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Basal metabolic rate and energy costs at rest and during exercise in rural- and urban-dwelling Papua New Guinea Highlanders

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Objective: (1) To evaluate inter-individual variations, regional and sex differences in the basal metabolic rate (BMR) and related variables; (2) to compare measured BMR with estimated BMR using predictive equations; and (3) to examine the net mechanical efficiency (NME) in step tests.
Design: BMR and energy costs at rest and during step tests were measured by the Douglas bag technique of indirect calorimetry. NME was calculated from BMR and energy costs of step tests.
Setting: Rural villages under subsistence agriculture and urban settlements under cash economy.
Subjects: Adult males and females ($n = 33$) including 16 rural villagers and 17 urban migrants.
Interventions: Step exercise test.
Results: There were significant regional differences in BMR (per body weight) in both sexes. The BMR predicted by Schofield equation correlated with the measured BMR (− 1 to + 3%), while the BMR predicted by Henry and Rees equations under-estimated the measured BMR by 6 − 11%. NME was higher in urban subjects with larger body size than in rural subjects for both sexes, albeit insignificantly. NME tended to be higher with increased stepping level in both sexes.
Conclusions: Urban migrants had lower BMR than rural dwellers, and the BMR predicted by Schofield equation correlated with the measured BMR in both sub-groups.
Sponsorship: The United Nations University Project on People, Land Management and Environmental Change.
Descriptors: basal metabolic rate; resting metabolic rate; step test; net mechanical efficiency; Papua New Guinea; rural and urban comparison
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Introduction

The FAO/WHO/UNU Expert Consultation (1985) adopted the principle of relying on estimates of energy expenditure to assess the energy requirements of adults. Basal metabolic rate (BMR) constitutes between 60 and 70% of the total energy expenditure (TEE). The average daily energy expenditure may also be estimated from the BMR, multiplied by an appropriate activity factor, which is dependent on the degree and duration of physical activity. Therefore, accurate measurement of BMR is important for the estimation of daily energy requirement based on TEE.

The BMR of adults can also be predicted with reasonable accuracy (ie with a coefficient of variation of 8%) from predictive equations (Shetty *et al*, 1996). However, the Schofield (1985) equations adopted for international use (FAO/WHO/UNU, 1985) often over-predict the BMR in a number of non-Western populations (Henry & Rees, 1991; Hayter & Henry, 1993; Shetty *et al*, 1996). There are also equations for the prediction of BMR in tropical populations (Henry & Rees, 1991), but few Melanesian populations are included in the database used by Henry and Rees (1991). These results point to differences in BMR among different ethnic groups. However, while some studies have shown a lower BMR in tropical and subtropical populations (Schofield, 1985; Henry & Rees, 1991), others have shown no differences between Indians and Europeans (Soares *et al*, 1993; Shetty *et al*, 1996). Furthermore, the influence of modernization or urbanization on BMR has not been examined thoroughly. Most studies that measured BMR were conducted in laboratories in industrialized and developed countries. To our knowledge, there are only limited studies that have reported measurement of BMR in traditional populations, probably due to difficult field conditions such as the lack of electricity.

The objectives of this study were firstly to employ indirect calorimetry (Douglas bag method) in Papua New Guinea Highlands to measure basal, resting and exercise energy expenditures in two adult populations (rural dwellers and urban migrants) of the Huli speaking people. We then compared these three different energy expenditure variables with the data of previous studies in other populations in order to evaluate inter-individual variations, regional differences (rural *vs* urban) and sex differences (males *vs* females). Secondly, it was intended to compare the measured BMR with estimated BMR using predictive equations (Schofield, 1985; Henry & Rees, 1991); and thirdly to determine the net mechanical efficiency (NME) in stepping exercise.

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Materials and methods

Study population
The Huli, one of the largest language groups in Papua New Guinea (PNG), inhabit the Tari basin, located 1600 m above sea level, between 142°70′ and 143°30′ east longitude and between 5°70′ and 6°20′ south latitude in the central part of Southern Highlands Province, Papua New Guinea. They heavily depend on sweet potato cultivation and pig raising for subsistence. Details of the villages are given elsewhere (Kuchikura, 1999; Umezaki *et al*, 1999). Migration of the highlanders, including the Huli, to Port Moresby, the capital city of PNG, has progressively increased since the 1970s, particularly at the time of independence of PNG in 1975. Migrants from rural villages established settlements in Port Moresby, by ethnic groups. Most of them have not been able to obtain jobs in a formal sector, and thus have depended for their livelihood on income from 'informal sector'-based jobs such as collection of empty bottles and selling of betel nuts, cigarettes and cooked meat in markets or settlements.

