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Validity of a Multisensor Armband in Estimating 24-h Energy Expenditure in Children

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Abstract

Physical activity (PA) and energy expenditure (EE) in children are frequently assessed using portable activity monitors. Algorithms used to predict EE by these monitors are often based on adult populations and may not be accurate for children.

Purpose: To evaluate the accuracy of the SenseWear Pro Armband (SWA) for assessing EE in African American children during treadmill exercise, sedentary activities, rest, sleep, and total 24-h EE, using indirect room calorimetry (IRC) as a reference standard.

Methods: Participants were healthy African American children (10 boys, 11 girls; age: 11.6 ± 0.9 yr; weight: 47.3 ± 13.0 kg; height: 151.6 ± 8.8 cm; BMI: 20.4 ± 4.8 kg·m⁻²). EE was measured simultaneously using IRC and SWA during a 24-h stay in the IRC. Recorded activities included sedentary behaviors, treadmill exercise, rest periods, and sleep. Results from both methods were matched minute-by-minute and compared by Bland–Altman plot. Multiple linear regression analysis was used to describe the relationship between EE assessed by both methods and children's descriptive characteristics.

Results: SWA overestimated EE compared with IRC during all activities and time periods, ranging from 116% during sleep to 143% during rest after treadmill exercise. The SWA-predicted EE was improved by using linear regression modeling. Simple equations for sedentary activities and treadmill exercise were $EE [kcal \cdot min^{-1}] = 0.462EE (SWA) [kcal \cdot min^{-1}] + 0.015 \times \text{body weight [kg]}$, and $EE [kcal \cdot min^{-1}] = 0.637EE (SWA) [kcal \cdot min^{-1}] + 0.034 \times \text{body weight [kg]}$, respectively. The prediction equation for RMR was $RMR [kcal \cdot min^{-1}] = 0.453EE (SWA) [kcal \cdot min^{-1}] + 0.011 \times \text{body weight [kg]}$.

Conclusion: EE estimated using SWA was significantly higher than EE measured using IRC in African American children ages 10–14 yr. Bias in individual EE estimated using SWA could be improved by an adjustment for the body weight of a child. The SWA manufacturer should work with researchers on improving existing algorithms for children.

Keywords

ACTIVITY MONITOR; WHOLE-ROOM INDIRECT CALORIMETRY; PHYSICAL ACTIVITY; SENSEWEAR ARMBAND

Healthy People 2010 lists physical activity (PA) as a leading health indicator and an important factor in preventing obesity in children (28). PA is integral to the normal health and development of children and adolescents, whereas physical inactivity is associated with a number of risk factors for obesity, hyperlipidemia, hyper-tension, cardiovascular disease, and type 2 diabetes (9). Therefore, a need for nonintrusive, accurate, and valid methods for the measurement of PA in free-living children and predicting energy expenditure (EE) is warranted to address important health issues. Because of the intrusiveness of direct observations, unreliability of self-reports, and complexity of heart rate analysis, current methodologies incorporate the use of portable electronic monitors of motion to objectively quantify PA and EE. Among these devices, accelerometers are becoming increasingly popular and are often used to predict EE and to classify levels of PA. These devices, however, should be validated or calibrated in specific study populations (6).

The SenseWear Pro Armband (SWA) is a relatively new, commercially available device to assess EE. It is worn on the upper arm (usually the dominant side) over the triceps muscle, and it monitors various physiological and movement parameters (13). A few studies have been reported recently assessing the SWA's validity in adult men and women (10,13,15,20). These studies usually have assessed validity of the SWA during relatively short bouts of aerobic exercise, such as treadmill walking or running and cycling. For example, Jakicic and colleagues (10) have shown that the SWA generalized proprietary algorithm underestimated resting EE and overestimated EE during treadmill or cycle ergometer exercise, but the EE prediction could be improved by using exercise-specific algorithms (13). None of these studies, however, assessed SWA validity to predict EE of sedentary activities or total 24-h EE. Moreover, there are no reports on calibration or validation of SWA against a reference method in children. The issue of age is not trivial, because changes in body composition associated with growth may affect the accuracy of EE prediction in children (17). In addition, there are differences in constituents of body composition, such as bone mineral content (7,14,18), bone density (23), and percent fat mass (8), in African American children versus those of other ethnic origins. Therefore, it is likely that the accuracy of EE prediction using SWA could be affected by descriptive variables in diverse populations.

