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Field Evaluation of the Computer Science and Application's Inc. Activity Monitor during Running and Skating Training in Adolescent Athletes

U. Ekelund[1,2], A. Yngve[1], M. Sjöström[1,2], K. Westerterp[3]

[1] Unit for Preventive Nutrition, Department of Medical Nutrition, Karolinska Institutet, Stockholm, Sweden
[2] Department of Physical Education and Health, Örebro University, Örebro, Sweden
[3] Department of Human Biology, Maastricht University, Maastricht, The Netherlands

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This study investigated the validity of the CSA activity monitor for assessment of the total amount of physical activity in adolescent athletes. Activity data were compared to data on daily energy expenditure and its derivatives measured by the doubly labeled water method. Seven athletes (speed skaters) with a mean age of 18.2 ± 1.1 y were monitored twice (off-season and pre-season) by the activity monitor for eight consecutive days. The primary training during the off-season period was running whereas the pre-season period mainly involved skate training (i.e. inline skating, slideboard training, and skating imitations). Activity counts were significantly correlated to all energy estimates during the off-season period ($r = 0.93 – 0.96$; $P < 0.01$) whereas not during the pre-season period ($r = 0.32 – 0.57$). A two-way multivariate analysis of variance showed a significant period effect for activity counts (668 ± 163 vs. 548 ± 91; $P = 0.026$) whereas not for total daily energy expenditure (15.7 ± 2.1 $MJ \times d^{-1}$ vs. 16.0 ± 1.0 $MJ \times d^{-1}$; $P = 0.71$). The relationship between activity counts and total daily energy expenditure seems to be affected by different training conditions. Therefore these circumstances have to be carefully considered in the interpretation of activity monitor data.

Key words: Accelerometer, doubly labeled water, energy expenditure, physical activity.

Introduction

Energy balance and nutritional status affect athletic performance. However, the current understanding of the energy intake and expenditure of young athletes is limited [17]. One of the reasons for this is the difficulty in measuring either total daily physical activity or total daily energy expenditure (TDEE). The assessment of physical activity includes self-report methods, such as questionnaires and activity diaries, as well as heart rate monitoring, accelerometers, and the doubly labeled water method (DLW). Advantages and disadvantages of the different methods have been discussed [12,13,15]. The self-report methods have been found to underestimate the total energy expenditure in athletes [3]. Heart rate monitoring has been validated against indirect calorimetry and DLW and seems to provide a close estimation of TDEE [5,9]. The validity of accelerometers for use in athletes remains to be elucidated.

The DLW method is the reference method for the assessment of energy expenditure in subjects under free living conditions. It provides a measure of total energy expenditure over periods of 1 – 3 weeks and therefore the average TDEE can be estimated [14,21]. DLW measurements of TDEE have an accuracy of 4 – 7% [14]. Together with an estimate of resting metabolic rate (RMR) the physical activity level (PAL = TDEE/RMR) can be calculated. The absolute amount of energy expenditure from physical activity, energy expenditure (AEE), can also be calculated by subtracting RMR from TDEE. Due to the high costs of the stable isotopes and the need for isotope ratio mass spectrometry for analysis, the application of the method is limited to small samples. Furthermore the DLW method does not provide any information about the intensity, frequency, or duration of physical activity. Nevertheless the method is today the best method for validation of other physical activity assessment techniques in field settings.

The Computer Science and Applications Inc. (CSA) activity monitor (model 7164) is a small (5 × 5 × 1.5 cm) and light weight (43 gram) uniaxial accelerometer which can store data for up to 22 days when data are sampled at a one minute interval. A high inter-instrument reliability ($r = 0.87$) during walking and jogging at three different speeds on the treadmill have been found in 10 – 14 y old boys and girls [18]. The correlation between energy expenditure (EE) measured by indirect calorimetry and activity counts was high ($r = 0.87$). An equation for prediction of EE was developed and cross validated in a subsample, showing a high correlation ($r = 0.93$) between measured and predicted EE values. A similar treadmill study, performed in adult subjects, has demonstrated a high correlation between activity counts and steady state EE ($r = 0.88$) [7]. It was also shown that body weight together with activity counts were the only significant predictors of EE [7,18].

