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Physical activity ratio of selected activities in Indian male and female subjects and its relationship with body mass index

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The physical activity level of an individual can be determined by assigning physical activity ratios (PAR) to different activities. The PAR is the ratio of the energy expended in a particular activity and the BMR, and is thought to be independent of body weight. PAR values of selected activities in Indian male and female subjects were measured and their association with BMI was assessed. The BMR and energy cost of selected activities were measured in thirty male and thirty female subjects in the age group of 20–40 years, who were categorised into different groups of BMI. The PAR values of the underweight male subjects were significantly lower than the overweight subjects for activities such as walking at 3·2 and 4·8 km/h and walking at 3·2 km/h with a 5 kg load. In the female subjects, the underweight subjects had significantly lower PAR values for floor swabbing, and walking at 3·2 and 4·8 km/h when compared with overweight females. The mean data of the male and female subjects of the present study were slightly but significantly different to the previously reported FAO, WHO and United Nations University values and other compilations. The BMI was significantly correlated with the PAR value of the studied activities. In India, where a large proportion of the population have BMI below 18·5 and above 25 kg/m^2, considerations of the influence of body weight and BMI on PAR become important in accurately determining total energy expenditure.

Physical activity ratio: Body mass index: Indians

The measurement of total daily energy expenditure is an important aspect of the assessment of human health and nutrition. The determination of total energy expenditure (TEE) has gained further importance, with the Joint Consultation of the FAO, WHO and United Nations University (UNU) (Food and Agriculture Organization, 1985, 2004) adopting the method of quantifying energy requirements in terms of energy expenditure rather than energy intake.

TEE can be determined as the product of the BMR and the physical activity level (PAL). While the BMR can either be measured or be predicted from body weight (Food and Agriculture Organization, 1985, 2004), the PAL can be determined by questionnaires. These methods seek to define activity patterns during the day; the PAL can be calculated by assigning physical activity ratios (PAR) to these activities. The PAR is the ratio that expresses the energy cost of an individual activity per min, as multiples of BMR (James & Schofield, 1990). The PAR of activities can be obtained either by direct measurements or from data in the published literature. Published data on the PAR of different activities in primarily Western subjects are available (Food and Agriculture Organization, 1985, 2004; James & Schofield, 1990; Ainsworth *et al.* 1993, 2000). These databases were compiled using the data from previously published literature. Ainsworth *et al.* (1993) assigned metabolic equivalent (MET) values to each activity, and in the case of activities not listed in the original lists, a MET value was estimated from similar known activities. A MET is defined as the ratio of work metabolic rate to a standard RMR. Previously published data have certain limitations with regard to the provision of methodological details, small sample size, unclear measurement duration and extent of variability.

A recent study from India (Sujatha *et al.* 2000) documented the PAR of activities such as household chores, childcare and occupational activities in urban women from a low socioeconomic group. The study found the PAR values to be lower than the FAO/WHO/UNU (Food and Agriculture Organization, 1985) values for activities such as sitting, standing and walking, while PAR was higher for activities such as cooking, sweeping and washing clothes. Further, Kanade *et al.* (2001) measured the energy cost of sitting and standing in urban Indian men and women. The PAR values recalculated

Abbreviations: MET, metabolic equivalent; PAL, physical activity level; PAR, physical activity ratio; TEE, total energy expenditure; UNU, United Nations University.

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from this study using the RMR values were found to be slightly higher for sitting (1·25) and standing (1·43) in men when compared with the FAO/WHO/UNU (Food and Agriculture Organization, 1985) values (1·2 for sitting and 1·4 for standing), and was lower in women for sitting (1·13) and standing (1·22) when compared with the FAO/WHO/UNU (Food and Agriculture Organization, 1985) values (1·2 for sitting and 1·5 for standing). Thus, there is still uncertainty whether the PAR values of Indian subjects are similar to, or different from, published values (Food and Agriculture Organization, 1985, 2004; Ainsworth *et al.* 2000), and also to what extent the difference may be.

The main reason for using the BMR multiple approach to calculate energy requirements is that it is assumed to compensate for differences in body weight between individuals. However, studies on the association between body weight and PAR values of activities are few. Haggarty *et al.* (1997), while studying the interaction between body weight and energy expenditure in well-nourished subjects, demonstrated that the energy expenditure in programmed work activities showed a significant increase with increasing body weight, suggesting that the assumed constancy of BMR multiples across a wide range of body weights might not be valid. Studies by Racette *et al.* (1995); Howell *et al.* (1999) and Staten *et al.* (2001) suggest that the available MET values may need modification when applied to subjects with high fat content. Indian subjects have lower BMI when compared with Western populations; however, they have a higher percentage of body fat (World Health Organization Expert Consultation, 2004). Since there is an epidemic of non-communicable diseases such as diabetes, and the metabolic syndrome (Ramachandran *et al.* 2003) in India, measurements of TEE and PAL as protective risk factors have become more important in an urban context and it is important to have carefully conducted PAR measurements of common physical activities in urban settings. Further, it is important to determine if the PAR values of activities are different in the different BMI groups of male and female subjects who have a range of body fat content.