The objective of this study was to test a null hypothesis that, in children, 24-h EE predicted by SWA is not different from the EE simultaneously measured using indirect room calorimetry (IRC) as a reference standard. Our secondary goal was to develop simple prediction equations for EE during rest and PA that would apply to 10- to 14-yr-old African American children.

METHODS

Participants

Twenty-one healthy African American children (10 boys, 11 girls) ages 10–14 yr participated in the study. Children were recruited through Vanderbilt Medical Center and Meharry Medical College e-mail systems, flyers, and word of mouth. The purpose of the study, study-related activities, benefits, and risks were explained to the children and their parents or legal guardians. Before participation in the study, the participants and parents/legal guardians signed informed consent or assents approved by the institutional review boards at Vanderbilt Medical Center and Meharry Medical College in accordance with the Declaration of Helsinki. Inclusion criteria included age between 9 and 14 yr, healthy, willing to stay in the room calorimeter for 24 h,

and being able to perform light to moderate exercise (Fig. 1). Children were excluded if they were experiencing any illness or if a study physician identified concerns during the physical examination or electrocardiograph (ECG).

Study Protocol

Health history and physical examination that included height, weight, age, body temperature, blood pressure, and ECG were completed before the study. The study was conducted at the general clinical research center (GCRC) at Vanderbilt University Medical Center. In the morning, after an overnight stay and fast, SWA was placed on the participant's upper arm and activated to start data collection. The child entered the IRC at approximately 0700 h and followed a structured protocol (Fig. 1). Meals were delivered through the pass window. All activities except resting metabolic rate (RMR) measurements were performed in the fed state. Individual nutritional needs were calculated according to body weight, and food choices were made according to the child's preferences. The diet was prepared at the GCRC metabolic kitchen and contained $55 \pm 5\%$ of the energy from carbohydrate, $30 \pm 3\%$ from fat, and $15 \pm 3\%$ from protein, and all required micronutrients. Upon entering IRC, the child sat quietly and performed sedentary activities until shortly after breakfast. The child rested in a reclined position for 30 min before treadmill exercise. The treadmill exercise protocol involved walking on a treadmill at a fixed speed, which corresponded to 60% of each child's predetermined maximal oxygen uptake ($\dot{V}O_{2\max}$), determined from a fitness test performed at least 1 d before IRC study. After the exercise, the child remained quietly seated, viewing television or reading, until lunch was served. In the afternoon, the child followed a semi-structured sedentary activities protocol (from 1300 to 1600 h). During this period, the child was free to move around the IRC, but primarily this time was spent in a variety of sedentary activities such as reading, writing, painting, playing cards, assembling puzzles, playing computer games, viewing television, using a laptop computer, listening to music, singing, and playing small instruments. In addition, participants completed two 10-min bouts of either riding a stationary bicycle or walking back and forth across the room. Time after dinner was spent on sedentary activities. Participants were given an evening snack at 2000 h and went to bed at 2200 h or earlier. The following morning, the child was awakened at approximately 0600 h and was asked to stay awake but not arise from the bed, and to avoid any movements as much as possible for the next 40 min. During this period, RMR was measured. Following the RMR measurement, the child rested for 10 min in a reclined position, and then the study was completed (0700 h).

Anthropometric Measurements

Body weight was measured to the nearest 0.05 kg with a monthly calibrated digital scale (Detecto-Medic, Detecto Scales, Inc, Northbrook, IL), with the participant wearing light clothing and no shoes. Height was measured using a wall-mounted stadiometer, calibrated on wall installation and recalibrated yearly (Perspective Enterprises, Portage, MI). Fat mass (FM), fat-free mass (FFM), and percentage of body fat (%BF) were assessed by dual-energy x-ray absorptiometry (DXA, Lunar Prodigy, GE Medical Systems, Madison WI; pediatric software, version 9.15). DXA is considered a valid method for assessing lean body mass in children and was shown to assess (31) body composition in African American children better than air-displacement plethysmography (2).

