Journal of Exercise Physiologyonline

Volume 14 Number 3 June 2011

Official Research Journal of the American Society of Exercise Physiologists

ISSN 1097-9751

JEPonline

The Ability of the SenseWear® Armband to Assess a Change in Energy Expenditure in Children While Sitting and Standing

Mark E. Benden[1], Lexie Mancuso[1], Hongweizhao[1], Adam Pickens[1]

[1]School of Rural Public Health, Texas A&M Health Science Center, College Station, Texas, USA

ABSTRACT

Benden M, Mancuso L, Zhao H, Pickens A. The Ability of the SenseWear® Armband to Assess a Change in Energy Expenditure in Children While Sitting and Standing. **JEPonline** 2011;14(3):1-14. Increasing physical activity levels of children in school has become a primary method of combating the growing trend of childhood obesity. As part of a large field trial that is currently seeking to evaluate the impact of the stand-biased desk on children's energy expenditure in school, this study first evaluated the degree to which the SenseWear® Armband measures a change in energy expenditure in children while sitting and standing at a desk in a controlled laboratory environment. If the device is found sensitive enough to detect differences in the laboratory, the research team plans to use it in the larger school study. This study was conducted with 21 children between 7 and 10 yrs of age. The children wore the SenseWear® Armband while sitting at a traditional desk and while standing at a height-adjusted standing desk with footrest for 30 min each. The mean energy expenditure for sitting was 0.63 kcal·min^{-1}, ranging from 0.39-1.08. The mean energy expenditure for standing was 0.71 kcal·min^{-1} (range = 0.40 to 1.10). Paired comparisons indicated that the average energy expenditure was significantly higher when the subjects were standing versus sitting ($P<0.0001$). Therefore, we concluded that the SenseWear® Armband is sensitive enough to detect changes in energy expenditure in children 7 to 10 yrs of age while sitting and standing. The use of the SenseWear® Armband to assess slight changes in energy expenditure in children is both practical and sensitive.

Key Words: BMI, School, Childhood Obesity, Desk

INTRODUCTION

The Obesity Epidemic

Childhood overweight and obesity is a growing concern. Recent results from National Health and Nutrition Examination Survey (NHANES) 2007-2008 reported 16.9% of all children 2 through 19 yrs old were obese and 31.7% were overweight (30). It is not only a concern that these percentages are high, but also that they are increasing. When comparing data from NHANES 1976-1980 to NHANES 2003-2006 (Table 1), it can be seen that the prevalence of obesity has increased for children in each age range (8,31).

Table 1. Obesity prevalence from NHANES (1976-1980 and 2003-2006).

Age (yr)	NHANES (1976-1980)	NHANES (2003-2006)
2-5	5.0%	12.4%
6-11	6.5%	17.0%
12-19	5.0%	17.6%

Non-exercise Activity Thermogenesis

Although lack of physical activity is often recognized as a contributing factor of obesity, research also points to the importance of energy expenditure (EE) during non-exercise activities (23,26). Almost one-third of daily EE is accounted for in activity thermogenesis, which is made up of exercise and "non-exercise activity thermogenesis" (NEAT) (23). NEAT is defined as the EE of all physical activity other than sporting-like exercise. Though EE during NEAT may seem insignificant, NEAT studies show that this small change can help prevent obesity because a large part of caloric expenditure is from NEAT (23,24,26). For example, NEAT has been shown to be a mediator in resistance to weight gain with overfeeding in sedentary, non-obese adults (24). Just as occupation is a significant determinant for NEAT in adults, the environment in schools may also be altered for presumably the same effect of preventing obesity in children (23,27). One option is giving children the choice to stand at their desks to promote more NEAT, in turn, helping to prevent further weight gain and obesity prevalence.

Review of the SenseWear® Armband (SWA)

Studies using the SWA have been conducted for both adults and children. For healthy adults, validation studies (18,29) have confirmed that the SWA is precise and gives accurate measurements of resting EE when compared to indirect calorimetry. When compared to the IDEEA monitor, the SWA showed non-significant differences in mean EE for postures and movements including lying down, sitting, standing, and walking (38). One study (33) had subjects perform the same activities on different days and the results showed the SWA to be highly reproducible. Some findings suggest the SWA is more accurate for routine daily EE compared to those with extreme levels of EE, like athletes (36).

