

High Prevalence of Excess Fat and Central Fat Patterning Among Mongolian Pastoral Nomads

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ABSTRACT This paper presents information on body size, body composition, and fat patterning in a sample of 750 pastoral nomads aged 5 to 84 years, native residents of Moost district, Mongolia and evaluates the results from the perspective of morphological adaptation to a cold climate. Mongolian nomad men and children have average BMIs close to the U.S. 25th percentile while women have average BMIs close to the U.S. reference median. The prevalence of excess fatness assessed by the Arm Fat Index rises from 5 to 15% during childhood to 65% or more in each adult age-sex group except women 70+ years. The pattern of fat deposition is markedly central (abdominal) among women and children while it is normally so among men: women and children have a very high ratio of waist-to-hip circumference and children have a moderately high ratio of subscapular-to-triceps skinfold compared with other populations. A body composition favoring centrally deposited fat may be adaptive to a cold stressed population because it would aid in heat production (abdominal fat is thermogenic) and heat conservation (more spherical body size and better insulation) in the age-sex groups that are usually at a thermal disadvantage because of small body size and/or low basal metabolic rate relative to men. © 1992 Wiley-Liss, Inc.

Body size and body composition of indigenous north Asian populations are relevant to a classic question in human biology about the relationship between morphology and climate. The general relationship expressed by Bergmann's rule states that populations living in climates with low mean annual temperatures will have a large body mass. A comprehensive analysis of the world literature confirmed the applicability of this rule to humans although it did not include information on indigenous north Asian populations (Roberts, 1973). Theoretically, large body size could be advantageous several ways in a cold climate. It favors conservation of body heat geometrically by reducing the ratio of body surface area to volume and it may influence thermoregulation physiologically by enhancing heat production. Large body mass could be the result of high levels of muscle or fat or both. The different routes to large body mass have different theoretical thermal benefits and metabolic costs. More muscle could produce heat, but at a caloric cost. More fat could insulate, but might elevate risk of disease. In particular,

abdominal fat may convey benefits vis-à-vis cold stress because it could simultaneously insulate, increase spherical shape, and increase metabolism in response to catecholamines produced by cold stress (Shephard, 1991). However, abdominal fat is associated with elevated risk of chronic disease (Bjorntorp, 1985).

The purpose of this report is to examine these issues by assessing body size, composition, and fat patterning throughout the life cycle in an indigenous north Asian population in a cold climate. It uses anthropometric data obtained from a sample of 750 pastoral nomads aged 5-84 years of age who are natives of Hovd province, Mongolia, where the mean annual temperature is -1.7°C and the mean January temperature is -17.6°C .

MATERIALS AND METHODS

Sample

The sample is drawn from the pastoral nomad population in three brigades of the

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herding collective of Moost district (latitude approximately 47°N, longitude approximately 93°E), Hovd province, Mongolia (formerly Mongolian Peoples' Republic), an independent country that from 1921 to 1990 was part of the political sphere of influence of the former USSR. The Moost nomads herd yak, sheep, goats, camels, and horses on open grassland at altitudes of 2,400–3,050 m. They live in traditional style round felt tents and move camp 5–20 times a year to locate near new pastures. Their livelihoods derive from salary and goods received as members of a government organized herding collective and from the products of their private herds. The socialist Mongolian system provides cradle to grave social benefits. Health care is free and nearly all women receive prenatal care and give birth in hospitals. Similarly, nearly all children are enrolled in free schools and almost all adults are literate. (Aspects of the economic system and benefits are changing since the study ended as Mongolia moves from a centrally planned to a free market economy.)

The long and very cold Mongolian winters and strong winds throughout the year cause year-round cold exposure. Average temperature in Moost is below 0°C from October through April, and from December through February mean monthly temperatures range from -15 to -17°C. Wind speeds range from 5.1 to 8.6 kph from October through April. The combined temperature and wind stress result in conditions described by western meteorologists as very cold and bitterly cold. During the 5 months of the year when temperatures average above 0°C and windspeeds range from 2.9 to 6.8 kph, conditions range from very cool to very cold (Pearce and Smith, 1984). The Moost nomads are exposed to this cold stress during the course of everyday activities including herding on horseback all day long every day of the year, and fetching water and fuel.

