

Measurement of Energy Expenditure among Free Living Active and Sedentary Women (18-23 Years): Results of Objective and Self-Reported Assessment

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Abstract Background: Heart rate monitoring has been advocated for assessing energy expenditure in field studies. The aim of the study is to determine and compare the energy requirements by heart rate method and factorial method and measure PWC_{170} for young active and sedentary women. **Methods:** A cross-sectional study on 30 collegiate women (18-23 years) was conducted. Young active (Group A) (n=15) and age matched sedentary women (Group S) (n=15) were selected based on an inclusion criterion. Using standard procedures, data was collected on general information, anthropometry, blood pressure, body composition, PWC_{170} , HR- VO_2 relationship, diet and physical activity to compute energy requirements. **Results:** Individual HR- VO_2 equations were developed. Mean TDEE by factorial method for Group A was 2256 ± 246 kcal and for Group S was 1772 ± 163 kcal. Mean TDEE by heart rate method of Group A was 1952 ± 68 kcal and of Group S was 1579 ± 116 kcal. Mean PWC_{170} for Group A and Group S were 94.8 ± 6.9 and 93.5 ± 13.9 watts respectively. PAL for Group A was 32% higher than Group S. **Conclusion:** The heart rate technique is a useful tool for computing energy requirement of active groups because of its simplicity and potential use in free living conditions.

Keywords: energy requirement, heart rate method, PWC_{170} , factorial method, total daily energy expenditure

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1. Introduction

The energy expenditure of individuals and groups are of vital interest to nutritionists for policy, therapeutic and research purposes. The body needs energy for maintaining body temperature and metabolic activity and for supporting physical work and growth. Energy balance is achieved when input (i.e. dietary energy intake) is equal to output (i.e. total energy expenditure), in adults. Human energy requirements are estimated from measures of energy expenditure plus the additional energy needs for growth, pregnancy and lactation [1]. Various methods, suitable for field studies, have been developed for computing energy expenditure. Evaluation of two of the methods, heart rate monitoring and activity diaries is addressed in this paper.

Heart rate monitoring is a method of estimating energy expenditure that is based on the strong positive correlation that exists between heart rate and oxygen consumption [2,3]. The development of small instruments which measure and store heart rate (HR) minute-by-minute for long periods of time has considerably improved the applicability of this technique to the measurement of total daily energy expenditure (TDEE). The relationship between HR and oxygen consumption (VO_2), is unique to

each individual and is normally described as linear at energy expenditure above basal and below maximal output [4]. Individual calibration to obtain VO_2 - HR relationship and is a cardinal feature of most studies using HR to obtain energy expenditure (EE) [2,5].

Physical activity is an integral part of everyday life. In general the capacity to transform chemical energy into mechanical work is the work capacity of the organism. Physical work capacity (PWC) is defined as the maximal amount of oxygen that a subject can consume during short term maximal exercise (1 or 2 min) [6]. The purpose of this study is to determine and compare the energy requirements by two methods namely heart rate and factorial method respectively, and measure PWC_{170} for young active and sedentary women in the age group of 18-23 years.

2. Subjects and Methods

Thirty healthy, collegiate women (18-23 years) participated in the study. Young active women in the college basketball team (n=15) and age matched sedentary women (n=15) were selected from Lady Irwin College, New Delhi. Active women were enrolled in the study based on an inclusion criteria of being unmarried, not suffering from any kind of respiratory illness and not

having any history of diseases like diabetes, cardiovascular disease, asthma, hypertension, etc.; not consuming any hormones or drugs; being in their prefollicular/ premenstrual phase of menstrual cycle and involved in active sport for one year, at least 1 hour/day, 5 times a week. Sedentary women were included based on a similar inclusion criterion except being actively involved in any sport for at least 1 hour/day, 5 times a week. The study had an institution ethical clearance. A formal informed consent was obtained from all subjects and they agreed to adhere to their regular food intake and activity patterns; and maintained their current training program throughout the course of the study.