Since obesity is associated with a low NEAT, and NEAT can be increased by standing at a desk as opposed to sitting (23), changing the chair-based environment that has facilitated a seated lifestyle seems to be a promising intervention for obesity. Despite some differences in EE estimates, the SWA has shown better results than similar devices that measure EE (21,36,38). In practice, it has proven to be a useful tool for daily EE estimations (36), and has shown improvements in the accuracy and usability of its software over time (14). Other researchers also find the SWA an accurate and reliable method of estimating EE. After studies of the SWA showed a high reliability of estimating EE in adults (21,29) and children (1,3) compared with indirect calorimetry, in adults (36) and children (2) compared with doubly labeled water (DLW), the SWA was used in a study as the only EE assessment device (35) and a criterion measure (6). Additionally, in a previous study by Arvidsson et al. (2), children responded positively and showed a preference for wearing the SWA for activity monitoring.

Although, in the study by Arvidsson et al. (4), the SWA did not detect a change from resting in the supine position to sitting with child algorithms in place, the improved algorithms used in the Calabro et al. study (7) showed that the device is sensitive enough to detect a difference in EE from resting to sitting. With this recent finding of sensitivity of the SWA in children and the potential EE benefits discussed for standing rather than sitting, the current study was conducted to address these topics. The purpose was to assess the sensitivity of the SWA in its ability to detect a within subjects difference in EE between sitting and standing in 7 through10 yrs old children under controlled conditions in a simulated school environment.

METHODS

Subjects

Following approval by both the Institutional Review Board (IRB) at Texas A&M University and the College Station Independent School District (CSISD) Research Committee, an IRB approved letter of invitation to participate was sent to the parents of the children in the classrooms of children ages 7 to10 yrs of age. Twenty-one subjects were recruited (14 males and 7 females). Each subject received a $20 gift card to Premiere Cinemas as compensation for participation.

Procedures

The EE measurement device used for this study was the SenseWear® Pro 3, Serial No. 7480991, (Body Media, Inc., Pittsburgh, PA). This is a multiple-sensor device that relies on pattern recognition using a series of non-invasive sensors and individual characteristics of a subject to estimate EE through an age and activity-specific proprietary algorithm. The individual characteristics of the subject used to determine EE calculations included: gender, age, height, weight, handedness, and whether the subject smokes. The device contains five different sensors that are monitored 32 times per sec including: 2-axis accelerometer, heat flux, galvanic skin response, skin temperature, and near-body ambient temperature. The 2-axis accelerometer measured motion and maps it to forces exerted on the body (37). The heat flux sensor measured the amount of heat being dissipated from the body using thermally resistant materials and thermocouple arrays (37). Using hypo-allergenic stainless steel electrodes, the galvanic skin response sensor measured the skin's electrical conductivity affected by sweat and emotional stimuli as an indicator for evaporative heat loss (37). The skin temperature sensor is thermistor-based. It measured skin temperature, which is reflective of the body's core temperature (37). Near body temperature measures the temperature of the cover on the side of the armband (37) and, according to the manufacturer, combines this with skin temperature to determine the temperature of the environment around the subject.

The SenseWear® Adjustable Velcro Strap from BodyMedia, Inc., Pittsburgh, PA was used to attach the device to the subject. To obtain descriptive characteristics of each subject, a scale and stadiometer were used. The scale is the BF-679W Scale plus Body Fat Monitor with Body Water %, (Tanita Corporation, Arlington Heights, IL). The stadiometer used was the HM200P Portstad, (Seca Corporation, Hanover, MD). During the study segments, the subjects used a sitting desk (Safco® desk, Safco Products Company, New Hope, MN), a chair (Chair, 9000 classic series, Virco, Torrance, CA), and a standing desk (Prototype standing desk with footrest that was developed by researchers from an Archetype desk by, Artco-Bell Inc., Temple, TX). During the activities of the study segments, the subjects used a desktop computer (OptiPlex 755, Dell Inc., Round Rock, TX), monitor (2408WFP

Flat Panel Monitor, 2408WFPb, Dell Inc., Round Rock, TX), and mouse (2-Button USB Optical Mouse, Part # XN966, Dell Inc., Round Rock, TX). A digital timer (Sunbeam® Digital Timer, Robinson Home Products Inc., Buffalo, NY) was used by the researcher to time the segments.

