NUTRITIONAL STATUS AND PHYSICAL FITNESS OF PYGMY HUNTER-GATHERERS LIVING IN THE AFRICAN RAINFORESTS

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ABSTRACT Pygmy hunter-gatherers living in the tropical rainforests of central Africa have attracted the attention of anthropologists for many decades because they are extremely short in stature. The investigation of their nutritional status and physical fitness can offer important information for the interpreting corresponding data from all human populations; however, quantitative nutritional and physical fitness surveys of Pygmy hunter-gatherers have been limited. The nutritional status of 23 male and 24 female Pygmy hunter-gatherers (Baka) was surveyed, and their physical fitness was examined by performing heart rate measurements at 2 resting positions (sitting and standing) and 2 exercise levels (step-test, 15 and 30 steps/min).

The average stature was intermediate relative to other Pygmy hunter-gatherers, and the participants were generally well nourished. In more than 85% of the participants, the body mass index (BMI; kg/m^2) was within the normal range ($18.5 \le BMI < 25.0$). The results of correlation analyses between anthropometrical indices and physical fitness indicators show that taller and heavier (especially in fat-free mass) subjects were significantly fitter than shorter and lighter subjects. In addition, skinfold thickness and body fat were negatively associated with physical fitness.

Key Words: Pygmy hunter-gatherers; African rainforests; Physical fitness; Nutritional status; Heart rate.

INTRODUCTION

Because Pygmy hunter-gatherers have an extremely small body size among human populations, they have attracted considerable attention from researchers in biological anthropology, medicine, health sciences, and other related fields. Thus far, a relatively large amount of information is available on their body size, such as their height and body weight, while the body composition (e.g., body fat mass and lean body mass) and nutritional status of these populations have rarely been studied (Dietz et al., 1989). This is mainly because of the difficulties inherent in measuring body fat mass and lean body mass in field conditions with very limited availability of electricity and equipment. Although skinfold thickness measurements taken with a skinfold caliper do not require electrical devices, it takes considerable training and practice to master the technique.

It is known that the physical fitness level (e.g., maximal oxygen consumption) of an individual tends to be high when the body size is large. Pygmy hunter-gatherers, however, have evolved and adapted as small-sized. It is therefore important to examine the relation between body size and physical fitness in Pygmy hunter-gatherers from the perspective of human evolution and adaptation. However, such research has been rare (Ghesquiere & Karvonen, 1981; Ferretti et al., 1991).

The purposes of this study are:

1. To assess the nutritional status of adult Pygmy hunter-gatherers by collecting detailed anthropometric measurements focusing on chronic nutritional deficiency. In addition, to evaluate the results by comparison with other Pygmy hunter-gatherer populations reported in previous studies.
2. To determine physical fitness indices by measuring heart rate (HR) at rest (sitting and standing) and exercise (2 levels of step-test) conditions and to examine the relationship between fitness level and nutritional status.

PARTICIPANTS AND METHODS

Study Population and Participants

The Baka are one of the groups of so-called "Pygmies" that dwell in the tropical rainforests across the Central African Republic, Republic of Congo, and Republic of Cameroon. Their population is estimated to number between 30,000 and 40,000 (Althabe, 1965). Details of the study area are provided elsewhere (Sato, 1998; Yamauchi et al., 2000a). We conducted field research on 47 adults (23 males and 24 females) culled from among Pygmy hunter-gatherer married couples dwelling in the southeastern of Cameroon.

Measurements

Anthropometry

Anthropometric dimensions were measured following a standard protocol (Weiner & Lourie, 1981). Stature was measured to the nearest 1 mm by using a field anthropometer (GPM, Switzerland), and weight was measured to the nearest 0.1 kg using a portable digital scale (Tanita model 1597, Japan). Upper arm circumference (UAC) was measured with a measuring tape. Skinfold thickness was measured at the triceps and subscapular sites to the nearest 0.2 mm using skinfold calipers (Holtain, Briberian, UK). All anthropometric measurements were performed by the same investigator (TY). The two-site skinfold equation of Durnin & Womersley (1974) was used in combination with the Siri equation (1956) to estimate body fat percentage (%fat) (Yamauchi et al., 2001a). Body mass index (BMI; kg/m^2) was calculated as body weight (kg)/height (m)^2.