Data were collected from September through November 1990 and from May to June 1991 by visiting from tenthold to tenthold in two brigades and by visiting the local boarding school attended by virtually all nomad children between 8 and 16 years of age. Individuals of all age groups from Brigades Two and Three of this district were asked to participate in an anthropometric survey as were school children from Brigade One. Seventy-five percent of the members of

one brigade, 49% of another, and nearly all the school children of the third were included. Altogether, 883 people aged 1 month to 84 years were measured. The 29 women who were pregnant or had given birth within the past year and the 104 children under 5 years of age are excluded from analysis for this report.

Age

Birthdates were obtained from birth certificates, birth records, and "internal passports" (obtained at age 18 in exchange for birth certificates), and from reports of animal years. Of the birthdates 81% were verified by birth certificate, birth record, or internal passport. Individuals over 35 were asked their birthyear according to the traditional 12 year animal cycle calendar system because in some cases (particularly among people over 50) internal passport birthdates were based on the individual's report of his or her "Asian" age which overestimates "Western" ages by an average of 18 months (Beall, 1981).

Anthropometry

Measurements of body size and composition were made according to published protocols, (Cameron et al., 1971; Harrison et al., 1988; Mueller et al., 1989), selecting measurements with good reliability (Bray and Gray, 1988; Frisancho, 1990). Measurement of upper arm circumference and triceps skinfold thickness enable calculation of upper arm cross-sectional fat and muscle areas and thereby estimated energy reserves (Frisancho, 1990).

Measurements of waist and hip circumferences were obtained from 266 Mongolians 8+ years in the spring 1991 season (Calloway et al., 1988). Waist measurements were taken over skin and hip measurements were taken over underwear. Hip circumference was corrected for underwear thickness (measured using skinfold calipers). Waist-to-hip ratio is a "convenient and specific method for measuring sites of body fat predominance" (Van Itallie, 1988, p. 147).

Analysis

Average body size measures of height and weight were calculated for yearly age groups from 5–17 and for adults 18–24, 25–39, 40–54, 55–69, and 70+ years. In addition, the body mass index (BMI, kg/m²), arm fat index (AFI, the percentage fat in the calculated

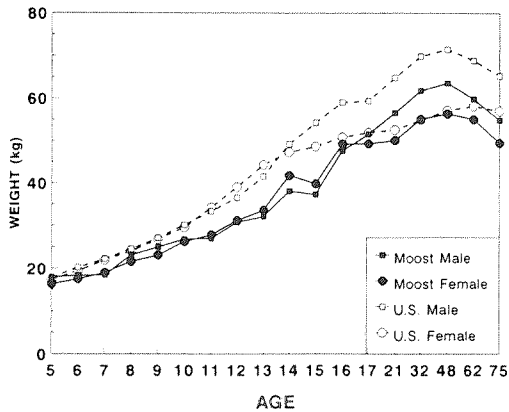


Fig. 1. Mean weight (kg) for age of Moost district males and females compared with the 25th percentile of a U.S. reference (Frisancho, 1990).

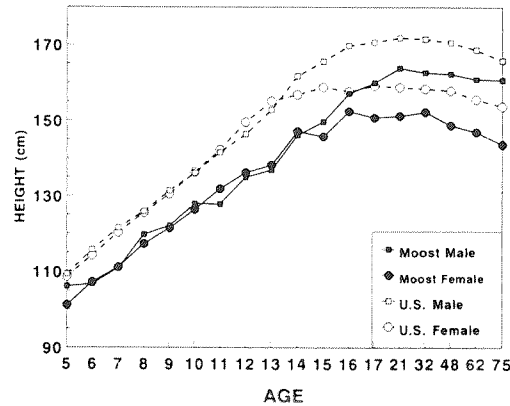


Fig. 2. Mean height (cm) for age of Moost district males and females compared with the 25th percentile of a U.S. reference (Frisancho, 1990).