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Since the CSA activity monitor is an uniaxial accelerometer, it could be hypothesised that physical activity would be less accurately estimated in subjects engaged in specific training programs or performing physical activities which cause small movements in the vertical plane (e.g. bicycling and inline skating).

The purpose of the present study was to validate the CSA activity monitor for assessment of the total amount of physical activity under free living conditions in adolescent athletes (speed skaters). All measurements were performed twice, during different training conditions (off-season, pre-season). The predominate physical activity during the off-season period was running. The pre-season period was a skating technique training (i.e. inline skating, slideboard, skating imitations) period. The study is a part of a larger study examining energy intake, total energy expenditure, and physical activity in young athletes. It shows that activity monitors may be most useful for determination of the total amount of physical activity but the data have to be carefully interpreted.

Methods

Subjects

Originally eight adolescent boys (mean ± SD, age = 18.5 ± 1.2 yr., height = 179 ± 2.5 cm, body mass = 73.3 ± 2.2 kg) participated in the study. One subject was excluded from the study because of malfunction with the activity monitor. All subjects had been involved in regular physical training for at least four years. The mean maximal oxygen uptake ($\dot{V}O_2max$) was 64.5 ± 2.5 ml × kg^{-1} × min^{-1}. All subjects were living at a boarding school for young athletes. Before entering the study, all participants or their parents provided written informed consent. The research ethics committee of Karolinska Institutet, Stockholm, Sweden, approved the study protocol.

Study design

The study was designed in order to reflect two different training conditions. Measurements were made during two 10 d periods five months apart while the subjects were following their normal living. During the first period, which was an off-season period, all physical training was voluntary. During the second period the coach planned all physical training. The subjects followed their own individual training program. Both periods were preceded by an individual calibration for the relationship between EE, heart rate (HR), and activity counts during standardised activities (i.e. walking, running, and ergometer cycling). Physical activity was measured by the CSA activity monitor and by minute-by-minute HR monitoring for the first eight days over the two 10 d periods. Average TDEE was measured by the DLW technique over the two 10 d periods. Body weight was measured on both day one and day 10 to investigate energy balance. Within one week after each period RMR was measured by indirect calorimetry.

Laboratory calibration

Due to practical reasons all laboratory measurements were performed in a temporary laboratory set up at the students' school. The calibration procedure consisted of three 6 min periods of walking at two different speeds (4.5 km × h^{-1} and 6.5 km × h^{-1}) and running at 10 km × h^{-1} on a motorised treadmill. All activities were done in sequence (i.e. without rest between the bouts). These were followed by two 6 min periods of exercising on an ergometer bicycle (Monark 819, Monark AB, Varberg, Sweden) at 120 W and 180 W. Subjects were asked to refrain from prior exercise on the same day, and the measurements were made at least 3 h after a meal.

Oxygen uptake ($\dot{V}O_2$) was measured in 15 s intervals using an on-line lightweight portable telemetric system, Cosmed K4 (Cosmed Srl., Rome, Italy). Respiratory frequency was measured by a photoelectric bi-directional turbine flowmeter, and the ventilation was calculated to BTPS conditions. FE_{O_2} and FE_{CO_2} were analysed with a thermostated electro-chemical O_2-sensor and an infrared CO_2-sensor, respectively. Ambient temperature and relative humidity were measured by a polyometer (Lambrecht GMBH, Göttingen, Germany) and entered into the receiver unit. The receiver unit contained an electronic barometer, which adjusted the factor converting gas volumes BTPS into gas volumes STPD. The receiver unit was connected to a portable computer equipped with a gas analyzing software program (Cosmed K4 Win 3.0, Cosmed Srl., Rome, Italy). The system was calibrated against gases of known concentrations prior to testing, and the flowmeter (Ø 28 mm) was calibrated against a 3.0 l-syringe (Hans Rudolph Inc., Kansas City, MO, USA). Calibration procedures described by the manufacturer were otherwise followed. The portable ergospirometer system used has been validated showing accurate readings for oxygen uptake measurements from sitting rest to maximal exercise [8].

