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VALIDATION OF SENSEWEAR PRO₂ ARMBAND TO ASSESS ENERGY EXPENDITURE DURING TREADMILL EXERCISE IN CHILDREN 7 – 10 YEARS OF AGE

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ABSTRACT

Andreacci JL, Dixon CB, Dube JJ, McConnell TR. Validation of SenseWear Pro₂ Armband to Assess Energy Expenditure during Treadmill Exercise in Children 7 – 10 Years of Age. *JEPonline* 2007;10(4) 35-42. The purpose of this investigation was to examine the accuracy of a newly developed, child-specific exercise algorithm for the assessment of energy expenditure (EE) using the SenseWearTM Pro₂ armband (SWA) in children. Thirty-three children (16 females; 17 males) between 7 – 10 years of age participated in this study. All participants performed three 8-minute sub-maximal exercise bouts on a motorized treadmill (1.7 mph, 0% grade; 2.5 mph, 0% grade; and 3.4 mph, 0% grade) each separated by a 5-min seated rest period. EE was assessed using the SWA and compared to indirect calorimetry (IC), the criterion measure. The total EE estimates of the SWA were not significantly different from IC. The results demonstrate that the SWA, when equipped with the child-specific exercise algorithms, accurately estimates EE during intermittent sub-maximal treadmill exercise in children.

Key Words: Energy Expenditure, Indirect Calorimetry, Physical Activity, Children

INTRODUCTION

The prevalence of obesity in children and adolescents in the United States and other industrial countries has increased in the past 2 decades [1,2,3]. Increases in sedentary behaviors (i.e. TV viewing, playing video games) and decreases in physical activity have been related to the rise of obesity in children [4]. Childhood obesity has been associated with significant pediatric health problems such as; impaired glucose tolerance [5], type 2 diabetes [6], dyslipidemia [7], hypertension [8], reduced cardiorespiratory/aerobic fitness [9], and is an important risk factor for adult morbidity and mortality [10,11]. Physical activity has been demonstrated to improve the health status of obese children and adolescents [12]. Thus, developing non-invasive methodologies to examine energy expenditure (EE) during physical activity in children and adolescents is important.

Various methods of assessing physical activity have been used to calculate EE in children. Indirect calorimetry (IC) is the most commonly used measure for determining oxygen consumption and the calculation of EE during acute bouts of exercise. Doubly labeled water is also often recommended for the accurate determination of EE over time [13]. However, both methods require sophisticated equipment and trained personnel to administer, which may not always be practical. Pedometers have been used to assess EE by counting the number of steps taken, however there is possible error when steps are converted into energy expended [14]. Furthermore, pedometers are limited to a single mode of activity. Physical activity questionnaires have also been used, however accuracy of this technique is limited when compared to other more objective techniques [15]. An accurate non-invasive method for the assessment EE in children remains elusive.

Through advances in technology, portable continuous body monitors, like the SenseWear™ Pro₂ armband (SWA, BodyMedia®, Inc., Pittsburgh, PA, USA) have been developed as a practical alternative for estimating EE. The accuracy of the SWA for estimating EE has been examined in healthy adults at rest [16], during various modes of physical exercise [17,18] and in cardiac patients [19]. Jakicic et al. [17] and Cole et al. [19] concluded that the SWA may provide a more accurate estimate of EE during exercise than other commonly used portable EE monitors. The SWA estimates EE using physiological and environmental data from multiple sensors. Further, the SWA is worn on the lateral head of the triceps making it ideal for monitoring EE during activities of daily living. Despite the validation in adults, preliminary evidence by Crawford et al. [20] and Potter et al. [21] indicates that the adult-based algorithms are inaccurate for adolescents and children. The purpose of this investigation was to examine the accuracy of the SWA to assess EE in children using newly developed child-specific exercise algorithms.

METHODS

Subjects

A total of thirty-three healthy children (age = 8.6 ± 1.3 years; BMI = 19.6 ± 4.2 kg/m²) participated in this investigation. Thirteen subjects (7 girls, 6 boys) were randomly-selected from this current study and these data were provided to the manufacturer for the development of child-specific exercise proprietary equations. The remaining twenty children (9 girls, 11 boys) were used for the cross-validation of the newly-developed child-specific algorithms. Study participants were recruited through advertisements in the community. Prior to participation, parents' informed written consent and subjects' written assent were obtained according to the requirements established by the Bloomsburg University Institutional Review Board. Subject characteristics are presented in Table 1.