2.1. Anthropometric Assessment

Body weight (to nearest 0.1 kg) was measured using a digital balance and height (to nearest 0.1 cm) was measured using anthropometric rod. Prior to the measurements the subjects were told to dress in light clothing and were instructed to stand barefoot and straight with the head in the Frankfurt plane. Body mass index was calculated as weight (kg) divided by height (m) squared. Mid- upper arm circumference was measured using a flexible non- stretchable tape made of fibre glass on the left hand at the midpoint of the upper arm, between the acromion process and tip of the olecranon, to the nearest 0.1 cm. Hip circumference was measured at the largest posterior extension of the buttocks and waist circumference was measured at the midpoint between subcostal and suprailiac landmarks. Waist circumference was measured using an inelastic tape, kept in contact with skin without pressing it [7]. Measurements were taken in duplicate.

Blood pressure was measured using sphygmomanometer. Two readings separated by 5 minutes were averaged to get a precise measurement. The TANITA Body Composition Analyzer (BC- 420 MA) was used to measure the body composition. Estimated values of Lean body mass (LBM), Body fat % (BF %) and Total body water (TBW) were obtained.

2.2. Cardio Respiratory Index- PWC₁₇₀

Cardio respiratory fitness or PWC₁₇₀ (Physical Work Capacity) was assessed in Exercise Physiology Lab, Defence Institute of Physiology and Allied Sciences (DIPAS) using a modified physical working capacity test (PWC) on a Monark cycle ergometer that predicted the workload at an HR of 170 beats·min⁻¹ (PWC₁₇₀). Participants were instructed to avoid vigorous exercise on the day of testing, and not to consume food, alcohol, caffeine or tobacco products two hours before testing. After briefing the subjects on the procedure of the test, each subject was given a warm up trial test at a lower load of 25 watts (W). Each test stage lasted for 2 minutes and the wattage was increased from 25W to 50 W to 75W to 100W to 125W depending on the subject's cardio respiratory fitness. Pedaling frequency throughout the test was to be kept at 60 rev·min⁻¹. At the end of each minute of the test, the heart rate was recorded, measured via Polar Sports tester heart rate monitor (RS 400) placed around the chest at the level of the xiphoid process of the sternum. The watch like receiver was worn on the wrist. The participant's heart rate at the end of the stage was used to

determine the change in resistance for the next stage and resistance for each stage was recorded. Cycle ergometers were calibrated before each day's testing. The PWC₁₇₀ was calculated by using the loads and the heart rates by the following Eq. (1) and Eq. (2) [8]:

When $Hf_2 > 170$, then,

$$PWC_{170} = L_2 - L_1 / Hf_2 - Hf_1 (Hf_2 - 170) \quad (1)$$

When $Hf_2 < 170$, then,

$$PWC_{170} = L_2 + L_1 / Hf_2 - Hf_1 (170 - Hf_2) \quad (2)$$

Where, PWC₁₇₀ = Physical Work Capacity at Heart Rate 170, L₁ and L₂ are two different loads, and Hf₁ and Hf₂ are heart rates at L₁ and L₂.

2.3. Dietary Intake (24-hour Dietary Record)

To assess the intake pattern, the subjects maintained a 24-hour dietary record for one working day. A record sheet was given to the subjects. The energy intake was calculated by converting food items into raw ingredients and then calculating the calorific values from Nutritive Value of Indian Foods [9]. 'Diet soft' software version 1.1.7 was used to calculate the nutrient intake.

2.4. Heart Rate Method

The use of HR to estimate EE was based on the assumption of a close individual linear relationship between HR and VO₂ and thus also between HR and EE [2]. The heart rates were recorded using the Polar Sports tester heart rate monitor (RS 400). HR monitoring was done for one working day beginning at 7:00 am for active women and at 9:00 am for sedentary women; and ending at the same time next day. The heart rate recorder was disconnected when the subjects were bathing or sleeping during the day. The average length of HR monitoring was > 12 hours for each subject. The recorded data was transferred via the Infra-red device to Polar Pro Trainer 5 software for complete analysis. Aberrant readings, if observed, were replaced by the average of the previous and subsequent values.

2.5. Activity Record

Subjects completed 24 hour activity record for the same day of the HR monitoring to reflect the EE. The form included three columns; first column was time, second column was activity and the last column was remarks. A sample record of activities as a guideline was given to the study subjects prior to obtaining the information.