upper arm cross sectional area), and upper arm muscle area (UMA, the calculated upper arm cross sectional area, cm^2) (Frisancho, 1990) were used as indicators of body composition. The ratio of waist-to-hip circumferences and the ratio of the subscapular to the triceps skinfold thickness were used as indicators of fat distribution (Haffner et al., 1987). (Tables of means and standard deviations are available from the authors.) The Moost nomads are compared with a U.S. national reference sample (Frisancho, 1990, 1991) by calculating age and sex appropriate z-scores. Z-score values of more than ± 1.036 reflect values either below the 15th or above the 85th percentile, i.e., outside the average range, of the U.S. reference population (Frisancho, 1990). No reference exists for waist-to-hip circumference ratio; therefore, an "effect size" measure, analogous to z-score, is calculated by dividing the Mongolian-U.S. sample differences in mean waist-to-hip circumference ratio by the standard deviation of the Mongolian mean (Cohen, 1988).

RESULTS

Mongolian nomads are substantially shorter and lighter for age than their U.S. counterparts from 5 to 84 years of age. Average weight of male Mongolian nomads is below the U.S. 25th percentile throughout the life cycle (Fig. 1). Average weight of Mongolian girls is also below the U.S. 25th percentile, while the average weight of women ap-

proximates the U.S. 25th percentile after the age of 16 (Fig. 1). Average weight-for-age z-score of males is -1.25 and that of females is -1.03 indicating that average weights of males are below the U.S. reference population average range, while average weights of females are at the border of the below average and average ranges. Figure 2 illustrates the shorter height of Moost Mongolians compared with the U.S. 25th percentile. Average z-scores for height are -2.06 and -2.08 for males and females, respectively, indicating that heights average more than two standard deviations below the U.S. reference mean.

Because weights are not as far below the U.S. reference average range as are heights, Moost nomad children and men have an average BMI close to the U.S. 25th percentile, while postpubertal women are heavier (Fig. 3). Average BMI-for-age z-scores for males and females are -0.42 and -0.27 , respectively. Only 1% of men and 3% of women age 18+ years of age have a BMI above the U.S. 85th percentile and would be classified as obese.

AFI reveals a dramatic rise from 5 to 15% prevalence of excess fatness (AFI above the U.S. 85th percentile) during childhood to a very high prevalence of excess fatness after puberty that exceeds 65% in all age-sex categories except women 70+ years of age (Fig. 4). Mongolian children have AFI slightly lower than the U.S. mean. Average z-scores of AFI among boys and girls are -0.4 and -0.2 , respectively. Mongolian females begin

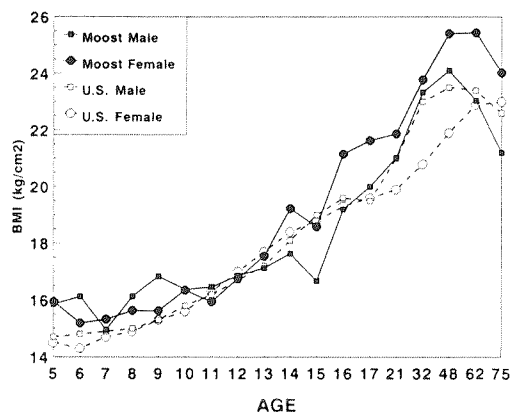


Fig. 3. Mean BMI (kg/m^2) for age of Moost district males and females compared with the 25th percentile of a U.S. reference (Frisancho, 1990).

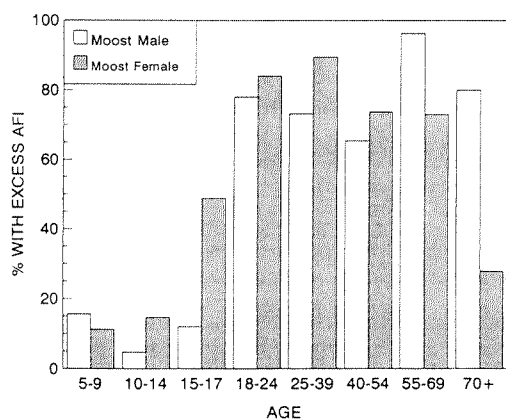


Fig. 4. Prevalence of excess Arm Fat Index (greater than the 85th percentile of a U.S. reference, Frisancho, 1990) among Moost nomads.

to diverge to higher, positive AFI z-score values at age 14, the median age at menarche (unpublished data), and males follow suit around age 17. Mongolian children have UMA relative to their heights that are slightly greater than the U.S. mean UMA for height. The average z-score of UMA for boys is +0.4 and for girls is +0.2.