The data were analyzed using the same Dell computer with a Microsoft® operating system (Microsoft® Windows® XP Professional, 5.1.2600, Redmond, WA). The software used for data analysis was SenseWear® Professional software, Version 6.1.0.1528 (English), BodyMedia, Inc., Pittsburgh, PA; Microsoft® Office Excel® 2007 (12.0.6514.5000) SP2 MSO (12.0.6425.1000), Microsoft Corporation, Redmond, WA; and Stata®/IC 11.0 for Windows (32-bit), StataCorp LP, College Station, TX. The subject data collection sessions took place either on a weekday between the hours of 3 p.m. and 8 p.m. or on the weekend between 8 a.m. and 8 p.m., depending on parental preference. The time of day and the day of the week were not controlled since the comparison is being made within the same child, on the same day in the same time period. The location of the study was at the School of Rural Public Health in the Laboratory Building. At each meeting, those present at all times were the researcher, the subject, and at least one of the subject's parents.

The study procedures described were performed consecutively during one 1.5 hr meeting on the same day. Upon arrival, the parents were asked to sign an IRB-approved Parent Permission Form to provide consent for their child to participate in the study. Following the parent's consent, and child assent was granted, the researcher placed the SWA on the dry skin of the child's arm explaining that, within a few minutes the device will sound a few beeps, vibrate and, then, sound a few more beeps. The child was told that the sound is normal and not to be alarmed. The device was adjusted by the researcher for size using the elastic, adjustable, Velcro strap until it fit snuggly on the arm to ensure that the sensors maintained contact with the skin. The researcher was careful not to over-tighten the armband. The subject was asked if the device was comfortable on the arm in order to determine the appropriate adjustment needed. The device was worn on the back of the right arm, over the triceps brachii muscle midway between the acromion process and the olecranon process. This decision was made based on the manufacturer's recommendation and the practices of previous researchers using the device. Once secured to the subject, it took about 5 min for the sensors to detect the subject and start collecting data.

Individual characteristics were obtained from the subject for use in data analysis and study procedures. The subjects were asked to remove their socks, shoes, and jacket before stepping on to the Seca stadiometer for a stature measurement and, then, the Tanita scale for a weight and body fat percent measurement. The standing elbow height was also measured using the stadiometer according to Kodak's Ergonomic Design for People at Work (11). Afterwards, the subjects were allowed to put their socks, shoes, and jacket back on. All the subjects' birth date, handedness, and gender were recorded. Two TV shows were chosen from a specified list to watch during the study. The parents were given the option to choose the TV shows from a list or to allow their children to choose. The list contained TV shows available online for free viewing, their TV Parental Guideline ratings (only Y, Y7, and G) and the websites from which the TV shows were watched. Online games were also chosen to play during the study. The children were given a choice of word finds from eduplace.com or Spot the Difference from uptoten.com.

The study consisted of three segments (Table 2). The first segment was 30 min long and the subject sat at the Safco desk in the Virco chair. Once the child was sitting in the chair, the Timestamp/Status button on the SWA was pressed by the researcher to indicate the beginning of the sitting segment, a 30-min timer was started, and the activities (described later in this section) began. The subject was asked to sit in the chair without leaning on the desk. During this 30-min period, the researcher adjusted the standing desk to the appropriate height according to the subject's resting elbow height.

Table 2. Study design timeline.

Segments	Duration	Activities during each period
	10 Min	Watch TV Show
Sitting	10 Min	Play Online Game
	10 Min	Watch TV Show
Beak	1 Min	Remain Sitting
	10 Min	Watch TV Show
Standing	10 Min	Play Online Game
	10 Min	Watch TV Show

The second segment was a break segment. No data were collected during this segment. The subject remained seated in the chair for at least 1 min in order to have a clear separation between timestamps when uploading the data into the software. During this time, the researcher exchanged the sitting Safco desk with the stand-biased desk.

The third segment was 30 min long and the subject stood at the stand-biased desk (Figure 1). The researcher familiarized the subject with the desk and the footrest. Once the child was standing at the desk, the Timestamp/Status button on the SWA was pressed by the researcher to indicate the beginning of the standing segment, a 30-min timer was started, and the activities (described later) began. The subject was asked not to lean on the desk and to use the footrest as desired.

Figure 1. Model Demonstrating the Stand-Biased Desk.