Heart rate (HR) at rest and exercise conditions

HR measurements at resting positions (sitting and standing) and during step-tests were also conducted. During the survey, each participant was asked to perform 2 different step-tests following the authors' instructions in Pidgin French and/or Baka language. The duration of each step-test was 3 minutes and the height of the step was 0.3 m. Each participant stepped up and down at a constant pace of 15 and 30 times per minute, respectively (STP-1 and STP-2). HR was monitored every 15 seconds. The average HR value obtained during the last 1 minute (i.e., average of 4 HRs, 1 per 15 seconds) was used for analysis. HR was continuously monitored after the step-test and the HR at 1 minute after the STP-2 was used as the index of cardiovascular restoration (HR recovery, HRR). We further determined the Flex-HR, which discriminates between resting and exercise HR values (Ceesay et al., 1989; Leonard, 2003), as the mean of the mean HR during standing positions and the HR during STP-1 (Yamauchi et al., 2000b; 2001b).

Physical work capacity at an HR of 150 bpm (PWC150)

Submaximal aerobic power was assessed as an index of physical work capacity at an HR of 150 bpm (PWC150). First, the basal metabolic rate (BMR) was estimated by using the FAO/WHO/UNU equations (1985) based on the participant's body weight, gender, and age group. Second, the energy cost of each step-test was calculated based on the assumption that the net mechanical efficiency (NME) of each step-test was equal to 16% (Yamauchi & Ohtsuka, 2000) on using the following formula:

$$\text{NME (16\%)} = 100 \times \text{Work load (J/min)/Energy cost (J/min)}$$
$$= 100 \times \text{Wt} \times \text{Ht} \times 9.8 \times \text{N}/(\text{EE} - \text{BMR}),$$

where Wt = body weight (kg), Ht = height of steps (m), N = number of ascents/min, EE = energy expenditure of stepping (J/min), and BMR = basal metabolic rate (J/min).

Using each participant's EE vs. HR regression line, the EE at an HR of 150 bpm was calculated and the PWC150 (kpm, 1 kpm = 9.81 Nm) was determined.

In summary, we determined and analyzed 3 physical fitness indices in this study: HRR (HR at 1 minute after STP-2), Flex-HR (HR threshold that discriminates between resting and active conditions), and PWC150 (physical work capacity at an HR of 150 bpm).

RESULTS

Participants' anthropometric characteristics including calculated indices of body composition (BMI and %fat) are shown in Table 1. Men were significantly taller ($P < 0.0001$), heavier ($P < 0.001$), and had a higher fat-free mass (FFM, $P < 0.0001$) compared to women, whereas women had larger skinfold thicknesses (triceps and subscapular) and %fat ($P < 0.0001$ for each index). No sex differences were found in BMI and UAC. The mean BMI was in the "normal" range ($18.5 \leq \text{BMI} < 25.0$, WHO, 2000) for both sexes.

Table 1. Anthropometric characteristics of the adult Baka hunter-gatherers

	Males n = 23		Females n = 24	
	Mean	SD	Mean	SD
Stature (cm)	154.6	5.8	146.6**	4.7
Weight (kg)	49.7	5.8	43.7*	5.2
BMI (kg/m^2)	20.7	1.6	20.5	1.5
Upper arm circumference (cm)	26.0	1.7	25.1	1.6
Skinfold thickness (mm)				
Triceps	5.6	1.0	9.9**	3.3
Subscaplar	9.7	1.8	13.7**	4.0
Body fat (%)[1]	13.3	2.5	24.1**	4.3
Fat-free mass (kg)	43.0	4.5	33.4**	3.8

[1]Estimated by sum of two skinfolds (Durnin & Womersley, 1974; Siri, 1956).
Significant difference between males and females: *P < 0.001, **P < 0.0001.

