Body Mass Index and Chronic Energy Deficiency of Adult Males of Central Indian Populations

D. K. ADAK,[1] R. K. GAUTAM,[2] S. BHARATI,[3] A. K. GHARAMI,[2] M. PAL,[4] AND P. BHARATI[5]

Abstract Data on body weight, height, and sitting height from 11,496 adult males, age 18–62 years, belonging to 38 different populations of five major social groups (scheduled tribes, scheduled castes, "other backward castes," general castes, and Muslims) of Central India were taken for our analysis to assess the nutritional status of these groups. Cormic index and body mass index (BMI) were computed, and an analysis of variance (ANOVA) was carried out among different populations as well as among social groups separately on Cormic index and BMI. Shape, size, and generalized distances among the different social groups were computed and dendrograms were drawn. The level of malnutrition is the lowest among the general castes. The opposite is the case with the scheduled castes and scheduled tribes. Comparison of the coefficient of variation shows that there is variation in weight and BMI but that there is no marked variation in the other anthropometric variables. The ANOVA on Cormic index and BMI suggests that the people within a population are more homogeneous than the people between populations. There is a positive but statistically insignificant correlation between Cormic index and BMI. The five social groups differ more in size distance than in shape distance. According to the dendrogram of generalized distance values, the Muslims and the general castes can be grouped into one cluster and the scheduled castes, scheduled tribes, and other backward castes can be grouped into another cluster.

In the assessment of the nutritional status of individuals and communities, anthropometric measurements play an important role. The assessment is done by observing the departure of the anthropometric measures from the normal standards. The basic causes of undernutrition in developing countries are poverty,

[1]Anthropological Survey of India, Field Station, Dr. H. S. Gour University, Sagar-470003, Madhya Pradesh, India.
[2]Department of Anthropology, Dr. H. S. Gour University, Sagar-470003, Madhya Pradesh, India.
[3]Sociological Research Unit, Indian Statistical Institute, Kolkata, India.
[4]Economic Research Unit, Indian Statistical Institute, Kolkata, India.
[5]Biological Anthropology Unit, Indian Statistical Institute, Kolkata, India.

Human Biology, April 2006, v. 78, no. 2, pp. 161–178.

KEY WORDS: BODY MASS INDEX, ANTHROPOMETRICS, CHRONIC ENERGY DEFICIENCY, NUTRITIONAL STATUS, CASTES, SCHEDULED CASTES, SCHEDULED TRIBES, MUSLIMS, INDIA.

poor hygienic conditions, and little access to preventive and health care (Mitra 1985; World Health Organization 1990). In developing countries such as India, anthropometry, despite its inherent limitations, still remains the most practical tool for assessing the nutritional status in the community (Ghosh et al. 2001). Quetlet or body mass index (BMI) is widely accepted as one of the best indicators of nutritional status in adults (James et al. 1988; Ferro-Luzzi et al. 1992; Shetty and James 1994; Naidu 1994; Bailey and Ferro-Luzzi 1995). BMI may be nutritionally rather than genetically related (Rolland-Cachera 1993), despite wide variation in weight and height among human populations (Eveleth and Tanner 1990; Majumder et al. 1990). Thus the use of BMI as an anthropometric indicator of nutritional status may be more appropriate in a country with diverse ethnic groups such as India (Khongsdier 2001).

Central India has one of the fastest growing populations in the country. This part of India is also known for its poor demographic and health situation. The reasons behind this can be traced to the high levels of mortality that have persisted over time along with the low levels of social, economic, and infrastructure development in the rural areas. Literature on the BMI of adult Indians is limited to certain geographic areas or populations. Noteworthy in the literature are the studies of BMI in the Northeast Indian population (Khongsdier 2001) and the South Indian population (Ferro-Luzzi et al. 1992). However, little is known about the BMI of populations in the central part of India. In the present study of 11,496 adult males, age 18–62 years, belonging to 38 different populations of 5 major social groups (scheduled tribes, scheduled castes, "other backward castes," general castes, and Muslims of Central India), we assessed the nutritional status of these groups.

Populations

Historically, India is a subcontinent with a variety of ethnic groups and divergent climatic zones. Before British rule or in the precolonial period, there were many large, medium, and small kingdoms and provinces. A rigid caste hierarchy is one of the empirical features of Indian Hinduism, with Brahmins at the top enjoying their priestly occupation. Kshatriyas and Vaishyas are in the middle position, as fighters (as well as rulers) and businessmen, respectively; the scheduled castes are placed at a lower level of the social strata than the former three. Many of scheduled castes used to be regarded as untouchable. Although untouchability has been abolished by law (Singh 1999), it still exists among Hindus, particularly in rural areas. In the 1931 census the Commissioner of Census identified some criteria for classification of the depressed classes and prepared a list of depressed classes who had been suffering from serious social and political handicaps on account of their degraded position in Hindu society. Accordingly, the Indian Franchise Committee passed an order to the Provincial Government

of the State to prepare a list of depressed classes under the banner of "scheduled castes" (Mandal et al. 2005).

The president of India, by special power, declared some indigenous groups in various pockets of India as scheduled tribes (under Article 342 of the Constitution of India, January 26, 1950). Tribal communities, the indigenous groups of India, are neither Hindus nor Muslims nor Christians, but because of assimilation as well as Sanskritization, adoption of these religions is noticed among some of them.

Central India has been the homeland of autochthonous tribal and caste populations. Numerous river valleys and the presence of uplands, such as Malwa and the highlands of Bastar in the east, gave rise to diverse variations in climate, altitude, temperature, and rainfall in subregions of the area (Basu et al. 1994). Taking into consideration the historical perspectives of the country and for the convenience of this study, we divided the population into five social groups, namely, scheduled tribes, scheduled castes, other backward castes, general castes, and Muslims.

Scheduled Tribes. Altogether nine tribal groups—the Bhil, Gond, Kol, Korku, Korwa, Manjhi, Oraon, Sahariya, and Sonr—are taken into consideration in the present study. They depend mainly on cultivation for their subsistence. Food gathering, hunting, and fishing are also practiced by many of them. Besides Hindi, they have their own languages or dialects. Within their own groups they communicate in their traditional language and use Hindi for intergroup communication. Of these nine groups the Korwa and Sahariya are scheduled as primitive tribes. According to the 1991 census, the total population of scheduled tribes is 8.08% of the total population of India. In Madhya Pradesh, including Chhattisgarh, which can be included in Central India, scheduled tribes make up 23% of the total population. In comparison to strength of numbers of tribal population, Central India is at the top with the largest population of tribal populations.