Measurement of Descriptive Variables

Height was measured to the nearest 0.5 cm using a stadiometer with the subject not wearing shoes. Body weight was measured to the nearest 0.2 kg on a balance-beam scale with subjects wearing only a t-shirt and shorts.

Algorithm Validation

All participants performed three separate 8-minute bouts of walking/jogging on a motorized treadmill. Workloads were completed as follows: 1) 1.7 mph, 0% grade; 2) 2.5 mph, 0% grade; and 3) 3.4 mph, 0% grade. Each 8-minute, sub-maximal exercise workload was followed by a 5-minute seated rest period. Heart rate was measured continuously throughout the exercise test using a Polar HR Monitor (Polar Electro, Inc., Woodbury, NY). Laboratory temperature was maintained at a constant 23.5 °C for all tests and testing was administered at the same time of day for all subjects.

Open Circuit Calorimetry

The criterion method of assessing EE during the exercise protocol was IC by open circuit spirometry. A ParvoMedics TrueMax 2400 metabolic measurement system (Salt Lake City, UT) was used to measure minute-by-minute oxygen uptake and respiratory exchange ratio (RER). The metabolic measurement system was calibrated with gases of known concentrations before each testing session according to the manufacturer's guidelines. The EE (kcal/min) was computed multiplying the oxygen uptake (L/min) by the caloric equivalent based on RER.

SenseWear Pro₂ Armband

SenseWear Pro₂ armband was developed by BodyMedia, Inc (Pittsburgh, PA). Information provided by the manufacturer (www.bodymedia.com) indicates that the SWA uses non-invasive biometric sensors to continuously measure physical parameters (i.e. heat flux, galvanic skin response, skin temperature, near-body temperature, and two-axis accelerometry) and demographic characteristics (i.e. gender, age, height, weight) to estimate EE [16,17].

The SWA body monitor was worn on the right arm over the triceps muscle at the midpoint between the acromion and olecranon process. The armband was placed on the subject's arm and worn while in a seated position for a period of 20 min prior to data collection to allow for acclimation to subjects' skin temperature. EE during the treadmill exercise workloads were computed at 1 min intervals by means of the child-specific exercise algorithms (Interval Research Software Version 4.2).

Statistical Analyses

Statistical analyses were performed using SPSS 11.0 for Windows (SPSS Inc, Chicago, IL). Data were analyzed separately for each exercise workload. All values are expressed as mean \pm standard deviation (*SD*). Statistical significance was established *a priori* at $p < 0.05$. Comparison of EE between IC and the SWA, at each exercise intensity, and for the entire exercise protocol were analyzed with dependent *t*-tests. Bland-Altman plots were used to explore for individual differences between EE measured by IC and estimated by the SWA.

RESULTS

Subject characteristics for all study participants are presented in Table 1. No differences in EE were observed between IC and the SWA for the entire exercise session (30.5 ± 6.0 kcal vs. 29.7 ± 7.4 kcal, $p = 0.702$) or during any of the exercise workloads (Figure 1). Significant ($p < 0.00001$) correlations

for EE between the two methods were found at each workload 1.7 mph ($r = 0.92$), 2.5 mph ($r = 0.90$), 3.4 mph ($r = 0.96$) and for the entire exercise session ($r = 0.94$).

Table 1. Participant characteristics.

Conditions	Females	Males
N	16	17
Age (y)	8.8±1.4	8.3±1.2
Height (cm)	135.8±8.8	132.9±8.4
Body Mass (kg)	34.3±8.3	37.3±12.0
BMI (kg/m²)	18.4±3.0	20.7±4.9

Bland-Altman plots of EE between both methods of assessment are depicted in Figures 2A-D, respectively. In the figures, the difference between the two methods (IC – SWA) is plotted against the EE determined by IC, the criterion measure. The solid line represents the mean difference and the dashed lines correspond to ± 2 SD. At 1.7 mph, a significant correlation was observed between the mean difference between methods and the magnitude of the EE ($r = -0.61$; $p < 0.01$). However, the difference between IC and the SWA was unaffected by the magnitude of EE at the 2.5 mph and 3.4 mph exercise workloads and for the entire exercise session (Figures 2B-D).

All values are mean \pm SD.