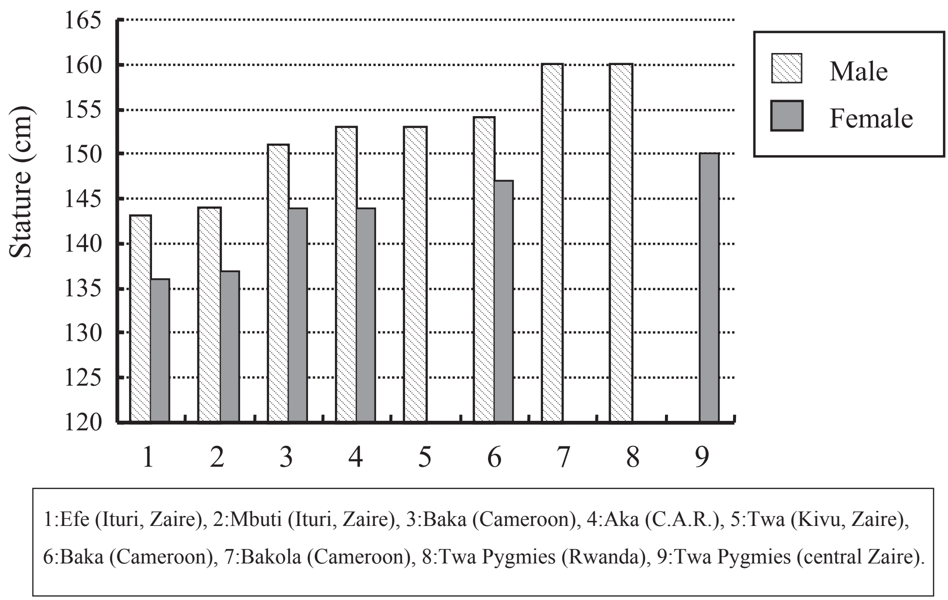

Fig. 1. Mean adult stature of African Pygmy populations.

Population (country), source and sample size (males/females):
1. Efe (Ituri, Zaire): Bailey 1991 (143/136).
2. Mbuti (Ituri, Zaire): Cavalli-Sforza 1986 (144/137).
3. Baka (Cameroon): Kesteloot et al. 1996 (151/144).
4. Aka (C.A.R.): Pennetti et al. 1986 (153/144).
5. Twa (Kivu, Zaire): Ghesquiere & Karvonen 1981 (153/not available).
6. Baka (Cameroon): Yamauchi et al. 2000a (154/147)*.
7. Bakola (Cameroon): Ferretti et al. 1991 (160/not available).
8. Twa Pygmies (Rwanda): Eveleth & Tanner 1976 (160/not available).
9. Twa Pygmies (central Zaire): Pagezy 1978 (not available/150).

*The subject of this study (23/24) are part of Yamauchi et al. 2000a and the mean height of both males and females are identical.

For the assessment of height, the mean height of the participants was compared with the previously reported heights of 8 African Pygmy populations (Fig. 1). The heights of the 9 African Pygmy populations, including the present study, showed considerable variations of 17 cm (range, 143–160 cm) in men and 14 cm (range, 136–150 cm) in women. On the range of heights of the African Pygmy populations, the height of the Baka was in the middle or on the slightly tall side. Among these groups, detailed anthropometric data are only available for the Efe (Dietz et al., 1989). Although the Baka are taller (by 10 cm), heavier (by 5–6 kg), and have larger UAC and skinfold thickness than the Efe, the smallest among the Pygmies, BMI and the %fat are similar between the two (Table 2).

