FAT INDICES IN HIGH AND LOW ALTITUDE POPULATIONS IN SOUTHWESTERN SAUDI ARABIA

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The present study was undertaken to determine the fat indices in high and low altitude populations in Southwestern Saudi Arabia. Measurement of weight, height, mid-upper arm circumference, mid-upper arm muscle area, and skinfold thickness over the triceps region in 261 males living at high altitude (3150 meters above sea level) and 237 males living at low altitude (500 meters above sea level) in Southern Saudi Arabia are reported. The assessment of fatness by calculation of percent body weight is supported by correlation of triceps skinfold thickness with body mass index (BMI). In both high- and lowlanders the triceps skinfold thickness has significant correlation with BMI ($P<0.001$ for both). BMI also showed significant correlations with body weight, mid-upper arm circumference and mid-upper arm muscle area ($P<0.001$ for all). The findings show that the use of skinfold thickness in the prediction of degree of fatness in both groups seems to be a practical and useful method. However, it appears that there is a need for densitometric studies among Saudi populations to enable the derivation of valid regression equations for the calculation of body fat from skinfold thickness measurements. In the absence of skinfold measurements the BMI appeared to be a reliable indicator for assessment of body fat in Saudi high- and lowlanders *Ann Saudi Med 1997;17(3):*

The fat content of the human body provides useful information about the nutritional status of individuals and communities. Recently, however, there has been an increasing interest in the accurate estimation of body fat due to the recognition of its association with various chronic diseases such hypertension[1] and diabetes mellitus.[2] The relationship of body fat to blood pressure has been recently reconfirmed in southern Saudi Arabia.[3]

The Southwestern region of Saudi Arabia is characterized by high and low altitude areas. Using anthropometric techniques, the present study was undertaken to determine the fat indices in populations at both altitudes in this region. The objective was to provide baseline information which can be used for future studies in the area.

Materials and Methods

This study was carried out in the Asir region of Saudi Arabia, which has a topography varying from an altitude of 3150 meters to sea level. Two villages, Alsoda and Alsoga, were selected at high altitude (3150 meters, barometric pressure 550 mm Hg and atmospheric oxygen tension 110 mm Hg), while Alraish village was selected at low attitude (500 meters, barometric pressure 720 mm Hg and oxygen tension 145 mm Hg). The permanent residents in the three villages are racially homogenous—all are Arabs and Saudi nationals. Meat, chicken and rice constitute the major dietary items for the people living in the three villages.

Data were collected from 261 healthy adult males aged 15-60 years, born and living permanently at high altitude (about 47.3% of total adult male population registered in Alsoda and Alsoga health centers) and 237 healthy adult males aged 16-60 years, born and living permanently at low altitude (about 46.5% of total adult male population registered in Alraish health center). These two groups will be referred to as “highlanders” and “lowlanders.” Subjects were randomly selected from different age groups representing different households. Subjects in whom pathology was detected by clinical examination, as well as subjects who were not born or living permanently in Alsoda and Alsoga or Alraish, were excluded from this study. We saw a total of 670 subjects (63.1% of the total adult male population registered in Alsoda, Alsoga and Alraish health centers). A total of 172 persons (16.2% of the registered total adult male population) 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 at the health centers.

Body weight for each subject was measured and recorded using an Avery Beam weighing scale to the nearest 0.1 kg. Standing height was measured and recorded to the nearest 0.5 cm with a stadiometer. The left

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TABLE 1. *The number and percentages of Saudi high- and lowlanders in each group.*

Age groups (years)	Highlanders	Lowlanders	*P*-value
15-20	73 (28%)	81 (34.2%)	NS
21-30	58 (22.2%)	39 (16.5%)	NS
31-40	37 (14.2%)	38 (16%)	NS
41-50	36 (13.8%)	39 (16.5%)	NS
51-60	57 (21.8%)	40 (16.9%)	NS

NS=not significant.