Measurement of EE

IRC—The room calorimeter provides a seminaturalistic free-living environment, strictly controlled temperature and humidity, and a force platform covering most of the floor for movement detection. It has a window to the outside, a window to the adjacent room, a food pass window, a sink, and a toilet, and it is equipped with desk, armchair, fold-down mattress, multimedia audiovisual equipment, and wireless Internet access. Exercise equipment includes

a treadmill and a stationary bicycle. A window in the door and intercom system allows research and nursing staff to monitor a participant during the stay. A pull-down shade over the windows provides privacy when needed. EE was calculated from the rates of oxygen consumption ($\dot{V}O_2$) and carbon dioxide production ($\dot{V}CO_2$), multiplied by the flow. This allowed EE to be calculated on a minute-by-minute basis (24), with the accuracy of > 99% for a 24-h study period and > 90% within a single minute. This methodology allowed precise measurements of the EE of PA during short bouts of exercise and has been described previously (24). In each activity period, the increase or decrease in mechanical work detected by the force platform was marked as the starting and ending point. Respectively, RMR was measured during a 40-min awake period after an overnight fast. The force platform monitored body motion during the RMR measurement. Periods with detected major body movements were removed from RMR calculations, as described previously (3).

PA Monitoring

The SenseWear Pro Armband (Body Media, Pittsburgh, PA) is a commercially available PA monitor to estimate EE. According to information provided by the manufacturer (www.bodymedia.com), the SWA incorporates a variety of measured parameters (accelerometry, heat flux, galvanic skin response, skin temperature, near-body temperature) and descriptive characteristics (gender, age, height, weight) into proprietary algorithms to estimate minute-by-minute EE. Technical characteristics of SWA have been described previously (10,13). As recommended by the manufacturer, the child wore the SWA on the right arm over the triceps muscle at the midpoint between the acromion and olecranon processes. Descriptive characteristics were entered into the software program before initializing the monitor. Upon entering the room calorimeter, the child remained in a seated position for a period of 10 min before data collection started.

Data Analysis

Minute-by-minute data from SWA were analyzed using The InnerView Research Software (version 4.1) provided by BodyMedia, Inc. Total EE was computed at 1-min intervals using the generalized proprietary algorithm developed by the manufacturer. Minute-by-minute oxygen consumption and carbon dioxide production EE from IRC were converted to energy equivalents ($\text{kcal} \cdot \text{min}^{-1}$) using Weir's equation (29). These IRC-derived total EE values were synchronized minute-by-minute with total EE from SWA and compared at specific time periods or activities such as rest before treadmill exercise, treadmill exercise, rest after exercise, sedentary activities, sleep, RMR measurement, and total 24-h EE.

Statistical Analysis

All data are presented as means $\pm$ SD. The differences in age, height, and body composition between boys and girls were tested using two-sample *t*-tests. Paired *t*-tests (equivalent to one-sample *t*-tests for the difference between paired measurements) and Wilcoxon signed-rank tests were used to test the mean differences between the EE of various activities and periods obtained from SWA and IRC. Bland–Altman plots (1) were used to assess the agreement between the EE from IRC and the EE from SWA. The 95% limits of agreement are presented as the mean difference $\pm$ 2 SD of the differences. Multiple linear regression was used to examine which descriptive characteristics (age, body weight, height, FFM, FM) can explain the discrepancy between the EE from SWA and the EE from IRC during various activities. Based on this information, we developed new prediction equations using multiple linear regression models. The new equations predict EE using the EE from SWA and the child's body weight as predictors. To validate these equations, an independent set ($N = 8$) of children who completed the same protocol was used. All analyses were performed with the software STATA 9.2 (StataCorp, College Station, TX) and R (www.r-project.org).

RESULTS

Participants' characteristics

Descriptive data for the study participants are presented in Table 1. There were no significant differences in age, height, weight, BMI, FFM, and %BF between boys and girls. Therefore, for the subsequent analyses, data from boys and girls were combined.