Therefore, the first aim of the present study was to carefully measure the PAR in selected activities that are common in young to middle-aged Indian urban men and women. Since there may be an effect of body weight and BMI on PAR, we also measured the PAR of these selected activities in low, normal and high BMI ranges.

Materials and methods

Subjects

The subjects included staff, students and residents of the neighbouring areas of St John's Medical College and Hospital (Bangalore, India). Normal, healthy male and female subjects in the age range of 20–40 years were recruited for the study. Subjects with any hormonal or organ dysfunction were excluded from the study. The male subjects included medical students, helpers, research assistants and technicians, while the female subjects included medical students, research assistants, helpers and garment factory workers. To assess the effect of BMI on PAR, equal numbers of subjects were recruited into the following BMI groups (<18·5, 18·5–24·9 and >25 kg/m^2). These groups were based on the cut-offs recommended by the World Health Organization (2000) to define low BMI (underweight), normal BMI (normal weight) high BMI (overweight) respectively. The sample size of subjects in each BMI group was calculated to detect 10 % significant difference between the PAR measurements across the BMI groups. The power was set at 90 % at an α level of 0·05. Thus, the sample size was calculated as ten subjects in each BMI group in both male and female subjects (for a total of sixty subjects). The subjects were recruited by word of mouth and by posted flyers. The study was reviewed and approved by the institutional ethical review board of St John's Medical College (Bangalore, India).

Experimental protocol

Measurement of basal metabolic rate and physical activity ratio. The subjects reported to the metabolic laboratory of the Division of Nutrition, St John's Medical College at 06.30 hours on the day of the experiment and were instructed to lie quietly for 30 min before the actual measurements were made. The BMR and the energy cost of activities were measured using a metabolic cart (VMax 29 series; Sensor Medics Corp., Yorbe Linda, CA, USA) based on indirect calorimetery. The ambient room temperature ranged from 25°C to 28°C. The BMR measurements were made after a 12 h overnight fast and about 8 h sleep. During the BMR measurement, the subject was made to lie quietly, without moving and the measurement was made for a period of 20 min. The breath volume was measured using a mass flow sensor (Mass flow sensor™; Sensor Medics Corp.), which was calibrated with a 3 litre syringe (catalogue no. 763722/series 9519; Sensor Medics Corp.) and the measurement of O_2 consumption and CO_2 production was made in a breath-by-breath analysing mode. The BMR was calculated using Weir's equation (Weir, 1949). Analysers were calibrated using calibration grade standard gases : 15·87 % O_2, 3·94 % CO_2 (Praxair India Pvt Ltd, Bangalore, India) and 26·02 % O_2, 0 % CO_2 (Bhoruka Gas Ltd, Bangalore, India).

The energy cost of ten selected activities was measured in the male and female subjects. The activities were chosen from the occupational, non-occupational and exercise domains of subjects' habitual physical activity, which was determined through qualitative questioning of several subjects before the study. The selected activities for the male subjects were sitting, standing, desk-work, ironing, sweeping, cycling, dusting, and walking at 3·2 km/h, 4·8 km/h and at 3·2 km/h with a 5 kg load. The selected activities for the female subjects were sitting, standing, desk-work, ironing, washing utensils, kneading dough, floor swabbing, dusting, and walking at 3·2 and 4·8 km/h. The technique of measurement of each activity is presented in the Appendix. The PAR was calculated for each subject and activity as follows:

$$\text{PAR} = \frac{\text{Energy cost (kJ) of an activity per min}}{\text{Energy cost (kJ) of the BMR per min}}$$

Anthropometric measurements. The anthropometric measurements included body weight, height, and skinfold thickness. All the measurements were standardised according to the anthropometric standardisation manual (Harrison *et al.* 1988). Skinfold measurements were carried out using Holtain skinfold calipers (Holtain, Crymych, Wales, UK), at four sites (i.e. biceps, triceps, subscapular and supra iliac). The average sum of the two, three or four skinfold measurements were used to compute body density using the age- and sex-specific equations (Durnin & Womersley, 1974) and percentage body fat was derived from body density (Siri, 1961). These equations were previously validated in a group of men and women from Bangalore and it was found that the skinfold method can be used as a reasonably accurate method for estimating body composition of groups (Kuriyan *et al.* 1998).