Table 3 shows the means and standard deviations (SD) of HRs at resting positions (sitting and standing) and during exercise (STP-1 and STP-2) as well as calculated physical fitness indices (HHR, Flex-HR, PWC150, and PWC150 adjusted according to body weight [PWC150/BW]) and body temperature by sex. Women had systematically higher values than men for most HR measurements and physical fitness indices. However, no significant difference was found in HRR and PWC150/BW between men and women.

HRs at resting positions and during exercise significantly correlated with anthropometric measurements and body composition indices (Table 4). HR values negatively correlated with height, body weight, FFM, and BMR, and positively correlated with skinfold thickness, %fat, and body temperature. Conversely, PWC150 positively corresponded to height, body weight, FFM, and BMR, and negatively corresponded to skinfold thickness (triceps), %fat, and body temperature. No significant correlation was found between HRR and all anthropometric measurements.

DISCUSSION

Nutritional Status of African Pygmy Populations

According to WHO standards (2000), the mean BMI of the participants was within the ‘normal’ range (18.5 ≤ BMI < 25.0; Table 2). 5 participants (2 men and 3 women) were categorized as ‘underweight’, but their BMIs ranged between 17.9 and 18.4, and they can therefore be classified not as having severe nutritional deficiencies but as having ‘mild thinness’ (17.0 ≤ BMI < 18.5, WHO, 1995). In this regard, James et al. (1988) defined chronic energy deficiency (CED) as a BMI < 18.5 associated with a physical activity level (PAL) < 1.4. In addition, the results of the daily energy expenditure survey showed that PAL was above 1.4 in 3 out of 4 participants who were monitored for energy expenditure (Yamauchi et al., 2000a). Therefore, it is not likely that the 5 participants who had a BMI lower than 18.5 can be classified as ‘CED’. None of the participants were categorized as ‘overweight’ (25 ≤ BMI < 30) or as having ‘obesity’ (BMI ≥ 30).

For both men and women, the mean BMI of the participants was identical to that of the Efe Pygmies (Dietz et al., 1989) (Table 2). Furthermore, Kesteloot et al.

Table 2. Comparison of anthropometric dimensions of Baka with Efe Pygmies

	Male		Female	
	Baka[1]	Efe[2]	Baka	Efe
N	23	26	24	27
Stature (cm)	154.6	144.8	146.6	136.5
Weight (kg)	49.7	43.0	43.7	39.7
BMI (kg/m^2)	20.7	20.5	20.5	21.3
Upper arm circumference (cm)	26.0	20.6	25.1	19.2
Triceps skinfold (mm)	5.6	6.7	9.9	10.4
Subscapular skinfold (mm)	9.7	8.5	13.7	10.3
Body fat (%)	13.3	13.4	24.1	25.0

Source: [1]present study; [2]Dietz et al. (1989).

Table 3. Heart rate indicators and physical fitness indices

	Males (n = 23)		Females (n = 24)	
	Mean	SD	Mean	SD
Heart rate (beat/min)				
Sitting	73.0	9.5	88.1***	13.1
Standing	81.7	10.5	97.2***	14.6
Flex[1]	93.0	9.9	109.2***	14.0
Step test 1	104.3	11.0	121.0***	13.9
Step test 2	140.8	15.9	150.5*	14.2
1st min recovery	48.2	11.6	45.3	10.8
PWC150[2] (kpm/m)	529.5	147.7	410.5*	165.4
PWC150/BW[3] (kpm/m)	10.6	2.4	9.4	3.7
Body temperature (°C)	36.9	0.4	37.3**	0.4
BMR4 (kJ/min)	4.21	0.22	3.40***	0.20

[1]Flex HR = mean of standing HR and step test 1 HR.
[2]Physical working capacity at a heart rate of 150 beat/min.
[3]PWC150 adjusted by body weight.
[4]Estimated by sex, age, and body weight (FAO/WHO/UNU, 1985).
Significant difference between males and females: $*P < 0.05$, $**P < 0.005$, $***P < 0.0001$.