HR was measured in 15 s intervals using a Polar Vantage HR monitor (Polar Electro OY, Kempele, Finland) throughout the calibration procedure. Steady-state EE (kJ × min^{-1}) and HR were calculated as the average of the last three minutes on each exercise occasion. The individual relationship between EE (kJ × min^{-1}) and HR was determined by regression analysis.

The CSA activity monitor instrumentation has been described elsewhere [19]. The monitor was secured directly to the skin as close as possible to the centre of gravity (i.e. lower back) using elastic waist belt and initialised as described by the manufacturer [6]. A 15 s time interval (epoch) was used, and activity counts for the last three minutes were averaged and expressed as counts per minutes for each exercise condition. The same activity monitor was used for each subject on each test occasion, and after each testing session the activity monitor was immediately removed and downloaded on a portable computer.

RMR was measured between 6.30 a.m. and 8 a.m. after an overnight fast of at least 10 h. Before each measurement the subjects comfortably rested in the supine position for 30 min. Oxygen uptake and carbon dioxide production were measured for 40 min using the same metabolic system as described above. A small flowmeter (Ø 18 mm) was used, and the time sampling interval was 30 s. Measurements were made in the supine position, and the subjects were visually monitored by one of the investigators to make sure that they were lying still but awake. RMR was calculated by using the Weir equation [20]. The average value for the last 15 min of the measurement period was used as RMR.

Field study

EE was measured over two 10 day periods five months apart with doubly labeled water. Dose, sampling protocol, sample analysis, and calculation procedure have been described before [23]. The subjects were given a weighed dose of water with a measured enrichment of about 5 atoms % of ^2H and 10 atoms % ^{18}O so that baseline levels (PPM) were increased with 150 for ^2H and 300 for ^{18}O. Urine samples were collected for isotope measurement, before DLW administration, from the second and last voiding of the following day and from days 5 and 10. Isotope abundance in the urine samples was measured with an isotope-ratio mass spectrometer (Aqua Sira; VG Isogas, Middlewich, Cheshire, England). All samples were measured in duplicate. CO_2 production was calculated from the elimination rates of the isotopes as calculated from the slope of the elimination curve, correcting for changes in body water assumed to be proportional to changes in body mass from day 1 to day 10. CO_2 production was converted to TDEE using an energy equivalent based on the individual food quotient (FQ) calculated from the macronutrient composition of the diet as described by Black et al. [2], and assumed RQ was equal to FQ.

Energy intake (EI) was calculated from weighed food records. All subjects recorded their food intake for the first seven days of the two measurement periods. The subjects were carefully instructed by a nutritionist to separately weigh and immediately record all food items consumed. All food consumed (i.e. at home, at restaurants, and at school) was weighed on a household scale. EI was calculated from the food records by means of computerised nutrient calculation software using the Swedish nutrient database (National Food Administration).

Assuming that 10% of TDEE was due to the diet induced thermogenesis (DIT) [11], the energy expenditure associated with physical activity was calculated as TDEE minus (RMR + TDEE × 0.1). Physical activity was also calculated as a multiple of RMR (PAL = TDEE/RMR).

The subjects were instructed to wear the activity monitor and the HR monitor during the awake time of day one to day eight except during water activities. The subjects wore the same monitor during both occasions. In addition all subjects recorded when they attached the monitors and when they took it off. The time, type, intensity, frequency, and duration of all physical training were recorded in a structured training diary. All subjects kept the training diary on a regular basis. The training diaries were used for calculation of time spent in physical training during the both periods. In addition training diaries were compared to data from the activity monitor for calculation of average activity counts corresponding to different physical exercises performed. The laboratory derived equation for the relationship between activity counts and EE during walking and running on the treadmill was used for calculation of EE during physical training sessions. EE from activity counts during these training sessions was calculated minute-by-minute using a written computer macro. The activity monitor was initialised and tightly secured to the body as described above, and the 60-s epoch was used. The total amount of physical activity from the activity monitor was expressed as the average of total counts per minute of registered time (i.e. time when the activity monitor was worn).