2.5.1. BMR Estimation

Basal metabolic rate of each subject was predicted by using equations based on body weight, age and sex [1]. The Eq. (3) used for females (18-30 years) was:

$$BMR = 14.818 \times \text{Body Weight (Kg)} + 486.6. \quad (3)$$

The calculated BMR was used in computing day's requirement as described in FAO/WHO/UNU (2004). PAR and PAL was also computed for both the groups.

2.6. HR and VO₂ Measurement during Activities

HR and O₂ consumption (VO₂) were measured simultaneously. The subjects were briefed on the procedure of the test to obtain VO₂ and HR on a Monark ergometer (828 E) in Exercise Physiology lab, Defence Institute of Physiology and Allied Sciences (DIPAS). Daily records of ambient room temperature and relative humidity were recorded. The face mask was put on and held by stretchable rubber straps. The subjects were seated on the bicycle ergometer for 2 minutes and then the loads were increased till exhaustion. Two consecutive readings of VO₂ and HR were obtained with the subject sitting idle on the bicycle ergometer. The average of two readings was used as the RMR and it was expressed as shown by Eq. (4):

$$RMR \text{ (Kcal / min)} = 5 * VO_2 \text{ (L / min)} \quad (4)$$

A calorific equivalent of 5 kcal/l of oxygen [10] was used to convert the VO₂ values to EE. For HR above FHFLEX, corresponding EE was determined by using the regression equations applicable to individual subjects. Total Energy Expenditure (TEE) was computed using the Eq. (5):

$$TEE = (t1 * BMR) + (t2 * RMR) + (t3 * dEE) \quad (5)$$

Where, t1 = time spent at BMR, t2 = time spent at HR < FHFLEX and t3= time spent at different HR > FHFLEX.

2.7. Estimates of EE from HRM

Individual estimates of EE were made with HR monitoring technique. Individual regression equations were developed to predict EE in Kcal/min from HR. The regression was introduced as the relationship between HR and VO₂ over the range of heart rates. Regression equations were established from all sub maximal heart rates and VO₂ measurements. It is well documented that there is a different HR-VO₂ relationship at low and higher energy expenditure activities. Therefore, it was necessary to determine the point of inflection, which is referred to as FHFLEX. The heart rates above FHFLEX were used to calculate VO₂ from calibration curve/ regression equation and heart rates below the FHFLEX were calculated from different regression equations. Flex HR was calculated as the mean of the highest resting pulse and the lowest on exercise + ten [11]. The mean daily heart rate was applied to the single line regression equation to estimate the mean energy expenditure. The individual calibration data was used to predict minute-by-minute energy expenditure for each person.

2.8. Estimates of EE from Activity Record

EE was calculated from activity records using the energy cost of activities found in the literature. Typical training activities for active women playing basket ball included warming up, running, basketball practice, stretching exercises and residual time. For the sedentary women, the typical activities throughout the day were attending theory and practical classes and lunch time in between.

3. Statistical Analysis

The entire data was expressed in mean ± SD. Unpaired t test was used for comparison between active and sedentary women. Pearson's correlation was calculated for HR (≥ FHFLEX) and corresponding EE and individual linear regression equations were calculated to establish the relationship between HR and corresponding EE for active and sedentary subjects. Level of significance was kept at 0.05. Statistical analysis was done using SPSS (17.0) software.

4. Results

Several methods have been used to determine EE for computing energy requirements of groups of individuals. The findings of the study were based on thirty young collegiate women in the age range of 18-23 years. Mean age of young women belonging to the active and sedentary group was 20.0 years. Comparison of the anthropometric measurements between Group A and Group S are presented in Table 1.

Table 1. Anthropometric and body composition data of Group A and Group S (Group A, Active; Group S, Sedentary; BMI, body mass index; WC, waist circumference; HC, hip circumference; MUAC, mid-upper arm circumference; FFM, fat free mass; TBW, total body water; BMR, basal metabolic rate. Mean ± SD in rows; range in parentheses (all such values). 1 Equation used: BMR= 14.818 X Body Weight + 486.6 [1].)