Statistical analysis

The data are presented as means and standard deviations. The CV of each measurement was calculated ((SD/mean) × 100) to provide a measure of relative variation. For the assessment of body size on PAR, the primary analysis was carried out using BMI categories. One-way ANOVA with *post hoc* tests were used to ascertain significant differences in the PAR values and anthropometric parameters between the different BMI groups among the male and female subjects. In addition, the relationship of PAR and BMI was evaluated using scatterplots for all the measured activities in both the male and female subjects. However, only the scatterplots for activities such as ironing, and walking at 3·2 km/h, 4·8 km/h and 3·2 km/h with a 5 kg load in males and activities such as sitting, standing, ironing, walking at 3·2 km/h and 4·8 km/h and swabbing in females which showed statistically significant relationship are presented in Figs. 1 and 2. Simple linear regression was performed to determine the predictive capability (r^2) of BMI on the PAR value of activities. The relationship of PAR with body weight was also evaluated using scatterplots. In order to assess the relationship of percentage body fat with the PAR values of activities, partial correlations were carried out in the male and female subjects between the PAR values of activities and percentage body fat while adjusting for body weight and also with fat mass adjusted for body weight. Additionally, partial correlations of PAR with body weight adjusted for height were also performed in the male and female subjects. The PAR values obtained from the present study were compared with the previously reported values of FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004) and Ainsworth *et al.* (2000) using a one-sample *t* test. An independent *t* test was used to ascertain whether significant differences existed between the male and female subjects in the PAR values. The statistical analysis was performed using SPSS version 13 (SPSS Inc., Chicago, IL, USA) and the results were considered significant if the observed significance level (*P* value) was less than 0·05.

Results

The physical characteristics of the male and female subjects are summarised in Table 1. The age and height of the subjects were not significantly different between the different BMI groups, while significant differences were observed in body weight, percentage body fat and fat-free mass between the three BMI groups in the male and female subjects.

Means, standard deviations and CV of the PAR values in the three BMI groups of male subjects are summarised in Table 2. The mean PAR values for all the activities ranged from 1·20 for sitting to 4·14 for brisk walking. The activities of sitting, standing, desk-work and dusting had PAR values below 1·7, while activities such as sweeping, cycling, walking at 3·2 km/h, 4·8 km/h and with a load of 5 kg had PAR values greater than 3·0. CV ranged from 5·2 % for desk-work (lowest) in the normal BMI group to 9·3 % (highest) for cycling in the overweight group. The activities such as sitting, standing and desk-work had lower CV (<7 %), while the more strenuous activities such as cycling and walking at the two levels and with a load had CV which ranged from 7·3 to 9·3 %. Although there was a trend of increasing PAR values with increasing BMI in the male subjects, no significant differences between the BMI groups in the PAR values related to sitting, standing, desk-work, sweeping, dusting and cycling. The overweight subjects had a significantly higher PAR value for ironing, walking at 3·2 km/h, 4·8 km/h and with a 5 kg load when compared with underweight subjects. The normal-weight subjects

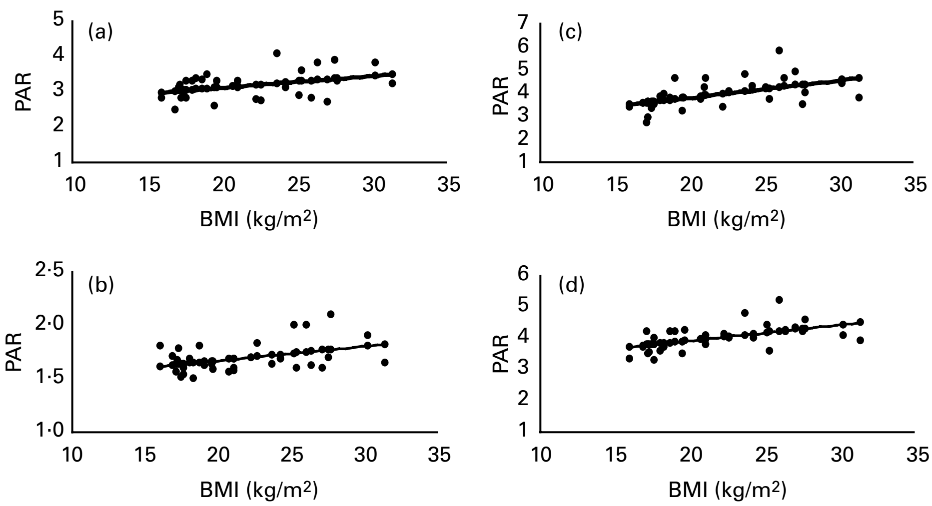

Fig. 1. Scatterplots of the relationship between BMI and the physical activity ratio (PAR) values in thirty male subjects. Simple linear regressions were performed and r^2 was determined for (a) walking at 3·2 km/h (r^2 0·13), (b) ironing (r^2 0·16), (c) walking at 3·2 km/h with a 5 kg load (r^2 0·26), and (d) walking at 4·8 km/h (r^2 0·28). All correlations were statistically significant ($P<0·05$).

