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Is elbow breadth a measure of frame size in non-Caucasian populations? A study in low- and high-altitude Central-Asia populations

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The concept of frame size has not undergone a thorough evaluation in non-Caucasian populations. Using data from the Central Asia High Altitude Population (CAHAP) study, we tested whether: (1) the relationship between frame size and body composition is different in high-, medium- and low-altitude populations; (2) elbow breadth is a better index of frame size than biacromial and biiliac breadth; and (3) measures of frame size are associated with blood pressure, cholesterol and triglycerides. A number of 334 male subjects aged 33 ± 10 years (mean $\pm$ standard deviation) were selected from the CAHAP population ($n = 384$) on the basis of the availability of breadth measurements. The subjects were 85 high-altitude Kirghizs, 105 medium-altitude Kazakhs, 79 low-altitude Kirghizs and 65 low-altitude Uighurs. A detailed anthropometric evaluation and blood pressure, cholesterol and trygliceride measurements were performed on all individuals. Among breadths, elbow had the lowest correlation with arm fat area, thigh fat area, calf fat area and the sum of trunk skinfolds ($r \leq 0.196$, $P < 0.01$). Even if elbow breadth did not have the highest correlation with muscularity indexes, its constantly lower association with adiposity indexes shows that it is a better measure of frame size than biacromial breadth and biiliac breadth. The relationship between frame size and body composition did not differ in high-, medium- and low-altitude subjects ($P =$ not significant, analysis of co-variance). Only a weak association was present between breadths, blood pressure, cholesterol and triglycerides ($r \leq 0.230$, $P < 0.01$) and it was not influenced by altitude ($P =$ not significant, analysis of co-variance). Elbow breadth was significantly correlated only with diastolic blood pressure ($r = 0.121$, $P < 0.05$). In conclusion: (1) the relationship between frame size and body composition is similar in high- and low-altitude populations; (2) elbow breadth is an index of frame size independent of altitude; and (3) elbow breadth is correlated with diastolic blood pressure, but this correlation is of doubtful biological relevance.

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Introduction

The concept of frame size was introduced in the 18th century with the aim of identifying body dimensions able to explain the inter-individual variability in body weight that could not be accounted for by height and age (Himes, 1991). Nowadays, the most important question regarding an index of frame size is whether it can add to the prognostic value of weight and weight:height indexes (Himes & Frisancho, 1988; Himes, 1991). Given the lack of evidence relating frame size with morbidity and mortality, the choice of an index of frame size is based at present on indirect assumptions regarding its use. Since skeletal dimensions are correlated with fat-free mass (Behnke, 1959), an index of frame size is expected to have a high correlation with fat-free mass and a low correlation with fat mass (Himes and Frisancho, 1988; Himes, 1991).

In epidemiological studies, measurements of fat mass and fat-free mass are not feasible, and skinfolds are employed as indexes of body fat. Using data from the NHANES study, Frisancho & Flegel (1983) selected elbow breadth over bitrocanteric breadth as a measure of frame size because of its lower correlation with the sum of triceps and subscapular skinfolds. As compared with biacromial breadth, elbow breadth also showed a lower correlation with subscapular skinfold corrected for arm muscle area and age (Frisancho, 1990). Even if wrist and ankle breadths have consistently shown the lowest correlations with fat mass and its indexes (Himes & Bouchard, 1985; Himes & Frisancho, 1988; Himes, 1991), the lack of nationally representative values has discouraged their use for the development of anthropometric and nutritional standards (Himes & Frisancho, 1988; Himes, 1991).

The majority of studies on frame size have been conducted on Caucasian subjects and the concept of frame size has not undergone a thorough evaluation in non-Caucasian individuals (Himes, 1991). Moreover, it is not known whether living at high altitudes — a factor that is known to influence body composition (Frisancho, 1993) — may also influence the relationship between frame size and body composition. Using data from the Central Asia High Altitude Population (CAHAP) study, we tested whether: (1) the relationship between frame size and body composition is different in high- and low-altitude populations; (2) elbow breadth is a better index of frame size than biacromial breadth and biiliac breadth; and (3) measures of frame size are associated with prognostic indicators such as blood pressure, cholesterol and triglycerides.