TABLE 2. *The body measurements together with the calculated MUAMA, MUAC and BMI in Saudi high- and lowlanders.*

	Highlanders (n=261)	Lowlanders (n=237)	*P*-value
Age	35.2±16.5	34.8±15.7	NS
Weight (kg)	63.2±14.1	57.9±7.4	<0.001
Stature (cm)	161.2±7.5	157.2±14.4	<0.001
Triceps fold (mm)	11.4±7.3	11.7±5.0	NS
MUAC (cm)	25.9±4.3	26.0±4.5	NS
MUAMA (cm)	29.9±11.4	29.0±11.5	NS
BMI (kg/m^2)	24.2±5.0	23.4±5.1	NS

NS=not significant; MUAMA=mid-upper arm muscle area; MUAC=mid-upper arm circumference.

mid-upper arm circumference (MUAC) was measured to the nearest 1 mm with a fibreglass tape measure at the midpoint between the olecranon and the acromial processes. The skinfold thickness over the triceps was measured to the nearest 0.05 mm with a Harpenden caliper at standard sites.[4] No subscapular and suprailiac skinfold measurements were possible.

Body mass index (BMI) for each subject was calculated from the weight and the height (weight in kg/ height in m^2). The following equations were used to calculate percentage of body fat and body fat in kilograms using triceps skinfold:

$Y_1 = 4.019 + 0.89X$ (Formula I)
$Y_2 = 2.360 + 0.722X$ (Formula II)
(where Y_1= percentage fat of body weight,
Y_2= fat in kg and X= triceps skinfold in mm)

Fat mass index (fat mass normalized for height) was calculated according to Vanitallie et al.[6] Mid-upper arm muscle area (MUAMA), including bone, was derived from the formula of Jelliffe.[7]

To determine the relationship of age to body fat, subjects were divided into different age groups—15-20, 21-30, 31-40, 41-50 and 51-60 years. Table 1 shows the number and percentages in each age group.

SPSS Package has been used for statistical analysis. Student's t-test and Z test were used to determine statistical significance for continuous variables. Spearman correlation coefficient was used to test for the association between BMI on one hand and triceps fold, MUAC, MUAMA, weight and height on the other hand. $P<0.05$ was considered statistically significant.

Results

Table 2 shows the body measurements together with the calculated BMI and MUAMA of Saudi high- and lowlanders. The study was confined to adult males ranging in age from 15-60 years. Compared to lowlanders, highlanders were found to be significantly heavier and taller. The triceps skinfold thickness, MUAC, MUAMA and BMI were nearly the same in highlanders as in lowlanders.

The mean values and standard deviation of the fat indices of Saudi high- and lowlanders are given in Table 3. No significant differences in the percentage of fat, fat mass (kg) and fat mass index (fat mass normalized for height) were detected between high- and lowlanders.

The effect of age on fat indices is shown in Figure 1. In both high- and lowlanders, all fat indices including BMI increased progressively with increase in age until the age of 50 years and decreased thereafter.

Correlations between BMI and other body measurements are presented in Table 4. Except for height in both high- and lowlanders, it is evident that all correlation coefficients are significant. The men at low altitude showed higher correlations of triceps fold, MUAC, MUAMA and weight with BMI than highlanders. In both high- and lowlanders, body weight showed the best correlation with BMI.

Discussion

Overweight prevention and control is directed against excess weight due to fat. While direct anatomical[8] and electrical[9] methods for estimation of body fat are not suitable for large-scale epidemiologic surveys, indirect methods such as estimation of fat mass from measures of skinfold thickness[5] meet the need for simple tests of relative fatness. However, expressing fat mass by weight was found to be unsatisfactory in simplifying the task of interpreting the clinical significance of values for fat mass in individuals of differing heights. One other index was recently introduced, namely fat mass index (fat mass normalized for height).[6] This index was believed to minimize the effect of height and therefore allowed for comparison of values of fat mass in individuals of differing heights. In this study the body fat expressed as a percentage of body weight, fat mass (kg) and fat mass index (kg/m^2) were nearly the same in highlanders as in

TABLE 3. *The mean values and standard deviations of percent body fat, fat mass and fat index in Saudi high- and lowlanders.*

	Highlanders (n=261)	Lowlanders (n=237)	*P*-value
% fat	14.3±6.7	14.5±4.3	NS
Fat mass (kg)	10.7±5.4	10.8±3.5	NS
Fat mass index (kg/m^2)	4.1±2.0	4.3±1.4	NS

NS=not significant.