Parameters	Group A (n = 15)	Group S (n = 15)
Height (cm)	156.96 ± 3.42 (153.4-163.0)	158.65 ± 4.93 (146-167.2)
Weight Kg)	52.25 ± 7.67 (40.0-65.0)	55.19 ± 6.5 (45-66.8)
BMI (Kg/m ²)	21.27 ± 3.02 (16.8-26.0)	22.08 ± 3.17 (18.3-29.1)
WC (cm)	71.6 ± 6.75 (58.4-83.8)	72.8 ± 8.14 (66.0-91.4)
HC(cm)	94.9 ± 7.5 (83.8-111.8)	96.4 ± 6.3 (86.4-107.9)
MUAC (cm)	24.4 ± 3.24 (20.3-30.0)	25.09 ± 2.57 (21.5-29)
Fat %	20.13 ± 7.26 (7.5-32.4)	22.07 ± 6.22 (11.4-30.2)
Fat mass (Kg)	11.7 ± 5.35 (3.9-22.9)	12.53 ± 4.77 (5.2-20.2)
FFM (Kg)	41.86 ± 2.89 (38-47.7)	42.56 ± 2.25 (39-46.6)
Muscle mass (Kg)	39.55 ± 2.93 (35.7-45.3)	40.47 ± 2.13 (37-44.2)
TBW (Kg)	29.03 ± 2.55 (25.6-34.0)	29.78 ± 1.82 (27.0-33.0)
TBW %	55.7 ± 4.69 (48.2-65.6)	54.35 ± 3.91 (47.6 - 60.0)
BMR(Kcal/d) ¹	1261 ± 114 (1194-1505)	1304 ± 96 (1231-1453)

Mean systolic BP for Group A was 113.7 ± 4.73 mm Hg and for Group S was 118.3 ± 7.22 mm Hg. Mean diastolic BP for Group A was 73.5 ± 4.45 mm Hg and for Group S it was 75.06 ± 6.01 mm Hg. Mean systolic BP of Group S was 4% higher as compared to Group A and mean diastolic BP of Group S was 2% higher as compared to Group A. This difference was significant (p < 0.05) between Group A and Group S for systolic blood pressure.

Body composition was determined using TANITA Body Composition Analyzer (BC- 420 MA) for Group A and Group S. Comparison of body composition between Group A and Group S are given in Table 1. High correlations were observed between anthropometric and body composition variables for Group A and Group S (Table 2). BMI of Group S was higher as compared to the Group A by 3.8%. Mean PWC₁₇₀ values for Group A and Group S were 94.8 ± 6.9 and 93.5 ± 13.9 watts respectively. PWC₁₇₀ of Group A was just 5% higher than Group S.

Table 2. Correlation Analysis for Group A and Group S (Pearson correlation coefficient, $p < 0.01$. Group A: Active; Group S: Sedentary; BMI- body mass index; FFM- fat free mass; TBW- total body water)

Group A	Weight (Kg)	Fat %	Fat mass (Kg)	FFM (Kg)	TBW (Kg)	TBW %	BMI (Kg/m ²)
Weight (kg)	1.00	0.98	0.92	0.91	0.97	-0.97	0.96
Fat %		1.00	0.9	0.84	0.92	-0.99	0.96
Fat mass (Kg)			1.00	0.94	0.91	-0.84	0.86
FFM (Kg)				1.00	0.97	-0.79	0.83
TBW (Kg)					1.00	-0.89	0.88
TBW %						1.00	-0.94
Group S	Weight (Kg)	Fat %	Fat mass (Kg)	FFM (Kg)	TBW (Kg)	TBW %	BMI (Kg/m ²)
Weight (kg)	1.00	0.92	0.97	0.84	0.87	-0.90	0.87
Fat %		1.00	0.99	0.58	0.63	-1.00	0.92
Fat mass (Kg)			1.00	0.94	0.91	-0.84	0.86
FFM (Kg)				1.00	1.00	-0.53	0.54
TBW (Kg)					1.00	-0.59	0.59
TBW %						1.00	-0.92

Table 3. TDEI and TDEE (HR and Factorial Method) of Group A and Group S (¹Unpaired t test, $p < 0.05$. Group A: Active; Group S: Sedentary; HR- heart rate; TDEE- total daily energy expenditure; TDEI- total daily energy intake.)