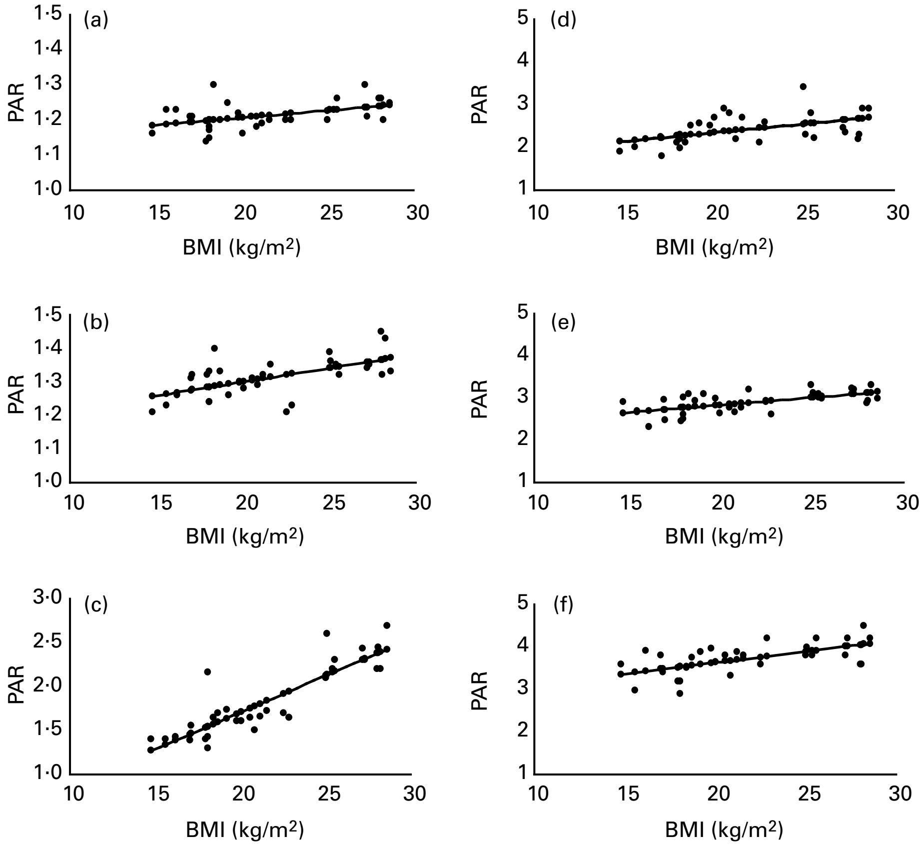

Fig. 2. Scatterplots of the relationship between BMI and the physical activity ratio (PAR) values in thirty female subjects. Simple linear regressions were performed and r^2 was determined for (a) sitting (r^2 0·20), (b) standing (r^2 0·33), (c) ironing (r^2 0·76), (d) floor swabbing (r^2 0·23), (e) walking at 3·2 km/h (r^2 0·32), and (f) walking at 4·8 km/h (r^2 0·35). All correlations were statistically significant ($P<0·05$).

Table 1. Physical characteristics of subjects

(Mean values, standard deviations and ranges)

	Underweight (BMI <18·5 kg/m²)			Normal weight (BMI 18·5–24·9 kg/m²)			Overweight (BMI >25 kg/m²)		
Parameters	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range
Males (*n*)			10			10			10
Age (years)	23·9	3·3	21·0–32·0	27·9	6·8	22·0–38·0	28·2	3·8	23·0–24·0
Body weight (kg)	47·1*	2·7	42·3–49·8	58·2	7·0	46·9–66·5	74·4*†	13·1	51·0–92·3
Height (cm)	165·0	4·0	156·4–170·1	164·8	7·3	155·2–177·0	166·9	7·0	155·0–175·8
BMI (kg/m²)‡	17·4	0·6	16·0–18·3	21·4	1·8	19·1–24·3	28·0	2·7	25·2–33·0
Body fat (%)§	10·5*	3·5	5·6–17·4	21·3	4·2	11·6–26·4	28·3*†	2·7	24·5–33·4
Fat-free mass (kg)§	38·3	11·5	5·9–45·1	46·4	4·7	35·8–53·9	56·2†	7·9	44·8–66·5
Fat (kg)§	4·8*	1·8	2·4–8·5	12·6	2·9	7·1–17·2	22·7*†	4·2	16·1–27·4
Females (*n*)			10			10			10
Age (years)	22·8	5·8	20·0–29·0	24·6	4·5	20·0–31·0	24·7	7·5	20·0–32·0
Body weight (kg)	40·3*	3·31	34·4–46·5	48·9	4·4	41·0–56·4	62·9*†	6·1	51·3–72·3
Height (cm)	152·5	4·4	148·0–161·2	153·2	5·6	147·2–161·2	153·2	5·0	143·4–160·8
BMI (kg/m²)‡	17·2	1·1	14·8–18·4	20·8	1·2	18·7–22·9	27·1	1·6	25·0–28·6
Body fat (%)§	17·9*	4·1	11·2–22·3	24·3	4·8	18·1–29·2	32·1*†	2·9	28·8–38·0
Fat-free mass (kg)§	33·1	2·4	30·4–36·9	36·6	3·8	31·0–43·2	42·8*†	3·8	34·0–46·7
Fat (kg)§	6·8*	2·1	3·30–9·60	12·5	3·1	8·1–17·7	20·9*†	3·4	17·5–27·5

* Mean value was significantly different from that for the normal-weight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).
† Mean value was significantly different from that for the underweight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).
‡ BMI is a grouping variable and so no significance is depicted.
§ Calculated from the sum of two, three or four skinfold measurements and applying the formulae of Durnin & Womersley (1974).