Table 4. Correlations between anthropometric demensions and physical fitness characteristics

	Sitting HR	Standing HR	Flex HR	STP-1 HR	STP-2 HR	HRR	PWC150
Stature	-0.30*	-0.30*	-0.38**	-0.43**	-0.33*	0.15	0.56***
Weight	-0.28	-0.31*	-0.36*	-0.38**	-0.25	0.23	0.54***
BMI	-0.01	-0.10	-0.09	-0.09	0.02	0.20	0.23
Arm C.	-0.14	-0.23	-0.23	-0.21	-0.05	0.12	0.28
Triceps Skinfold	0.51***	0.45**	0.51***	0.54***	0.47**	0.09	-0.40**
Subscap Skinfold	0.37**	0.39**	0.40**	0.37*	0.25	-0.06	-0.18
%fat	0.54***	0.51***	0.55***	0.55***	0.39**	-0.03	-0.36*
FFM	-0.42**	-0.44**	-0.51***	-0.53***	-0.36*	0.19	0.57***
BMR	-0.50***	-0.51***	-0.56***	-0.58***	-0.37**	0.18	0.54***
Body temp.	0.46**	0.39**	0.43**	0.44**	0.35*	-0.08	-0.35*

Significant difference between males and females: $*P<0.05$, $**P<0.005$, $***P<0.0001$.

(1996) also reported that the Baka Pygmies in Cameroon had BMIs in the normal range (20.0 ± 2.4, n = 65 in men and 19.8 ± 3.0, n = 86 in women), although these values are slightly lower than our results (Table 2). It was therefore considered that the nutritional status of the Baka Pygmy population, including the participants of this study, was of a normal level.

Physiological Indicators

Few studies focusing on physiological indicators such as HR and body temperature have been conducted in African Pygmy populations. Austin & Ghesquiere (1976) reported that the mean and SD of the resting HR of adult Batwa Pygmy men was 82.3 ± 13.5 bpm (n = 30), but no detailed information on posture (e.g., lying, sitting, or standing) was provided in the article. Moreover, the data reported were carotid artery pulse measurements obtained by palpation, and thus the accuracy of the data might be poorer than that of data obtained by using an HR monitor. Kesteloot et al. (1996) measured resting HR (sitting position) in the Baka Pygmy and found no significant difference between men (83.1 ± 12.5 bpm, n = 65) and women (83.9 ± 13.0 bpm, n = 86). Compared with the previous study, our results were 10 bpm lower in men but 4 bpm higher in women, and a significant sex difference (women > men) was observed (Table 3).

By contrast, Pagezy (1978) reported resting HRs of 64.05 ± 6.43 bpm in the lying position and 66.26 ± 6.94 bpm in the seated position for 18 adult Twa Pygmy women. The sitting HR was 20 bpm lower than our result. Resting HRs change during the day in relation to the outside temperature (Pagezy, 1978). The above-mentioned sitting HR of the Twa women (66.26 bpm) was obtained at 6 o'clock when the outside temperature was 22.5°C, and the sitting HR increased to 76 bpm at 8 o'clock (26°C) and to 89 bpm at 10 o'clock (31°C) (Pagezy, 1978). The sitting HR for women in this study (88.1 bpm) was almost identical to that of the Twa women at 10 o'clock when the outside temperature was 31°C.

Austin & Ghesquiere (1976), who studied adult Batwa Pygmy men as already mentioned above, reported that the mean and SD of the oral (sublingual) temperature was 37.18 ± 0.28°C, which was almost the same as our armpit (axillary) temperature measurements in Baka Pygmy men (36.9 ± 0.4°C, Table 3). They found a negative correlation between oral temperature and body weight in Batwa Pygmy men (Austin & Ghesquiere, 1976), whereas no significant correlation was found between armpit temperature and body weight in our participants. Meanwhile, the rectal temperature during sleep was significantly correlated with the %fat in a mixed group of Pima Indians and Caucasians (r = 0.30, $P < 0.04$) as well as in a Caucasian group (r = 0.55, $P < 0.005$) (Rising et al., 1995), which is supported by our findings of a significant positive correlation (r = 0.44, $P < 0.005$, n = 47) between armpit temperature and %fat (data not shown). We observed a significant negative correlation (r = –0.42, $P < 0.005$, n = 47) between armpit temperature and BMR, although no such significant correlation was found between rectal temperature and TEE or sleeping EE in Pima Indians (Rising et al., 1995).

