Energy expenditure of urban Colombian women: a comparison of patterns and total daily expenditure by the heart rate and factorial methods[1–3]

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ABSTRACT The heart rate and factorial methods of measuring both total daily energy expenditure (TDEE) and the daily pattern of energy expenditure (EE) were compared in nonpregnant, nonlactating women aged 19–43 y living in urban conditions of economic deprivation. The methods were applied on each of 2 successive days. There were no significant differences between the 2 d by either method. Women who worked at their household chores at home (n = 29) and those who also worked for remuneration (at work) in various kinds of employment (n = 23) were compared. The factorial method gave values for TDEE and for the pattern of EE that were significantly lower than those obtained by the heart rate method. This was related to lower values for EE for certain activities obtained from the literature than for values measured in these subjects. Women at work had significantly higher values for both TDEE and for the pattern of EE than did those at home. The TDEE at home by the heart rate method was 8.83 ± 1.94 MJ/d and at work was 9.99 ± 1.91 MJ/d (P = 0.036); this difference disappeared when adjusted for body weight or fat-free mass. Physical activity levels were 1.83 ± 0.43 for women at home and 1.90 ± 0.46 for women at work, which indicate moderate to heavy work. The factorial method should be used with measured EE values in the present subject population. The heart rate method can detect differences in TDEE and in the pattern of EE between women engaged in different activities and may offer an experimental approach to the study of the effects of daily variations in EE on nutritional energy intake. *Am J Clin Nutr* 1996;63:870–8.

KEY WORDS Energy expenditure, energy cost of activities, heart rate monitoring, factorial method, energy balance, physical activity, pattern of energy expenditure

INTRODUCTION

The expectation that > 50% of the population of Latin America will be city dwellers by the end of this century is indicative of the importance of nutrition research on subjects living in urban environments (1). Although energy expenditure (EE) is an important component of the overall nutritional dynamic, there have been few reports of its measurement in free-living subjects in urban tropical populations (2, 3). Furthermore, there have been few attempts to delineate patterns of EE, particularly in studies of people engaged in different kinds of activities.

Usual methods of estimating total daily EE (TDEE) in free-living subjects include the doubly labeled water (DLW) technique (4), minute-by-minute heart rate (HR) recording (5, 6), and the factorial method, which involves the observation and recall of activities during specified periods (7, 8). Dietary energy intake (EI) has also been used to estimate the level of physical activity in epidemiologic studies (9, 10). Although the DLW method is the most accurate technique for free-living individuals (4), it is expensive (11) and, like the dietary-intake approach, does not allow the investigator to follow the pattern of EE during the measurement periods. The factorial method is well known, has been described in detail (7, 8), and has been validated with whole-body indirect calorimetry (12). The method of estimating dietary energy requirements proposed by the FAO/WHO/UNU (8) is based on the factorial procedure of determining TDEE and has been reported to underestimate TDEE and hence the energy needs of adult males (13–15).

The minute-by-minute HR method uses individual calibration curves in which oxygen consumption ($\dot{V}O_2$) is obtained differently below and above a flexion point (flex-HR) in the calibration curve (16, 17) and is referred to as the flex-HR method. It has been validated by comparison with both indirect calorimetry (17, 18) and DLW (19, 20) in adults (17–19) and children (20). Others also compared it with the DLW method and found it suitable for use in free-living female subjects (21, 22). HR and factorial methods provide the most likely way of estimating TDEE under field conditions, because budgets and sophisticated laboratory facilities required for the DLW method may be limited.

Studies from our laboratory have used the flex-HR method to measure the pattern of EE, defined here as the changes in average EE in successive 30-min periods during the active portion of the day. In these studies, we showed differences with

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age in schoolchildren (5), between well- and undernourished school-aged boys (6), and we compared girls and women (2).

The present study contrasts the flex-HR and factorial methods for describing patterns of EE in adult women and, in the process, answers several questions: *1*) Do these two methods give repeatable results on the pattern of EE and TDEE for 2 successive days? *2*) Are the patterns of EE and TDEE determined by the two methods different? *3*) Is it possible to discern a difference in pattern between a group of women working at home and another group working outside the home? *4*) If the factorial method gives values that are different from those found with the flex-HR method, what are the reasons for the difference?

SUBJECTS AND METHODS

Subjects and environment

The subjects were 29 nonpregnant, nonlactating (NPNL) women 19–43 y of age doing their own housework at home and 23 NPNL women 21–40 y engaged in earning income from various sources. The former group is referred to as women "at home" and the latter as women "at work." HR was recorded and activities were observed on the same 2 successive weekdays for all subjects. The women were residents of two very poor neighborhoods (barrios) located on the outskirts of Cali, Colombia. The city has suffered from social problems associated with rural to urban migration during the past 30–35 y, which has resulted in large populations of people living in severe economic deprivation. Cali is a city of ≈2.2 million inhabitants located 1000 m above sea level, 3°22′ N of the equator. Informed consent was obtained from all subjects after recruitment and explanation of the purposes of their involvement in the study. All subjects received a physical examination by a physician at a neighborhood medical clinic and were certified as able to participate. The protocols were approved by the Human Research Review Committee of the Medical College of Wisconsin and by the Research Committee of the Universidad del Valle.