Table 2. Physical activity ratios in male subjects
(Mean values, standard deviations and coefficients of variation)

	Underweight (BMI <18·5 kg/m²) (*n* 10)			Normal weight (BMI 18·5–24·9 kg/m²) (*n* 10)			Overweight (BMI >25 kg/m²) (*n* 10)		
	Mean	SD	CV(%)	Mean	SD	CV(%)	Mean	SD	CV(%)
Sitting	1·20	0·05	6·6	1·22	0·32	7·2	1·22	0·19	6·6
Standing	1·29	0·09	7·1	1·29	0·05	6·3	1·30	0·08	6·8
Desk-work	1·35	0·09	6·4	1·32	0·09	5·2	1·38	0·07	5·4
Ironing	1·64	0·11	7·4	1·64	0·08	6·1	1·80*	0·19	6·1
Sweeping	3·63	0·25	7·7	3·67	0·38	6·3	3·69	0·32	5·5
Dusting	1·55	0·11	7·7	1·56	0·12	6·7	1·64	0·17	6·8
Cycling	3·14	0·78	7·3	3·33	0·67	8·1	3·36	0·31	9·3
Walking at 3·2 km/h	2·95	0·22	7·5	3·06	0·28	7·5	3·38*†	0·26	7·4
Walking at 4·8 km/h	3·53*	0·25	6·6	3·88	0·24	7·1	4·14†	0·49	7·3
Walking at 3·2 km/h with a 5 kg load	3·30*	0·32	7·0	3·92	0·51	6·3	4·06†	0·59	7·6

* Mean value was significantly different from that for the normal-weight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).
† Mean value was significantly different from that for the underweight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).

had a significantly higher PAR value when compared with the underweight subjects for walking at 4·8 km/h, while there was no significant difference in the PAR values of walking at 3·2 km/h between the normal-weight and overweight subjects.

Means, standard deviations and CV of the PAR values in the three BMI groups of female subjects are summarised in Table 3. The mean PAR values for all the activities ranged from 1·20 for sitting to 3·74 for brisk walking. The activities of sitting, standing, desk-work, ironing and dusting had PAR values below 1·7, while activities such as kneading dough, floor swabbing, and walking at 3·2 and 4·8 km had PAR values greater than 2·0. CV ranged from 5·6 % (lowest) for sitting in the underweight group to 9·4 % for walking at 4·8 km/h (highest) in the normal-weight group. Activities such as sitting, standing and desk-work had lower CV (<7 %), while the more strenuous activities such as floor swabbing, kneading dough, washing utensils, and walking at 3·2 and 4·8 km/h had CV which ranged from 7·2 to 9·3 %. There were no significant differences observed between the subjects of the different BMI groups in the PAR values of sitting, standing, desk-work, ironing, washing utensils, kneading dough and dusting. The PAR value of floor swabbing was significantly higher in the overweight and normal-weight group of subjects, when compared with the underweight group. The PAR value of walking at 3·2 km/h was significantly higher in the overweight subjects when compared with the subjects of the underweight and normal-weight group. Significant differences existed between the underweight and overweight subjects in the PAR for walking at 4·8 km/h.

The bivariate relationship of BMI with the measured PAR of each activity was evaluated using scatterplots. In males, there was no significant relationship between BMI and the PAR values of activities such as sitting, standing, desk-work, sweeping, cycling and dusting. A significant positive relationship existed between BMI and the PAR values of activities such as ironing, walking at 3·2 km/h, walking at 4·8 km/h and walking at 3·2 km/h with a 5 kg load. These findings are depicted in Fig. 1. The BMI significantly correlated with the PAR values of activities such as ironing, walking at 3·2 km/h, walking at 4·8 km/h and walking at 3·2 km/h with a 5 kg load with r^2 values of 0·16, 0·13, 0·28 and 0·26 respectively. Similar results were observed with body weight, which significantly correlated with the PAR values of activities such as ironing, walking at 3·2 km/h, walking at 4·8 km/h and walk-

Table 3. Physical activity ratios in female subjects
(Mean values, standard deviations and coefficients of variation)

	Underweight (BMI <18·5 kg/m²) (*n* 10)			Normal weight (BMI 18·5–24·9 kg/m²) (*n* 10)			Overweight (BMI >25 kg/m²) (*n* 10)		
	Mean	SD	CV(%)	Mean	SD	CV(%)	Mean	SD	CV(%)
Sitting	1·20	0·05	5·6	1·20	0·02	6·4	1·24	0·03	6·0
Standing	1·29	0·06	6·7	1·29	0·04	6·5	1·31	0·06	6·2
Desk-work	1·33	0·08	6·5	1·34	0·10	6·6	1·36	0·05	6·4
Ironing	1·51	0·25	7·9	1·65	0·07	8·4	1·59	0·12	8·6
Kneading dough	2·10	0·25	7·6	2·34	0·25	7·9	2·35	0·19	7·2
Washing utensils	1·55	0·29	7·2	1·77	0·18	7·3	1·78	0·19	7·8
Swabbing floor	2·08*	0·16	8·0	2·56	0·25	6·9	2·59†	0·40	7·1
Dusting	1·34	0·08	6·2	1·43	0·13	6·6	1·44	0·07	7·8
Walking at 3·2 km/h	2·63*	0·28	8·9	2·78	0·21	8·4	3·16†	0·22	9·3
Walking at 4·8 km/h	3·37	0·29	9·3	3·65	0·30	9·4	3·74†	0·30	8·9