The results of this study and those of previous studies suggest that a variety of body temperature measurements such as oral, armpit, and rectal exist, and that attention should be paid when the results of various studies are compared. In addition, body temperature seems to positively correlate with %fat, whereas there is no consensus on the relation between body temperature and body weight or body temperature and energy expenditure. Further studies are required at this point.

Body Composition, HR Indices, and Physical Fitness Level

PWC150, an index of submaximal aerobic power, positively correlated with height, body weight, FFM, and BMR, and negatively correlated with skinfold thicknesses, %fat, and body temperature. The results indicate that those who had less fat mass (more muscle mass) and a larger body size had a higher physical fitness level, whereas those who had more fat mass were at a lower physical fitness level. By contrast, physical fitness indices based on HR negatively correlated with height, body weight, FFM, and BMR, and positively correlated with skinfold thicknesses, %fat, and body temperature. Taken together with the PWC150 results and HR indices, it is suggested that those who had a lower HR tended to be at a higher physical fitness level, whereas those who had a higher HR tended to be at a lower physical fitness level.

These findings are consistent with those of previous studies. Panter-Brick et al. (1996) showed that the Flex-HR provided a good reflection of individual physical fitness levels in Nepalese boys. Furthermore, the study suggested that physical fitness levels were reflected not only by the Flex-HR, but also by resting HR (lying, sitting and standing) and the HR obtained during a step-test, with those who had lower HRs having higher physical fitness levels than those who had higher HRs. In addition, Katzmarzyk et al. (1994) reported that among indigenous Siberian populations, village dwelling groups who had a low physical fitness level had a significantly lower Flex-HR than those who had a high physical fitness level (Brigade). These results suggest that individual physical fitness levels can be assessed by HR indices such as the Flex-HR, resting HR, and exercise HR. Based on these results, it can be concluded that individuals with low HR values tend to have higher physical fitness levels.

In contrast to our findings regarding aerobic power (PWC150) and the HR index (Flex-HR) in this study, we found no significant correlations between cardiovascular fitness (HRR) and anthropometric measurements, BMR, or body temperature. A possible reason for this is that because the participants were not obese and generally may have had higher levels of physical fitness due to traditional lifestyles, they were able to recover their HR values within 1 minute. In fact, HR values at 1 minute after the STP-2 were 93 bpm in men and 105 bpm in women (Table 3), which were almost equal to the Flex-HR values for each sex. The results suggest that participants' HRs recovered to the upper limit of the resting HR at 1 minute after the step-test. These findings suggest that in order to utilize the HRR as an efficient indicator of physical fitness, the load of the step-test should be increased (e.g., by using a step with a taller height and/or faster pace of climbing up and down) and HR values should be measured at less than 1 minute after exercise (e.g., 30 seconds).

CONCLUSIONS

We conducted anthropometry (body measurements) and HR measurements at resting conditions (sitting and standing) and during exercise (2 levels of step-tests) for 47 adult Baka Pygmy hunter-gatherers living in the southeastern of Cameroon. The average stature was intermediate relative to other Pygmy hunter-gatherers. The nutritional status was generally good and chronic energy deficiency was not observed. We also examined the relationships between physical fitness indices and body size and composition and found that those who had a large body size, small fat mass, and low body temperature tended to have high physical fitness levels. Further studies are needed to improve our understanding of the nutritional status and physical fitness of Pygmy hunter-gatherers, for example, studies that not only measure HR but also measure energy expenditure at resting positions and during exercise via indirect calorimetry (expired gas analyses).

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