Measured EE

EE obtained from the two methods is presented in Table 2. There were significant differences (all $P < 0.01$) between EE measured using IRC and SWA during treadmill exercise, rest before and after treadmill exercise, sedentary activities, sleep, and RMR measurement. The estimates of the mean differences and the corresponding 95% confidence intervals (CI) for activity periods are shown in Figure 2. The largest difference between the two measurements was observed during treadmill exercise ($0.777 \pm 0.897 \text{ kcal} \cdot \text{min}^{-1}$). A ratio of the EE measured using SWA and IRC ranged from 116% during sleep to 143% during rest following exercise (Table 2). The Bland–Altman plots (Fig. 3) clearly show that the SWA overestimated EE compared with EE measured by IRC.

Prediction equations

Body weight (kg) was negatively associated with the difference between EE measured using SWA and IRC during RMR measurement ($P = 0.028$), sedentary activities ($P = 0.025$), treadmill exercise ($P < 0.001$), and total 24-h EE ($P = 0.001$). The predicted lines and the corresponding 95% confidence intervals for sedentary activities and treadmill exercise are shown in Figure 4. Body weight explained 24% of the variability of the difference between the two measurements during sedentary activities, 45% during treadmill exercise, and 46% for the total 24 h. We developed simple equations for predicting EE, using body weight and the EE from SWA as predictors. The regression coefficients for the prediction models are shown in Table 3. The new models explain 99%, 99%, and 98% of the variability in the EE from IRC during RMR measurement, sedentary activities, and treadmill exercise, respectively. The prediction equations are as follows:

$$\begin{aligned} \text{RMR} \left[\text{kcal} \cdot \text{min}^{-1} \right] &= 0.453\text{EE (SWA)} \left[\text{kcal} \cdot \text{min}^{-1} \right] + 0.011 \times \text{body weight} \left[\text{kg} \right], \text{ Sedentary EE} \left[\text{kcal} \cdot \text{min}^{-1} \right] \\ &= 0.462\text{EE (SWA)} \left[\text{kcal} \cdot \text{min}^{-1} \right] + 0.015 \times \text{body weight} \left[\text{kg} \right], \text{ and treadmill exercise EE} \left[\text{kcal} \cdot \text{min}^{-1} \right] \\ &= 0.637\text{EE (SWA)} \left[\text{kcal} \cdot \text{min}^{-1} \right] + 0.034 \times \text{body weight} \left[\text{kg} \right]. \end{aligned}$$

To evaluate these equations, EE was predicted for treadmill exercise and sedentary activities in the current study participants ($N = 21$) and an independent validation group of children ($N = 8$). The predicted EE and the EE from the equations and the estimated EE from SWA were compared with IRC. As shown in Figure 5, EE for sedentary activities and treadmill exercise from SWA (upper panel) and EE predicted by the new equations (lower panel) were plotted against the EE from IRC. To quantify the prediction error for the validation set of participants, we calculated sums of squared errors (SSE) by adding the squared differences between the predicted EE from the new equations or from the SWA and the EE from IRC across subjects for each activity. The SSE from our equation was smaller than the SSE from SWA for both sedentary activities (0.1 vs 0.4) and treadmill exercise (1.8 vs 2.5).

DISCUSSION

In this study, we examined the validity of the SWA to estimated total 24-h EE and its components in 10- to 14-yr-old healthy African American children, using IRC as a reference standard. The results show that the SWA overestimated 24-h EE expenditure in this population. The overestimation was negatively correlated with body weight (the lower the body weight, the higher the overestimation). Our results suggest that the current SWA model has decreased accuracy for predicting EE in children.

As technology advances, accelerometry-based activity monitors become smaller, more sensitive, and capable of monitoring activity for extended periods. The SWA is one of these monitors, but, in addition to movement, it registers various physiological parameters including heat flux, galvanic skin response, skin temperature, and near-body temperature. The variable information is used by preformulated proprietary equations (10). As with any other new PA monitoring device, it should be validated or calibrated in various populations, including children (4).

