

## RELATIONSHIP OF BODY WEIGHT TO ALTITUDE IN SAUDI ARABIA

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Measurement of weight and height in 451 Saudi nationals ages 17 to 72 years, born and living permanently at high altitude (3150 meters) and Saudi nationals ages 17 to 76 years, born and living permanently at low altitude (500 meters) are reported. The native highlanders were significantly heavier ( $P < 0.005$  for men and  $< 0.001$  for women) and taller ( $P < 0.001$  for both men and women) than lowlanders. Body mass index ( $BMI = kg/m^2$ ) was used for assessment of normal weight, overweight or obesity, and underweight or thinness in the two communities. Only 30.8% of all highlanders and 34% of all lowlanders were found to have normal weight. The prevalence of overweight or obesity was significantly greater among highlanders (55.7%) than among lowlanders (42.9%) ( $P < 0.01$ ), while underweight or thinness was significantly more common among lowlanders (23.1%) as compared to highlanders (13.5%) ( $P < 0.01$ ). Among highlanders, overweight or obesity was significantly more common in women than men ( $P < 0.01$ ) while underweight or thinness was more common among men than women, although the difference was not statistically significant. This sex difference in the prevalence of overweight or obesity and underweight or thinness was not apparent among lowlanders. The percentage of overweight or obese highland and lowland men and women increased after the age of 39 years; conversely, the incidence of underweight or thinness in highland and lowland men and women decreased after the age of 39 years. The findings of this study indicate that overweight or obesity and, to a lesser extent, underweight or thinness are major nutritional problems in the two groups studied. *Ann Saudi Med 1994;14(4):300-303.*

Studies of human adaptability to high altitudes have shown that although native highlanders have greater weight for height than lowlanders, they have thinner skin folds.<sup>1</sup> However, to our knowledge, no such studies specific to the southwestern heights of the Kingdom of Saudi Arabia have been reported. Furthermore, no attempts were made to determine the prevalence of overweight or obesity in a high altitude population.

Overweight or obesity is a major risk factor for many diseases including cardiovascular disease,<sup>2</sup> maturity onset diabetes mellitus,<sup>3</sup> and some types of cancer.<sup>4</sup> At high altitudes, obesity predisposes to chronic hypoxia, hypoxic hypertensive pulmonary vascular diseases and chronic mountain sickness.<sup>5</sup> The present study was therefore undertaken to: a) determine the average weight and height and the prevalence of overweight and underweight in selected groups of native highlanders of the southwestern heights of the Kingdom of Saudi Arabia and to compare them with their counterparts living at low altitude, and b) determine the relationship of age and sex to the prevalence of overweight and underweight.

### Method

*Site:* The study was conducted in the Al-Soda region (altitude 3150 meters above sea level, barometric pressure of 550 mm/Hg, winter temperature range from 5°C to 15°C and summer temperature range from 16°C to 28°C) and Al-Raish region (altitude of 500 meters above sea level, barometric pressure 720 mm/Hg, winter temperature range from 25°C to 35°C and summer temperature range from 30°C to 45°C).<sup>6</sup> The two areas have an electricity supply and drinking water is obtained from wells. Meat, chicken, and rice constitute the major dietary items for people living in the two areas.

The Al-Soda region lies in the southwestern heights of the Kingdom of Saudi Arabia about 600 km south of Jeddah and 17 km northwest of Abha - the capital of the southwestern region. The area comprises several small villages of which two were selected for this study (Al-Soda and Al-Soga). The two villages are about 3 km apart and have a population of about 2500. Medical care to the entire region is provided by four health centers, two of which are situated in Al-Soda and Al-Soga. Each health center is staffed by a qualified medical practitioner, a midwife, and two nurses. The original occupation of the villagers is farming but an increasing number of them now commute to Abha City for work.

The Al-Raish region lies in Tihama Valley about 90 km northwest of Abha. Medical care to the area is provided from a large health center staffed by three qualified medical

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practitioners, a dentist, a midwife, a lab technician and three nurses. The original occupation of people is farming and goat breeding. The population of Al-Raish is estimated to be about 3000 and is increasing.