Subjects
Basal metabolic rate (BMR) and energy costs at rest and during step tests were measured in rural and urban populations of the Huli. Adult males and females ($n = 33$) were selected as the subjects of this study and included 16 villagers (nine males and seven females) from two rural villages in Tari basin, and 17 (nine males and eight females) from two urban settlements in Port Moresby. The urban subjects were born and always lived in their homeland in the Tari basin. Subjects were selected non-randomly and cases with obvious disfigurement, ill health and pregnant women were excluded. Because rural subjects did not know their exact age, their ages were determined from the census data of PNGIMR (Papua New Guinea Institute of Medical Research) Tari branch, and estimated through interviews by one of the authors (TY) when the census data were not available (Yamauchi *et al*, 2000).

Anthropometry
Anthropometric dimensions were measured following standard protocol (Weiner & Lourie, 1981). Stature was measured to the nearest 1 mm 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). Skinfold thickness was measured at the triceps, biceps, subscapular and suprailiac sites, to the nearest 0.2 mm, using Holtain skinfold calipers (Holtain, Briberian, UK). All anthropometric measurements were performed by the same investigator (TY). The four-site skinfold equation of Durnin and Womersley (1974) was used in combination with the equation of Siri (1956) to estimate body fat percentage. Body mass index (BMI; kg/m^2) was calculated as body weight (kg)/height $(m)^2$.

Basal metabolic rate (BMR)
BMR was measured using open-circuit indirect calorimetry with the Douglas bag technique (Douglas, 1911). On the previous day to the measurement, subjects were transported to the lodges used as laboratories near the villages and settlements. Subjects were familiarized with experimental procedures before the day of measurement. On the following day, the measurement was done between 06:00 and 07:00, 10–12 h after the last meal. While the subject was lying quietly on a bed with a blanket, a Rudorufu mask was attached and, after 10 min of stabilization, expired air was collected for 10 min.

Energy expenditure at rest and during step-tests
For each subject, energy expenditure (EE) and heart rate (HR) were measured for three resting positions (lying, sitting and standing) and three exercise levels. The exercise data were collected while the subject performed a standard step test. The steps used were a 30 cm block for men and a 21.5 cm block for women. Stepping exercises were conducted by each subject in three exercise levels: 15, 22.5 and 30 steps/min. For both the resting and exercising conditions, HR was measured continuously via a portable HR monitor (Polar Vantage XL HR monitor; Polar Electro, Kempele, Finland). Energy expenditure was measured using indirect calorimetry, similar to BMR. Expired air samples were collected for 5 min under resting conditions and during the final minute of each 3 min exercise. Resting metabolic rate (RMR) was calculated as the mean of EE values for lying, sitting and standing.

Measuring energy expenditure
A galvanic cell oxygen and carbon dioxide monitor (METS-900, Vise Medical, Japan) was used to determine the oxygen and CO_2 contents of the expired air. The O_2/CO_2 monitor was calibrated with precalibrated gas from tanks containing 16% O_2 and 5% CO_2, and pure N_2 gas to ensure accurate measurements. The volume of expired air was determined using a dry gas volume meter (WFMU-5100, Vise Medical, Japan) and converted to standard temperature and pressure and dry gas (STPD). The energy values were calculated using the equation of Elia and Livesey (1992):

$$\text{Energy expenditure (kJ)} = 15.82 \times O_2\ (l) + 5.18 \times CO_2\ (l).$$

Net mechanical efficiency of step-tests
Energy costs of the step test were used to calculate the net mechanical efficiency (NME) of stepping for each subject. The mechanical efficiency reflects the amount of work performed as a percentage of the metabolic cost associated with the task. NME was calculated as:

$$\begin{aligned}\text{NME (\%)} &= 100 \times \text{work load (J/min)/energy cost (J/min)}\\ &= 100 \times \text{wt} \times \text{ht} \times 9.8 \times N/(\text{EE} - \text{BMR})\end{aligned}$$

where wt = body weight (kg), ht = height of steps (m), N = number of ascents/min, EE = energy expenditure of exercise level (J/min) and BMR = basal metabolic rate (J/min).