Scheduled Castes. Different caste groups, such as the Balai, Chamar (Jat), Khati, Koli, Kumbhar, Kori, Mahar, Mehra, and Satnami, are categorized as scheduled caste groups. Agriculture is the mainstay of their livelihood. Many also work as agricultural and daily laborers. In addition, many scheduled castes practice their traditional occupations; for example, the Chamars practice shoe making and repairing, the Kumbhars are pottery makers, and the Koris are weavers or textile makers. According to the 1991 census, 16.48% of the population in India is listed as a scheduled caste, whereas in Central India (Madhya Pradesh and Chhattisgarh) their proportion is approximately 15%.

Other Backward Castes. In caste hierarchy the other backward castes are above the scheduled castes and tribes; they are socially, economically, and politically more affluent and dominate the scheduled castes and scheduled tribes. But the other backward castes are below the general castes, who are on the top in all

aspects. In the present investigation, 17 caste groups of other backward castes were considered. Cultivation is their primary occupation. They are traditional farmers and hard laborers. Besides agricultural practices, they also earn their livelihood through daily wages. Some of them depend on other kinds of occupations for their subsistence; for example, the Ahirs are pastoralists and the Lohars are blacksmiths.

General Castes. In this study Brahmins and Rajputs are considered general castes. In the Hindu caste hierarchy the Brahmins, regarded as the priestly caste, occupy the topmost position. They are the principal landowning caste in Central India and hardly practice agriculture. The Rajputs are traditional rulers and warriors. They observe Brahminical customs and traditions and occupy a high position in the social hierarchy. Today, they practice agriculture for their livelihood. This group is socially, economically, and politically affluent and dominates over Indian society and polity.

Muslims. The Muslims of Central India are distributed throughout the area. They have no caste in the real sense of the term, but they are divided into classes and subclasses. The main two sections of the Muslims are Shias and Sunnis (Basu et al. 1994). Agriculture is their primary occupation.

Materials and Methods

The study sample is based on the basic anthropometric data collected from adult males, age 18–62 years, by the Anthropological Survey of India (Basu et al. 1994). In the present study 38 populations of Central India (Figure 1), including mainly the states of Madhya Pradesh and Chhattisgarh, were taken into consideration. The study sample consists of 11,496 adult males. Data were collected by the trained physical anthropologists of the Anthropological Survey of India, following standard techniques (Martin and Saller 1956). Therefore we can assume that the data are accurate. In general, from each district, individual measurements were taken from the major social groups (castes, tribes, and religious groups) according to the availability of subjects (Basu et al. 1994). For convenience, measurements were taken only on adult males who looked normal. Efforts were also made to exclude closely related individuals, such as brothers and fathers and sons, and individuals with any kind of physical deformities. Therefore the samples were free from any selection bias.

In this study we look at body weight, height, and sitting height. We calculated Cormic index (sitting height/height) and body mass index (weight/height^2) for each individual. We also calculated central tendency (arithmetic mean), dispersion (standard deviation), and relative dispersion (coefficient of variation) for each population and group of populations using MS-Excel and SPSS software packages. Subsequent calculations were also done using the SPSS software.

Figure 1. Map of India with Central India shown as shaded region.

For screening of chronic energy deficiency (CED) grades, we took 18.5 as the cutoff point, following James et al. (1988), Ferro-Luzzi et al. (1992), and Khongsdier (2001).

Because there are five social groups, it is interesting to find their distances to see how close the groups are. The coefficient of racial likeness (CRL), proposed by Pearson (1926), is used for this purpose. It is defined as

$$\text{CRL} = C_H^2 = \frac{1}{k}\sum_{i=1}^{K} d_i^2, \tag{1}$$

where d_i is the difference of the standardized means (the values are divided by their respective standard deviations before or after taking the means) of the two populations for the ith characteristics and K is the number of characters measured for the study. The CRL is thus the mean square distance. This coefficient can be broken down into two components, size and shape (Penrose 1947, 1954), defined as

$$\text{Size distance} = C_Q^2 = \left(\sum_{i=1}^{K} \frac{d_i}{K}\right)^2, \tag{2}$$

$$\text{Shape distance} = C_Z^2 = \frac{1}{K}\sum_{i=1}^{K} d_i^2 - \left(\sum_{i=1}^{K} \frac{d_i}{K}\right)^2. \tag{3}$$

The CRL, which is also known as the generalized distance (C_H^2), is the sum of size and shape distance:

$$C_H^2 = C_Q^2 + C_Z^2 = \frac{1}{K}\sum_{i=1}^{K} d_i^2. \tag{4}$$

Although this measure does not take into account correlations between the characteristics, as in Mahalanobis's D^2 measure, the two measures are close. Penrose (1954) found in one case that the correlation coefficient between the two measures was as close as 0.99.

Results and Discussion

Means and standard deviations of height, sitting height, body weight, Cormic index, and BMI of 38 ethnic groups in Central India are given in Table 1. In comparing the five major groups (scheduled castes, scheduled tribes, other backward castes, general castes, and Muslims), we can see that the scheduled tribes and the general castes take the extreme positions. The scheduled tribes are the shortest, with an average height 161.86 cm, and the general castes are the tallest, with an average height 166.30 cm. The ranking is more or less in the following order: scheduled tribes $<$ scheduled castes $<$ other backward castes $<$ Muslims $<$ general castes. The picture is similar with sitting height, weight, Cormic index, and BMI with some minor variations. Further classification of the ethnic groups leads us to the Jats, who are the tallest (mean height 168.60 cm) and the Korwas, who are the shortest (mean height 155.11 cm). It is rather surprising that the Jats are the tallest because they are one of the other backward castes, which occupy a middle rank. This result shows that there is a lot of within- and between-group variation. Thus statistical tests of significance of means are called for. Because the Korwas are the shortest, they have the highest mean BMI (20.80). Because BMI also depends on weight, we may not always get the same picture. In fact, the Mahars, with a mean BMI of 17.21, have the lowest mean BMI. But they are not the tallest group. Irrespective of social group, when all the populations are taken into consideration, the mean BMI is 18.43. This value is lower than that of well-to-do individuals in India (Bharati 1989; Khongsdier 1997; Reddy 1998), but it is not as low as the value found among South Indian populations (Ferro-Luzzi et al. 1992).