Heart rate was monitored minute-by-minute using the same heart rate monitor as described above. HR and activity monitor data were compared for all periods of physical training. Minute-by-minute EE from HR was individually calculated from calibration data. An additional computer program was written to compute EE from HR data.

Statistical analyses

Data are presented as mean ± SD. The relationship between EE and activity counts during laboratory calibration was tested by linear regression analyses. Correlation coefficients (Pearson's r) and standard error of estimate (SEE) were computed. For these analyses data from the treadmill speeds were pooled and treated as independent observations. The same analysis was performed individually for the relationship between EE and heart rate including treadmill and ergometer bicycle data. Associations between activity counts and TDEE and its derivatives during the field test were assessed by Spearman correlation coefficients. The effect of subject and period (off-season vs. pre-season) on TDEE and activity counts were tested by a two-way multivariate analysis of variance (MANOVA). Differences between energy expenditures estimated from activity counts and heart rate during physical training were tested by paired t-test. Independent t-test was used to test for differences within subjects (height, body weight, laboratory calibration data). The level of significance was set at $P < 0.05$. All statistical calculations were performed using SPSS for Windows version 6.1. (SPSS Inc. Chicago, Ill, USA).

Results

There were no significant differences in height or body weight for the subjects between the periods. In addition no significant differences were observed in the calibration data between the periods. In Table **1** the mean and SD for the physiological variables and activity counts, during the calibration procedure are shown. The following regression equation for the relationship between EE and activity counts was found:

$$\text{EE } (\text{kJ} \times \text{min}^{-1}) = 0.005753 \text{ counts} + 4.119 \quad (R^2 = 0.95, \text{ SEE} = 3.97 \text{ kJ} \times \text{min}^{-1})$$

In this homogenous group of adolescents, predicted EE was not further improved when body weight was included in a multiple linear regression model. The individual correlation coefficients ranged from 0.95 – 0.99.

In Table **2** mean and SD for all measured variables of energy expenditure, activity counts and registered time are shown. Most off- and pre-season data were similar to each other. However, a significant period effect ($P = 0.026$) was observed for activity counts. The standard deviations for TDEE and all the activity variables were at least twice as high during the first period compared to the second as a result of a greater variation in physical activity. The mean difference for TDEE and RMR was 292 kJ × d^{-1} and 316 kJ × d^{-1}.

The observed correlation coefficients between activity counts and the separate energy estimates are given in Table **3**. Similar correlation coefficients were observed for TDEE and all its derivatives during each of both periods. All correlations were sig-

Table 1 Mean (± SD) for $\dot{V}O_2$, energy expenditure (EE), heart rate (HR), and activity counts during laboratory calibration whilst walking and running on a treadmill and cycling on an ergometer bicycle (n = 7)

	$\dot{V}O_2$ (ml × kg^{-1} × min^{-1})	EE (kJ × min^{-1})	HR (bpm)	Activity counts (cnts × min^{-1})
Treadmill speed				
4.5 (km × h^{-1})	12.9 ± 1.1	19.2 ± 1.2	85 ± 5	2337 ± 350
6.5	19.1 ± 1.2	28.8 ± 1.7	102 ± 6	4809 ± 288
10.0	35.9 ± 2.4	53.5 ± 3.3	146 ± 14	9544 ± 756
Bicycle (work load)				
120 (W)	27.9 ± 1.5	39.8 ± 3.0	123 ± 10	
180	35.4 ± 3.1	53.1 ± 3.8	143 ± 12	

Table 2 Mean (± SD) of energy expenditure variables, activity counts and registered time during two different training periods (n = 7)