Anthropometry and body composition

Height was measured with a wall stadiometer and body weight with a Homs-Beam Balance to ± 25 g (Homs Corp, Belmont, CA). Skinfold thicknesses at the triceps, subscapula, and suprailiac were taken in triplicate on the left side with a Lange skinfold caliper (Cambridge Scientific Industries, Cambridge, MD) and body diameters (midupper arm, waist, hips, and thigh) with a flexible tape. Midupper arm muscle area was calculated according to the method of Frisancho (23). All anthropometric measurements were made by the same trained technician. Fat-free mass (FFM) was estimated with an empirical equation derived from this population of women (24). Body fat was calculated as the difference between body mass and FFM. Blood hemoglobin concentration was obtained on fingertip blood by the cyanmethemoglobin method.

Factorial method

The factorial method of estimating TDEE was done by continuous observation and the minute-by-minute recording of activities using a coded system based on the usual activities of women in the socioeconomic group being studied. Technicians who lived in the barrios under study were intensively trained in the technique of observation and recording required. The intention was to have observers from the area who were not a threat to the subjects, who did not require special attention, and who could fade into the background while the subject carried out her daily activities. Observation began at ≈0600–0630 and continued until ≈2030–2100. Two observers alternated 4-h shifts to reduce boredom on their part and thereby errors from inattention. The results were checked periodically by simultaneous observation by one of us (DLD), who had extensive experience in this technique. At the beginning of each shift, the observers recorded the ambient temperature with a small portable thermometer. We currently have ambient temperatures measured around 0600, 1000, 1400, and 1800 for 308 d over ≈3 y of the present study. Also, during these periods of observation, extensive data were obtained on socioeconomic variables related to personal possessions and house construction.

Activities were coded based on a three-level code that specified body position, a principal activity, and a secondary activity or a descriptor for additional information. Body position was coded as lying, sitting, standing, "milling about", or walking slowly, moderately, or rapidly. Milling about is defined as movement that occurs in a confined space, such as in a house, when a person alternates standing and walking a few steps at a time. Some 65 different activities were observed and defined, and these, in combination with body position, gave a total of 159 two-level codes defining specific activities. EE values (kJ/min) for 110 of these were obtained from those provided for adult women by the FAO/WHO/UNU (8). The remaining activities did not match those in the FAO/WHO/UNU list and the EE value of a closely related activity was agreed on by the authors as a substitute. The one exception (cycling leisurely) came from McArdle et al (25). Because the factorial method is more likely to be used in field situations, where facilities for measuring oxygen consumption are not available, basal metabolic rate (BMR) for this procedure was estimated from the equations of Schofield (26), and resting metabolic rate (RMR) as BMR × 1.27 (8). To determine the effect of these estimates of BMR and RMR on the results, TDEE was also calculated by using the measured BMRs and RMRs (*see* below). The TDEE by the factorial method was then the sum of minute-by-minute observations, BMR during sleep, and RMR for the time not accounted for by sleep or observation. On the basis of conventions described by James and Schofield (27), the ratio of TDEE to BMR is referred to as the physical activity level (PAL) and the ratio of the EE of a specific activity to the BMR as the physical activity ratio (PAR).

Energy expenditure of activities

For purposes of comparing the EE of activities in our subjects with the estimates provided by the FAO/WHO/UNU, oxygen consumption ($\dot{V}O_2$) resulting from sweeping the floor (n = 6) and from hand-washing clothes (n = 14) was measured by indirect calorimetry by using a Douglas Bag procedure similar to that described for BMR. The meteorologic balloon and tubing were worn over the subject's shoulder and attached to their back. They were instructed to perform these tasks in their customary manner and worked for 1–2 min at one of the two tasks before collection began while continuing to work. Expired air was collected for 5 min. The procedure was repeated three times in each subject and the average data used. These women were also part of the main study so that data were available for BMR and for EE of lying, sitting, and standing quietly and for walking slowly (2.4 km/h, or 1.5 miles/h) on the treadmill at 0% elevation (n = 20). $\dot{V}O_2$ was converted to kJ/min as in the BMR measurements. Eight of the 20 subjects were also members of the group of women measured for TDEE and pattern of EE at home.

Basal and resting metabolic rates

The method used to measure BMR was described in detail previously (5, 6, 28). Measurements were done in duplicate on each of 2 successive weekdays on all subjects in their homes after an overnight fast. The subjects were instructed not to eat or to get out of bed before the technical team arrived between 0600 and 0700. Subjects usually had to be wakened. All had been familiarized with the mouthpiece and nose clip in at least one previous session and were in their own beds and completely relaxed with the technical team, both of whom were familiar to them.

After 1 min of flushing the mouthpiece and connecting tubing, a 10-min sample of expired air was collected from the subject in a 200-L meteorologic balloon. During the collection, duplicate aliquots of room air were obtained in oiled glass or plastic 50-mL syringes for analysis of inspiratory concentrations of oxygen and carbon dioxide. Immediately on termination of the expired air collection, duplicate aliquots of mixed expired air were obtained in syringes for subsequent analysis at the base laboratory.