Statistical analysis
Data were expressed as mean ± s.d. Differences between groups were examined for statistical significance using Student's *t*-test. A P value < 0.05 denoted the presence of a significant statistical difference. The method of Bland and Altman (1986) was used to compare between measured BMR and predicted BMR.

Results

Anthropometry
Table 1 shows the anthropometric measures for rural and urban men and women. Urban men and women were significantly younger than their rural counterparts ($P < 0.005$ for males and $P < 0.05$ for females). This reflects the fact that urban migrants consisted mostly of young single men, or young married couples and their children. Rural subjects were shorter than their urban counterparts, with the differences being significant for men ($P < 0.005$), but not for women. Rural subjects were also lighter than their urban counterparts, with the differences being significant for men ($P < 0.05$) and for women ($P < 0.0005$). Urban women were even heavier than rural men, with the difference being 4.0 kg on average. Similarly, the BMI of urban women was significantly greater than that of rural women ($P < 0.001$), although it was similar in rural and urban men (Table 1).

Differences in the sum of skinfold thickness and body fat were also evident between rural and urban inhabitants (Table 1). Rural subjects were significantly lower in sum of skinfolds ($P < 0.05$ in males and $P < 0.005$ in females) than their urban counterparts. The difference was particularly evident in women. The sum of skinfolds in urban women was twice that in rural women. Also rural women had significantly lower body fat ($P < 0.005$) than their urban counterparts, but this was not significant in men.

Basal, resting and stepping energy expenditures
Table 2 shows basal and resting energy costs for men and women of the rural and urban subjects expressed per kilogram body weight. A significantly higher BMR was noted in rural than urban subjects in both males and females ($P < 0.05$ for males and $P < 0.0001$ for females). When adjusted for estimated fat-free mass (FFM), calculated from body fat (%), the difference disappeared in women but not in men. On the other hand, in resting conditions (ie lying EE, sitting EE, standing EE and RMR), rural women had significantly higher EE values than urban counterparts; however, in men, significant difference was found only in standing EE. When adjusted for estimated FFM, all these differences disappeared both in women and men. Moreover, there were no significant gender differences in both rural and urban groups in BMR and any of the resting conditions.

Table 3 presents the measured BMR, two estimated BMRs (from the Schofield (1985) and Henry and Rees (1991) equations), and differences between measured and estimated values (%). The Schofield-derived BMR was similar to the measured BMR, with the difference being within 3%. However, the Henry and Rees BMR significantly underestimated the measured BMR with a difference ranging from 6 to 11%.

Figure 1 is a plot of the differences in BMR (between measured and estimated) against the average measurement according to Bland and Altman (1986). All the estimated BMR by both Schofield and Henry and Rees fell within 2 s.d. of the mean difference ($x \pm 2$ s.d. $= -0.01 \pm 0.84$ in Schofield; 0.51 ± 0.43 in Henry and Rees). In Schofield *vs* measured BMRs (Figure 1A), there was no significant bias between the methods and the slope was not significant; however, in Henry and Rees *vs* measured BMRs (Figure 1B), there was a significant relationship between the difference and average ($P < 0.001$).

Physical activity rate (PAR) and net mechanical efficiency (NME) of step tests
The physical activity rate (PAR = EE/BMR) at each stepping level for the rural and urban samples in both