Group A	TDEI ¹ (Kcal/d)	TDEE ¹ (Kcal/d) HR Method	TDEE ¹ (Kcal/d) Factorial Method	Group S	TDEI ¹ (Kcal/d)	TDEE ¹ (Kcal/d) HRMethod	TDEE ¹ (Kcal/d) Factorial Method
A1	1620	2008	2526	S1	1687	1639	2014
A2	1720	2082	2528	S2	1424	1566	1671
A3	2243	2029	2133	S3	1507	1534	1794
A4	2040	2003	2295	S4	1549	1554	1952
A5	1467	1934	2330	S5	1478	1653	1526
A6	1912	1962	2149	S6	1555	1502	1979
A7	1665	1950	2591	S7	1441	1628	1826
A8	1697	1933	2377	S8	1542	1713	1590
A9	1783	1875	1975	S9	1313	1417	1707
A10	1655	1900	2395	S10	1975	1433	1737
A11	1930	1934	2043	S11	1462	1487	1701
A12	1884	1904	2603	S12	1634	1763	1963
A13	1883	1997	1979	S13	1556	1790	1921
A14	1564	1974	2075	S14	1444	1559	1553
A15	2085	1802	1846	S15	1339	1450	1647
MEAN	1810	1952	2256	MEAN	1527	1579	1772
SD	212	68	246	SD	159	116	163

4.1. Estimates of Total Daily Energy Intake (TDEI)

To compute TDEI, 24 hour dietary record was used for all the subjects. Intake was recorded for the same day as energy expenditure was measured. The energy intakes of active women were slightly higher than sedentary women (Table 3). Significant difference was obtained between Group A and Group S for TDEI ($p < 0.05$).

4.2. Estimates of EE from Activity Record Method

The mean values of TDEE by the factorial method for Group A and Group S are presented in Table 3. Mean TDEE for Group A was 27% higher than the sedentary women. Significant difference was obtained between Group A and Group S for TDEE ($p < 0.05$).

4.3. Estimates of EE from Heart Rate Method

Energy expenditures for a period of time were obtained by using the HRM. Estimates of TDEE were made for individual subjects by heart rate monitoring (Table 3). Mean TDEE of Group A was 1952 ± 68 Kcal and of Group S was 1579 ± 116 Kcal. Significant difference was obtained between Group A and Group S for TDEE ($p < 0.05$).

It is well documented that there are different HR/EE relationships for low and high levels of activity. Therefore, FHFLEX was determined, above which HR/EE relationship can be applied and below which RMR was used. BMR value given by FAO/WHO/UNU report (2004) was used for duration of sleep [1]. FHFLEX i.e. the point of inflection was determined individually for all the subjects. Mean time spent in sleep by Group A and Group S subjects was 554 ± 50.8 minutes and 577 ± 72.9 minutes respectively. Mean time spent by Group A and Group S in activities >FHFLEX was 295 ± 75.3 and 175 ± 90.8 minutes respectively. Mean time spent in activities <FHFLEX by Group A and Group S subjects was 591 ± 104.8 and 688 ± 80.95 minutes respectively. No

significant difference between Group A and Group S for EE in sleep and below FHFLEX activities was obtained at $p < 0.05$ level. However significant difference of EE in activities $>$ FHFLEX was obtained at $p < 0.05$. On an average the sample of active women spent 70 ± 9.4 minutes in sports and their mean EE was 164 ± 15.7 Kcal; 2.4 ± 0.3 Kcal/minute; or 3.23 ± 0.5 Kcal/ Kg BW.

HR method and factorial method separately gave a significant difference between Group A and Group S at $p < 0.05$. Significant difference was also obtained between Group A and Group S with respect to the estimation of EE by the two methods. The factorial method gave nearly 16% higher values ($p < 0.05$) than the heart rate method for EE of Group A and 12% higher values ($p < 0.05$) for Group S.