TABLE 4. *Intercorrelation between BMI and other body measurements.*

	Highlanders (n=261)	Lowlanders (n=237)
Triceps fold	0.3775*	0.5282*
MUAC	0.622*	0.8698*
MUAMA	0.4378*	0.7694*
Weight	0.9162*	0.9312*
Height	0.0762 (NS)	0.0653 (NS)

*P<0.001; NS=not significant.

TABLE 5.

	Highlanders (n=261)	Lowlanders (n=237)
% fat predicted by formula I*	14.3±6.7 *P*<0.001	14.5±4.3 *P*<0.001
% fat mass from fat mass formula II	16.6±5.4	18.2±4.7
Fat mass calculated from% fat formula I	9.6±4.4 kg *P*<0.02	9.0±3.8 kg *P*<0.001
Fat mass predicted by formula II*	10.7±5.4 kg	10.8±3.5 kg

*The mean values ± standard deviations of the means of percentage of fat predicted by formula I, percentage of fat calculated from fat mass (formula II), fat mass calculated from percentage of fat (formula I) and fat mass predicted by formula II in Saudi high- and lowlanders.

lowlanders. This is in agreement with previous studies in other parts of the world[10,11] which indicated that there was no difference in body composition between highlanders and sea-level residents. In addition to age and genetic factors, the fat content of the human body is known to be influenced by socioeconomic status and the level of physical activity of individuals. In general, there is an apparent tendency for body fat to increase with increase in age.[12,13] Poor socioeconomic conditions[12] and lower levels of physical activity[14] are often associated with increase in body fat. However, our subjects at high and low altitude do not only have the same ethnic and cultural backgrounds but also the same dietary habits, and there is no difference in the mean age or age range between high and low altitude subjects. In addition, in a study on the same population, Khalid[15] found no difference in the levels of strenuous physical activity between high and low altitude residents. However, in this study, Formula II was found to give high values for percentage of fat and fat mass. The regression equations which were used here were derived from studies in Czech sportsmen. In the case of highlanders, the difference between the calculated percentage of fat (using Formula II) and the predicted percentage of fat (using Formula I) and the difference between the predicted fat mass (using Formula II) and the calculated fat mass (using Formula I) were 2.3% (P<0.001) and 1.1 kg (P<0.02), respectively (Table 5). These differences were even more pronounced in lowlanders, being 3.7% and 1.8 kg (P<0.001 for both). This shows that there is a need for densitometric estimation of fat in Saudi Arabs to enable valid regression equations to be derived.

The present study also showed that the level of fatness expressed in whatever form increased progressively with age until the age of 50 years and decreased thereafter (Figure 1). Fatness is a potent risk factor for many diseases, including hypertension,[1] diabetes mellitus[2] and certain types of cancer.[16] In particular, high altitude fatness predisposes to chronic hypoxia, hypoxic hypertensive pulmonary vascular disease and chronic mountain sickness.[17] The drop in the level of fatness after the age of 50 years is a reflection of a better state of health beyond that age.

The body mass index [wt (kg)/ht (m^2)] has been widely used in the assessment of fatness in individuals and communities. This is because the index is correlated with other estimates of fatness[18] and it applies to all populations without the need for a reference population. In this study, we confirmed the relationship between body mass index and other body measurements which we used in the estimation of body fat, namely triceps fold. In addition, the body mass index showed significant correlations with mid-upper arm circumference and mid-upper arm muscle area. The latter gives good indication of muscle mass. However, a clinically useful and biologically meaningful body mass index must be independent of stature and dependent on weight.[19] The present study confirmed that body mass index is highly correlated with weight and insignificantly with stature (Table 4). In the absence of skinfold measurements, the body mass index appeared to be a reliable indicator for assessment of body fat in Saudi high- and lowlanders.

Although the findings of this study were obtained from selected groups of high- and lowlanders (i.e., only males) they certainly provide baseline information for future studies in this region of the Kingdom. It appears from the present study that there is a need for densitometric studies among the Saudi population to enable the derivation of valid regression equations for the calculations of body fat from skinfold thickness measurements.

FIGURE 1. The relationship of different fat indices to age in high- and lowlanders.

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