Table 1 Anthropometric characteristics of the subjects

	n	*Age (y)*	*Weight (kg)*	*Height (m)*	*BMI*[a]	*∑4 skf (mm)*[b]	*Body fat (%)*[c]
Males							
Rural	9	41 ± 7	59.1 ± 6.1	1.57 ± 0.05	23.8 ± 1.8	24.0 ± 4.3	14.2 ± 2.4
Urban	9	29 ± 8	68.1 ± 7.5	1.63 ± 0.08	25.4 ± 2.6	34.3 ± 12.6	15.2 ± 4.2
P		< 0.005	< 0.05	< 0.005	n.s	< 0.05	n.s.
Females							
Rural	7	37 ± 4	46.3 ± 4.1	1.47 ± 0.04	21.4 ± 2.0	29.9 ± 9.7	22.2 ± 4.1
Urban	8	28 ± 6	63.1 ± 8.6	1.52 ± 0.05	27.4 ± 3.1	66.4 ± 21.9	30.8 ± 4.8
P		< 0.05	< 0.0005	n.s.	< 0.001	< 0.005	< 0.005

Values expressed as mean ± s.d.
[a]Body mass index. [b]Sum of four skinfolds: triceps, biceps, subscaplar and superiliac. [c]Estimated by sum of four skinfolds (Durnin & Womersley, 1974; and Siri, 1956).

Table 2 Basal metabolic rate and energy costs of resting positions of the subjects

		BMR		*Lying EE*	*Sitting EE*	*Standing EE*	*RMR*[a]
	n	*(kJ/kg/day)*	*(J/kg/min)*	*(J/kg/min)*	*(J/kg/min)*	*(J/kg/min)*	*(J/kg/min)*
Males							
Rural	9	112.1 ± 8.1	77.8 ± 5.6	102.1 ± 10.4	102.1 ± 10.1	121.0 ± 11.0	108.4 ± 10.4
Urban	9	101.9 ± 8.6	70.8 ± 6.0	91.7 ± 11.3	92.7 ± 12.2	107.5 ± 14.9	97.3 ± 12.6
P		< 0.05	< 0.05	n.s.	n.s.	< 0.05	n.s.
Females							
Rural	7	109.2 ± 2.8	75.8 ± 1.9	101.4 ± 7.6	102.7 ± 5.2	125.1 ± 6.7	109.8 ± 6.0
Urban	8	95.7 ± 5.1	66.5 ± 3.5	89.1 ± 6.6	89.3 ± 9.2	107.3 ± 9.9	95.2 ± 6.7
P		< 0.0001	< 0.0001	< 0.001	< 0.005	< 0.005	< 0.001

Values expressed as mean ± s.d.
[a]RMR calculated as the mean energy cost of the three resting positions (lying, sitting and standing).

Table 3 Comparison of measured and estimated basal metabolic rate

	n	*Measured BMR (MJ/day)*	*Schofield BMR (MJ/day)*	*Henry and Rees BMR (MJ/day)*	*Schofield difference*[a] *(%)*	*Henry and Rees difference (%)*
Males						
Rural	9	6.61 ± 0.65	6.54 ± 0.30	5.88 ± 0.28	− 0.5 ± 6.7	− 10.5 ± 6.0
Urban	9	6.91 ± 0.64	7.09 ± 0.41	6.46 ± 0.38	3.0 ± 6.8	− 6.1 ± 6.0
Females						
Rural	7	5.05 ± 0.43	5.09 ± 0.24	4.70 ± 0.20	1.2 ± 6.6	− 6.5 ± 4.3
Urban	8	6.04 ± 0.84	5.94 ± 0.48	5.55 ± 0.44	− 0.8 ± 6.9	− 7.3 ± 6.4

Values expressed as mean ± s.d.
[a]Estimated BMR − measured BMR.