Expired air volumes were measured with a Parkinson-Cowan dry gas meter (CD4; C Poe Co, Houston), and the concentrations of oxygen and carbon dioxide in expired and ambient air were measured with Beckman medical gas analyzers (OM-14 and LB-2, respectively; Sensormedics, Anaheim, CA) calibrated with gases standardized by the Scholander (29) technique. $\dot{V}O_2$ and carbon dioxide production ($\dot{V}CO_2$) were calculated by using the open-circuit methods described by Consolazio et al (30). Inspired gas concentrations were those obtained in the subject's room during the BMR measurements. In the calculations of EE, $\dot{V}O_2$ was converted to MJ/d by using the nonprotein energy equivalents of oxygen (31). Because the second BMR measurements on each of the 2 d of measurement were significantly lower than the first measurements, but were not significantly different from each other, the average value of the second measurements was used in the data reported. The CV of these two measurements averaged 7%.

The RMR was determined in the laboratory 2–3 h after a light breakfast at home on a different day from those on which the BMR values were obtained. RMR was measured with the subject lying down, sitting, and standing quietly. $\dot{V}O_2$ was measured continuously at 1-min intervals by measuring inspiratory gas volume with the Parkinson-Cowan meter and sampling expired air from a mixing chamber by using a Costill-Willmore (R-Pel Co, Altos, CA) apparatus. Measurements were repeated until $\dot{V}O_2$ leveled off at minimum values (difference ≤ 30 mL/min). RMR was expressed as the mean of the minimum $\dot{V}O_2$ values in each of the three positions. HR was recorded from hard-wired precordial lead CM5.

Total daily energy expenditure

TDEE was estimated by the flex-HR method, which involves the calibration of each subject, the measurement of HR minute-by-minute during the awake portion of the day, and the determination of BMR and RMR. The details of its use and the calculations involved were presented previously for both children (5) and adults (17). Briefly, the calibration procedure was carried out immediately after the determination of RMR described above and within the same 5-d period as the estimates of TDEE. Beginning at a treadmill speed of 2.4 km/h (1.5 miles/h) and 0% grade, the speed and/or grade were increased every 2 min in 8–12 successive steps until an HR of ≈150 beats/min was achieved. $\dot{V}O_2$ and HR were measured during the last 30 s of each workload by using the methods described above for RMR. The calibration curve was obtained from the least-squares regression of $\dot{V}O_2$ on HR for use in calculating EE from HR during the day. The HR recorders, described previously (17), were attached and started immediately after termination of the BMR measurements. Recording was continued for 12–16 h (mean: 14.5 h) and then the recorder was detached to download the HRs into a computer. The time at the beginning and end of HR monitoring and of going to bed and getting up were recorded for each subject. TDEE was obtained as the sum of EE while the subject was on the HR monitor, BMR during the hours of sleep (8.5 ± 0.9 h), and RMR for the average time of 67 min not accounted for by HR monitoring or sleep.

Patterns of energy expenditure

According to the factorial method, the PAR of a given activity was allotted to each minute of the time recorded for that activity. This was repeated for each activity during the period of observation. With the flex-HR method, each HR was converted to EE/min as described. Consequently, each minute of observation or HR recording had a value for EE/min. The pattern between 0700 and 2000 was then calculated as the average EE during each 30-min period obtained by each of the two methods.

Dietary intake

The observers of subject activity also recorded food intake during the 2 d of the factorial method and HR recording. Volumetric measurements of serving utensils and tableware were completed in each subject's home before estimates of food intake began. Energy and nutrient intakes were calculated by using published food-composition tables (32, 33), local recipes collected during periods of observation, and proximate analyses of 15 samples of common foods. The latter were completed by the Colombian Institute of Family Welfare (ICBF) in Bogotá according to the standard methods of analyses of the Association of Official Analytical Chemists (34).

Statistics

Data are expressed as means ± SDs. Statistical analyses were done by unpaired t comparisons between groups (home compared with work) or paired t analyses of variables within groups (35). The patterns of EE were analyzed by two-way analysis of variance (ANOVA) using repeated measures in the time dimension and in the comparison of methods. An unpaired analysis was used between groups (36). The null hypothesis was rejected at the 0.05 level.