In contrast, the average AFI z-score for age among men and women 18+ years of age is +2.1, while average z-scores for UMA among men and women 18+ are -1.5 and -1.3, respectively. Thus, the Mongolian nomads do not have a high prevalence of excess

weight, but do have a high prevalence of excess arm fat and low UMA after puberty.

The ratio of waist-to-hip circumference reveals that Mongolian children and women have consistently higher average ratios than other adequately nourished samples (Fig. 5A, B, and D). The effect size offers perspective on the magnitude of the Mongolian-U.S. population difference in mean ratios. The effect on waist-to-hip ratio of being a Mongolian boy increases from small at age 10 ($d = 0.3$) to moderately large at age 14 ($d = 0.8$). For girls at ages 10 and 14, the effect increases from medium ($d = 0.6$) to very large ($d = 1.5$) (compared with Gillum, 1987, U.S. white). The trend toward larger effects at older ages continues among women: at age 40-54 and 55-69 the very large effect sizes are 2.0 and 2.6, respectively (compared with Shimokata et al., 1989). That is, the average waist-to-hip ratio of Mongolian women is 2+ standard deviations above the average ratio of U.S. women. Thus, Mongolian children have average levels of fatness as measured by AFI, while exhibiting a tendency to deposit relatively more fat in the abdomen. Mongolian women have high levels of fatness and a marked pattern of preferential deposition in the abdomen.

In contrast, Mongolian men have waist-to-hip ratios generally lower than in other samples to a similar degree that women's

Fig. 5. (A) Average waist-to-hip circumference ratio of Moost district boys compared with U.S. and Dutch samples (U.S. White and Black from Gillum, 1987; Dutch from Weststrate et al., 1989). (B) Average waist-to-hip circumference ratio of Moost district girls compared with U.S. and Dutch samples (references as in A). (C) Average waist-to-hip circumference ratio of Moost district men compared with other adequately nourished samples [U.S. (a) from Shimokata et al., 1989; U.S. (b) from Laws et al., 1990; Swedish from Larsson et al., 1984; British from Jones et al., 1986; U.S. Mexican American (a) and Non-Hispanic White (a) from Haffner et al., 1986; European, South Asian and Afro-Caribbean from McKeigue et al., 1991; U.S. White from Williams, 1987; U.S. Mexican American (b) from Haffner et al., 1987]. (D) Average waist-to-hip circumference ratio of Moost district women compared with other adequately nourished samples [U.S. (a) from Shimokata et al., 1989; U.S. (b) from Laws et al., 1990; Swedish from Lapidus et al., 1984; European and South Asian from McKeigue et al., 1991; U.S. Mexican-American and Non-Hispanic White (a) from Haffner et al., 1991; U.S. Non-Hispanic White (b) and U.S. Mexican-American (b) from Haffner et al., 1988; U.S. Mexican-American (c) from Haffner et al., 1987; Dutch from Seidell et al., 1989; British from Ashwell et al., 1985; Chinese from Shen et al., 1990; and U.S. Mexican-American (d) and U.S. Non-Hispanic White (c) from Haffner et al., 1986].