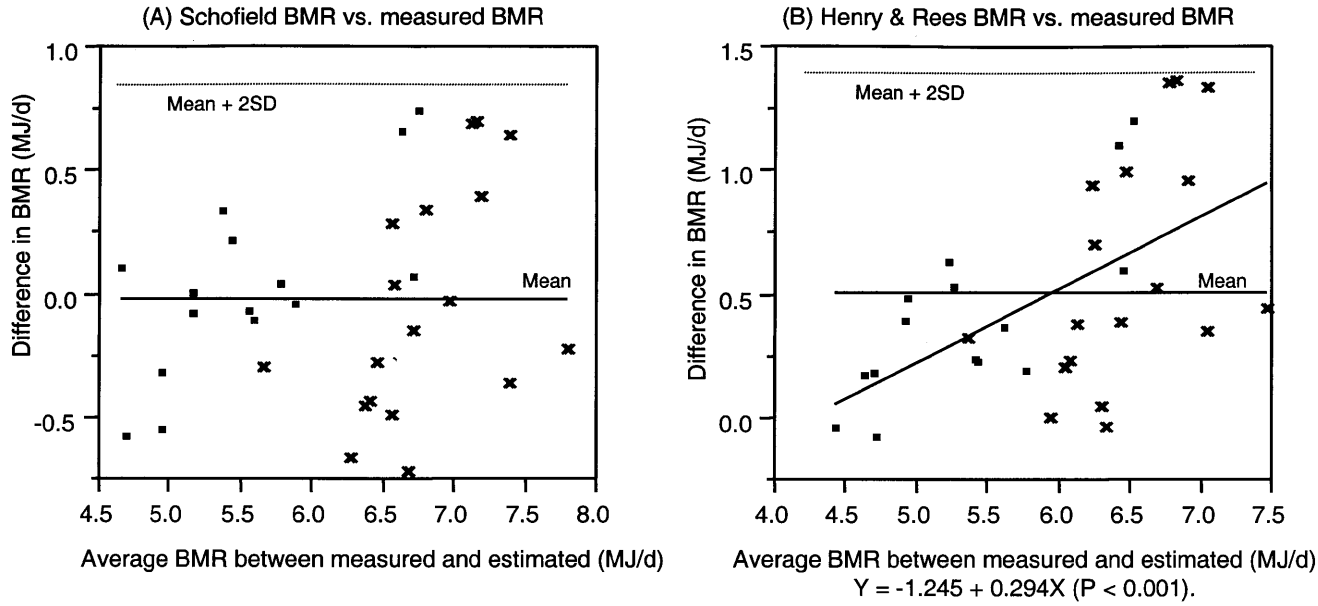

Figure 1 Differences between basal metabolic rate (BMR, measured − estimated) and mean BMR between measured and estimated. Males (×) females (■).

sexes are presented in Figure 2. Energy costs were higher in men than women at each stepping level in both rural and urban samples. This reflected the fact that men used higher steps than women (30 cm for men compared with 21.5 cm for women), and consequently, the workload was higher in men than in women. Significant regional differences were found only in level 2 (22.5 ascents/min) in men (5.9 in rural men *vs* 7.5 in urban men, $P < 0.05$).

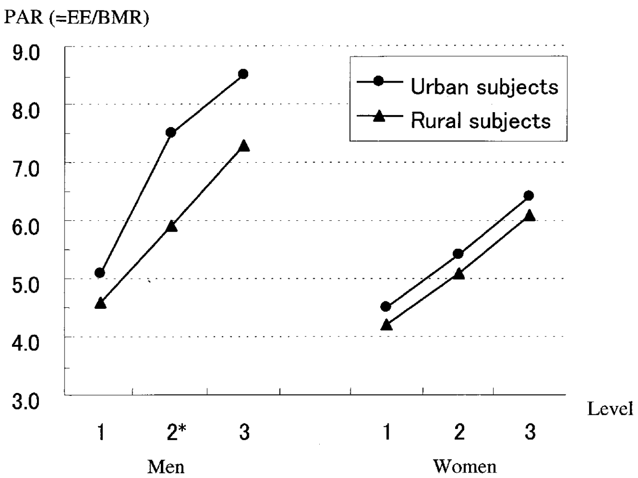

Figure 2 Physical activity rate (PAR) of the three levels of the step test. *$P < 0.05$.

The NME of stepping is presented in Table 4. At each stepping level, the NME tended to be higher in urban than in rural subjects for both sexes, but not in level 2 in men. This regional difference of NME was strong in female subjects. However, no significant difference was found between rural and urban subjects in both sexes at each stepping level. In addition, NME values tended to be higher with increased stepping levels in both sexes, except for urban males.