DISCUSSION

The present investigation examined the accuracy of newly developed, child-specific algorithms for the assessment of EE using the SWA in children. The exercise protocol required the children to walk/jog on the treadmill at three different workloads each separated by a 5-min rest interval. IC, measured by open circuit spirometry, served as the criterion measure in this investigation. When using the SWA

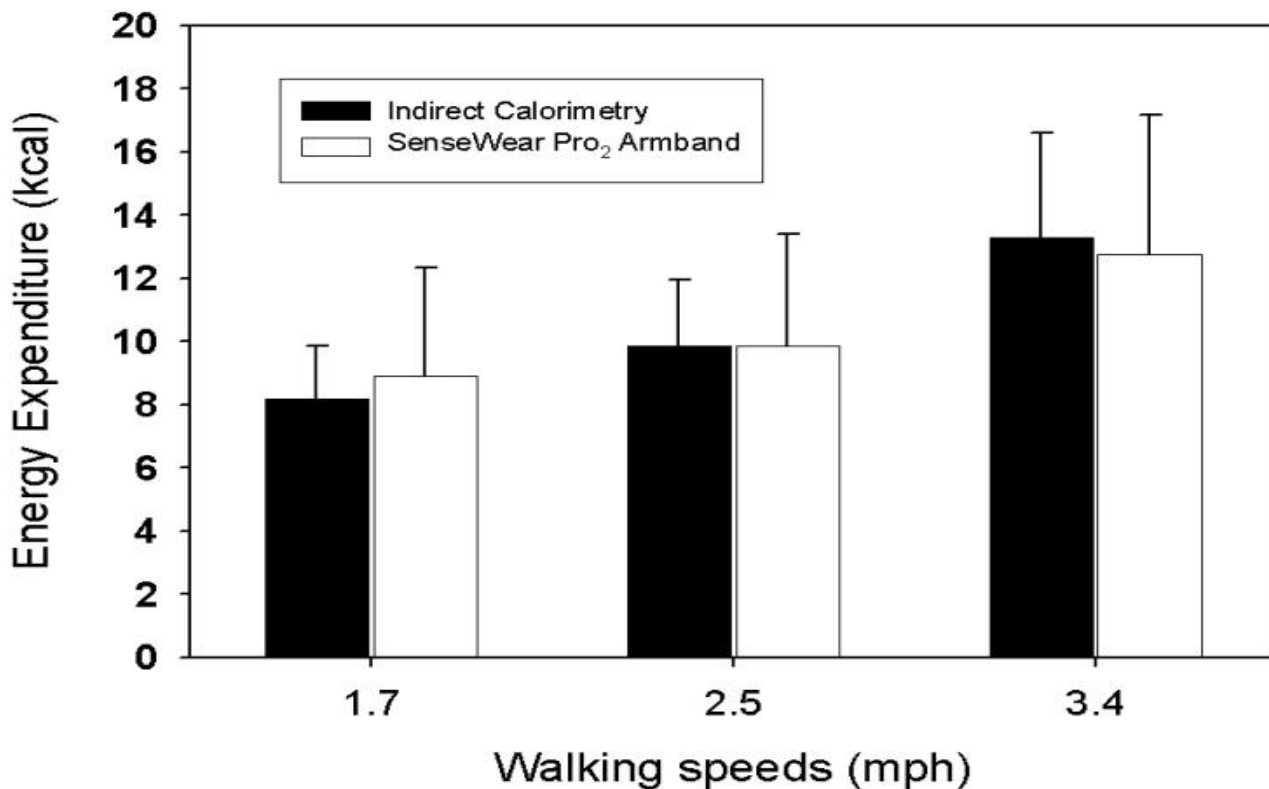


Figure 1. Total energy expenditure determined by indirect calorimetry and the SenseWear Pro₂ armband for each exercise workload (mean \pm SD).

equipped with new child-specific exercise algorithms, no differences for EE were observed between methods at any exercise intensity or for the entire exercise session.

Previous research has examined the accuracy of the SWA for estimating EE following treadmill exercise in adults [17-19]. King et al. [18] compared the SWA and other portable activity monitors to estimate EE during treadmill exercise. Although the SWA overestimated EE when compared to IC, the authors concluded that the SWA provided the best estimate of total EE at most treadmill speeds [18]. Cole et al. [19] also examined the use of the SWA to estimate EE in cardiac rehabilitation patients. No differences were observed between EE estimated by the SWA and IC during treadmill exercise [19].