	Off-season training	Pre-season training
TDEE (MJ × d^{-1})	15.7 ± 2.1	16.0 ± 1.0
RMR (MJ × d^{-1})	8.9 ± 0.5	8.6 ± 0.5
AEE (MJ × d^{-1})	5.2 ± 2.1	5.8 ± 1.0
TDEE/BM (kJ × kg^{-1} × d^{-1})	214 ± 31	218 ± 18
AEE/BM (kJ × kg^{-1} × d^{-1})	71 ± 30	79 ± 14
PAL	1.76 ± 0.3	1.86 ± 0.1
Activity counts (cnts × min^{-1})	668 ± 163	548 ± 91*
Registered time (min × d^{-1})	901 ± 40	900 ± 35
Sleep time (min × d^{-1})	508 ± 38	522 ± 39
Non-registered wake time (min × d^{-1})	31 ± 17	18 ± 11

TDEE, Total daily energy expenditure; BM, body mass; RMR, Resting metabolic rate; AEE, Activity energy expenditure (AEE = TDEE minus [RMR + TEE × 0.1]); PAL, Physical activity level (PAL = TDEE/RMR)
* period effect (MANOVA), P = 0.026

Table 3 Spearman correlation coefficient's (r) for mean activity counts (cnts × min^{-1}) vs. energy expenditure variables (n = 7)

	Off-season training	Pre-season training
TDEE (MJ × d^{-1})	0.93**	0.46
AEE (MJ × d^{-1})	0.96**	0.46
TDEE/BM (kJ × kg^{-1} × d^{-1})	0.90**	0.57
AEE/BM (kJ × kg^{-1} × d^{-1})	0.96**	0.36
PAL	0.96**	0.32

TDEE, Total daily energy expenditure; BM, body mass; RMR, Resting metabolic rate; AEE, Activity energy expenditure (AEE = TDEE minus [RMR + TEE × 0.1]); PAL, Physical activity level (PAL = TDEE/RMR)
** denotes P < 0.01

nificant during the first period whereas not in any case during the second.

In Table **4** the absolute amount of time spent on different physical exercises during the two periods are shown. The subjects were engaged in physical training on average 29 ± 13 min × d^{-1} during the first period compared to 49 ± 19 min × d^{-1} (P = 0.01) during the second period. Seventy-two percent (19 ± 9 min × d^{-1}) of time spent exercising during the first period was running compared to 6% (3 ± 3 min × d^{-1}; P = 0.002) during the second period. During this period 24 ± 14 min × d^{-1} were spent on inline skating and on slideboard training. No differences were observed for time spent bicycling between the periods. Fig. **1** shows the average activity counts during different kinds of physical activities performed by the subjects. The average value for running was more than 2.5 times higher compared to the other activities.

In Table **5** EE estimated from activity counts and HR are shown. All energy estimates obtained by the activity monitor were significantly lower (P < 0.01) compared to HR, except for running. EE estimated from activity counts during running was almost identical to EE from HR (65.4 kJ × min^{-1} vs. 63.0 kJ × min^{-1}).

Discussion

We found high and significant correlations (r = 0.90 – 0.96) between activity counts and all of the energy estimates during the off-season period (running training). A high value for PAL, AEE, and AEE in relation to body weight was not accompanied by a high value for activity counts during the pre-season period (skate training). We believe that the absence of high activity counts during this period as well as a significant decrease in activity counts in combination with an unchanged TDEE were caused by the difference in type, and not amount, of physical activities performed.

The physical training during the pre-season period was focused on technique training before the ice-training period. This training included inline skating, slideboard training, and skating imitations. Circuit training and weight training were also scheduled. The subjects spent significantly more time in physical training during the pre-season period, probably due to the type of exercise performed. In contrast to the off-season period this type of training included intermittent exercises whereas the running training was entirely continuous. The difference in activity counts (cnts × min^{-1}) from running compared to the other types of activities is substantial (Fig. **1**). An average running time of 20 minutes per day corresponds to approximately 236 cnts × min^{-1} or 35% of the total number of counts accumulated per day during the off-season period. In contrast 20 minutes of continuous inline skating is equal to approximately 90 cnts × min^{-1} or 16% of counts accumulated per day during the pre-season period.