**Subjects:** The data presented in this paper were obtained from 451 persons ages 17 to 72 years, born and living permanently at high altitude (about 45% of total adult population registered in Al-Soda and Al-Soga health centers) and 468 persons ages 17 to 76 years born and living permanently at low altitude (about 40% of total adult population registered in Al-Raish health center). Subjects were selected on the basis of their willingness to accept the invitation to be seen, conveyed by the medical practitioners, local people working in the health centers or heads of tribes (sheikhs). Each subject was first subjected to a detailed clinical examination. Subjects in whom pathology was detected by clinical examination as well as pregnant women and subjects who were not born and living permanently in the Al-Soda or Al-Raish regions have been excluded from this study. We saw a total of 1460 persons (67.2% of the total adult population registered in Al-Soda, Al-Soga, and Al-Raish health centers). A total of 541 persons (24.9% of total adult population registered) were excluded because they did not fulfill the criteria for inclusion in this study. All persons sampled were Arabs and of Saudi nationality. All measurements were made in the health centers. This study was carried out during the months of October, November, and December of 1991.

**Measurements of weight and height:** Careful measurements of weight and height were made and recorded using equipment of well-tested design and calibrated at frequent intervals. Body weight was measured using an Avery Beam weighing scale to the nearest 0.1 kg. All subjects were weighed partly dressed and a correction of 0.5 kg was made for clothing. Standing height was measured to the nearest 0.5 cm with stadiometer (without shoes).

Body mass index (BMI) for each subject was calculated from the weight and height (weight in kg/height in meters squared). Overweight or obesity was defined as a value for the BMI greater than or equal to 25; normal weight was defined as a value for the BMI of 20 to less than 25 and underweight or thinness was defined as a value for the BMI less than 20.<sup>7</sup>

To determine the relationship of age to the prevalence of overweight or obesity, normal weight and underweight or thinness subjects were divided into age groups from 17 to 39, and 40 years and above. Table 1 shows the number and percentage in each age group by gender in adult highlanders and Table 2 shows the number and percentage in each age group by gender in lowlanders.

**Statistical analysis:** At different stages of the study, the collected data were compiled and fed into a computer. SPSS package has been used for standard statistical

analysis. Student's t-test and Z test were used where appropriate to determine statistical significance.  $P < 0.05$  was considered statistically significant.

## Results

The native highlanders were found to be significantly heavier and taller than their counterparts living at low altitude. This was true for both males and females age 17 years and above. The average height and weight of a highland man were 162.1 cm and 65.1 kg respectively, while the average height and weight of a lowland man were 158.9 cm and 61.3 kg respectively ( $P < 0.001$  and  $< 0.005$  respectively). In a highland woman, the average height and weight were 149.7 cm and 61.9 kg respectively, compared with an average height of 147.1 cm and an average weight of 52.4 kg in a lowland woman ( $P < 0.001$  for both height and weight).

Tables 1 and 2 show the distribution of height and weight and BMI ( $\text{kg}/\text{m}^2$ ) by age and sex. Among highland and lowland men and women, the mean weight and BMI increased between the age groups 17 to 39 and 40 years and above, while the mean height decreased between the same age groups.

Body mass index ( $\text{BMI} = \text{kg}/\text{m}^2$ ) was used for assessment of normal weight, overweight or obesity and underweight or thinness in the two communities. Only 30.8% of all highlanders and 34% of all lowlanders were found to have normal weight (the difference was not

TABLE 1. Mean values  $\pm$  standard deviation (SD) of weight, height and body mass index (BMI) in adult highlanders by age and sex.

Age (yr)	No.	%	Weight (kg)	Height (cm)	BMI ( $\text{kg}/\text{m}^2$ )
<i>Men</i>					
17-39	139	58.4	62.9 $\pm$ 13.3	162.8 $\pm$ 7.1	23.7 $\pm$ 4.8
40-72	99	41.6	68.1 $\pm$ 12.2	161.1 $\pm$ 6.0	26.2 $\pm$ 4.5
Total	238	100	65.1 $\pm$ 13.1	162.1 $\pm$ 6.7	24.8 $\pm$ 4.8
<i>Women</i>					
17-39	138	64.8	60.9 $\pm$ 12.9	150.0 $\pm$ 5.8	27.1 $\pm$ 5.6
40-72	75	35.2	63.8 $\pm$ 13.3	149.1 $\pm$ 4.8	28.6 $\pm$ 5.6
Total	213	100	61.9 $\pm$ 13.1	149.7 $\pm$ 5.5	27.6 $\pm$ 5.7

TABLE 2. Mean values  $\pm$  standard deviation (SD) of weight, height and body mass index (BMI) in adult lowlanders by age and sex.