Table 1. Means and Standard Deviations (in Parentheses) of Height, Sitting Height, Weight, Cormic Index, and BMI of 38 Ethnic Groups of Central India

Population	*Sample Size*	*Height (cm)*	*Sitting Height (cm)*	*Weight (kg)*	*Cormic Index*	*BMI*
Scheduled tribes	2,066	161.86 (5.82)	80.31 (3.34)	48.66 (5.63)	0.496 (0.016)	18.56 (1.78)
1. Bhil	401	161.42 (5.48)	80.05 (3.33)	47.57 (5.78)	0.521 (0.017)	18.28 (1.98)
2. Gond	904	162.34 (5.61)	80.21 (3.31)	49.00 (5.48)	0.494 (0.016)	18.57 (1.69)
3. Kol	200	161.16 (5.74)	80.13 (3.47)	48.76 (5.00)	0.497 (0.016)	18.75 (1.50)
4. Korku	101	162.45 (5.34)	80.82 (2.45)	47.98 (5.23)	0.498 (0.015)	18.17 (1.70)
5. Korwa	51	155.11 (6.53)	78.42 (3.20)	50.24 (6.17)	0.506 (0.015)	20.83 (1.73)
6. Majhi	50	158.42 (5.72)	79.21 (2.92)	48.76 (5.04)	0.499 (0.013)	19.40 (1.49)
7. Oraon	99	163.19 (5.34)	80.32 (2.74)	52.17 (6.26)	0.492 (0.013)	19.55 (1.80)
8. Sahariya	204	162.78 (5.97)	81.79 (3.47)	48.12 (5.45)	0.502 (0.016)	18.12 (1.44)
9. Sonr	56	162.06 (7.11)	80.93 (3.80)	46.43 (5.67)	0.499 (0.016)	17.64 (1.50)
Scheduled castes	2,523	163.03 (6.11)	81.38 (4.09)	48.31 (6.16)	0.499 (0.020)	18.16 (1.96)
10. Balai	497	162.71 (6.42)	80.38 (3.76)	48.06 (6.24)	0.494 (0.019)	18.13 (1.98)
11. Chamar (Jat)	1,062	163.69 (6.06)	81.92 (3.94)	48.51 (6.10)	0.500 (0.019)	18.09 (1.91)
12. Khati	50	163.54 (5.98)	81.44 (3.05)	49.04 (4.24)	0.498 (0.013)	18.35 (1.47)
13. Koli	50	162.94 (7.07)	81.76 (3.01)	48.70 (6.88)	0.502 (0.018)	18.29 (1.93)
14. Kori	50	162.00 (6.76)	81.87 (3.22)	46.66 (5.81)	0.505 (0.014)	17.75 (1.70)
15. Kumbhar	413	163.77 (5.96)	81.68 (5.30)	49.15 (6.72)	0.499 (0.029)	18.30 (2.09)
16. Mahar	50	161.39 (6.56)	80.38 (3.23)	44.80 (5.05)	0.498 (0.017)	17.21 (1.86)
17. Mehra	201	160.66 (4.96)	80.10 (3.47)	46.88 (5.59)	0.498 (0.016)	18.15 (1.98)
18. Satnami	150	161.31 (5.21)	81.84 (3.25)	48.69 (5.37)	0.507 (0.015)	18.71 (1.86)
Other backward castes	3,331	163.75 (6.13)	81.80 (3.76)	50.11 (6.80)	0.499 (0.017)	18.66 (2.10)
19. Ahir	600	163.71 (5.85)	81.93 (3.42)	49.41 (6.35)	0.500 (0.016)	18.40 (1.96)
20. Barala	51	162.43 (6.18)	77.93 (3.70)	48.04 (7.16)	0.480 (0.017)	18.18 (2.27)
21. Gujar	100	166.50 (7.32)	83.05 (4.66)	54.84 (9.57)	0.498 (0.016)	19.69 (2.66)
22. Jat	50	168.60 (6.62)	85.57 (3.64)	55.28 (7.86)	0.507 (0.016)	19.38 (1.96)
23. Kachi	253	162.96 (5.49)	81.47 (4.62)	48.70 (5.28)	0.499 (0.024)	18.33 (1.71)
24. Kaller	50	162.96 (6.78)	80.25 (3.92)	51.80 (8.14)	0.492 (0.014)	19.46 (2.51)
25. Kannar	55	162.54 (7.32)	80.40 (4.21)	50.33 (7.57)	0.494 (0.013)	18.97 (2.02)
26. Kulmi	50	166.03 (6.79)	83.91 (4.10)	52.90 (6.33)	0.505 (0.016)	19.18 (1.91)
27. Kurmi	349	165.78 (6.11)	82.28 (3.39)	52.38 (6.67)	0.496 (0.016)	19.05 (2.17)
28. Kurumbhanshi	51	163.67 (5.95)	82.14 (3.10)	52.10 (5.17)	0.501 (0.015)	19.45 (1.70)
29. Lodha	51	164.67 (5.12)	83.26 (3.23)	49.46 (4.97)	0.505 (0.014)	18.35 (1.71)
30. Lodhi	300	164.41 (5.48)	81.41 (3.51)	50.87 (6.39)	0.495 (0.016)	18.79 (2.00)
31. Lohar	50	164.92 (6.56)	82.69 (3.13)	49.02 (6.31)	0.501 (0.020)	18.08 (2.54)
32. Lora	56	163.87 (6.88)	82.48 (4.24)	49.32 (5.37)	0.503 (0.015)	18.34 (1.35)
33. Panka	57	157.39 (6.49)	78.22 (3.57)	44.40 (4.72)	0.496 (0.014)	17.92 (1.60)
34. Rawat	52	156.79 (5.48)	77.92 (3.01)	45.21 (4.82)	0.497 (0.015)	18.37 (1.57)
35. Teli	1,156	163.28 (5.70)	81.89 (3.40)	49.66 (6.78)	0.501 (0.017)	18.60 (2.19)
General castes	1,815	166.30 (5.89)	83.80 (3.53)	53.32 (7.85)	0.504 (0.017)	19.25 (2.48)
36. Brahmin	1,114	166.45 (5.68)	84.60 (3.35)	53.97 (8.10)	0.508 (0.016)	19.45 (2.59)
37. Rajput	701	166.06 (6.21)	82.54 (3.44)	52.29 (7.32)	0.497 (0.017)	18.94 (2.27)
38. Muslims	1,761	164.96 (5.71)	83.02 (3.56)	51.58 (7.73)	0.503 (0.021)	18.93 (2.53)
Total	11,496	163.90 (6.41)	82.00 (3.87)	50.00 (7.02)	0.500 (0.191)	18.43 (2.18)