Discussion

Inter-individual variations of BMR

Shetty *et al* (1996) reviewed a number of studies and reported that the inter-individual coefficient of variation (CV) of BMR ranged from 8 to 13%. The inter-individual CVs of BMR in the present study are similar to those of previous studies: 9.8 and 9.3% in rural males and females, and 8.5 and 13.9% in urban males and females. Furthermore, the inter-individual CV of BMR decreased when body weight was controlled (7.2 *vs* 9.8% in rural males, 8.4 *vs* 9.3% in rural females, 2.6 *vs* 8.5% in urban males, and

Table 4 Net mechanical efficiency (NME) for step tests

	n	*Level*[a] *1*	*Level 2*	*Level 3*
Males				
Rural	9	15.2 ± 3.5	16.0 ± 3.1	16.8 ± 3.4
Urban	9	16.5 ± 2.3	15.4 ± 1.7	18.0 ± 3.2
P		n.s.	n.s.	n.s.
Females				
Rural	7	12.7 ± 1.6	14.7 ± 2.8	16.0 ± 2.3
Urban	8	15.2 ± 5.3	16.7 ± 3.2	17.6 ± 2.2
P		n.s.	n.s.	n.s.

Values expressed as mean ± s.d.
[a]Rates of stepping: 15, 22.5 and 30/min, respectively.

5.3 *vs* 13.9% in urban females). These findings suggest that inter-individual CV of BMR is reflected in the CV of the body weight, since the latter contributes substantially to the BMR of an individual.

Comparison with previous studies

Although the measurement of BMR is theoretically simple, it can be difficult to do (Ulijaszek, 1995). Studies on measurement of BMR have been limited, especially under field conditions. In Papua New Guinea, only a few studies have been conducted in adult males living near a highland town (Mount Hagen), male students of a medical college in Port Moresby (Hipsley, 1969), and adult males living near a highland town (Goroka; Koishi, 1990). The results of these two studies and those of Norgan *et al* (1974) measuring RMR of highland and island people are summarized with the present findings in Table 5.

Our results of BMR and EE in the resting position were comparable to those of previous studies on PNG highlanders (Hipsley, 1969; Norgan *et al*, 1974; Koishi, 1990). The present study showed that energy expenditure tended to be higher in rural men and women than in their urban counterparts. The same observation was reported by Norgan *et al* (1974) between highlanders and islanders; energy expenditure was higher in highlanders than in islanders of both sexes. Furthermore, Katzmarzyk *et al* (1994) demonstrated high resting metabolic costs in subsistence-level populations (ie Nepal, Upper Volta, PNG and Siberia), and Katzmarzyk *et al* (1996) suggested that these changes were due to the influence of thermal stress. In our study, the average temperatures at the time of measurement were 19.2 and 28.1°C for rural and urban areas, respectively. Therefore, it is possible that the observed differences in BMR between the two groups reflected the influence of thermal stress.

According to FAO/WHO/UNU (1985), with adults less than 60 y old the effect of age is relatively unimportant, since at a given weight the BMR decreases by only about 1% per decade. Therefore, it is not likely that the difference in BMR was due to the difference of age between rural and urban subjects.

Evaluation of predictive equations of BMR

The BMR values predicted by Schofield equations closely correlated with the measured BMR in the present study (− 1 to + 3%), while those predicted by Henry and Rees equations were 6 − 11% less than the actual values (Table 3). There are two possible reasons for the underestimated BMR by the Henry and Rees equations. The first is climate influence on BMR, especially ambient temperatures. The rural subjects live in the highlands at 1600 − 1900 m above sea level where the temperature ranges from 13 to 24°C. Thus, this population is not truly tropical in terms of climate. Similar to the rural subjects, urban subjects living in Port Moresby were born and lived in their homeland in PNG highlands. The average length of living in Port Moresby was 9.9 y (range, 1 − 24) for males and 9.4 y (1 − 22) for females. In addition to this, the average ages of these individuals when they migrated to Port Moresby were 19.4 and 18.9 y for males and females, respectively. Thus, the urban subjects could not be truly considered a tropical population. Therefore, in this study, the Henry and Rees equations, which were formulated for tropical populations, could not accurately predict BMR for either rural or even for urban subjects compared with the Schofield equations.