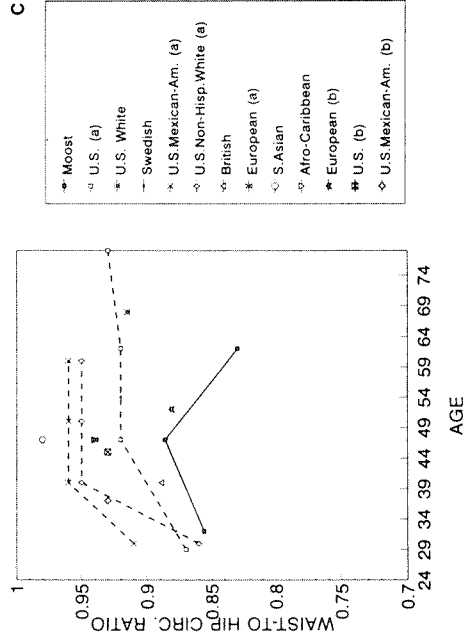
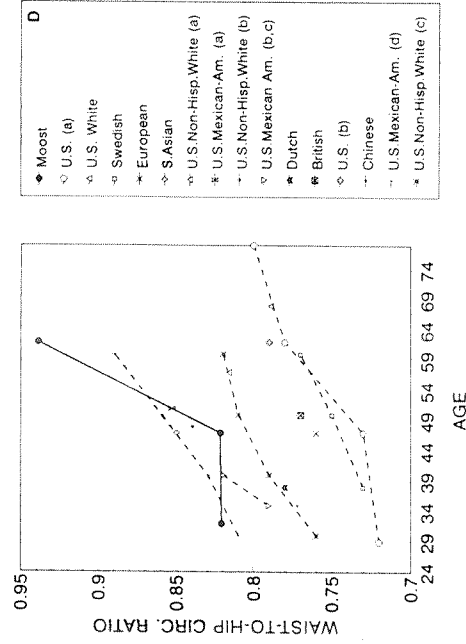
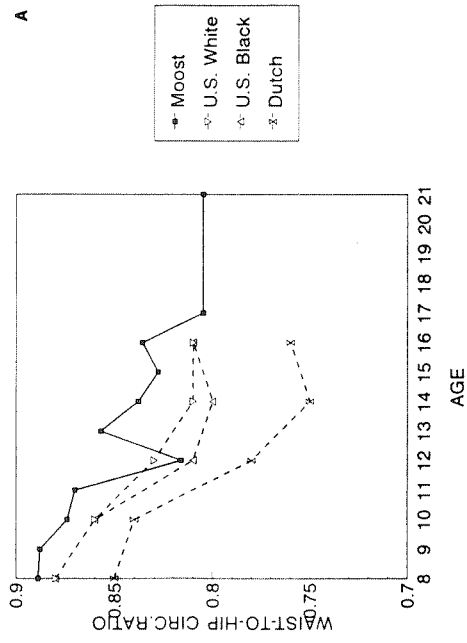
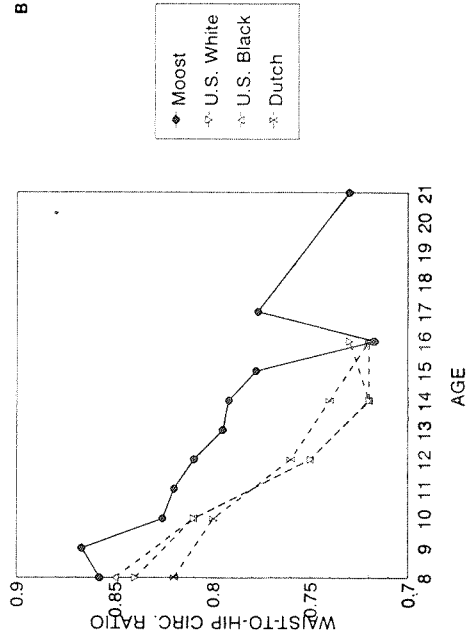


Fig. 5.

ratios are relatively high (Fig. 5C). The effect size among men 40–54 is medium ($d = 0.7$) and it is large for men 55–69 years of age ($d = 2.7$) (compared with Shimokata et al., 1989).

The ratio of subscapular-to-triceps skinfolds reveals a trend toward preferential fat deposition on the trunk of Mongolians, although the contrast is not as marked as that for waist-to-hip ratio. Compared to U.S. reference data and with other U.S. samples, Mongolian boys and girls tend to deposit relatively more fat on the trunk than the limb (Fig. 6A–D). However, Mongolian women differ little from the U.S. reference and have lower subscapular-to-triceps skinfold ratios than Mexican-American women. The average z -scores of this ratio are +0.4 and +0.3 for boys and girls, respectively, and +0.1 among women 18+ years. In contrast, men 18+ years have relatively low subscapular-to-triceps ratios and have an average z -score of -0.3.