The best way to see the variation of these parameters among the 38 populations and among the 5 social groups is to examine their coefficients of variation. The coefficient of variation is highest for weight (Table 2). Height and sitting height do not depend much on the food habits and other socioeconomic and demographic parameters. Thus variation in height is expectedly low within a given population or social group. But weight depends on many factors. The coefficient of variation of BMI is also high because of the high variation in weight.

In Table 3 we present the results of the ANOVA for Cormic index and BMI for the 38 populations and 5 social groups. The ANOVA shows that the between-group variation is significantly greater than the within-group variation for both Cormic index and BMI. Unlike the coefficients of variation, we cannot differentiate between Cormic index and BMI using their relative dispersions.

The results of the statistical tests of significance for differences between pairs of means of BMI and Cormic index for the five social groups are presented in Table 4. The table reveals statistically significant differences in BMI and Cormic index for most pairs. The only differences in mean that were not significant were for the pair scheduled castes and other backward castes for Cormic index and the pair scheduled tribes and other backward castes for BMI. Thus the other backward castes are closer to scheduled castes and scheduled tribes than to the general castes and Muslims.

The distribution of BMI among different social groups is shown in Table 5 and Figure 2. Considering 18.5 as the cutoff point for screening individuals into the normal and chronic-energy-deficient groups, we found that the prevalence of CED among the general castes is the lowest (43.1%) compared to the scheduled castes (60.3%), scheduled tribes (51.5%), other backward castes (51.7%), and Muslims (47.5%). Scheduled castes are the most affected of all. The better level of nutritional status among the general castes is corroborated by their higher social and economic status.

For a clear view of the situation we present the mean values of the Cormic index and BMI in a bivariate plot (Figure 3). As can be seen in the figure, the populations of Central India can be classified into the following three groups and that the rest of the populations can be put in a separate group, based on the relationship between the Cormic index and BMI. These groups are as follows:

Group A (Cormic index = 0.493–0.505; BMI = 17.9–18.5): Ahir, Kachi, Khati, Bhil, Balai, Korku, Kumbhar, Mehra, Panka, Chamar (Jat), Lohar, Sahariya, Koli, Lodha, Lora, and Rawat

Group B (Cormic index = 0.494–0.498; BMI = 18.7–19.2): Kol, Lodhi, Kannar, Kurmi, and Rajput

Group C (Cormic index = 0.498–0.509; BMI = 19.1–19.8): Gujar, Majhi, Kurumbhanshi, Brahmin, Jat, and Kulmi

Other: Oraon, Kaller, Gond, Barala, Sonr, Mahar, Kori, Satnami, Teli, Muslim, and Korwa

Table 2. Coefficient of Variation (CV) of Height, Sitting Height, Weight, Cormic Index, and BMI of 38 Ethnic Groups of Central India

Population	*Sample Size*	*CV of Height*	*CV of Sitting Height*	*CV of Weight*	*CV of Cormic Index*	*CV of BMI*
Bhil	401	3.39	4.15	12.15	3.26	10.83
Gond	904	3.45	4.12	11.18	3.23	9.10
Kol	200	3.56	4.33	10.25	3.21	8.00
Korku	101	3.28	3.03	10.90	3.01	9.35
Korwa	51	4.20	4.08	12.28	2.96	8.30
Majhi	50	3.61	3.68	10.33	2.60	7.68
Oraon	99	3.27	3.41	11.99	2.64	9.20
Sahariya	204	3.66	4.24	11.32	3.18	7.94
Sonr	56	4.38	4.69	12.21	3.20	8.50
Balai	497	3.94	4.67	12.98	3.84	10.92
Chamar (Jat)	1,062	3.70	4.80	12.57	3.84	10.55
Khati	50	3.65	3.74	8.64	2.61	8.01
Koli	50	4.33	3.68	14.12	3.58	10.55
Kori	50	4.17	3.93	12.45	2.77	9.57
Kumbhar	413	3.63	6.48	13.67	5.81	11.42
Mahar	50	4.06	4.01	11.27	3.41	10.80
Mehra	201	3.08	4.33	11.92	3.21	10.90
Satnami	150	3.22	3.97	11.02	2.95	9.94
Ahir	600	3.57	4.17	12.85	3.20	10.65
Barala	51	3.80	4.74	14.90	3.54	12.48
Gujar	100	4.39	5.61	17.45	3.21	13.50
Jat	50	3.92	4.25	14.21	3.15	10.11
Kachi	253	3.36	5.67	10.84	4.80	9.32
Kaller	50	4.16	4.88	15.71	2.84	12.89
Kannar	55	4.50	5.23	15.04	2.63	10.64
Kulmi	50	4.08	4.88	11.96	3.16	9.95
Kurmi	349	3.68	4.12	12.73	3.22	11.39
Kurumbhanshi	51	3.63	3.77	9.92	2.99	8.74
Lodha	51	3.10	3.87	10.04	2.71	9.31
Lodhi	300	3.33	4.31	12.56	3.23	10.64
Lohar	50	3.97	3.78	12.87	3.99	14.04
Lora	56	4.19	5.14	10.88	2.98	7.36
Panka	57	4.12	4.56	10.63	2.82	8.92
Rawat	52	3.49	3.86	10.66	2.92	8.54
Teli	1,156	3.49	4.15	13.65	3.39	11.77
Brahmin	1,114	3.41	3.95	15.00	3.14	13.31
Rajput	701	3.73	4.16	13.99	3.42	11.98
Muslim	1,761	3.46	4.28	14.98	4.17	13.36