Age (yr)	No.	%	Weight (kg)	Height (cm)	BMI ( $\text{kg}/\text{m}^2$ )
<i>Men</i>					
17-39	103	54.5	62.2 $\pm$ 13.2	160.3 $\pm$ 6.1	23.4 $\pm$ 5.0
40-76	86	45.5	62.7 $\pm$ 12.5	157.2 $\pm$ 6.0	25.3 $\pm$ 4.4
Total	189	100	61.3 $\pm$ 12.9	158.9 $\pm$ 6.3	24.3 $\pm$ 4.8
<i>Women</i>					
17-39	198	71.0	50.9 $\pm$ 10.4	147.2 $\pm$ 5.6	23.5 $\pm$ 4.5
40-76	81	29.0	56.1 $\pm$ 11.2	147.0 $\pm$ 6.0	26.0 $\pm$ 4.8
Total	279	100	52.4 $\pm$ 10.9	147.1 $\pm$ 5.7	24.2 $\pm$ 4.7

statistically significant). The remaining 69.2% of all highlanders and 66% of all lowlanders were either overweight or obese, or underweight or thin. Figure 1 shows the incidence of normal weight, overweight or obesity and underweight or thinness by age and sex.

The overall prevalence of overweight or obesity (BMI  $\geq$  25) was significantly greater among highlanders (55.7%) than among lowlanders (42.9%) ( $P < 0.01$ ). In highlanders, overweight or obesity was significantly more common in women than in men ( $P < 0.01$ ). However, in lowland women the prevalence of overweight or obesity (42.7%) appeared to be almost the same as that of lowland men (43.4%). When the same sexes were compared at different altitudes, the prevalence of overweight or obesity among highland women (67.6%) was found to be significantly greater than their counterparts living in lowlands (42.7%) ( $P < 0.01$ ). As for men, the percentage of overweight or obese highlanders (45%) was slightly greater than for lowlanders (43.4%). The rate of overweight or obesity among highland men and women increased in the age group 40 years and above. The relationship of age to overweight or obesity showed the same trend in lowland men and women.

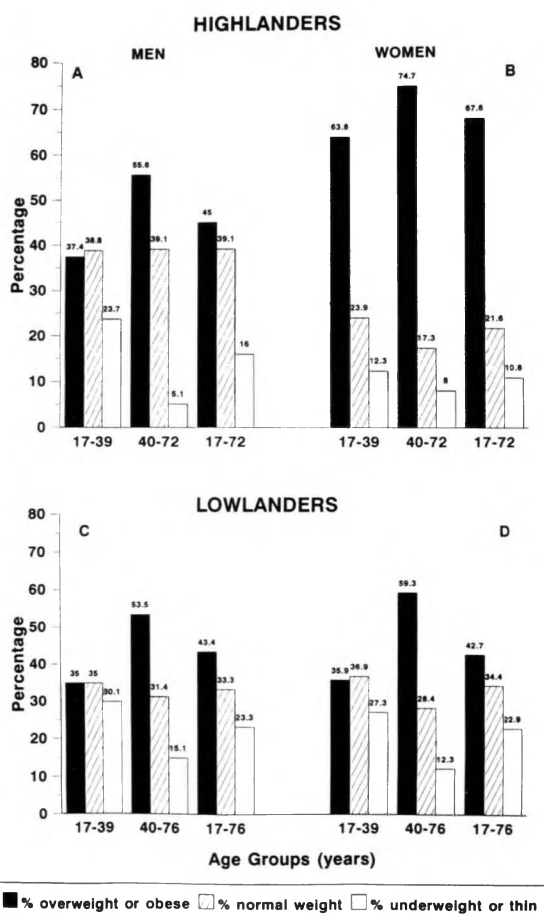


FIGURE 1. Prevalence of normal weight, overweight or obesity and underweight or thinness in adult high and lowlanders by age and sex.

Underweight or thinness (BMI < 20) was significantly more prevalent among lowlanders (23.1%) than their counterparts living at highland (13.5%) ( $P < 0.01$ ). Proportionally more highland men than highland women were underweight or thin, although the difference was not statistically significant. However, this sex difference in the rate of underweight or thinness was less apparent in lowlanders. Compared with highland men, lowland men have a higher incidence of underweight and thinness, but the difference was not statistically significant. Similarly, the incidence of underweight or thinness was greater among lowland women than highland women. In this case, the difference was highly significant ( $P < 0.01$ ). The incidence of underweight or thinness among highland and lowland men and women decreased between the age groups 17 to 39 and 40 years and above.