Fat pattern is correlated with fatness in this sample. Men and women age 18+ with higher BMI have higher waist-to-hip ratios (men: $r = 0.61$, women: $r = 0.62$, $P < .01$). Women with higher BMI also have higher subscapular-to-triceps skinfold ratios ($r = 0.20$, $P < .02$). Figure 7A plots average waist-to-hip ratio against average BMI for the samples of males plotted against age in Figure 5C. It illustrates a cross-population trend toward a larger average waist-to-hip ratio with higher average BMI. The probable explanation for the relatively small waist-to-hip ratio for age of Moost men is their relatively low BMI. Plotting average subscapular-to-triceps skinfold ratios against BMI yields the same results (not shown). A similar analysis of values for Mongolian women re-emphasizes their distinctively large waist-to-hip ratio (Fig. 7B). Mongolian women are low to middle in the reported range of population variation in BMI and have a higher waist-to-hip ratio than most samples, including 5 of the 8 with higher BMI.

DISCUSSION

Relative to a U.S. reference sample, Mongolian pastoral nomads have small body size and low to average BMI throughout the life cycle. They do not have large body size as predicted by Bergmann's Rule. However,

this comparison with a U.S. sample is inappropriate, since Roberts' (1973) analysis of the relation between temperature and male body weight revealed differences among major continental groups in body weight at a given mean annual temperature. Roberts' regression equation for "S.E. Mongoloids" predicts an adult male weight of 57.2 kg for an Asian population with an MAT of -1.7°C . This is close to the observed 61.7 kg for 25- to 39-year-old men in Moost and suggests that this sample conforms generally with theoretical expectations for Asian populations. Young adult males from Moost are similar to the average weight range of 62–66 kg reported for other samples in Mongolia (Anonymous, 1990).

The usual age related change in fat pattern is observed. A decrease in waist-to-hip ratio during childhood is followed by an increase during young and middle adulthood, and an increase in subscapular-to-triceps skinfold ratio is evident throughout life. The usual sexual dimorphism of larger ratios of waist-to-hip circumference and subscapular-to-triceps skinfolds among men is also observed, although it is smaller in Moost nomads than U.S. samples. Waist-to-hip ratios of Moost boys are 3–5% higher than those of girls from 8 to 16 years and waist-to-hip ratios of Moost men are 4–8% higher than those of women. In contrast, waist-to-hip ratios of U.S. boys are 3–5% higher than those of girls at age 8–10, but this sex difference increases to 8–9% at age 14–16 years. Ratios of men are 10–19% greater during adulthood in the U.S. (Gillum, 1987; Shimokata et al., 1989). Similarly, average subscapular-to-triceps skinfold ratios of Moost boys are only 0.1–0.3 larger than those of girls 14–16 years compared with 0.2–0.4 in the U.S. (Frisancho, 1991). Sex differences in this ratio in Moost adults are just 0.3–0.4

Fig. 6. (A) Average subscapular-to-triceps skinfold ratio of Moost district boys compared with a U.S. reference (Frisancho, 1991) and a Mexican-American sample (Kaplowitz et al., 1989). (B) Average subscapular-to-triceps skinfold ratio of Moost district girls compared with a U.S. reference and a Mexican American sample (references as in A). (C) Average subscapular-to-triceps skinfold ratio of Moost district men compared with U.S. (a) and U.S. (b), two Mexican-American, and one Non-Hispanic White samples (Haffner et al., 1986, 1987). (D) Average subscapular-to-triceps skinfold ratios of Moost district women compared with U.S. (a) and U.S. (b); two Mexican-American and two non-Hispanic White samples (Haffner et al., 1986, 1991).