Table 3. Analysis of Variance for Cormic Index and BMI

	Comparison	*Sum of Squares*	*Degrees of Freedom*	*Mean Square*	*F*	*Significance*
38 Populations						
Cormic index	Between groups	0.22	37	0.006	17.501	0.000
	Within group	3.97	11,457	0.000		
	Total	4.19	11,494			
BMI	Between groups	618.37	37	70.767	15.484	0.000
	Within group	367.65	11,458	4.570		
	Total	986.03	11,495			
5 Social groups						
Cormic index	Between groups	0.08	4	0.019	53.529	0.000
	Within group	4.12	11,490	0.000		
	Total	4.19	11,494			
BMI	Between groups	1,425.47	4	356.368	76.456	0.000
	Within group	53,560.56	11,491	4.661		
	Total	54,986.03	11,495			

It appears from the classification that the groups do not provide any interesting corroboration with their intra- and intergroup relationships. The mean values of Cormic index, however, do not vary much in these groups (see Table 1).

Norgan (1994) suggested that BMI is correlated with sitting height, that is, that BMI is lower for individuals who have a higher sitting height. The findings of the present study, however, do not support this view. Although the general castes show higher mean BMI with higher mean sitting height, the scheduled castes and scheduled tribes show lower mean BMI with lower mean sitting height (see Table 1). Strickland and Tuffrey (1997) observed lower values of BMI with lower values of the Cormic index in the non-Asian (caste) populations of Nepal.

Table 4. Values of the *t* Statistic and Associated Significance Level[a] of Difference of Means of the Cormic index (Above Diagonal) and BMI (Below Diagonal) for Each Pair of Five Social Groups

	Social Group				
Social Group	*Other Backward Castes*	*Scheduled Tribes*	*Scheduled Castes*	*General Castes*	*Muslims*
Other backward castes	–	6.7 (0.00)	0.4 (0.68)	8.7 (0.00)	6.3 (0.00)
Scheduled tribes	1.7 (0.08)	–	5.4 (0.00)	14.0 (0.00)	11.1 (0.00)
Scheduled castes	9.3 (0.00)	7.2 (0.00)	–	7.7 (0.00)	5.7 (0.00)
General castes	9.1 (0.00)	10.1 (0.00)	16.2 (0.00)	–	1.5 (0.15)
Muslims	4.1 (0.00)	5.3 (0.00)	11.2 (0.00)	3.9 (0.00)	–

a. Level of significance (p value) is given in parentheses.

Table 5. Distribution (%) of BMI in the 38 Ethnic Groups According to Severity of Chronic Energy Deficiency

Population	*CED Grade III (Severe) (BMI < 16.0)*	*CED Grade II (Moderate) (BMI = 16.0–16.99)*	*CED Grade I (Mild) (BMI = 17.0–18.49)*	*Low Weight Normal (BMI = 18.5–19.99)*	*Normal (BMI = 20.0–24.9)*	*Obese Grade I (BMI = 25.0–29.99)*	*Obese Grade II (BMI > 30)*	*Total*
Scheduled tribes	6.82	10.79	33.93	28.65	19.55	0.24	0.00	100
Bhil	10.47	14.46	36.16	22.44	15.71	0.75	0.00	100
Gond	6.31	9.73	34.96	29.98	18.92	0.11	0.00	100
Kol	3.50	8.00	34.50	34.50	19.50	0.00	0.00	100
Korku	8.91	15.84	32.67	22.77	19.80	0.00	0.00	100
Korwa	0.00	1.96	5.88	23.53	66.67	1.96	0.00	100
Majhi	2.00	4.00	18.00	42.00	34.00	0.00	0.00	100
Oraon	2.02	4.04	22.22	31.31	40.40	0.00	0.00	100
Sahariya	7.84	15.69	37.25	30.88	8.33	0.00	0.00	100
Sonr	12.50	10.71	50.00	21.43	5.36	0.00	0.00	100
Scheduled castes	11.34	15.77	33.17	24.06	15.42	0.20	0.04	100
Balai	10.66	18.31	32.39	23.94	14.29	0.40	0.00	100
Chamar (Jat)	12.15	15.63	33.80	23.73	14.60	0.09	0.00	100
Khati	4.00	10.00	48.00	20.00	18.00	0.00	0.00	100
Koli	8.00	12.00	40.00	22.00	18.00	0.00	0.00	100
Kori	12.00	14.00	40.00	24.00	10.00	0.00	0.00	100
Kumbhar	10.90	15.74	30.51	25.67	16.46	0.48	0.24	100
Mahar	22.00	20.00	42.00	10.00	6.00	0.00	0.00	100
Mehra	12.44	16.42	33.33	20.40	17.41	0.00	0.00	100
Satnami	7.33	10.00	26.00	34.00	22.67	0.00	0.00	100

Table 5. (Continued)