Methods

Study protocol

The CAHAP study was aimed at characterizing from an anthropological, physiological, nutritional and genetic point of view selected Central Asia populations for which little information was available in the international literature (Battistini *et al*., 1995; Bedogni *et al.*, 1997; Facchini *et al.*, 1997, 1998; Pettener *et al.*, 1997; Comas *et al.*, 1998; Perez-Lezaun *et al.*, 1999; Fiori *et al.*, 2000a,b). High-altitude (HA) Kirghizs, medium-altitude (MA) Kazakhs, low-altitude (LA) Kirghizs and LA Uighurs were studied. These turko-mongolic populations have a similar genetic background but a very different living environment. HA Kirghizs are mostly shepherds, MA Kazakhs are shepherds and farmers, whereas LA Kirghizs and LA Uighurs are mostly farmers (Fiori *et al.*, 2000b). The CAHAP population represent a convenience sample of these populations (Fiori *et al.*, 2000b).

Subjects

Based on the availability of breadth measurements, 334 subjects were selected from the entire CAHAP population of 384 subjects (Fiori *et al.*, 2000b). They were 85 HA Kirghizs from Sary Tash (3200 m), 105 MA Kazakhs from the Keghen Valley (900 m), 79 LA Kirghizs from Talas (600 m) and 65 LA Uighurs from Pendjem (600 m).

Anthropometry

Weight, height, circumferences (arm, mid-thigh and calf), skinfolds (triceps, biceps, subscapular, pectoral, midaxillary, suprailiac, abdominal, mid-thigh and calf) and breadths (elbow, biacromial and biiliac) were measured following the *Anthropometric Standardization Reference Manual* (Lohman *et al.*, 1988). Body mass index (BMI) was calculated as weight (kg)/height $(m)^2$ (Garrow & Webster, 1985). Muscle and fat areas of the arm, thigh and calf were calculated as described by Heymsfield *et al.* (1984) without correction for bone size. Limb fat indexes were obtained by dividing the limb fat area by the total limb area and multiplying the obtained value by 100 (Frisancho, 1990). The subscapular, pectoral, midaxillary, suprailiac and abdominal skinfolds were summed so as to obtain a composite measure of trunk adiposity.

Blood lipids and blood pressure

Cholesterol and triglycerides were measured with commercial dry-chemistry kits (Menarini, Firenze, Italy). Systolic and diastolic blood pressure were measured as recommended by Perloff *et al.* (1993).

Statistical analysis

Statistical analysis was performed on a MacOS computer using the Statview 5.0.1 and SuperANOVA 1.1 software packages (SAS Institute, Cary, NC, USA). Some variables (biiliac breadth, biacromial breadth, limb fat areas, limb fat indexes and the sum of trunk skinfolds) were log-transformed to reach, or better approach, the normal distribution, and log-transformed values were used in all analyses involving these variables. Between-group differences were evaluated by analysis of variance using the Games–Howell test for *post-hoc* analysis. The association of breadths with body muscularity and adiposity was evaluated by correlation analysis. To establish the influence of altitude on this relationship, an interaction factor between altitude and the breadth of interest was entered in the model and tested for its significance (Fiori *et al.*, 2000b). The association of breadths with blood pressure, cholesterol and triglycerides was evaluated by correlation analysis. Statistical significance was set to a value of $P < 0.05$ for all tests.

RESULTS

The measurements of the study subjects are presented in Tables 1 and 2.

Age and height were similar in all groups ($P =$ not significant (ns)), while weight and BMI were significantly lower in highlanders than in the other groups ($P < 0.05$; Table 1). Cholesterol and triglycerides were similar in all groups ($P =$ ns), while systolic and diastolic blood pressure were higher in LA Uighurs and MA Kazakhs than in HA and LA Kirghizs ($P < 0.05$).

HA Kirghizs had the lowest values of muscle areas but their values of thigh muscle area and calf muscle area were not significantly different from those of LA Kirghizs ($P =$ ns; Table 2). HA Kirghizs had also the lowest values of fat areas, which were significantly lower than those of LA Kirghizs ($P < 0.05$). Similarly, the sum of trunk skinfolds was significantly lower in HA Kirghizs than in the other groups ($P < 0.05$). Significant between-group differences were found for biacromial and biiliac breadths ($P < 0.05$ for both) but not for elbow breadth ($P =$ ns).