To achieve the goal of validating SWA in children, we used a variety of activities likely performed by a free-living child, but we also included sleep and RMR. The RMR estimates using SWA were 22% higher than RMR measured using IRC. RMR is one of the most important components in total EE, and its estimates made by most accelerometers are calculated from specific equations, usually based on a person's sex, weight, height, and age. The predicted RMR model used by SWA is proprietary, but it may use both sensor data (e.g., temperature, heat flux) and descriptive characteristics of the wearer such as age, height, and weight (10). In the study with adults, Fruin and colleagues (10) found no significant differences between the RMR measured via indirect calorimetry and that estimated by the SWA. The measurements were highly correlated and had good agreement. In contrast, the difference between SWA and IRC found in our study indicates that the SWA model did not estimate RMR in children correctly. Indeed, we were able to improve resting EE predictions using SWA-estimated EE and the child's weight to achieve high levels of agreement with the EE values measured using IRC ($R^2 = 0.986$).

In many previous studies, accelerometers have been shown to underestimate EE for sedentary activities (16,30) and cycling exercise (5,12), and to overestimate EE for walking and running (5,12,19) in adults. In children, accelerometer-based activity monitors showed a strong correlation between measures of PA and EE under laboratory conditions (21,25) and a weaker correlation under field conditions (11,21,26). A recent report by Puyau et al. (22) indicates a poor predictive validity of activity monitors for point estimates of EE for individuals. The authors suggest that the validation protocols should include the range of sedentary activities in which children typically engage (22). This is because treadmill exercises used in a majority of reported studies do not reflect all accelerations associated with habitually performed, free-living, sedentary or light activities. The structured activity protocol used in our study represents a broad range of motor movements as well as spontaneous movements characteristic to children. Our results suggest that SWA also significantly overestimated EE for sedentary activities. We speculate that this overestimation could be related to the placement of the armband on a dominant hand, which could be actively moved during some sedentary activities such as playing computers games or writing.

The SWA in our study population also significantly overestimated EE for treadmill exercise. Our results are comparable with those found in triaxial accelerometer studies with adults (3, 10,15,19,27). For example, in a study of adult men and women, Fruin et al. (10) report that SWA overestimated the EE of walking by 14–18%. In a recent study, Trost and colleagues (26) have evaluated the validity of the commonly used Actigraph accelerometer to predict EE

in field conditions using equations developed for children and adolescents in laboratory conditions. The authors conclude that none of the equations accurately predicted EE during overground walking and running.

To our knowledge, no validation study that has used SWA to assess EE in children has been reported. Therefore, it is difficult to compare our results with results obtained by others. Several reports, however, have used similar methodology to validate other available accelerometers. In an elegant study, Puyau and colleagues (21,22) have validated three accelerometers (Actiwatch and Actical for 4 h and Actiwatch and Actigraph for 6 h) against the IRC in a group of 32 children; they found that the devices provided valid measures of EE during activities of daily living. Activity counts reflecting the amount of PA accounted for the majority of variability in EE for activity, with small contributions of age, sex, weight, and height. Body weight made a perceptible change in correlation coefficient (R^2) and standard error, indicating a benefit of correcting for this variable.

In a recent study, Jakicic et al. (13) have suggested that SWA may have the ability to provide a more accurate formula by incorporating exercise-specific algorithms into the estimate of EE and to develop a method for the device to switch between exercise-specific algorithms, with limited burden on the user. In the present study, we found an inverse relationship between the difference in EE estimation and the weight of the child. The results shown in Figure 4 suggest that this relationship was significant during both sedentary and moderate activities. Our regression equations using the weight of child significantly improved the estimates of EE (Table 3). From the regression analysis of the difference between SWA and IRC and body weight, we found that body weight explained 24, 24, and 45% of the variation during rest, sedentary activities, and treadmill exercise, respectively. Although FFM might be considered a better predictor of EE at rest in children than total body weight, it explained only 22, 26, and 24% of the variation of the difference between the SWA and IRC measurements in the present study. Because the two primary components determining the energy cost of work are body mass and speed, it seems reasonable to suggest that outside the laboratory environment, body weight is the most appropriate single variable to estimate EE in free-living children.

