth certificates, and weight and height were carefully measured and recorded using equipment of well-tested design, and calibrated at frequent intervals. The observed SDs of weight for height Z-score at both high and low altitude were, therefore, relatively constant (Tables 2 and 3) and fell within the expected range recommended by the WHO (0.85-1.1).10

As such, our results are contrary to the findings of the studies done in the Andes and Himalayas,3 but consistent with findings from the Simen mountains of Ethiopia.4 In the Andes and Himalayas, the differences in weight and height between highland and lowland children was attributed to the growth retarding effect of high altitude hypoxia as well as racial, dietary and socioeconomic factors of parents.3 In Ethiopia, the difference was related to high prevalence of intestinal parasitism in lowland children.4 In this study, we have attempted to reduce the contribution of racial and dietary factors by drawing our subjects from Saudi Arabs who not only had the same ethnic background but also the same dietary habits. Thus, the factor that appeared to be at work in our situation was purely environmental. Children born at high altitude had a lower birth weight when compared with their counterparts born at low altitude. This has been documented in a number of studies in this region11-13 and worldwide.14,15 The difference in birth weight was attributed to the intrauterine hypoxia to which the fetus is subjected. The intrauterine hypoxia appeared to be secondary to maternal hypoxia resulting from high altitude hypoxia.11,12 Infants with low birth weight have a
greater proportion of fat relative to lean body mass. Therefore, in effect they are obese if obesity is to be defined as excess of body fat. In addition, infants with low birth weight have an increased risk of developing overweight or obesity later in childhood especially if they are not breastfed exclusively. All these may explain the higher prevalence of overweight or obesity, although insignificant, among highland preschool children as compared to their counterparts at low altitude. However, as children grew older, those living at high altitude appeared to have an advantage over lowlanders. Because of the tropical nature of the studied area, the lowland children were exposed to more tropical infections. On the other hand, highland children were exposed to cold weather which is beneficial in reducing tropical infections. In this context, malaria was found to be prevalent in Tihama valley, whereas the Southwestern highlands of the Kingdom are free from malaria. The prevalence of other tropical infections such as leishmaniasis is also greater among people of the lowlands than those in the highlands. It is also worth mentioning that in this particular population of children, the prevalence of pathological intestinal parasites was significantly higher among lowland children (10.4%) than highland children (5.5%) (p<0.003). Malaria and intestinal parasitism are believed to be major causes of thinness in children. It is most likely, therefore, that the difference in the prevalence of thinness between high and lowland preschool children was related to the beneficial effects of the prevailing milder environmental conditions on the health of children at high altitude. However, this does not exclude other factors such as socioeconomic conditions of parents, which by implication are relatively unimportant.

Although, thinness is often associated with malnutrition, clinical examination of thin subjects at high and lowland did not reveal any feature related to malnutrition. However, since biochemical tests were not done in this study, it was not possible to exclude subclinical forms of malnutrition. In addition, the NCH reference used in this study is limited by biological and technical drawbacks. An important limitation is the fact that the distribution of weight for height was markedly skewed towards the higher end reflecting substantial rate of childhood obesity. The use of NCH reference is, therefore, likely to have underestimated the rates of overweight or obesity and overestimated the rates of thinness. This shows that anthropometric studies among Saudi children are required to enable valid growth charts to be drawn.

In conclusion, based on WHO criteria, the present study has given a clear indication that thinness is a major nutritional problem among preschool children of low lying areas while there is no such problem at high altitude. There was a lower prevalence of overweight and obesity in preschool children of both high and lowlands than what has been reported in other developing countries (3.3%). Our finding in this respect calls for further large scale studies to confirm these results. Such large scale studies will help in the planning and delivery of health care in this region.

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