The correlations of breadths with age and anthropometric variables are presented in Table 3. All breadths were positively correlated with weight, height and BMI. The fact that biiliac breadth had the highest correlation with weight can be easily explained by the fact that it is the more ‘weight-bearing’ of the three studied breadths. Elbow breadth had the lowest correlations with limb fat areas and the sum of trunk skinfolds. Interestingly, the associations of elbow breadth with arm, leg and calf adiposity were no more significant after standardization of fat area on total limb area ($P =$ ns). Biiliac breadth had the highest correlation with limb muscle areas. Elbow breadth was second to biacromial breadth as far as the association with arm muscle area is concerned, but it had the lowest correlation with thigh and calf muscle areas. After correction of breadths and anthropometric variables for height and

Table 1. Main characteristics of the study subjects*

	All	*HA Kirghizs*	*MA Kazakhs*	*LA Kirghizs*	*LA Uighurs*
Number	334	85	105	79	65
Age (years)	33±10	34±10[a]	33±9[a]	33±11[a]	31±12[a]
Weight (kg)	64.5±9.2	59.7±7.3[a]	66.9±8.8[b]	64.9±9.0[b]	66.4±10.1[b]
Height (m)	1.69±0.06	1.68±0.06[a]	1.69±0.07[a]	1.69±0.05[a]	1.68±0.06[a]
Body mass index (kg/m^2)	22.6±3.0	21.1±2.5[a]	23.3±2.6[b]	22.7±2.9[b]	23.4±3.6[b]
Cholesterol (mg/dl)**	151±29	152±28[a]	152±28[a]	152±34[a]	149±28[a]
Triglycerides (mg/dl)***	107±68	105±58[a]	105±68[a]	97±75[a]	119±72[a]
Systolic blood pressure (mmHg)	117±13	112±12[a]	120±10[b]	113±13[a]	126±15[c]
Diastolic blood pressure (mmHg)	80±8	78±7[a]	81±6[b]	77±7[a]	84±9[b]

*Values are mean±standard deviation. HA, high altitude; MA, medium altitude; LA, low-altitude.
**To convert to mmol/l, multiply by 0.02586.
***To convert to mmol/l, multiply by 0.01129.

age, the relative degree with which breadths were associated with muscularity and adiposity did not change (partial correlation analysis; data not shown). The interaction of altitude with breadths was significant only for the calf muscle area ($P<0.01$), suggesting that the relationship between breadths and body composition is largely independent from the living environment.

As far as the prognostic value of breadths is concerned: (1) elbow breadth was correlated only with diastolic blood pressure ($r=0.121$, $P<0.05$); (2) biacromial breadth correlated with diastolic blood pressure ($r=0.159$, $P<0.01$) and cholesterol ($r=0.156$, $P<0.01$); and (3) biiliac breadth correlated with all four variables of interest ($r=0.191$ for systolic blood pressure, $r=0.200$ for diastolic blood pressure, $r=0.230$ for cholesterol and $r=0.212$ for triglycerides; $P<0.01$ for all correlations). However, these correlation coefficients are low and of doubtful biological relevance. Furthermore, after correction of breadths for weight — the anthropometric variable with which they were mostly associated (cf. Table 3) — these correlations got even lower or disappeared (data not shown). The relationship between breadths and prognostic indicators was not affected by altitude ($P=$ ns).

Discussion

The CAHAP study was aimed to ascertain whether anthropological, physiological, nutritional and genetic differences exist between

Table 2. Breadths, adiposity and muscularity of the study subjects*

	All	*HA Kirghizs*	*MA Kazakhs*	*LA Kirghizs*	*LA Uighurs*
Elbow breadth (mm)**	71	70[a]	71[a]	71[a]	71[a]
Biacromial breadth (cm)**	39.9	39.5[ab]	40.1[bc]	40.7[c]	39.0[a]
Biiliac breadth (cm)**	28.6	28.1[a]	28.6[ab]	28.9[b]	28.8[ab]
Arm-muscle area (cm^2)	48.9±9.1	43.5±7.2[a]	50.9±7.3[c]	47.5±9.3[b]	54.2±9.6[c]
Thigh-muscle area (cm^2)	151.3±25.0	137.3±24.6[a]	157.3±20.5[b]	145.7±21.7[a]	166.9±24.4[c]
Calf-muscle area (cm^2)	82.4±11.6	78.8±13.3[a]	83.4±9.8[b]	82.4±11.6[a]	85.6±11.1[c]
Arm-fat area (cm^2)**	7.9	6.3[a]	8.3[b]	8.5[bc]	9.0[c]
Arm-fat index (%)**	14	12.7[a]	14.0[ab]	15.2[b]	14.3[ab]
Thigh-fat area (cm^2)**	13.9	11.2[a]	13.6[b]	15.3[bc]	17.2[c]
Thigh-fat index (%)**	8.6	7.9[a]	8.0[a]	9.5[b]	9.4[b]
Calf-fat area (cm^2)**	8.0	6.4[a]	7.7[b]	8.6[b]	10.4[c]
Calf-fat index (%)**	8.9	7.8[ab]	8.5[a]	9.5[ab]	10.8[b]
Sum of trunk skinfolds (mm)**	36.8	30.4[a]	37.1[b]	38.0[bc]	44.8[c]

*Values are given as mean±standard deviation unless stated otherwise. [abc]Values not sharing the same superscript are significantly different at the $P<0.05$ level. HA, high altitude; MA, medium altitude; LA, low-altitude.
**Geometric mean.