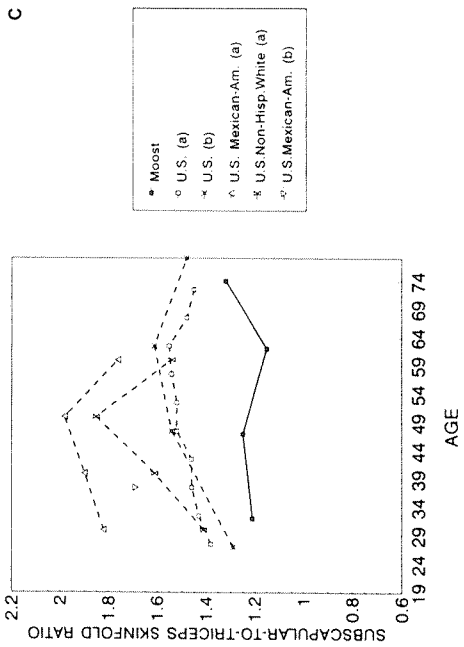
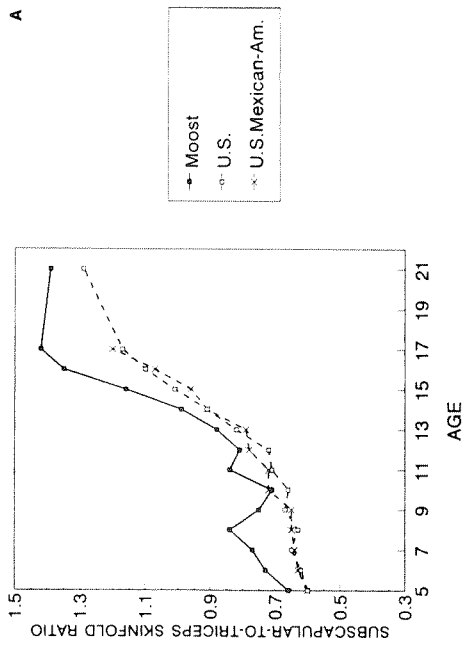
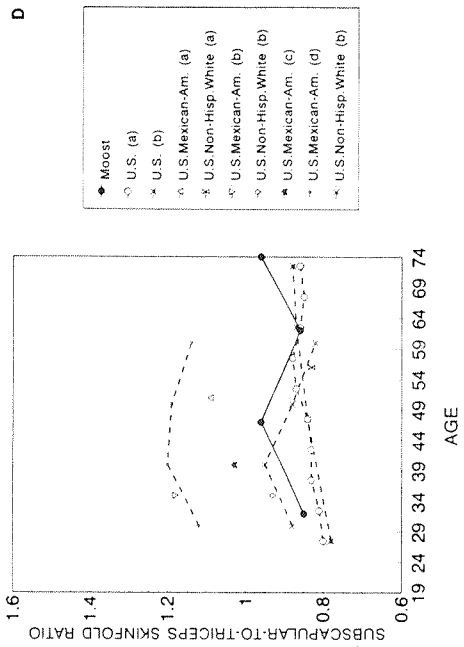
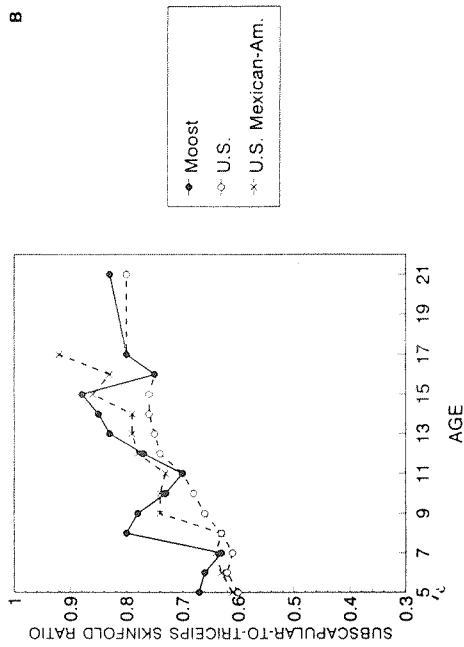


Fig. 6.