RESULTS

In a society that values home ownership highly, the formation of the poorest barrios begins with lots purchased legally or obtained by occupation during "invasions" of the land of others. First houses are made of inexpensive building materials but gradually evolve into more permanent brick and mortar homes. Consequently, the state of home construction of our subjects varied widely. Subjects had houses with roofs of cardboard or pieces of odd materials (18%) or clay tiles (42%), with walls of bamboo or cardboard (9%) or brick (67%), and with floors of dirt (20%) or concrete (65%). Most houses had inside plumbing of some sort (92%), although some subjects had to obtain drinking water from neighbors or public spigots (6%). Few houses had clothes washing machines (2%) but 87% owned television sets and 57% owned refrigerators. None owned automobiles or motorcycles, rather, residents depended on public transportation for travel beyond their neighborhoods. The average number of children living with their mothers was 1.7 ± 1.2, although the average total number of children per woman was significantly higher (2.3 ± 1.5; $P < 0.001$), perhaps indicating the need for extra help in supporting their children. The number of adults at home during the day ranged from none (12%) to > 5 (6%). The women averaged 6.4 ± 3.0 y of formal schooling. There were no significant differences between the two groups of women in any of the socioeconomic variables registered. The occupations at which the employed women worked were also indicative of socioeconomic status, which varied from domestic service in the homes of others to work in child day-care centers in the barrio where they lived (**Table 1**). Some ran small shops in their homes or on the street whereas others were factory workers or shop persons. Table 1 also lists body weights and EIs by occupation. A one-way ANOVA showed a significant difference in EI ($P = 0.02$) and the post hoc Newman-Keuls test was significant for EI of child care and factory workers. There were no significant differences in body weight (Table 1).

The results of the 308 d of measurement of ambient temperature ($\bar{x}$ ± SD) were 24.4 ± 1.4, 27.6 ± 2.1, 30.6 ± 2.4, and 28.4 ± 2.0 °C at 0600, 1000, 1400, and 1800, respectively. The average temperature in the laboratory at the time of calibration was 23.3 ± 1.3 °C (n = 80).

Blood hemoglobin concentrations of the subjects averaged 134 ± 11 g/L in both the women at home and in the women who worked. There was no significant correlation (r = 0.13) between hemoglobin concentration and TDEE. Anthropometric measures of the two groups are presented in **Table 2**. Whereas weight and height tended to be higher in working women, the differences were not significant. Scapular skinfold thickness was higher in the working women than in those who were at home. In comparison with North American women of the same age (37), the Colombian subjects were approximately at the 25th percentile for body mass, the 15th percentile for height, and the 50th percentile for body mass index (BMI). We commented previously (24) on normal BMIs in conjunction with high values for body fat (Table 2). It was suggested that this was due to higher values for subcutaneous fat in Colombian than in North American women (24). Anthropometric values for the 20 women who had measurements of the energy costs of activities were not significantly different from the values presented in Table 2 for women at home, except for hip circumference, which was significantly higher (93.9 ± 0.46 cm; $P = 0.04$).

Dietary EI, BMR, RMR, and TDEE obtained by flex-HR and the factorial methods for each of the 2 d of measurement and the average TDEE and PAL values for women at home and at work are presented in **Table 3**. There were no significant differences in dietary EI or EI:BMR between the two groups (Table 3). Measured BMR was slightly and significantly higher in the working women but when adjusted (38) for either body weight or FFM, the difference disappeared. The BMR estimated from the Schofield (26) equations was not significantly different between groups, but was significantly higher than measured BMR in the women at home ($P = 0.002$). However, in the women at work the difference between measured and

TABLE 1
Employment of subjects, body weight, and dietary energy intake by type of work[1]

Occupation	Body weight	Dietary energy[2]
	kg	*MJ/d*
Domestic service (n = 3)	51.0 ± 7.7	9.70 ± 1.16
Child day-care worker (n = 9)	57.03 ± 8.2	7.66 ± 2.01[3]
Sales at home or on street (n = 4)	61.4 ± 10.3	9.76 ± 0.97
Factory worker (light industry) (n = 4)	58.4 ± 9.8	10.84 ± 2.38
Shop person (n = 3)	50.6 ± 4.0	9.11 ± 0.54
Average (n = 23)	56.4 ± 8.54	9.04 ± 2.01

[1] $\bar{x}$ ± SD. There were no significant differences in body weight.
[2] Significant difference between means, $P = 0.02$ (one-way ANOVA).
[3] Significantly different from factory workers, $P < 0.05$ (Newman-Keul's test).

TABLE 2
Age, anthropometry, and body composition of female subjects working at home or outside the home[1]

	At home (n = 29)	At work (n = 23)
Age (y)	27.2 ± 6.8	28.6 ± 5.1
Measured values		
Body weight (kg)	52.2 ± 6.7	56.4 ± 8.5
Height (cm)	155.0 ± 5.8	158.1 ± 6.5
Skinfold thickness (mm)		
Triceps	18.4 ± 5.1	20.2 ± 5.8
Subscapula	18.8 ± 5.7	22.6 ± 6.9[2]
Illiac crest	17.7 ± 6.5	19.9 ± 7.6
Circumferences (cm)		
Midupper arm	24.7 ± 2.1	25.6 ± 1.9
Waist	67.1 ± 6.2	68.4 ± 5.6
Hips	90.6 ± 5.6	92.1 ± 6.2
Thigh	48.0 ± 4.0	48.9 ± 4.8
Derived values		
Body mass index (kg/m^2)	21.7 ± 2.4	22.5 ± 2.5
Midarm muscle area (cm^2)	28.7 ± 3.9	29.5 ± 4.3
Waist-hip ratio	0.741 ± 0.038	0.747 ± 0.052
Lean body mass (kg)	34.6 ± 3.3	35.2 ± 3.6
Percent body fat (%)	34.4 ± 5.1	36.4 ± 5.5

[1] $\bar{x}$ ± SD.
[2] Significantly different from at-home values, $P = 0.037$.