The second explanation is ethnic differences in BMR; it is possible that the BMR in Melanesian populations is relatively higher than other tropical populations. Indeed, it has been reported that the BMR of tropical and subtropical populations (eg Filipinos, Indians, Japanese, Brazilians, Chinese, Malayans and Javanese) is about 10% lower than that in Europeans (Schofield, 1985; Henry & Rees, 1991). However, in contrast to these earlier reports of low BMR in tropical populations, recent studies have shown no differences in BMR between Indians and Europeans (Shetty *et al*, 1996). The ethnic variability in

Table 5 Basal metabolic rate and resting metabolic rate in Papua New Guinea populations

Population	*n*	*Weight (kg)*	*BMR (J/kg/min)*	*Lying EE (J/kg/min)*	*Sitting EE (J/kg/min)*	*Standing EE (J/kg/min)*	*RMR*[a] *(J/kg/min)*
Hipsley (1969)							
Mt Hagen men (rural highland)	17	60.1	81.6 ± 9.1	—	—	—	—
Medical college men (urban)	7	58.6	65.5 ± 9.0	—	—	—	—
Norgen et al. (1974)							
Lufa men (rural highland)	32 − 34	57.5	—	93.3	99.1	107.1	99.8
Lufa women (rural highland)	29 − 31	50.5	—	92.1	100.4	107.0	99.8
Kaul men (rural island)	40 − 42	56.3	—	84.8	91.5	98.2	91.5
Kaul women (rural island)	41	48.1	—	89.7	94.1	103.7	95.8
Koishi (1990)							
Beha men (rural highland)	11 − 41	61.5 ± 4.8	71.5 ± 6.9	—	—	—	—
Present study							
Huli men (rural highland)	9	59.1 ± 6.1	77.8 ± 5.6	102.1 ± 10.4	102.1 ± 10.1	121.0 ± 11.0	108.4 ± 10.4
Huli women (rural highland)	7	46.3 ± 4.1	75.8 ± 1.9	101.4 ± 7.6	102.7 ± 5.2	125.1 ± 6.7	109.8 ± 6.0
Huli men (urban)	9	68.1 ± 7.5	70.8 ± 6.0	91.7 ± 11.3	92.7 ± 12.2	107.5 ± 14.9	97.3 ± 12.6
Huli women (urban)	8	63.1 ± 8.6	66.5 ± 3.5	89.1 ± 6.6	89.3 ± 9.2	107.3 ± 9.9	95.2 ± 6.7

[a]RMR calculated as the mean energy cost of the three resting positions (lying, sitting and standing).

BMR is still a controversial issue (Norgan, 1996). Since there is only limited information on BMR for Melanesian populations, further discussion is not possible until such data become available.

Net mechanical efficiency of step tests

WHO adopts 16% as the NME of stepping based on the studies conducted by Shepard (1967) and Shepard *et al* (1968) that measured the NME of stepping in laboratory (Anderson *et al*, 1971). Also, the NME of stepping in the present study were comparable with those described by Katzmarzyk *et al* (1996), who reviewed nine subsistence-level populations and reported that most of the NME of stepping were close to the figure of 16%. This indicates the NME of stepping is almost constant for different ethnic groups.

Norgan (1996) has stated that the NME of standardized exercise tasks, such as walking, cycling or stepping is quite constant between groups, and is affected by intensity and body size, small being more efficient, according to some investigators (Berry *et al*, 1993) but not others (American College of Sport Medicine, 1991). As shown in Table 4, at each stepping level, the NME tended to be higher in urban subjects with larger body size than in rural subjects for both sexes and the NME values tended to be higher in both sexes as the stepping level increased. Furthermore, the difference was more evident in women with a larger difference in body weight than in men. Thus, the results of this study suggest that NME of stepping exercise is considered to be dependent on body weight.

In conclusion, this study found significant regional differences in per body weight BMR in two sub-populations of Huli speaking people in PNG highlands; the BMR of rural dwellers was significantly higher than in urban migrants. This difference might reflect differences in thermal stress due to ambient temperatures, as suggested in other recent studies. Furthermore, the BMR predicted by the Schofield equations correlated well with the measured BMR (-1 to $+3\%$), whereas the BMR predicted by the Henry and Rees equations underestimated the measured value by 6–11%. One of the reasons for these differences is that our study population is not truly representative of a tropical but rather a temperate climate. The sources of bias in NME of stepping remain unclear, but may include the intensity of stepping rate and body size of the subject. Additional research is needed to identify those sources of bias in NME, the mechanism underlying ethnic differences in BMR and climate influence (ie ambient temperature) on BMR.

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