Energy status was also determined for Group A and Group S. Significant difference was observed between Group A and Group S according to TDEE and TDEI at $p < 0.05$. Paired sample t test showed a significant difference between TDEE and TDEI ($p = 0.028$) in Group A, but did not show a significant difference in Group S ($p > 0.05$). The mean energy requirement of Group A and Group S according to the ICMR (2010) recommendations [12] was 14.4% and 20.3% less than the recommendations respectively when the heart rate method was used to estimate EE. Factorial method gave higher EE as compared to the heart rate method and thus Group A subjects had 1.0% higher energy requirement as compared to the ICMR (2010) recommendations and Group S had 7.2% lower energy requirement as compared to the recommendations. The mean energy requirement of Group A and Group S according to ICMR (1990) recommendations [13] was 14.0% and 18.7% less than the recommendations respectively when the heart rate method was used to estimate EE. When expressed as multiples of BMR, mean PAL value for Group A was 1.79 ± 0.07 and for Group S it was 1.36 ± 0.07 . PAL value for Group A was nearly 32% higher as compared to Group S.

5. Discussion

The study was based on the premise that the energy requirement of Group A would be higher as compared to Group S. Further, the objective was to compare the two methods used for measuring EE and the accuracy of these two methods, namely HRM and the factorial method in the study groups. The study results showed that Group A and Group S subjects had a mean WC of 71.6 cm and 72.8 cm respectively. WHO/IASO/IOTF (2000) classification for adult women according to WC who are at risk for developing associated co-morbidities is >80 cm, [14] which indicated low risk for developing co-morbidities at this stage of life among both groups. BMI of Group S was higher as compared to the Group A by 3.8%. Asians generally have a higher percentage of body fat than white people of the same age, sex and BMI. Also, the proportion of Asian people with risk factors for type 2 DM and cardiovascular disease is substantial even below the existing WHO BMI cut-off point of 25 kg/m^2 for adults [15].

5.1. Physical Work Capacity

Physical work capacity data revealed that there was no difference among Group A and Group S. There is no clear consensus on whether cardiorespiratory fitness in youth is indicative of habitual moderate to vigorous physical activity. According to a review that included over 25 studies, there was only a small to moderate relationship between physical activity and cardiorespiratory fitness. While it is acknowledged that other factors, such as genetics, [16] contribute to individual levels of cardiorespiratory fitness, studies examining fitness and physical activity make reasonable arguments for the use of cardiorespiratory fitness as a proxy measure for habitual moderate to vigorous physical activity at the group level [17,18]. Exercise or training leads to the improvement of work capacity and a slightly higher PWC₁₇₀ of Group A indicated that they belonged to the active group. Despite of having >2 years of training the active group engaged only for 3 months actively in sports training per year. Thus only a small difference was obtained in the physical work capacity between Group A and Group S.

5.2. Activity Diary Method for Estimating EE

Factorial method studies of TDEE are useful for understanding energy balance in living human populations, and adaptations to different environmental and nutritional circumstances [19-23]. The study results showed that the factorial method gave higher values as compared to the heart rate method. Factorial method generally suffers from an inherent disadvantage of using literature costs. Use of literature values for estimating the energy cost of activities in the diary method could result specifically in overestimation of daily EE for two reasons. First, the use of energy values derived from discrete measurements to estimate the expenditure of serial activities may fail to account for transitions in EE from one activity to the next, and may, thus, give a higher energy value than is appropriate for those transition periods. Second, literature values could be overvalued for this population. Studies comparing the diary method with continuous 24 hour measurements of EE in a respiration chamber and accelerometers found individual discrepancies, but concluded that the factorial method was adequate for predicting population EE [20,23].

5.3. Heart Rate Method for Estimating EE

In view of energy intake data, HRM gave closer estimates of TDEE than factorial method for Group A and Group S. Heart rate monitoring is a method for estimating energy expenditure that is based on the strong positive correlation that exists between heart rate and oxygen consumption. The relationship between HR and oxygen consumption (VO_2), while unique to each individual, is normally described as linear at energy expenditure above basal and below maximal output. Among the various factors posture, site of muscle activity, emotions, temperature, meal, physical training affect the heart rate/energy expenditure relationship hence individual equations are used for computing energy expenditure from heart rate records. Heart rate is a better predictor of oxygen consumption at sub-maximal than maximal levels. The variation from this technique is probably ± 5 to 15% from continuously recorded values, depending on the amount of sedentary activity involved [5]. Figure 1 depicts

HR-VO₂ relationship curve for one subject belonging to Group A.