Table 4 Absolute amount of time (min) in different exercise activities during two different 10 d training periods (n = 7)

	Off-season training	Pre-season training
Running	1325	230
Bicycling	410	210
Inline skating	–	895
Circuit training	–	620
Slideboard	–	405
Weight training	–	400
Skating imitations	–	350
Other training	275	225
Total time	2010	3335

Table 5 Energy expenditure ($kJ \times min^{-1}$) estimated minute-by-minute from activity counts and heart rate during different types of training

	EE activity counts	EE heart rate
Bicycling (road, terrain)	10.2 ± 2.1	53.4 ± 11.3***
Weight training	11.9 ± 2.3	39.0 ± 4.3***
Slideboard	21.0 ± 1.6	51.5 ± 6.0***
Skating imitations	24.7 ± 4.2	44.7 ± 3.0**
Circuit training	25.6 ± 1.6	37.0 ± 7.5**
Inlines	27.7 ± 3.1	47.6 ± 6.9**
Running	65.4 ± 3.4	63.0 ± 7.5

** denotes P < 0.01; *** denotes P < 0.001

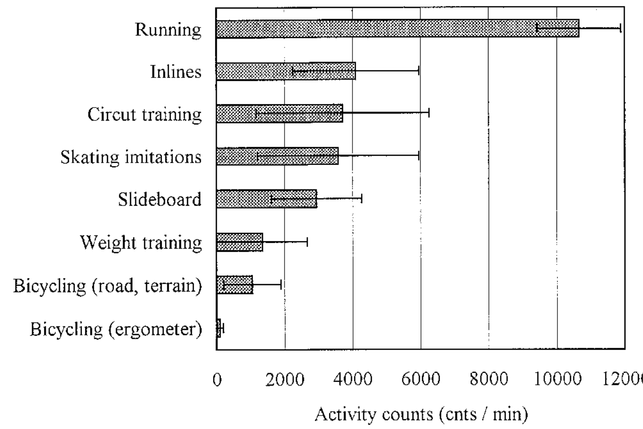

Fig. 1 Mean (± SD) activity counts ($cnts \times min^{-1}$) in different physical activities performed by the subjects. Data for running refers to the off-season period.

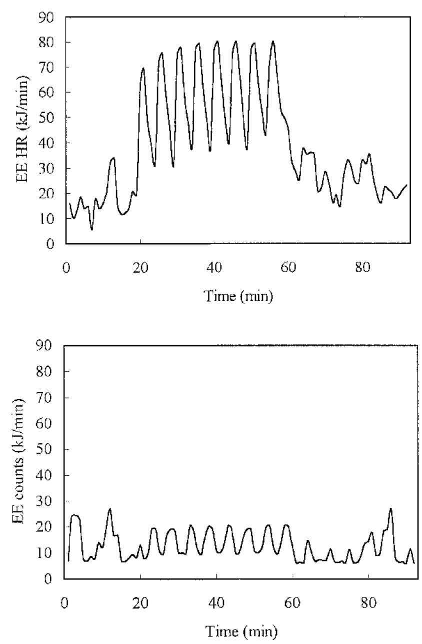

Fig. 2 Energy expenditure (EE) in time during a pre-season training session including 8 × 3 min on the slideboard. EE is calculated minute-by-minute from heart rate (**a**) and from activity counts (**b**).

Since the CSA activity monitor is a uniaxial accelerometer with respect to vertical accelerations, it is likely that activity counts will not reflect energy expenditure during the skating activities in a similar way as during running. By a direct comparison between energy expenditure estimated from activity counts and from heart rate during the different types of exercises performed, it was obvious that activity counts significantly and consistently underestimated energy expenditure as compared to heart rate during all activities except running (Table **5**). Mean EE was approximately 1.7 to 5 times as high when calculated from HR compared to activity counts. An example is given in Fig. **2**. The Figure compares one of the subjects EE calculated minute-by-minute from heart rate (Fig. **2a**) and activity counts (Fig. **2b**) during a training session including a 8 × 3 min interval training on a slideboard. EE was calculated from the individual relationship between activity counts, HR and EE obtained during the laboratory calibration procedure. In activities like bicycling, weight training, inline skating, and slideboard exercise the increase in vertical movement of the body, and thereby in activity counts, is significantly lower compared to running and may explain the discrepancy between activity counts and the different energy estimates during the pre-season period.