Population	*CED Grade III (Severe) (BMI < 16.0)*	*CED Grade II (Moderate) (BMI = 16.0–16.99)*	*CED Grade I (Mild) (BMI = 17.0–18.49)*	*Low Weight Normal (BMI = 18.5–19.99)*	*Normal (BMI = 20.0–24.9)*	*Obese Grade I (BMI = 25.0–29.99)*	*Obese Grade II (BMI > 30)*	*Total*
Other backward castes	6.93	13.30	31.52	26.33	20.74	1.14	0.03	100
Ahir	8.50	14.00	33.50	24.00	19.33	0.67	0.00	100
Barala	7.84	19.61	45.10	15.69	7.84	3.92	0.00	100
Gujar	2.00	10.00	29.00	21.00	34.00	4.00	0.00	100
Jat	0.00	8.00	28.00	34.00	30.00	0.00	0.00	100
Kachi	7.5	114.23	34.78	26.88	16.60	0.00	0.00	100
Kaller	2.00	12.00	30.00	24.00	28.00	4.00	0.00	100
Kannar	0.00	12.73	32.73	36.36	14.55	3.64	0.00	100
Kulmi	4.00	8.00	24.00	34.00	30.00	0.00	0.00	100
Kurmi	4.87	10.89	25.50	31.23	26.07	1.15	0.29	100
Kurumbhanshi	1.96	1.96	31.37	29.41	35.29	0.00	0.00	100
Lodha	3.92	13.73	43.14	19.61	19.61	0.00	0.00	100
Lodhi	6.00	12.00	28.33	27.33	25.67	0.67	0.00	100
Lohar	16.00	22.00	24.00	14.00	24.00	0.00	0.00	100
Lora	1.79	12.50	42.86	26.79	16.07	0.00	0.00	100
Panka	5.26	21.05	45.61	22.81	5.26	0.00	0.00	100
Rawat	5.77	13.46	38.46	30.77	11.54	0.00	0.00	100
Tèli	8.56	14.10	30.80	26.21	18.77	1.56	0.00	100
General castes	5.51	9.86	27.66	25.51	28.26	3.14	0.06	100
Brahmin	5.21	9.69	26.03	23.25	31.78	4.04	0.00	100
Rajput	5.99	10.13	30.24	29.10	22.68	1.71	0.14	100
Muslim	8.52	10.90	28.05	26.24	23.62	2.39	0.28	100
Total	7.90	12.48	31.18	26.10	20.99	1.28	0.07	100.00

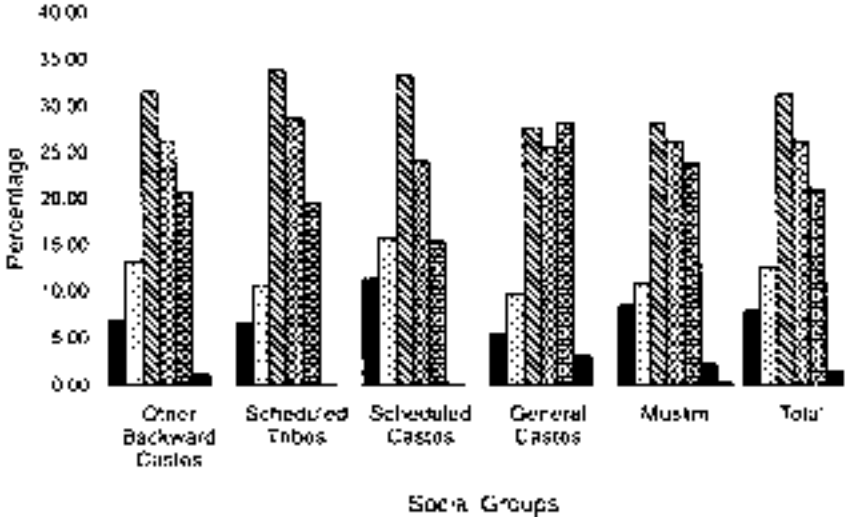

Figure 2. Distribution of BMI among different social groups. There are seven bars for each group, from left to right: CED grade III (severe) (BMI $<$ 16); CED grade II (moderate) (BMI = 16.0–16.99); CED grade I (mild) (BMI = 17.0–18.49); low weight normal (BMI = 18.5–19.99); normal (BMI = 20.0–24.9); obese grade I (BMI = 25.0–29.99); obese grade II (BMI $>$ 30).

In order to understand the relationships between sitting height, height, weight, Cormic index, and BMI of different populations, we have determined the coefficients of correlation in three different ways. The correlation coefficients have been calculated (1) using all 11,496 observations (raw data), (2) using the 38 population means, and (3) using the 5 social groups (Table 6). For the five social groups the averages of the correlation coefficients are reported in the table because the values do not differ much. The results are more or less similar. First, for all 11,496 observations, all the correlation coefficients, except the correlation between height and BMI, were significant at the 5% level. Sample sizes may play some role in determining whether a correlation coefficient is significant or not. Moreover, all these correlation coefficient values are positive, except those between height and Cormic index. The correlations using the 38 population means are not as significant as those using the raw data, although many of these have higher values. However, all the values are positive if significant. In particular, the correlation coefficients between BMI and Cormic index are 0.201 (all observations) and 0.086 (38 population means). In the populations means case the correlation coefficient is not statistically significant at the 5% level. The values for the correlation coefficient between Cormic index and BMI for the five social groups are 0.189, 0.210, 0.183, 0.191, and 0.194 for the other backward castes, scheduled tribes, scheduled castes, general castes, and Muslims, respectively. All these

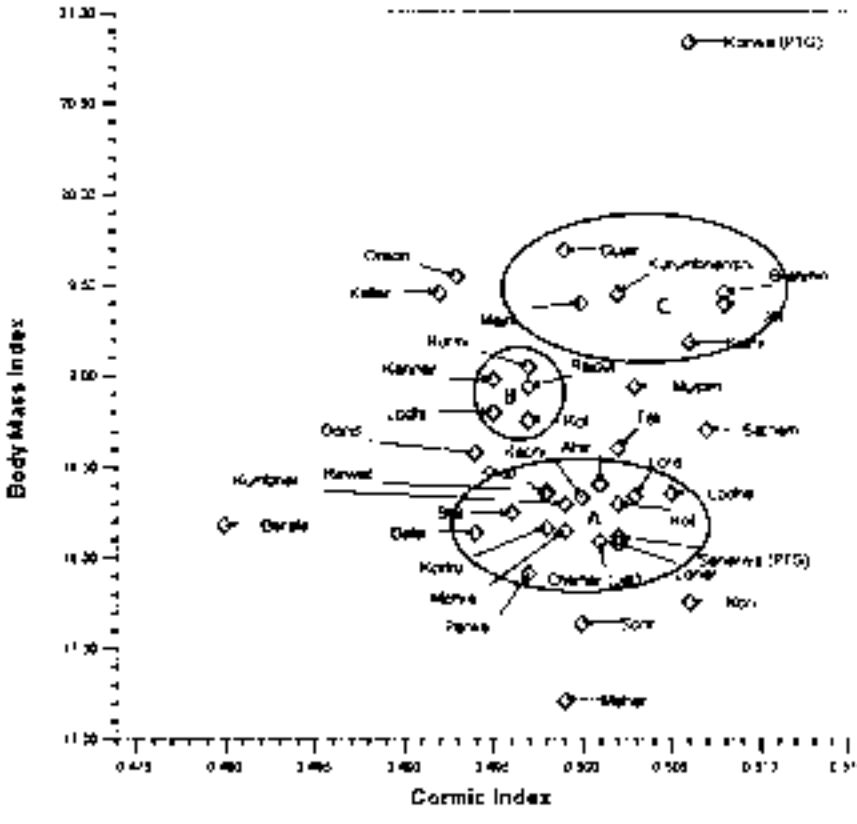

Figure 3. Bivariate scatter diagram of mean values of Cormic index and body mass index of the ethnic populations.

values are significantly different from 0. If we take sitting height and BMI, we find that the correlations are not significant for the case using all 11,496 observations or the 38 population means. However, if we compute the correlations separately for the five social groups, the value for each case is positive and significant. Thus the present findings seem to corroborate the findings of Strickland and Tuffrey (1997).