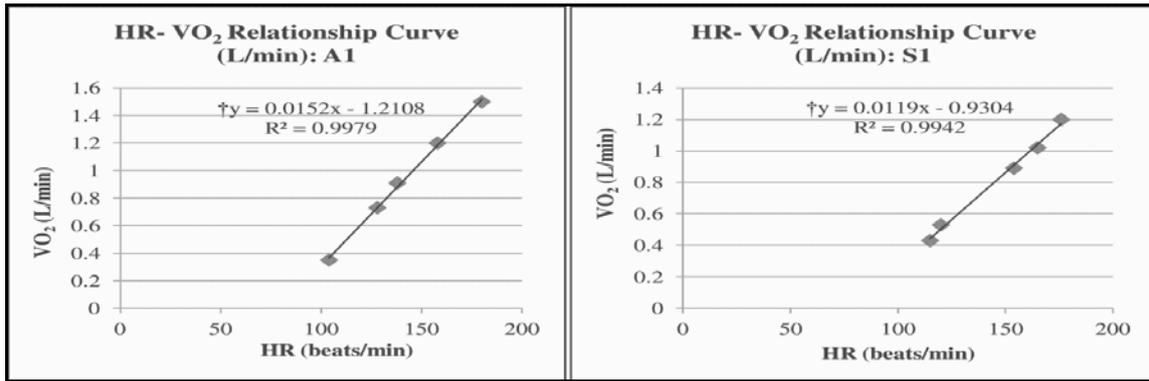


Figure 1. Individual HR-VO₂ relationship curve (HR- VO₂ curve for one subject showing a linear relationship between heart rate (HR) and oxygen consumption (VO₂) for one Group A and one Group S subject. † y= EE (Kcal/ minute), x= HR (beats/minute))

It is well documented that there are different HR/EE relationships for low and high levels of activity. Therefore, FHFLEX was determined, above which HR/EE relationship can be applied and below which RMR was used. BMR value given by FAO/WHO/UNU (2004) was used for duration of sleep [1]. FHFLEX i.e. the point of inflection was determined individually for all the subjects. The heart rates above FHFLEX were used to calculate VO₂ from the regression equations. Individual regression equations for Group and Group S are given in Table 4. Average of heart rates below FHFLEX was computed and used to calculate the TDEE. Mean FHFLEX values of

Group A and Group S were 104.5 ± 11.35 and 105.1 ± 7.16 beats/ minute respectively. In aerobically fit subjects the lower HR FLEX seems appropriate and the resting HR during standing can be as high as, or even higher than the lowest exercising HR. Thus, regression equations were derived for the time spent in activities where heart rate was more than FHFLEX. Individual graphs between VO₂ and HR were made to estimate VO₂ from HR above FHFLEX. The equation used to determine EE was:

$$EE \text{ (Kcal / min)} = 5 * VO_2 \text{ (L / min)} \quad (6)$$

Table 4. Individual Regression Equations for Group A and Group S (Group A, Active; Group S, Sedentary; EE, energy expenditure. † y= EE (Kcal/ minute), x= HR (beats/minute).)