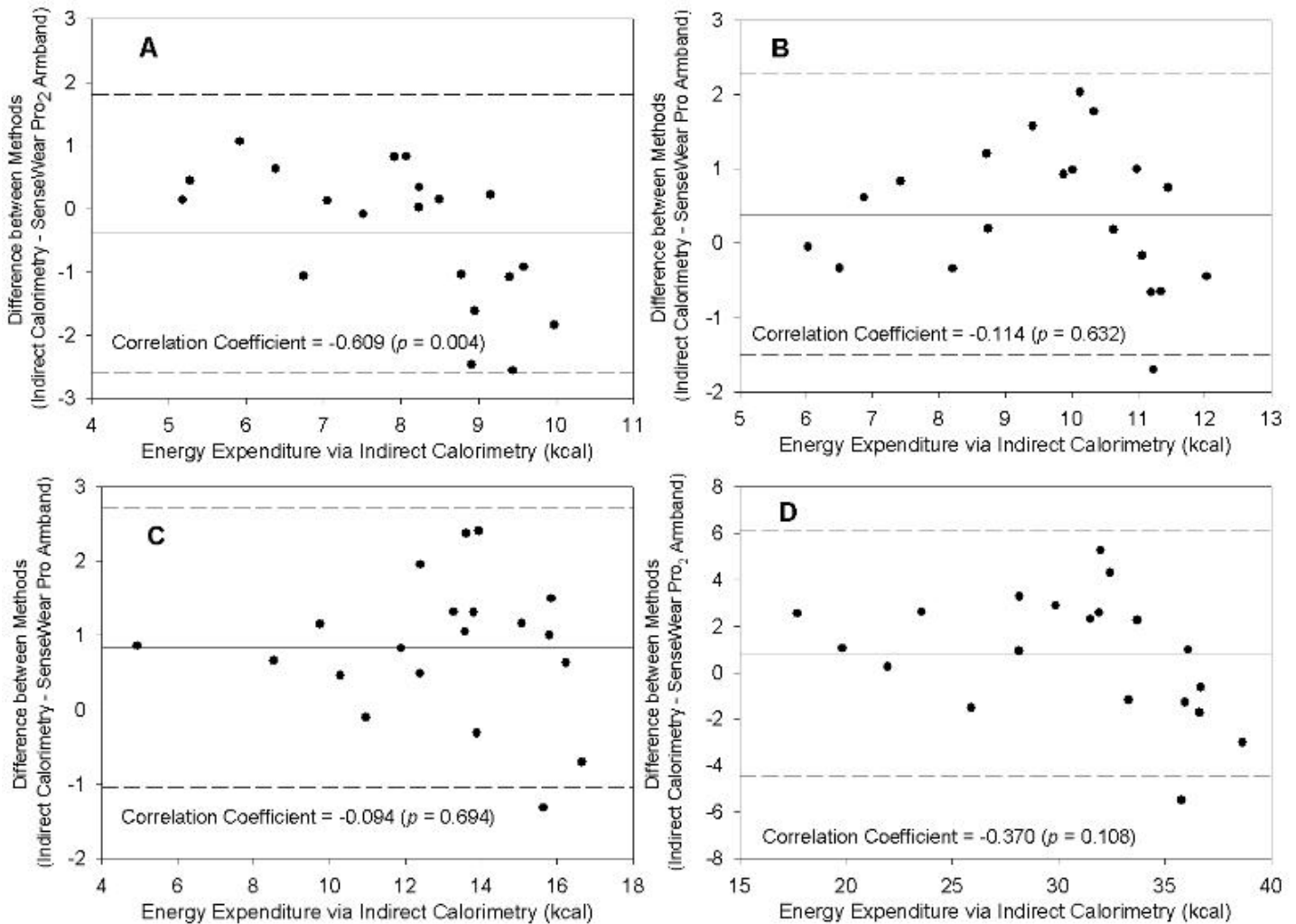


Figure 2. Bland-Altman plots exploring for individual differences in total energy expenditure between indirect calorimetry (IC) and the SenseWear Pro₂ armband (SWA) at (a) 1.7 mph, (b) 2.5 mph, (c) 3.4 mph, and (d) for the entire exercise session. The difference between the 2 methods is plotted against the criterion, IC. The mean difference is represented by the solid line, and the dashed lines represent ± 2 SD from the mean.