Our prediction equations improved the predictive ability of the SWA with simple adjustment for body weight in this specific population (Fig. 5). Therefore, the SWA may have the ability to provide a more accurate estimate of EE than the current proprietary algorithm. This could be done by modifying the currently used algorithms and, possibly, using age-specific algorithms for children. Nevertheless, further research is warranted before firm conclusions on the reliability, validity, and utility of the SWA in children can be made. Moreover, children of different ages, body sizes, and ethnicity should be included in these studies.

Our study has a few limitations. First, we assumed that the IRC measurements were accurate. Although we have reported previously that the data obtained using IRC are accurate in 14- to 18-yr-old African American children (4), we interpreted the data with caution. Second, our results are only applicable to healthy children with normal body weight and to those activities we evaluated in the room calorimeter environment. Finally, our study population was limited to a relatively small sample of 10- to 14-yr-old African American children. This may limit the ability to generalize findings to other ethnic groups and ages, which should be included in further studies.

In conclusion, we have found that the SWA overestimates EE during rest, sedentary activities, treadmill exercise, sleep, and total 24-h EE in 10- to 14-yr-old African American children. The magnitude of overestimation depended on activity and ranged from 16% during sleep to 43% during treadmill exercise. On an individual basis, total 24-h EE may be overestimated by $405 \pm 291 \text{ kcal} \cdot \text{d}^{-1}$. We strongly suggest that the SWA manufacturer should reexamine the

applicability of the existing algorithms for children and work with researchers on their improvement.

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FIGURE 1.
Schedule of activities during 24-h stay in the whole-room indirect calorimeter

FIGURE 2.

Difference between energy expenditure (EE) measured using SenseWear Pro Armband and whole-room indirect calorimetry used as a reference standard for various activities in 10- to 14-yr-old children ($N = 21$) during a 24-h stay in the room calorimeter. Exercise included walking on a treadmill at 60% $\dot{V}O_{2\max}$ for 30 min. RMR, resting metabolic rate. *Solid circles* correspond to the estimates of the mean difference, and *vertical lines* present the corresponding 95% confidence intervals (CI) of the mean difference. The *dashed line* is the reference line for no mean difference between the two methods.

FIGURE 3.

Bland–Altman bias plot between SenseWear Pro Armband (SWA) estimate and whole-room indirect calorimetry (IRC; reference standard) measurement of energy expenditure (EE) during sedentary activities for 3 h (*panel A*) and during treadmill exercise for 30 min at 60% $\dot{V}O_{2\max}$ (*panel B*) in 10- to 14-yr-old children ($N = 21$). Measurements were collected during a 24-h stay in the room calorimeter. The *middle dashed horizontal line* corresponds to the mean difference between the methods, and the *upper and lower dotted horizontal lines* represent the 95% limits of agreement given by the mean difference plus or minus the standard deviation of the difference. The 95% limits of agreements were equal to -0.25 to 0.93 for sedentary activities and -1.02 to 2.57 for treadmill exercise.

FIGURE 4.

Association between the difference of estimated SenseWear Pro Armband (SWA) and whole-room indirect calorimetry (IRC; reference standard) measurement of energy expenditure (EE), and body weight in 10- to 14-yr-old children ($N = 21$) during sedentary activities for 3 h (*panel A*) and during treadmill exercise for 30 min at 60% $\dot{V}O_{2\max}$ (*panel B*). The *solid line* corresponds to the line of best fit. The *dotted lines* represent the corresponding 95% confidence intervals. The *dashed lines* represent zero difference.

FIGURE 5.

Association between energy expenditure (EE) during sedentary activities and treadmill exercise, measured using whole-room indirect calorimetry (IRC) and predicted from SenseWear Pro Armband (SWA). Manufacturer algorithm (*top panel*) and EE predicted by the equations developed in this study (*bottom panel*) are shown. The *solid circles* represent the data set used to develop new equations ($N = 21$). The *open circles* represent the validation data set ($N = 8$). The *solid line* in each panel is the line of equality (measured EE = predicted EE). The R^2 for the proposed equations are 0.984 (sedentary activities) and 0.994 (treadmill exercise). SSE is a sum of squared errors for a validation set of participants ($N = 8$), calculated by adding squared differences between the EE predicted or the EE from SWA and the EE from IRC.