### Discussion

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.<sup>8</sup> Per Ward et al.,<sup>5</sup> certain biochemical, physiological, and microanatomical responses occur during acclimatization and adaptation to chronic hypoxia of high altitude. Among these responses are changes in the body build. Earlier studies in different parts of the world, including the Andes and Himalayas, have shown that people living at high altitude are shorter and more linear than their counterparts living at low altitude. The difference was attributed to growth-retarding effect of high altitude hypoxia as well as other racial, nutritional and economic factors.<sup>1</sup>

However, retarded body growth did not appear to be a feature of highlanders in the tropical region. A study on the native inhabitants of the Simen mountains of Ethiopia has shown that highlanders are taller and heavier than lowland inhabitants. In this case, the difference was related to the higher incidence of malaria and intestinal parasitism in the lowlanders.<sup>9</sup>

In this study, we have eliminated the racial factor by using low altitude residents of the same ethnic background as controls and we have shown that adult highlanders are heavier and taller than their counterparts living in the lowlands. Although the difference in height is small, it is highly significant ( $P < 0.001$ ). There are a number of factors at work here in addition to high altitude hypoxia. Records from the regional office of the Ministry of Health in Abha indicate that the Al-Soda region is free from malaria whereas malaria is prevalent in the Tihama Valley. The incidence of other tropical infestations such as bilharziasis and leishmaniasis are greater in lowlands than in highlands. This is not surprising in view of the fact that the lowlanders experience high and continuous temperature with high

humidity and, therefore, a higher incidence of tropical infestations. It is most likely that the adaptations made in Saudi Arabia are similar to those in Ethiopia.

Using the BMI as an indicator for overweight or obesity, the present study has shown that the prevalence of overweight or obesity was significantly greater among highland women compared to lowland women. As for men, the prevalence of overweight or obesity was found to be slightly greater in highlanders than in lowlanders. The higher incidence of overweight or obesity observed among highland women cannot be directly related to high altitude when other factors are not excluded. In addition to age and genetic factors, overweight or obesity is known to be influenced by socioeconomic status and the level of physical activity of individuals. In general, there is an apparent tendency for overweight or obesity to be more prevalent with increasing age.<sup>10,11</sup> Poor socioeconomic status<sup>11</sup> and lower levels of physical activity<sup>12</sup> are associated with increased incidence of overweight or obesity. However, with data such as these drawn from two communities of the same ethnic background and with different age groups being represented adequately, if the difference in the prevalence of overweight or obesity between highland and lowland women was related to high altitude environment or different socioeconomic conditions, then it is expected to also be more apparent between highland and lowland men. It is most likely that the difference in the rates of overweight or obesity between highland and lowland women was simply due to the fact that highland women were doing less physical work than those from the lowlands, and if altitude has any effect, it must be minimal. Because of cold temperatures, highland women tend to be sedentary for most of the day. Their main job is to look after their homes, and except for young women who attend high schools, hardly any leisure activity is performed by housewives. On the other hand, lowland women tend to be more active. Although their main job is to look after their homes, they also look after their domestic animals and a few leisure activities such as walking are common practice among lowland women.

One consistent trend in the literature on overweight or obesity is the tendency for overweight or obesity to be more prevalent with increasing age.<sup>10,11</sup> This trend was apparent for both Saudi highlanders and lowlanders. There was a clear increase in the prevalence of overweight or obesity between the age groups 17 to 39 and 40 years and above.

On the basis of the percentages of subjects underweight or thin, the present data have shown that proportionally more lowlanders than highlanders were underweight or thin. This was true for both men and women. The

difference can be inferred to be due to the higher incidence of infection among lowlanders, since dietary habits and economic status appeared to be the same in both communities. Although underweight or thinness is often associated with malnutrition, clinical examination of underweight or thin subjects at highland 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.

Although the findings of this study were obtained from selected groups of highlanders and lowlanders in the southwestern region of the Kingdom of Saudi Arabia, they certainly present a clear indication that overweight or obesity and, to a lesser extent, underweight or thinness are major nutritional problems in this region. Our findings in this respect call for further large scale studies to ascertain these results. Such large scale studies will help in the planning and delivery of health care to these regions.

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