TABLE 3
Dietary energy intake, energy expenditures, and ratios of energy to basal metabolic rate (BMR) of women working at home or outside the home[1]

	At home (n = 29)	At work (n = 23)
Dietary energy intake	8.87 ± 2.51	9.04 ± 2.01
Dietary energy:BMR	1.83 ± 0.49	1.73 ± 0.48
Measured BMR	4.89 ± 0.73	5.40 ± 0.98[2]
Estimate of BMR by Schofield	5.31 ± 0.38[3]	5.50 ± 0.49
Measured RMR	6.59 ± 0.90	6.81 ± 0.97
Estimated RMR[3]	6.85 ± 0.56	6.68 ± 0.93
Measured RMR:BMR	1.36 ± 0.19	1.29 ± 0.24
Flex-HR method		
TDEE, day 1	8.89 ± 2.11	9.92 ± 2.07
TDEE, day 2	8.76 ± 1.98	10.06 ± 2.25[4]
Average TDEE	8.83 ± 1.94	9.99 ± 1.91[2]
Average PAL	1.83 ± 0.43	1.90 ± 0.46
Factorial method using estimated BMR and RMR		
TDEE, day 1	7.79 ± 0.76[5]	8.31 ± 0.79[5,6]
TDEE, day 2	7.83 ± 0.74[5]	8.17 ± 0.80[5]
Average TDEE	7.81 ± 0.70[5]	8.24 ± 0.75[5]
Average PAL	1.47 ± 0.09[5]	1.50 ± 0.11[5]
Factorial method using measured BMR and RMR		
Average TDEE	7.39 ± 0.93	8.16 ± 1.18[7]
Average PAL	1.52 ± 0.10[8]	1.52 ± 0.13

[1] $\bar{x}$ ± SD. HR, heart rate; PAL, physical activity level (TDEE/BMR); RMR, resting metabolic rate; TDEE, total daily energy expenditure.

[2] Significantly different from at-home value, $P = 0.036$ (nonsignificant when adjusted for body weight or fat-free mass).

[3] Significantly different from measured BMR, $P = 0.002$. Estimated RMR = BMR by Schofield × 1.27.

[4,6,7] Significantly different from at-home value: [4] $P = 0.032$, [6] $P = 0.021$, [7] $P = 0.011$.

[5] Significantly different from comparable value determined by the flex-HR method, $P \leq 0.01$.

[8] Significantly different from comparable value derived by using estimated BMR and RMR.

estimated BMRs was not significant. When the data for both groups were combined ($n = 52$), measured BMR was significantly lower than estimated ($P = 0.011$). Neither measured nor estimated RMR were significantly different between groups nor were the measured and estimated values significantly different from each other. Ratios of RMR to BMR were also not significantly different between groups (Table 3).

There were no significant differences between values from the 2 d of measurement of TDEE by either method in either group. All measurements by the factorial method were significantly lower than by flex-HR ($P < 0.01$). Women at work expended significantly more energy than did women at home by both flex-HR ($P = 0.033$) and factorial ($P = 0.04$) methods but differences disappeared when TDEE was adjusted (38) for body weight or FFM. Comparison of EE measured by flex-HR with dietary EI showed no significant differences in women at home ($P = 0.93$) or at work ($P = 0.052$), although the latter difference was nearly significant. When estimated by the factorial method, EE was significantly less than dietary EI in women at home ($P = 0.018$) and at work ($P = 0.040$). To test for the possible error introduced into the factorial method by the use of estimated values for BMR and RMR, TDEE and PAL were calculated by using measured BMR and RMR. These results are also presented in Table 3. The only significant difference when the factorial method was used to estimate BMR and RMR was in the PAL value for women at home ($P < 0.001$); however, in absolute terms the difference was small (Table 3).

The patterns of daily EE in the women at home and at work between 0700 and 2000, expressed as 30-min averages for each of the 2 d of measurement, were analyzed by two-way ANOVA with repeated measures in the time dimension and between days 1 and 2. There were no significant differences between the 2 d of measurement by either method or group, but there was a significant difference in the time dimension by both methods ($P < 0.001$) and groups ($P < 0.001$). The interaction terms were not significant in either analysis.

In **Figure 1** (A and B), the averaged values of the 2 d of data obtained by both methods are plotted for comparisons of the women at home and at work. The pattern obtained by flex-HR was almost significantly higher in the women at work than in those at home, and was significantly different between the two groups by the factorial method. The interaction term was not significantly different by either method. Again, the time dimension was significant in both methods ($P < 0.001$). There are some similarities in the flex-HR pattern of EE between women at home and at work (Figure 1A). There was an overall increase in EE in women at work in the morning and a decrease in the afternoon, punctuated by a short period of decreased activity in midmorning and midafternoon (presumably rest breaks) and a reduced period of activity (EE) midday, which probably coincided with lunchtime. The pattern in the working women obtained by the factorial method was much lower than that obtained by HR monitoring and exhibited only a mild decline during the day.