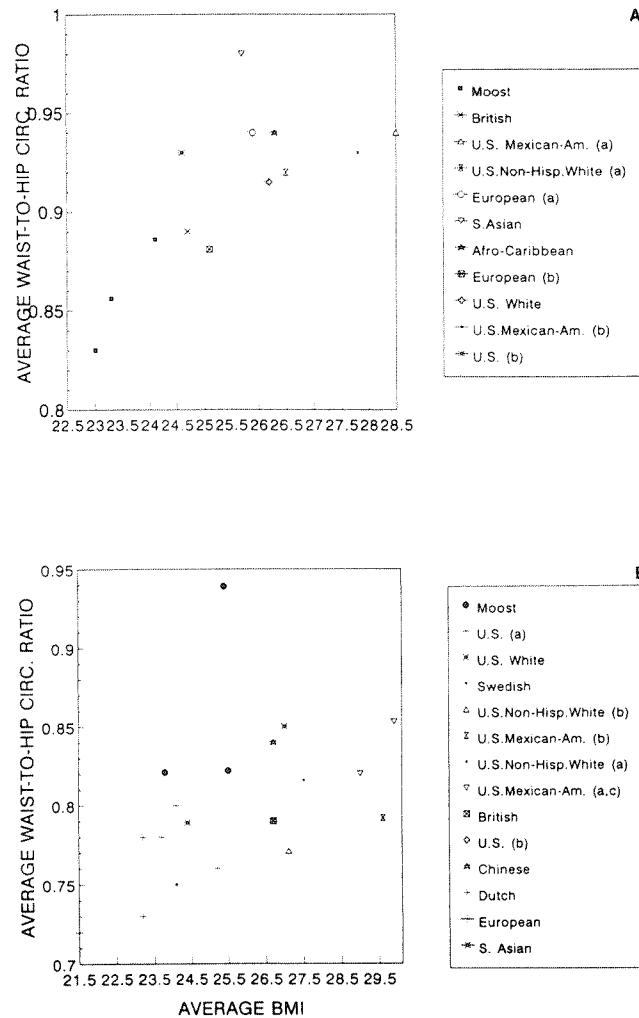


Fig. 7. (A) Average waist-to-hip circumference ratio relative to BMI for samples of men from Moost and elsewhere (references as in Fig. 5C). (B) Average waist-to-hip circumference ratio relative to BMI for samples of women from Moost and elsewhere (reference as in Fig. 5D).

compared with 0.6–0.7 in the U.S. (Shimokata et al., 1989).

These data provide a new perspective on the relationship between body morphology and climate by considering body composition and fat patterning in a cold stressed population. Mongolian nomads after puberty have an extremely high prevalence of excess fat as assessed by the AFI. While the average amount of fat is excessive at this extremity site, overall, fat actually is deposited preferentially on the abdomen and to

some extent on the upper trunk of women and children, but not of men, relative to other populations. The ratio of subscapular-to-triceps skinfold is slightly high among children relative to other populations. The Mongolian pattern of fat deposition results in a more "android" shape of children and women relative to other populations.

The distinctive metabolic characteristics of abdominal fat may be relevant to interpreting the Mongolian pattern. Abdominal fat can generate metabolic heat in response

to catecholamine stimulation and catecholamines can be released in response to cold stress (Shephard, 1991). It is hypothetically possible that selection favored the deposition of quickly available fuel for heat production in a cold climate where thermoregulation is essential for survival during daily exposure to subfreezing temperatures for at least 7 months a year. Centrally deposited fat could permit a facultative increase in metabolic heat production while subcutaneous fat throughout the body would promote heat conservation by insulation. Furthermore, resting metabolic rate is slightly (14%) greater among women with abdominal obesity than women with gluteofemoral obesity (van Besten et al., 1988) suggesting another avenue whereby abdominal fat might be adaptive under cold conditions. The central pattern of fat deposition might be especially beneficial to children who usually have the double jeopardy of small body size and little fat relative to adults (Little and Hochner, 1973) and to women who have small body size and lower basal metabolic rate relative to men. Centrally deposited fat would also aid in heat conservation by promoting a more spherical body shape consistent with the logic of Bergmann's Rule. Thus a body composition favoring fatness in general and centrally deposited fat in particular may be adaptive to a cold stressed population.

In conclusion, average heights and weights of Mongolian nomads for age are shorter and lighter than the U.S. average range, while the BMI is within the average range. After adolescence, Mongolian nomad adults have an extremely high prevalence of excess fat measured by the AFI. However, among children and women, fat is preferentially deposited on the abdomen relative to the hip compared with other populations, with the result that these age-sex groups have an unusually central pattern of fat deposition. Mongolian men have the degree of central fat deposition expected for their BMI. It is argued that this represents a morphological adaptation to enhance metabolic heat production by women and children (who produce less and lose more heat than men) in a severely cold climate.

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