* Mean value was significantly different from that for the normal-weight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).
† Mean value was significantly different from that for the underweight subjects (one-way ANOVA with *post hoc* tests; $P<0·05$).

ing at 3·2 km/h with a 5 kg load with r^2 of 0·18, 0·16, 0·22, and 0·14 respectively. In the female subjects, BMI significantly correlated with the PAR values of sitting, standing, ironing, swabbing floors, walking at 3·2 km/h and walking at 4·8 km/h with r^2 values of 0·20, 0·33, 0·76, 0·23, 0·32 and 0·35 respectively. These results are depicted in Fig. 2. Significant correlations were observed in the female subjects between body weight and the PAR values of activities such as sitting, standing, ironing, swabbing floors, walking at 3·2 km/h and walking at 4·8 km/h with r^2 values of 0·18, 0·28, 0·65, 0·21, 0·29 and 0·29 respectively.

The relationship of percentage body fat to the PAR values was assessed using a partial correlation in the male and female subjects, while adjusting for body weight. In the male subjects, a significant positive correlation existed between percentage body fat and the PAR values of walking at 4·8 km/h (r 0·45; P=0·01) and walking at 3·2 km with a 5 kg load (r 0·48; P=0·01). A significant positive correlation existed between percentage body fat and the PAR values of walking at 3·2 km/h (r 0·72; P=0·00) and walking at 4·8 km/h (r 0·48; P=0·01) in the female subjects. There were no significant correlations observed between percentage body fat and the PAR values of other activities in the male and female subjects. Similar results were obtained when the relationship of fat mass adjusted for body weight was assessed using a partial correlation in male and female groups. The partial correlation between the PAR and body weight, adjusted for height, showed that significant positive correlations existed between body weight and the PAR values of walking at 3·2 km/h (r 0·65; P<0·00), walking at 4·8 km/h (r 0·50; P<0·00) and walking at 3·2 km/h with a 5 kg load (r 0·54; P<0·00) in the male subjects, while significant positive correlations were observed in the female subjects between body weight and the PAR values of walking at 3·2 km/h (r 0·59; P<0·00), walking at 4·8 km/h (r 0·50, P<0·00), and swabbing (r 0·48; P<0·00).

The PAR values of the activities common to both the male subjects and females subjects were compared using the independent t test. The PAR values related to sitting, standing and desk-work did not show any statistical difference, while the PAR values for ironing, dusting, and walking at 3·2 and 4·8 km/h were significantly lower in the whole group of female subjects, when compared with the whole group of male subjects. When the PAR values were compared within the different BMI groups, between the male and female subjects, it was observed that the underweight females had significantly lower PAR values for activities such as dusting and walking at 3·2 km/h, while the normal-weight female subjects had significantly lower values for dusting and both walking at 3·2 and 4·8 km/h, while the PAR values of the overweight female subjects were significantly lower for activities related to ironing, dusting and walking at 4·8 km/h.

The mean PAR values of the present study were compared with the available database of the FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004) and Ainsworth *et al.* (2000). The data for the male and female subjects are depicted in Table 4. The PAR of all activities in the male subjects were significantly different from the FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004) and Ainsworth *et al.* (2000) values. Activities such as sitting, sweeping, cycling, and walking at 3·2 km/h, 4·8 km/h and with a 5 kg load had significantly higher PAR values when compared with the FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004) values, while standing, desk-work, ironing and dusting

Table 4. Comparison of the mean physical activity ratio values with reported values

Activities	Present study ‡	FAO/WHO/UNU (2004)§	Ainsworth *et al.* (2000)
Males			
Sitting	1·22*†	1·2	1·0
Standing	1·29*†	1·4	1·2
Desk-work	1·35*†	1·4	1·8
Ironing	1·69*†	3·5	2·3
Sweeping	3·66*†	3·0	4·0
Dusting	1·58*†	2·7	2·5
Cycling	3·28*†	3·0	3·0
Walking at 3·2 km/h	3·13*†	2·8‖	2·5
Walking at 4·8 km/h	3·85*†	3·8‖	3·3
Walking at 3·2 km/h with a 5 kg load	3·76†	NA	3·3
Females			
Sitting	1·21†	1·2	1·0
Standing	1·30*†	1·5	1·2
Desk-work	1·34*†	1·4	1·8
Ironing	1·58*†	1·4	2·3
Kneading dough	2·27*†	3·4	2·0
Washing utensils	1·70†	1·7	2·3
Swabbing floor	2·41†	NA	3·8
Dusting	1·40†	NA	2·5
Walking at 3·2 km/h	2·86*†	3·0‖	2·5
Walking at 4·8 km/h	3·58†	NA	3·0