Shape, size, and generalized distance values between different social groups are furnished in Tables 7–9, respectively. The means of shape and size distances are 0.59 and 0.72 respectively. Moreover, shape distance is greater than size distance in 7 out of 10 cases. Thus the five social groups differ more in shape than in size. On the basis of generalized distances we computed a dendrogram (Figure 4). It appears that there are two distinct clusters, which corroborate the

Table 6. Values of the Correlation Coefficients Among the Different Variables

	Height	*Sitting Height*	*Weight*	*Cormic Index*	*BMI*
Using raw data of all 11,496 individuals					
Height	1.00	0.648[a]	0.532[a]	−0.177[a]	−0.001
Sitting height		1.00	0.483[a]	0.621[a]	0.162[a]
Weight			1.00	0.076[a]	0.843[a]
Cormic index				1.00	0.201[a]
BMI					1.00
Using mean values of the 38 populations					
Height	1.000	0.867[a]	0.700[a]	−0.072	0.060
Sitting height		1.000	0.659[a]	0.441[a]	0.132
Weight			1.000	0.099	0.754[a]
Cormic index				1.000	0.086
BMI				1.000	
Using data separately for 5 social groups					
Height	1.000	0.622[a]	0.452[a]	0.604[a]	0.133[a]
Sitting height		1.000	0.508[a]	−0.224[a]	−0.037
Weight			1.000	0.045	0.837[a]
Cormic index				1.000	0.193[a]
BMI					1.000

a. Significant at at least the 5% level. All five correlation coefficients for the social group comparison are significant at at least the 5% level.

ethnographic background in general. Cluster 1 consists of Muslims and the general castes; cluster 2 consists of the other backward castes, scheduled castes, and scheduled tribes.

According to Ferro-Luzzi et al. (1992), BMI alone is sufficient to define CED in adults. Furthermore, as can be seen from Table 5, most of the individuals fall in the category of CED grade I. The findings of Ferro-Luzzi et al. (1992) on

Table 7. Shape Distance $\left[(m-1)C_Z^2\right]$ Among Social Groups

Social Group	*Other Backward Castes*	*Scheduled Tribes*	*Scheduled Castes*	*General Castes*	*Muslims*
Other backward castes					
Scheduled tribes	0.89				
Scheduled castes	0.05	0.65			
General castes	0.26	1.83	0.42		
Muslims	0.10	1.38	0.19	0.09	

Table 8. Size Distance $\left(mC_Q^2\right)$ Among Social Groups

Social Group	*Other Backward Castes*	*Scheduled Tribes*	*Scheduled Castes*	*General Castes*	*Muslims*
Other backward castes					
Scheduled tribes	0.31				
Scheduled castes	0.23	0.01			
General castes	0.71	1.96	1.74		
Muslims	0.21	1.03	0.88	0.15	

the BMI of South Indian populations thus corroborate the present status among the scheduled tribe and scheduled caste populations of Central India.

A cutoff point for BMI of 18.5 has been taken for most cases in the literature (Bailey and Ferro-Luzzi 1995; Ferro-Luzzi et al. 1992; Shetty and James 1994). The mortality rate is higher in men with a BMI below 16.0 compared with those with a BMI $>$ 18.5 (Reddy 1991). In fact it has become standard practice to take 18.5 as the cutoff point. Shetty and James (1994) are of the opinion that a BMI above 18.5 is compatible with good health among male soldiers and women in the United Kingdom and in individuals belonging to the high socioeconomic class in developing countries. In another report Shetty (1984) mentioned that male Indian laborers with a BMI less than 17.0 are physically fit according to standard texts, although their physical capacity is not known. Satyanarayana et al. (1991) showed that the difference in mortality rates between adult males with CED grade I and normal CED is only about 1% per year, but it increases rapidly when BMI is less than 17. Thus, in view of these findings, it can be said that apparently healthy individuals with CED grade I in the present study may be thin but physically active and healthy. However, further intensive investigation in these populations is called for, because BMI, as a measure of

Table 9. Generalized Distance $\left(D_p^2 = mC_H^2\right)$ Among Social Groups

Social Group	*Other Backward Castes*	*Scheduled Tribes*	*Scheduled Castes*	*General Castes*	*Muslims*
Other backward castes					
Scheduled tribes	1.20				
Scheduled castes	0.28	0.66			
General castes	0.97	3.79	2.16		
Muslims	0.31	2.42	1.06	0.24	

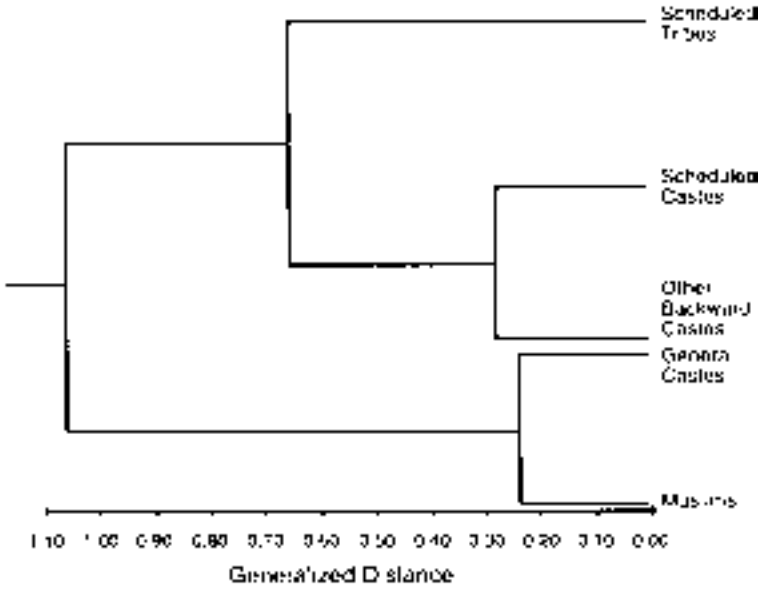

Figure 4. Dendrogram based on generalized distance of five social groups of Central India.