Statistical comparisons of the two methods in each group of women are shown in Figure 1 (C and D). Values obtained by the flex-HR procedure were significantly higher in both the working women and those at home ($P < 0.001$) and the interaction terms were significant in both groups.

Comparison of measured EE:BMR with values obtained from the FAO/WHO/UNU (8) for three common tasks and for lying, sitting, and standing quietly are presented in **Figure 2**. Measured PAR values for floor sweeping, clothes washing, and walking slowly tended to be higher than those given by the FAO/WHO/UNU (8). Measured and estimated values for resting activities (lying, sitting, and standing quietly) were very similar (Figure 2). Differences between measured PAR values and those from the FAO/WHO/UNU (8) are inset on Figure 2. The strong and significant correlation indicates that in this population there was an increasing discrepancy between measured PAR and estimated values with increasing activity levels.

DISCUSSION

The finding that the subjects were in approximately the 15th percentile of stature for North American women (37) reflects a history of moderate malnutrition in this population during the period of childhood growth (5, 6, 28). The only significant difference in anthropometry between the two study groups was higher subscapular skinfold thicknesses in the working women

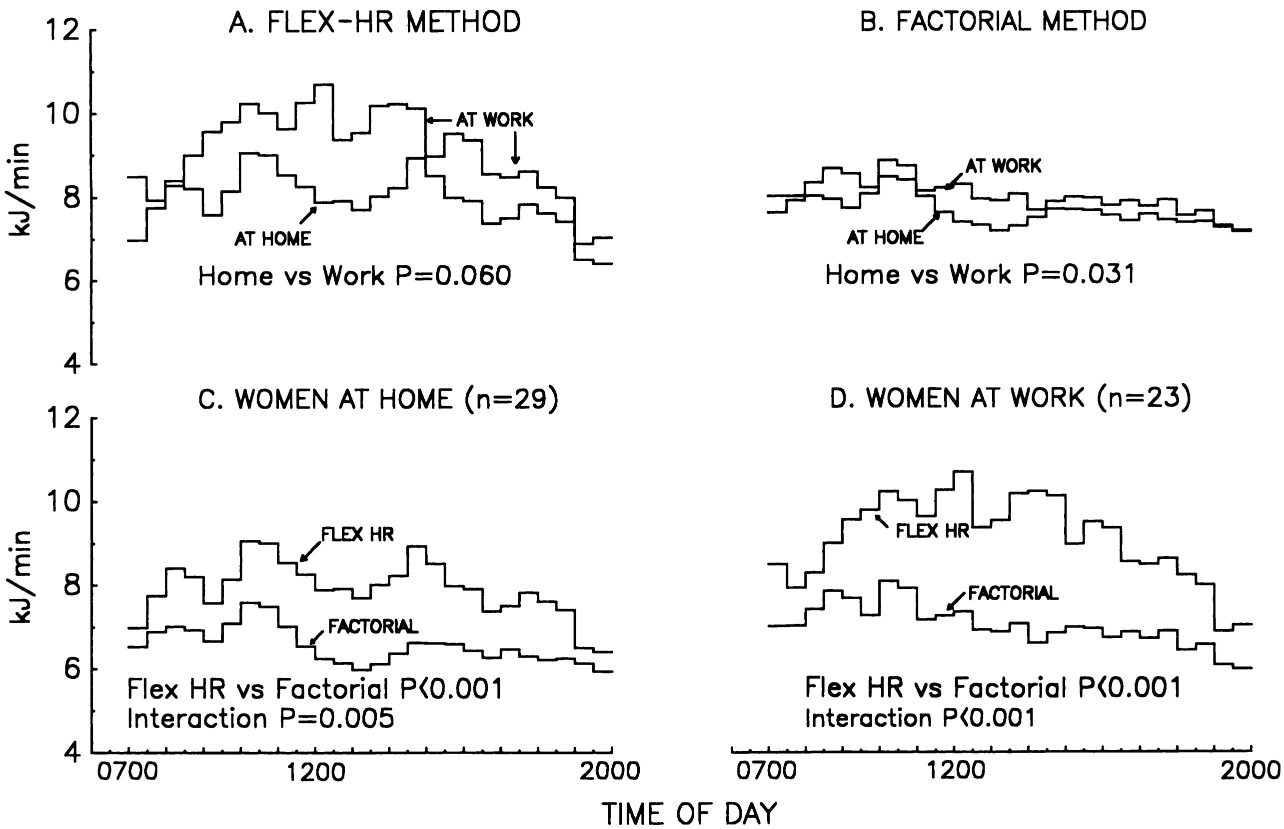

FIGURE 1. Averaged 2-d measurements comparing the patterns of energy expenditure in two study groups (work compared with home) and the two methods by two-way ANOVA with repeated measures in both dimensions with time and methods and in the time dimension between groups. The time dimension was significant in all analyses ($P < 0.001$). HR, heart rate.

(Table 2). If their outside income contributed to a better diet it was not reflected in the EI measurements made at the time of study. EI was not significantly different between the two groups (Table 3). The BMI of the Colombian women was comparable with the 50th percentile of North American subjects (37) and waist-hip ratios were within the normal range (39).