UNU, United Nations University; NA, not available.
* Significantly different from the values of FAO/WHO/UNU (2004).
† Significantly different from Ainsworth *et al.* (2000).
‡ Mean of all three BMI groups (thirty subjects).
§ Food and Agriculture Organization (2004).
‖ Values are for slow and fast walking with speed not mentioned.

had lower PAR values. The PAR values of the male subjects were significantly higher than the Ainsworth *et al.* (2000) values for activities such as sitting, standing, cycling, and walking at 3·2 km/h, 4·8 km/h and with a 5 kg load, and significantly lower for desk-work, ironing and dusting. The female subjects had significantly higher PAR values for activities such as sitting, standing and walking at 3·2 and 4·8 km/h when compared with the FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004) values, and significantly lower values for activities such as desk-work, ironing, kneading dough and floor swabbing. The PAR value of washing utensils was not significantly different. When compared with the PAR values in Ainsworth *et al.* (2000), the PAR values of the female subjects showed significantly higher values for sitting, standing, kneading dough, dusting and walking at 3·2 km/h and 4·8 km/h, and significantly lower values for desk-work, ironing, washing utensils, floor swabbing and dusting.

Discussion

The present study provides information on the PAR values of selected habitual activities measured across different BMI groups in male and female subjects, and also offers a measure of relative variation in the values of CV, which has not been reported in most of the earlier studies. The CV was below 10 % for all activities in the present study. The mean data of the male (*n* 30) and female (*n* 30) subjects of the present study were slightly but significantly different from the previously reported values of Ainsworth *et al.* (2000) and FAO/WHO/UNU (Food and Agriculture Organization, 1985, 2004). Although, at first sight, the values seemed comparable, a one-sample *t* test showed significant differences in the PAR values of all activities between the reported values and the values of the present study. These could translate into significant differences in an integrated index of activity such as PAL. For example, in a man spending 9 h for sleep, 6 h for sitting, 4 h for standing, 4 h for walking slowly and 1 h for walking quickly respectively, the calculated PAL values would be 1·53, 1·37 and 1·57 using the PAR values of the FAO/WHO/UNU (Food and Agriculture Organization, 2004), Ainsworth *et al.* (2000) and the values from the present study respectively. Obviously the extent of difference will depend on the type of activity and the time spent in it. The values of FAO/WHO/UNU (Food and Agriculture Organization, 2004) and the present study are therefore comparable, while the values of Ainsworth *et al.* (2000) seem to be lower; this may be due to the lower values of sitting and walking slowly. Differences in body weight and body composition could be one of the main reasons for the discrepancies in the values of the present study as compared with available literature. In addition, the published reports of Ainsworth *et al.* (2000) and FAO/WHO/UNU (Food and Agriculture Organization, 2004) were from previously carried out studies, some of which had small number of subjects and different methodologies. The PAR value for standing and walking obtained from the present study was lower than that obtained by Sujatha *et al.* (2000) (1·5 for standing and 3·4 for walking), while the PAR values of sitting were similar in both studies.

The 1985 FAO/WHO/UNU consultation group (Food and Agriculture Organization, 1985) recommended the use of measurements of TEE to arrive at measurements of energy requirements, and suggested the use of the factorial method of calculating TEE. The factorial approach involves the summation of the energy expended during the periods that an individual is sleeping and resting or engaged in occupational, discretional or maintenance physical activities, plus the energy needed for tissue accretion in growing children. The PAL can be measured through questionnaires, which defines activity patterns during the day and the PAL can be calculated by assigning PAR values to these activities. One of the main reasons for using the BMR-multiple approach of calculating TEE was the assumption that it compensates for differences in body weight between individuals. The findings of the present study indicate that differences in BMI could influence the PAR values of activities. There was a strong correlation observed in the present study between BMI and percentage body fat (males *r* 0·88; $P < 0.00$; females *r* 0·86; $P < 0.00$). In males, the PAR values of ironing, walking at 3·2 km and at 4·8 km and walking with a 5 kg load were significantly different across the different BMI groups. Similarly in women, the PAR values of floor swabbing and walking at 3·2 and 4·8 km/h were significantly higher in the overweight group as compared with the underweight group. The use of a common PAR value associated with an activity, measured in a group of individuals with the same body weight as in those in whom it is to be used, will not result in any error. On the other hand, errors would arise in a group of subjects having extreme ranges of body weight and BMI. For example, the PAR values obtained in the present study for walking at 4·8 km/h were 3·53, 3·88 and 4·14 for the underweight, normal-weight and overweight male subjects. Using these values, the energy expenditure for walking at this speed for 60 min would be 886·17 kJ (211·8 kcal), 974·04 kJ (232·8 kcal) and 1039·3 kJ (248·4 kcal) respectively. Thus, if the value of 3·53 was used as PAR for walking in an individual who is overweight, energy expenditure would be underestimated by 14 %. The extent of over- or underestimation of TEE due to body size will depend on the relative contribution of each activity performed to an individual's TEE and the degree of influence body weight has on the PAR value of those activities. The results of the present study imply that the PAR values of strenuous activities differ significantly with increasing body weight and BMI, and could lead to a significant error in estimation of TEE from questionnaires.