TABLE 1

Descriptive characteristics of study participants.

	Boys (<i>N</i> = 10)	Girls (<i>N</i> = 11)	Total Sample (<i>N</i> = 21)
Age (yr)	11.7 ± 1.0 (10.3–14.1)	11.4 ± .84 (10.7–13.3)	11.6 ± 0.9 (10.3–14.1)
Weight (kg)	45.0 ± 8.8 (25.0–53.6)	49.35 ± 16.1 (27.54–79.50)	47.3 ± 13.0 (25.0–79.5)
Height (cm)	150.4 ± 8.62 (130.8–162.6)	152.7 ± 9.26 (139.7–170.2)	151.6 ± 8.8 (130.8–170.2)
Body mass index (kg/m ²)	19.7 ± 2.6 (14.6–23.4)	21.0 ± 6.2 (14.1–36.6)	20.4 ± 4.8 (14.1–36.6)
Percentage of body fat (%)	17.0 ± 7.9 (7.0–29.6)	24.4 ± 12.5 (9.3–52.6)	20.8 ± 11.0 (7.0–52.6)

All variables are presented as means ± SD (ranges). There were no statistically significant differences between boys and girls in any variable (*P* > 0.05).

TABLE 2

Energy expenditure of children ($N = 21$) estimated from the SenseWear Pro Armband and measured by indirect calorimetry during various activities and during a 24-h stay in the whole-room indirect calorimeter.

Activity ^a	Energy Expenditure (kcal·min ⁻¹)		Confidence Intervals for Difference	Ratio ^b (%)	P Values ^c
	Whole-Room Indirect Calorimeter	SenseWear Pro Armband			
Rest before exercise (30 min)	1.46 ± 0.24	1.77 ± 0.69	0.01–0.60	121.81 ± 40.82	0.0070
Treadmill exercise (30 min)	5.49 ± 1.92	6.27 ± 1.80	0.37–1.19	118.41 ± 22.11	0.0040
Rest after exercise (90 min)	1.40 ± 0.19	1.97 ± 0.37	0.42–0.75	143.54 ± 28.80	0.0001
Sedentary activities	1.61 ± 0.24	1.95 ± 0.35	0.22–0.48	122.18 ± 19.98	0.0004
Sleep	0.92 ± 0.21	1.05 ± 0.14	0.07–0.18	116.13 ± 15.60	0.0007
Resting metabolic rate (RMR)	1.05 ± 0.18	1.22 ± 0.26	0.05–0.28	117.55 ± 26.31	0.0070
Total 24 h	1.42 ± 0.23	1.70 ± 0.16	0.19–0.37	122.04 ± 17.05	0.0001

Values are means ± SD

^aDetailed description of activities are in Methods

^bratio of energy expenditure (EE) predicted by Sensewear Armband to EE measured by using whole-room indirect calorimetry

^ccalculated from Wilcoxon signed-rank tests.

TABLE 3

Multiple linear regression models for resting and sedentary energy expenditure, and energy expenditure during exercise.

	Coefficient $\pm$ SE	P Values	R ²
Resting metabolic rate			0.986
Body weight (kg)	0.011 $\pm$ 0.002	<0.001	
EE from Sensewear (kcalImin ⁻¹)	0.453 $\pm$ 0.071	<0.001	
Sedentary activities			0.994
Body weight (kg)	0.015 $\pm$ 0.002	<0.001	
EE from Sensewear (kcalImin ⁻¹)	0.462 $\pm$ 0.050	<0.001	
Exercise (treadmill)			0.984
Body weight (kg)	0.034 $\pm$ 0.012	0.010	
EE from Sensewear (kcalImin ⁻¹)	0.637 $\pm$ 0.089	<0.001	