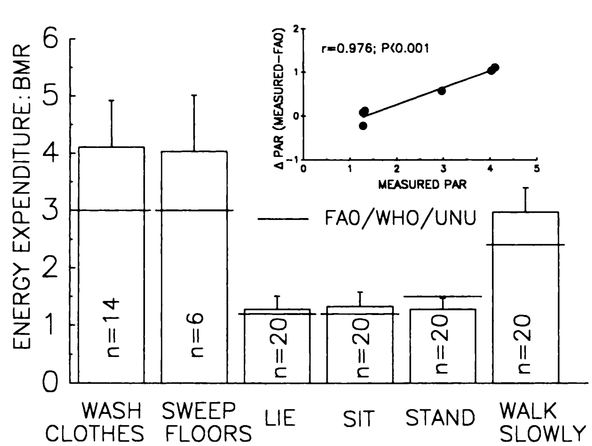

FIGURE 2. Comparison of measured values of energy expenditure of six activities with those obtained from the tables provided by the FAO/WHO/UNU (8). Inset shows the relation between the absolute measured physical activity ratio (PAR) and the measured difference in PAR minus the value from the FAO. $\bar{x} \pm$ SD.

Dietary EI (Table 3) was 8.87 ± 2.51 MJ/d (2122 ± 600 kcal/d) in the women at home and 9.04 ± 2.01 MJ/d (2163 ± 481 kcal/d) in the women at home; ratios of EI to BMR were 1.83 ± 0.49 and 1.73 ± 0.48, respectively, and were not significantly different between groups. Although there was variation in EI by occupation (Table 1), only the difference between child care and factory workers tended to be significant. However, if one does the same analysis of EI:BMR, the significant difference by ANOVA disappears. There is a close relation between BMR and body size (2) and body weights by occupation were not significantly different (Table 1). On average, the intake by women at home and at work was reflective of an adequate dietary EI and together with the anthropometric data indicated nutritionally normal subjects.

The flex-HR method for estimating average EE has been validated by both whole-body, indirect calorimetry (17, 18) and DLW (19, 20) and has been used satisfactorily in both field (21, 40) and laboratory experiments (22, 41).

Concern is sometimes expressed about the effect of differences in ambient temperature between calibration conditions in the laboratory and those existing in the environment during daily measurements of HR, particularly in the tropics. In the present study laboratory temperatures during subject calibration averaged 23.3 ± 1.3 °C. During the days of HR recording, ambient temperature increased from 24.4 ± 1.4 °C in early morning to a high of 30.6 ± 2.4 °C in early afternoon, declining thereafter. The effects of acclimation to hot environments on HR are well known. Important among them is the rapid reduction in HR response to hot environments, particularly when subjects are performing work (42, 43). In acclimatized subjects, HR responses to different workloads at ambient temperatures of 14, 22, and 30 °C were not significantly different (44). In the present study the subjects were poor women who do a lot of walking and their daily chores without the benefit of electrical appliances (washing machines, vacuum cleaners, etc) or air-conditioning, and can be presumed to be acclimated to the warm climate prevalent in Cali, where the mean annual temperature is usually > 24 °C (high of ≈29 °C in dry seasons; a low of ≈18 °C during wet seasons). The possible effects of ambient temperature and/or emotion on the measurement of EE by the flex-HR method have been major sources of doubt about its accuracy from its earliest application. There have been numerous validation studies (19–22) in which EE measured by DLW was satisfactorily compared with the EE measured by the HR method, even in warm climates (21). There were no significant differences between groups of subjects by the two methods (19–22). This means that in free-living subjects exposed to the usual vicissitudes of daily life, the factors of emotion or ambient temperature did not contribute sufficient error to the measurement of EE by the flex-HR method to produce a significant difference when compared with EE obtained from DLW.

In the present experiments, there were no significant differences in TDEE between the 2 d of measurement by either method in either group of women (Table 3). The higher average TDEE in the women at work (9.99 ± 1.91 MJ/d) compared with those at home (8.89 ± 2.11) was significant ($P = 0.036$). This difference disappeared when values were adjusted for body weight or FFM, indicating that body size was the reason for the difference (Table 2). PALs were not significantly different between the two groups (Table 3), perhaps because of difference in body weight and therefore in the BMR values of the two groups (Table 3). Average PAL values (1.83 and 1.90) are those classified as moderate and heavy work for women by the FAO/WHO/UNU (8). Stein et al (3) reported TDEE values of 9.45 ± 0.64 and 8.20 ± 0.30 MJ/d (by DLW) for women of upper and lower socioeconomic status living in Guatemala City. Schulz and Schoeller (45) reviewed measurements of TDEE by DLW and reported a value of 8.67 ± 2.16 for 31 women living in developing countries and a PAL value of 1.97 ± 0.40 for the same women. This was not significantly different ($P = 0.256$) from the combined values (1.86 ± 0.44) observed in our subjects (Table 3). In any event, our values obtained by the flex-HR method were close to what might be expected in NPNL, nutritionally normal women living in an urban environment of a developing country and were not significantly different from EIs.