The heart rate-energy expenditure relationship was established individually during walking and running at three different speeds and bicycling at two different workloads. This relationship may be different during specific types of exercise, for example strength conditioning exercises using a small muscle mass. The vast majority of physical training performed by the subjects in the present study was activities that included a large muscle mass. Under these circumstances the relationship between heart rate and energy expenditure is known to be robust [24]. Although the relationship between heart rate and energy expenditure may be somewhat different during the skating activities compared to calibration data, it is most unlikely that this would affect the found differences between energy expenditures estimated from heart rate and from activity counts (Table **5**). The present data indicate that the type of physical training performed affects the association between activity counts and DLW measured energy expenditures. Despite this a considerable variation in daily energy expenditure could be explained from activity counts in a period not including specific physical training. Given the fact that a large proportion of daily physical activity consists of sedentary and walking activities [1] and considering the accuracy of the CSA activity monitor to discriminate between exercise intensities during walking and running [7,18], the method seems to offer promising possibilities for the assessment of physical activity in free-living subjects while the activity monitor should be used with caution in specific athletic groups (i.e. speed skaters). Further studies, including a larger and more heterogeneous sample, are needed in order to develop equations for the prediction of total daily energy expenditure from activity counts and resting metabolic rate and anthropometric variables.

The placement of the CSA activity monitor at the lower back was selected in concordance with a previous accelerometer study performed during free-living conditions [4]. In Trost et al.'s [18] children and Freedson et al.'s [7] adult laboratory studies activity monitors were placed on the hip. The results from the laboratory calibration procedure in the present study are similar to and support the findings from Freedson et al. [7]. The activity monitor discriminates between different walking and running speeds on the treadmill. Opposed to the findings from Freedson et al. [7] and Trost et al. [18], body mass was not, together with activity counts, a significant predictor of EE in the present study. The homogenous group of subjects, with regard to body mass, participating in the present study could explain this. It is not known if total counts per minute differs if the activity monitor is placed on the hip or at the lower back but future studies are needed to confirm the best placement of the CSA activity monitor for assessment of daily physical activity in free-living subjects. A limited number of studies have compared activity monitor data with total energy expenditure from the DLW method [4,10]. Bouten et al. [4] found a significant relationship ($r = 0.58$, $P < 0.001$) between activity counts from a tri-axial accelerometer (Tracmor) in comparison with PAL. Another study [10] found that the Caltrac accelerometer significantly overestimated physical activity related energy expenditure in a group of free-living children. The lack of association between accelerometer output and DLW measurements in the study by Johnson et al. [10] may be explained by the limited number of days monitored or by different sensitivity in measuring vertical accelerations between monitors when used under free-living conditions. Compared to the Caltrac, the small size, robust design, and the ability to specify start and stop times makes the CSA activity monitor a preferred instrument. In addition counts can be stored over short time intervals permitting a detailed analysis of patterns of physical activity.

The RMR values for the subjects in the present study seem to be approximately 10% higher than expected from predictive equations using age, gender, height, and weight [16] or than predicted from fat free mass and fat mass [22]. However, it is not likely that any fault that may occur in the determination of RMR would effect the found associations between activity counts and daily energy expenditure. By recalculating PAL from estimated RMR according to Westerterp et al. [22], we found similar correlations between activity counts and PAL from the two periods respectively ($r = 0.96$ and $r = 0.33$). Moreover the correlation between activity counts and total energy expenditure, expressed as TDEE, was almost similar to the other energy estimates. In conclusion, the relationship between CSA activity counts and total daily energy expenditure seems to be affected by different training conditions. The CSA activity monitor accurately assesses daily energy expenditure during a running training period whereas activity counts seem to be unrelated to energy expenditure estimates during a skating training period. These circumstances have to be carefully considered in the interpretation of activity monitor data.

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Corresponding Author:

U. Ekelund

Department of Physical Education and Health
University of Örebro
70182 Örebro
Sweden

Phone: + 46 (19) 303371
Fax. + 46 (19) 303486
E-mail: ulf.ekelund@ioh.oru.se