Jakicic et al. [17] examined the SWA during various modes of exercise in adults aged 18-35 years. The SWA significantly underestimated total EE during walking, cycle ergometry, and stepping exercise, and overestimated total EE during arm ergometer exercise. As a result, exercise-specific algorithms were developed that resulted in non-significant differences in total EE between IC and the SWA for the walk, cycle, step, and arm ergometer exercises. They concluded that it is necessary to apply exercise-specific (i.e. mode) algorithms to the SWA to enhance to the accuracy of estimation during exercise [17].

In addition to the need for mode-specific algorithms, it is apparent that age-specific algorithms may also be necessary. Preliminary evidence by Crawford et al. [20] and Potter et al. [21] indicates that the adult-based algorithms are not accurate for estimating EE in adolescents and children. In the Crawford et al. [20] investigation, adolescents (13.8 ± 1.8 yrs) exercised on a treadmill and cycle ergometer at various intensities. They reported that the SWA significantly ($p < 0.001$) underestimated EE when compared to IC during both types of exercise. They suggested that a possible mechanism underlying the underestimation in EE was that the SWA algorithms were developed for adults and not for adolescents [20]. Potter et al. [21] examined the accuracy of the SWA for estimating EE in children ($10.1 \pm .7$ yrs) during exercise. When compared to IC, the SWA significantly ($p < 0.01$) overestimated the EE of children during 10 minutes of flat outdoor walking at a comfortable and brisk pace [21].

The previously mentioned investigations all involved adult participants or the inappropriate use of adult-based algorithms to assess EE during exercise in adolescents or children. The present investigation is the first to examine EE using the SWA with the child-specific exercise algorithms. In contrast to the previous work in children and adolescents [20,21], we found no differences in EE between methods at any treadmill exercise intensity or for the entire exercise session when the new algorithms were applied to the data. At 1.7 mph, the SWA armband underestimated EE at low and overestimated EE at high EE magnitudes. Despite this trend, each of the individual data points were within the 95% confidence interval (range = -2.6 to 1.8 kcal; Figure 2A). As demonstrated in Figures 2B-D, only 1 data point was outside the 95% confidence interval at 2.5 mph (range = -1.4 to 2.2 kcal; Figure 2B) and 3.4 mph (range -1.1 to 2.6 kcal; Figure 2C). In addition, as demonstrated in Figures 2B-D, the difference in EE between methods does not appear to be influenced by the individual's magnitude of EE during the exercise bout. Regardless of the workload, the EE assessed by the SWA for each of the children was within ± 2.6 kcal of the criterion value. This finding is of importance given that a child's daily activity pattern often consists of intermittent bouts of varying exercise intensity [22,23]. The treadmill speeds employed in the present investigation (1.7 mph, 2.5 mph and 3.4 mph, respectively) were selected based on the recent health recommendations regarding the importance of moderate physical activity in children [24,25]. These different workloads corresponded to 56%, 61% and 71% of their age predicted maximal heart rate. We feel that our intensity levels fairly represent those in which children would regularly engage in during the normal course of a day.

It is important to note that the child-specific exercise algorithms examined presently were developed using data generated during treadmill exercise in a controlled laboratory setting. The exercise protocol required the children to walk/jog on the treadmill at three different workloads, each 8-min in duration. It is unknown whether similar findings would occur during other modes of exercise (e.g., cycle and arm ergometry, stair climbing), different exercise intensities, or during exercise of different lengths of duration than used presently. In addition, the accuracy of the new algorithms during free-living walking/jogging activities that are less controlled cannot be determined from this study. If consistent with the previous findings in adults [17], the development of mode-specific exercise algorithms may be necessary to increase the accuracy of SWA estimation in children. Lastly, our subject sample was primarily Caucasian and representative of rural Pennsylvania. The accuracy and of these algorithms in other ethnic populations is unknown. Future investigations to explore these limitations are warranted.

The results of this study indicate that the SWA, when equipped with the child-specific exercise algorithms, accurately estimated EE in our sample of children between the ages of 7 to 10 years during treadmill exercise. It should be emphasized that the present findings examined intermittent sub-maximal treadmill exercise and that these findings must be considered representative only of the

specific group of children tested. Follow-up investigations should examine the validation of the SWA to assess energy expenditure during other modes of activity and in children of varying age and ethnicity.

Practical Applications

In the battle against pediatric obesity, which has reached epidemic levels, a need for an assessment tool like the SWA to monitor EE has arisen. This portable device uses wireless technology that captures continuous, objective and quantitative data. The SWA could be extremely beneficial to hospital/clinics, school districts and researchers in the fight against obesity and promotion of physical activity.

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