Group A	Regression equation [†]	Correlation Coefficient	Group S	Regression equation [†]	Correlation Coefficient
A1	y = 0.015x - 1.210	+0.99	S1	y = 0.011x - 0.930	+0.99
A2	y = 0.021x - 1.742	+0.99	S2	y = 0.012x - 0.902	+0.99
A3	y = 0.013x - 0.921	+0.99	S3	y = 0.014x - 1.427	+0.97
A4	y = 0.017x - 1.216	+0.99	S4	y = 0.010x - 0.754	+0.98
A5	y = 0.012x - 0.891	+0.97	S5	y = 0.016x - 1.512	+0.98
A6	y = 0.020x - 1.626	+0.99	S6	y = 0.012x - 0.929	+0.99
A7	y = 0.012x - 0.685	+0.99	S7	y = 0.015x - 1.634	+0.99
A8	y = 0.012x - 0.913	+0.99	S8	y = 0.014x - 1.061	+0.99
A9	y = 0.009x - 0.817	+0.99	S9	y = 0.012x - 1.020	+0.98
A10	y = 0.016x - 1.319	+0.99	S10	y = 0.008x - 0.577	+0.99
A11	y = 0.031x - 4.402	+0.99	S11	y = 0.010x - 0.633	+0.99
A12	y = 0.016x - 1.538	+0.92	S12	y = 0.015x - 1.259	+0.99
A13	y = 0.014x - 1.244	+0.99	S13	y = 0.016x - 1.403	+0.95
A14	y = 0.011x - 0.677	+0.99	S14	y = 0.011x - 0.986	+0.99
A15	y = 0.018x - 1.723	+0.99	S15	y = 0.011x - 1.056	+0.97

One of the inaccuracies of the minute by minute heart rate method is giving a slow return of the heart rate to resting levels than the EE after bouts of activity. This could lead to inaccurate data. Although the heart rate technique cannot give as accurate results as given by calorimetry or DLW method, it can give a close estimate of EE even in small groups in free living conditions.

On an average the active women were spending around 2.4 kcal/min and according to European Network for Prevention and Health Promotion in Family Medicine and General Practice (EUROPREV) guide on Promoting Health through Physical Activity, the EE for basketball game accounts for 7 METs i.e. 6.4 Kcal/min which is much above the expenditure by Group A in their basketball practice (body weight = 55 Kg for adult women [24]). Therefore, the only difference between Group A and Group S was that despite both being college students, Group A was spending 1 hour in the morning basketball practice session. Sixty minutes of daily exercise has been

advocated to increase the PAL of sedentary people to a value of 1.75 or greater, which assists in weight maintenance [1]. Simple efforts like this can raise the PAL from 1.36 to 1.75. If this 1 hour of physical activity is a sport or any other rhythmic exercise, the advantage of cardio-respiratory maintenance is gained additionally to weight maintenance. Such activities prevent chronic degenerative disorders and thus there is a recommendation in the society as a whole to become moderate workers by doing exercise.

6. Conclusion

Heart rate monitoring is a non-invasive technique which is ideal for the active population and allows free movement of the subjects. In view of energy intake data HRM gave closer estimates of TDEE than factorial method. The heart rate technique is a useful tool for

computing energy requirement of active groups because of its simplicity and potential use in free living conditions. More research is needed on heart rate method to measure EE on India's growing sedentary population.

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8. Conflict of Interest

The authors have no potential conflict of interests.

9. Abstract Publication

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10. List of Abbreviations

1. BF%- Body fat percent
2. BMI- Body Mass Index
3. BMR- Basal Metabolic Rate
4. BP- Blood pressure
5. DIPAS- Defence Institute of Physiology and Allied Sciences
6. DLW- doubly labelled water
7. DM- Diabetes Mellitus
8. EE- Energy expenditure
9. EUROPREV- European Network for Prevention and Health Promotion in Family Medicine and General Practice
10. FAO- Food and Agriculture Organisation
11. FHFLEX- heart rate where two HR-VO₂ relation curve change
12. HC- Hip circumference
13. HR- Heart rate
14. HRM- heart rate method
15. IASO- International Association for the Study of obesity
16. ICMR- Indian Council of Medical Research
17. IOTF- International Obesity Task Force
18. MUAC- Mid upper arm circumference
19. PAL- Physical Activity Level
20. PAR- Physical Activity Ratio
21. PWC- Physical work capacity
22. PWC₁₇₀- Physical work capacity at heart rate 170
23. RDA- Recommended Dietary Allowance
24. RMR- Resting Metabolic Rate
25. TBW- Total body water
26. TDEE- Total daily energy expenditure
27. TDEI- Total daily energy intake

28. TEE- Total energy expenditure
29. UNU- United Nations University
30. VO₂- Oxygen consumption
31. W- watts
32. WC- Waist circumference
33. WHO- World Health Organisation

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