CED, should be analyzed along with other aspects, such as morbidity and health status of a population.

Many observers (Roberts 1953; Newman and Munro 1955; Dobzhansky 1962; Schreider 1968) recognize that a lean linear body build with a low weight to surface area ratio is one of the general characteristics of the people living in tropical and subtropical climates. This may be one of the reasons behind the high number of individuals with CED grade I in most of the populations in Central India.

Received 18 July 2005; revision received 13 March 2006.

Literature Cited

Bailey, K. V., and A. Ferro-Luzzi. 1995. Use of body mass index of adults in assessing individual and community nutritional status. *Bull. WHO* 73(5):673–680.

Basu, A., D. P. Mukherjee, P. C. Dutta et al. 1994. *All India Anthropometric Survey: North Zone Basic Anthropometric Data,* v. 1, *Madhya Pradesh.* Calcutta, India: Anthropological Survey of India.

Bharati, P. 1989. Variation in adult body dimensions in relation to economic condition among the Mahishyas of Howrah district, West Bengal, India. *Ann. Hum. Biol.* 16:529–541.

Dobzhansky, T. 1962. *Mankind Evolving: The Evolution of Human Species.* New Haven, CT: Yale University Press.

Eveleth, P. B., and J. M. Tanner. 1990. *Worldwide Variation in Human Growth*, 2nd ed. Cambridge: Cambridge University Press.

Ferro-Luzzi, A., S. Sette, M. Franklin et al. 1992. A simplified approach of assessing adult chronic energy deficiency. *Eur. J. Clin. Nutr.* 46:173–186.

Ghosh, R., P. K. Das, and P. Bharati. 2001. Health and nutritional status of Ho preschool children of Orissa. *J. Hum. Ecol.* 12:109–113.

James, W. P. T., A. Ferro-Luzzi, and J. C. Waterlow. 1988. Definition of chronic energy deficiency in adults. *Eur. J. Clin. Nutr.* 42:969–981.

Khongsdier, R. 1997. The War Khasi of Meghalya: Implications of variation in adult body dimensions. *J. Hum. Ecol.* 6:299–305.

Khongsdier, R. 2001. Body mass index of adult males in 12 populations of northeast India. *Ann. Hum. Biol.* 28:374–383.

Majumder, P. P., B. U. Shanker, A. Basu et al. 1990. Anthropometric variation in India: A statistical appraisal. *Curr. Anthropol.* 31:94–103.

Mandal, H., A. Datta, P. K. Guha et al. 2005. *India: An Illustrated Atlas of Scheduled Castes.* Kolkata, India: Anthropological Survey of India.

Martin, R., and K. Saller. 1956. *Lehrbuch der Anthropologie*, v. 3. Stuttgart, Germany: Fisher.

Mitra, A. 1985. The nutrition situation in India. In *Nutrition and Development,* M. Biswas and P. Andersen, eds. Oxford: Oxford University Press, 142–162.

Naidu, A. N. 1994. Body mass index: A measure of the nutritional status in Indian population. *Eur. J. Clin. Nutr.* 48(suppl. 3):S131–S140.

Newman, R. W., and S. H. Munro. 1955. The relation of climate and body size in US males. *Am. J. Phys. Anthropol.* 74:385–392.

Norgan, N. G. 1994. Relative sitting height and the interpretation of body mass index. *Ann. Hum. Biol.* 21:79–82.

Pearson, K. 1926. On the coefficient of racial likeness. *Biometrika* 18:105–117.

Penrose, L. S. 1947. Some notes on discrimination. *Ann. Eugen.* 13:228–237.

Penrose, L. S. 1954. Distance, size, and shape. *Ann. Eugen.* 18:337–343.

Reddy, B. R. 1998. Body mass index and its association with socioeconomic and behavioral variables among socioeconomically heterogeneous populations of Andhra Pradesh, India. *Hum. Biol.* 70:901–917.

Reddy, V. 1991. Body mass index and mortality rates. *Nutr. News* (National Institute of Nutrition, Hyderabad), 12(1).

Roberts, D. F. 1953. Body weight, race, and climate. *Am. J. Phys. Anthropol.* 11:533–558.

Rolland-Cachera, M. F. 1993. Body composition during adolescence: Methods, limitations, and determinants. *Hormone Res.* 39(suppl. 3):25–40.

Satyanarayana, K., S. S. Rao, G. Radhiah et al. 1991. Body mass index and mortality rates. *Nutr. Rev.* (National Institute of Nutrition, Hyderabad), 12(1).

Schreider, E. 1968. Ecological rules, body-heat regulation, and human evolution. In *Environments of Man,* J. B. Bresler, ed. Reading, MA: Addison-Wesley, 55–66.

Shetty, P. S. 1984. Adaptive changes in basal metabolic rate and lean body mass in chronic undernutrition. *Hum. Nutr. Clin. Nutr.* 38C:443–451.

Shetty, P. S., and W. P. T. James. 1994. *Body Mass Index: A Measure of Chronic Energy Deficiency in Adults.* Food and Nutrition Paper 56. Rome: Food and Agricultural Organization.

Singh, K. S. 1999. *People of India: National Series II, Scheduled Castes.* Calcutta, India: Oxford University Press.

Strickland, S. S., and V. R. Tuffrey. 1997. *Form and Function: A Study of Nutrition, Adaptation, and Social Inequality in Three Gurung Villages of the Nepal Himalayas*. London: Smith-Gordon.

World Health Organization. 1990. *Diet, Nutrition, and the Prevention of Chronic Disease.* WHO Technical Report Series, no. 797. Geneva: World Health Organization.