Percentage body fat correlated well with the PAR values of walking at 4·8 km/h and walking with a 5 kg load in male subjects, after adjusting for body weight. Similarly in the female group, percentage fat correlated well with walking at 3·2 and 4·8 km/h. The estimation of body fat was made by the skinfold technique, which is known to be prone to systematic and random errors when compared with criterion methods. In an earlier validation against hydrodensitometry, we have shown that the skinfold method gave reasonably similar mean values to hydrodensitometry in men and women with low to normal BMI (Kuriyan *et al.* 1998). However, it is possible that the percentage fat of the subjects with higher body fat content could be underestimated by the skinfold method (McNeill *et al.* 1991), although, in that report, only women, who were appreciably older and had a much higher fat content, were studied. Even if this were so, the slope of the PAR–percentage fat relationship in the present study would be steeper, but it is probable that the same nature of relationship (that is, a positive and significant correlation) would persist. Earlier studies (Maffeis *et al.* 1993; Spadano *et al.* 2003) in children have demonstrated that walking or running at a given speed was significantly higher in obese prepubertal children than their non-obese counterparts. Recent studies in obese women also suggest that the available MET values may need modification when applied to subjects with high fat content (Racette *et al.* 1995; Howell *et al.* 1999; Staten *et al.* 2001; Lof *et al.* 2003). The reason a higher body fat is associated with a higher PAR may be simply related to the extra energy expended by the remaining lean tissue to carry the fat mass in the individual. However, the PAR values of the female subjects did not show any significant differences from the male subjects for sedentary activities such as sitting, standing and desk-work, and indeed, household chores such as ironing and dusting were significantly lower in the female subjects. This could have been due to the fact that these activities were regularly carried out by the female subjects with some acquired economy of movement, while they were ‘novel activities’ for the male subjects. The reason for the lower PAR values for activities related to walking in the females is not clear, and could be due to the female subjects adapting better to walking on the treadmill.

In conclusion, the findings of the present study suggest that both body weight and BMI are significant predictors of the PAR value of certain activities and the general use of a common PAR value for subjects with a wide range of body weight causes errors in the estimation of TEE. It has also been found that the reported values of PAR are not applicable to this Indian population.

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Appendix 1

Description of typical activity measurements

Each activity was measured and expired air was collected for a duration of 10 min. The subject practised the activity for 3 min, following which there was a 2 min acclimatisation period and then the actual measurement where the expired air was collected after the subject attained steady state.

Sitting

The energy expenditure for sitting was measured with the subject sitting quietly on a comfortable armchair without any movements.

Standing

The subject was made to stand quietly without any movements.

Desk-work

The subject was made to sit on a chair and do some desk-work such as writing or drawing on a notebook.

Ironing

The subject was made to stand and iron two pillow covers and a bed sheet. The iron box that was used was a National light-weight model (National Company, Bangalore, India) and the weight of the iron box was 1·5 kg.

Dusting

The subject was made to stand and dust about ten notebooks and the platform where the books were placed. He was instructed to dust each book and then place them in a pile and when completed, to dust the platform with a duster cloth. The weight of each book was about 100 g and the books were placed on a platform.

Cycling

The subject was made to cycle on a stationary bike set at a speed of 16 km (10 miles)/h.

Sweeping

The subject was made to walk forward holding a broom in a partially flexed position. The broom had a plastic handle and the patient was asked to bend forward while sweeping.

Walking

The subject was made to walk on a treadmill, while holding onto to the front railing of the treadmill. This was done as the subjects, especially the women, were not keen to walk without holding the railing. The first speed was 3·2 km/h, then 4·8 km/h and finally carrying a load of 5 kg on his back while walking at a speed of 3·2 km/h. The load was a plastic bag filled with 5 kg sand.

Kneading dough

The female subjects were made to knead wheat flour using water. Each subject was provided with 200 g wheat flour. The platform was about 0·9 m (3 feet) above the ground and the subject performed this activity in a standing position. The subject used her right hand to knead the dough and the left hand to hold the vessel and add more water if needed.

Washing utensils

The subject was made to wash three bowls, two katories (small bowls) and four spoons for a period of 10 min. Soap was applied to the utensils, they were scraped with a sponge scrubber, and the dishes were rinsed with water.

Floor swabbing

The subject was made to swab the floor with a wet cloth and was asked to move forward and backwards while swabbing the floor. The subject was in a squatting position, the cloth was dipped in a bucket of water and squeezed out, and the subject moved around swabbing the area using the right hand. This was done for a period of 10 min.