Table 3. Correlation of breadths and other anthropometric indexes in the pooled sample ($n = 334$)*

	*Elbow breadth***	*Biacromial breadth***	*Biacromial breadth***
Age	0.174[a]	0.039	0.298[a]
Weight	0.475[a]	0.531[a]	0.680[a]
Height	0.427[a]	0.389[a]	0.411[a]
Body mass index	0.288[a]	0.367[a]	0.521[a]
Arm-muscle area	0.313[a]	0.269[a]	0.376[a]
Thigh-muscle area	0.240[a]	0.269[a]	0.371[a]
Calf-muscle area	0.302[a]	0.317[a]	0.405[a]
Arm-fat area**	0.196[a]	0.320[a]	0.427[a]
Arm-fat index**	0.080	0.241[a]	0.320[a]
Thigh-fat area**	0.157[a]	0.260[a]	0.352[a]
Thigh-fat index**	0.067	0.175[a]	0.225[a]
Calf-fat area**	0.149[a]	0.201[a]	0.342[a]
Cal-fat index**	0.031	0.084	0.185[a]
Sum of trunk skinfolds[†]	0.175[a]	0.265[a]	0.434[a]

*Values are Pearson' s correlation coefficients. [a]$P < 0.01$ for the corresponding value of Pearson' s r.**Log-transformed values used for analysis.

LA, MA and HA Central Asia populations. In the present report, we tested whether: (1) the relationship between frame size and body composition differs in LA, MA and HA populations; (2) elbow breadth is a measure of frame size; and (3) frame size indexes are associated with blood pressure and blood lipids.

Ideally, an index of frame size should be inversely associated with fat mass and directly associated with fat-free mass (Himes & Frisancho, 1988; Himes, 1991). Direct measurements of fat mass and fat-free mass are not feasible during epidemiological studies, and surrogate measurements have to be used. Since we measured many skinfolds and circumferences during CAHAP, we had the possibility to validate potential indexes of frame size against multiple measures of muscularity and adiposity. Using this approach, we found that elbow breadth had not only the lowest correlation with arm fat area, thus confirming previous studies in Caucasian subjects (Frisancho & Flegel, 1983; Frisancho, 1984), but also with thigh fat area, calf fat area and the sum of trunk skinfolds. It is also to be pointed out that the correlation with arm, leg and calf adiposity disappeared when fat area was standardized on total limb area ($P = \text{ns}$). Thus, among the three measured breadths, elbow was that associated with adiposity to the lowest extent. Even if elbow breadth did not have the highest correlation with muscularity, its constantly lower association with body adiposity shows that it is a better index of frame size than biacromial and biiliac breadth. Despite marked differences in body composition, the relationship between frame size and body composition did not differ in LA, MA and HA subjects. Thus, our data suggest that elbow breadth is an index of frame size independent of altitude.

A still unresolved question is whether frame size can add to the prognostic value of weight and weight:height indexes (Himes & Frisancho, 1988; Himes, 1991). We found only a weak association between body breadths and blood pressure, cholesterol and triglycerides. Moreover, this association got lower or even disappeared after correction for weight, casting some doubts about the prognostic relevance of frame size measures. It is, however, of interest that the relationship of frame size indexes with these parameters was not affected by altitude.

In conclusion, our study shows that: (1) the relationship between frame size and body composition is similar in high- and low-altitude populations; (2) elbow breadth is an index of frame size independent of altitude; and (3) a weak correlation of doubtful biological significance exists between elbow breadth and diastolic blood pressure. Further studies on more numerous samples of non-Caucasian subjects are needed to ascertain whether an evaluation of frame size through elbow breadth can improve the classification of other anthropometric parameters, such as has been shown for Caucasian subjects (Frisancho, 1990). Even more important, these studies may offer the possibility to investigate more thoroughly the association between frame size and prognostic indicators.

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