PAL values of 1.47 and 1.50 for both groups obtained by the factorial method were barely the "baseline" energy needs reported by the FAO/WHO/UNU (8) and again suggest that this method produced unacceptably low TDEE values and therefore low PAL values in our subjects. The factorial method resulted in TDEE and PAL values that were not significantly different in the two groups (Table 3). In both the women at home and at work, TDEE and PAL values derived with the factorial method were significantly less than those obtained by HR monitoring. This finding agrees with that of previous studies that compared the factorial method with HR monitoring. Schulz et al (41) reported significantly lower TDEE values obtained from daily activity diaries than from HR monitoring. Leonard et al (40) also found lower TDEE values estimated by the factorial than by the flex-HR method in both men and women agriculturists in Ecuador. The relatively good agreement of the factorial method with calorimetry reported by Geissler et al (12) was probably related to the fact that the EE values of the various activities observed were measured by indirect calorimetry in the subjects studied as well as the fact that with a whole-body calorimeter, the restrictions imposed on activity would force comparisons between methods measuring low-intensity activities.

The subjects' pattern of EE during the time of study could only be measured by HR monitoring or factorial methods. Motion sensors may one day be useful either as an adjunct to HR monitoring or by themselves, but are not now in widespread use. There were no significant differences in the pattern of EE between days 1 and 2 in either group of women by either method of measurement, nor was there a significant interaction term in the two-way ANOVA with repeated measures. The analysis is sensitive enough, however, to detect significant variations with time during the day. It was therefore justified to average values for days 1 and 2 for the analysis presented in Figure 1. The comparison of patterns at home and at work in panel A of Figure 1 show an almost significant difference between the two groups of women. The midmorning, noontime, and midafternoon breaks in activity seen in the women at home also have their counterparts in the pattern of women at work. Differences are probably related to the fact that the women at home have control of their own schedules while at work the demands of the workplace take precedence. The variety of jobs in which the women were employed (Table 1) would seem to preclude a standard pattern of rest stops or even midday meals (Figure 1). The patterns obtained by the factorial method were significantly different in the two groups of women (Figure 1B). When averaged data from the two methods were compared (Figure 1, C and D), there was a marked and significant difference between them with the factorial method giving values lower than the flex-HR method. Even so, there is a marked similarity between the two methods in the patterns at home (Figure 1C).

The lack of difference between TDEE and EE values obtained on 2 separate days (Table 3) by either the flex-HR or factorial method means that 1 d of measurements is adequate for estimating the averages of groups when activities are similar on day 2. Although the advantages of measuring the pattern of EE may be obvious to anthropologists or work-exercise physiologists, it remains to be seen whether it will offer increased information for nutritionists. At the moment, answers to the mysteries of the equation EI = EE are still being sought without complicating the equation by adding a daily time factor to both sides, even though time may play a role. For example, it is known that an increase in the frequency of meal ingestion has metabolic effects (46, 47) and increases dietary-induced thermogenesis (47). However, there does not appear to be any effect on TDEE, BMR, or energy expended in activity (47). On the other hand, there do not appear to be any studies of the effects of alterations in the *pattern* of EE on energy metabolism or dietary EI. The ability to follow the pattern of EE may provide the opportunity for such studies. The flex-HR methods may also be useful in epidemiologic studies relating physical activity to various disease states or obesity. The use of activity-recall methods seems to be unsatisfactory.

In most reports of the use of the factorial method, as well as in the present study, it is customary to use EE values from published tables (7, 8) because of the additional time factor of individual task measurement in an already time-consuming procedure. This may be one of the causes of the low values observed with this method. The difference between values taken from the literature (8) and measured values shown in Figure 2 suggests that had we used the latter, the factorial method might have given results closer to those obtained by HR monitoring. Data in the inset of Figure 2 further indicate that there is closer agreement between sedentary values and that the difference between the two methods increases with intensity (EE) of the activity. A similar suggestion was made by Leonard et al (40). The fact that the present study relied on trained observers and not subject recall removes the latter as a factor in the low values obtained.

In summary, both the flex-HR and factorial methods of estimating daily EE give values for TDEE and the pattern of EE during the awake portion of the day that are very repeatable on 2 successive days. Consequently, 1 d of measurement is sufficient to describe the TDEE and pattern of EE of groups (although several days of measurement averaged for each subject will yield a smaller group SD and thus increase the chances of detecting significant differences among groups). However, the factorial method gives values for EE that are lower than those obtained by flex-HR. The latter method gives values for TDEE close to those expected from other studies and is better able to distinguish two groups of women working either at home or at work. Also, the flex-HR method is suitable for establishing patterns of EE in free-living subjects. The women at home and at work are working at levels considered moderate or heavy by FAO/WHO/UNU (8) standards.

Answers to the questions posed earlier are as follows: *1*) both methods give repeatable results on 2 successive days of similar activities, *2*) the patterns obtained by the two methods were very similar in women at home whereas they were quite dissimilar in women at work, *3*) the patterns of EE were different in the two groups of women studied and this difference was most readily discernible by the flex-HR method, and *4*) the low values obtained in these studies by the factorial method seem to be due to the fact that the energy costs of tasks obtained from published tables of values are lower than those measured by indirect calorimetry in these subjects.

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