The activities the participants performed during the sitting and standing segments were the same for each segment. Each activity involved a computer. Within the 30-min segments there were three 10-min periods. During the first 10-min period, the subjects watched the first segment of a TV show on the internet. The TV show was then paused. During the second 10-min period, the subjects played computer games on the internet. All games were controlled with the mouse and low intensity levels were similar between game options to keep the comparisons equivalent. During the third 10-min period, the subjects watched the last segment of the TV show on the internet.

The study design use of the 30-min segments for each activity was based on the function of the algorithms used to analyze data from the SWA. The algorithm uses the pattern of signals from the 10 min before and after each minute it is estimating in order to predict the activity being performed by the subject. This prediction is then used to determine which activity-specific algorithm to apply. Therefore, as per manufacturer recommendation, the first 10 min and the last 10 min of recorded activity by the SWA were not used when analyzing the data in order to acquire accurate results. The data analyzed included the middle 10-min period, and, therefore, 10 data points for each segment from minute by minute EE estimations.

Statistical Analysis

Using data from our pilot study at College Hills Elementary, the average EE for each child was calculated for each of the 5 days that data were collected while the child was at their desk (6,7) supplied with sitting or standing chairs. The EE mean differences between sitting and standing varied from -0.14 to 0.18. The standard deviations of these differences varied between 0.15 and 0.32. Assuming a standard deviation of 0.20 for the current study, a group of 32 subjects would provide 80% power for detecting a difference of 0.10 between treatment and control segments, using a two-sided paired t-test with an alpha level of 0.05. Therefore, the initial goal for recruitment was approximately 30 subjects.

However, since the variability of the data in the current study could have differed significantly from the College Hills study, after data were collected for the first 14 subjects, a recalculation of the sample variability was performed. First, the average EE was calculated for each student while sitting and standing. Then, the difference of the average EE from sitting to standing was calculated. The standard deviation of these differences was computed at 0.05. Based on this calculation, a group of 8 students would have provided more than 80% power for detecting a difference of 0.10 between the two segments, using a two-sided paired t-test with an alpha level of 0.05. Therefore, the final goal for recruitment was approximately 8 subjects. A total of 21 subjects participated in the study, 14 boys and 7 girls.

Minute-by-minute EE was analyzed in Stata for each subject during the second 10-min period of each sitting and standing segment. The within-person variability over the 10 measurements was calculated. An average EE over the 10 min was obtained for each child for each of the two segments. For each participant, the mean EE for sitting and the mean EE for standing were compared. The distribution of the data was checked using a histogram and box plot. Since there were no obvious outliers, a paired t-test was performed first to verify a significant difference in EE between sitting and standing. This was followed by a Wilcoxon signed rank test to confirm the findings since the data did not appear normally distributed. Multiple linear regression analysis was then performed to analyze whether or not other covariates in the study affected the differences in EE.

RESULTS

All 21 subjects had complete data for both sitting and standing segments. All subjects endured the procedure willingly and enjoyed themselves while participating. Subject characteristics are presented in Table 3. Sixteen of the subjects were 7 yrs of age, 1 subject was 8, 3 subjects were 9, and 1 was 10. Fourteen subjects were male and 7 were female. Fourteen subjects were of normal weight (5th percentile > BMI < 85th percentile), 2 subjects were overweight (85th percentile = BMI < 95th percentile), and 5 subjects were obese (BMI = 95th percentile).

Table 3. Physical characteristics and EE.

	All Participants (N = 21) Mean (SD)
Age (yr)	7.48 (0.93)
Weight (kg)	30.38 (8.98)
Height (m)	1.30 (0.09)
BMI ($kg \cdot m^{-2}$)	17.54 (2.87)
Sitting EE ($kcal \cdot min^{-1}$)	0.63 (0.18)
Standing EE ($kcal \cdot min^{-1}$)	0.72 (0.19)

The mean EE for sitting averaged over 21 subjects was 0.63 kcal, ranging from 0.39 to 1.08 for each subject. The mean EE for standing was 0.72 kcal, ranging from 0.40 to 1.10.

Individual within-subject standard deviations were analyzed and showed the overall within-subject variability was larger for the standing posture (Figure 2). The average within-subject standard deviation was 0.02 for sitting EE and 0.09 for standing EE. When averaged over the 10 measurements, the mean EE was higher for the standing posture for each participant even though some were only marginally higher as was the cases of subjects 1, 12, 17, and 19 (Figure 3). This averaged EE over 10 min is the unit for our primary analysis.

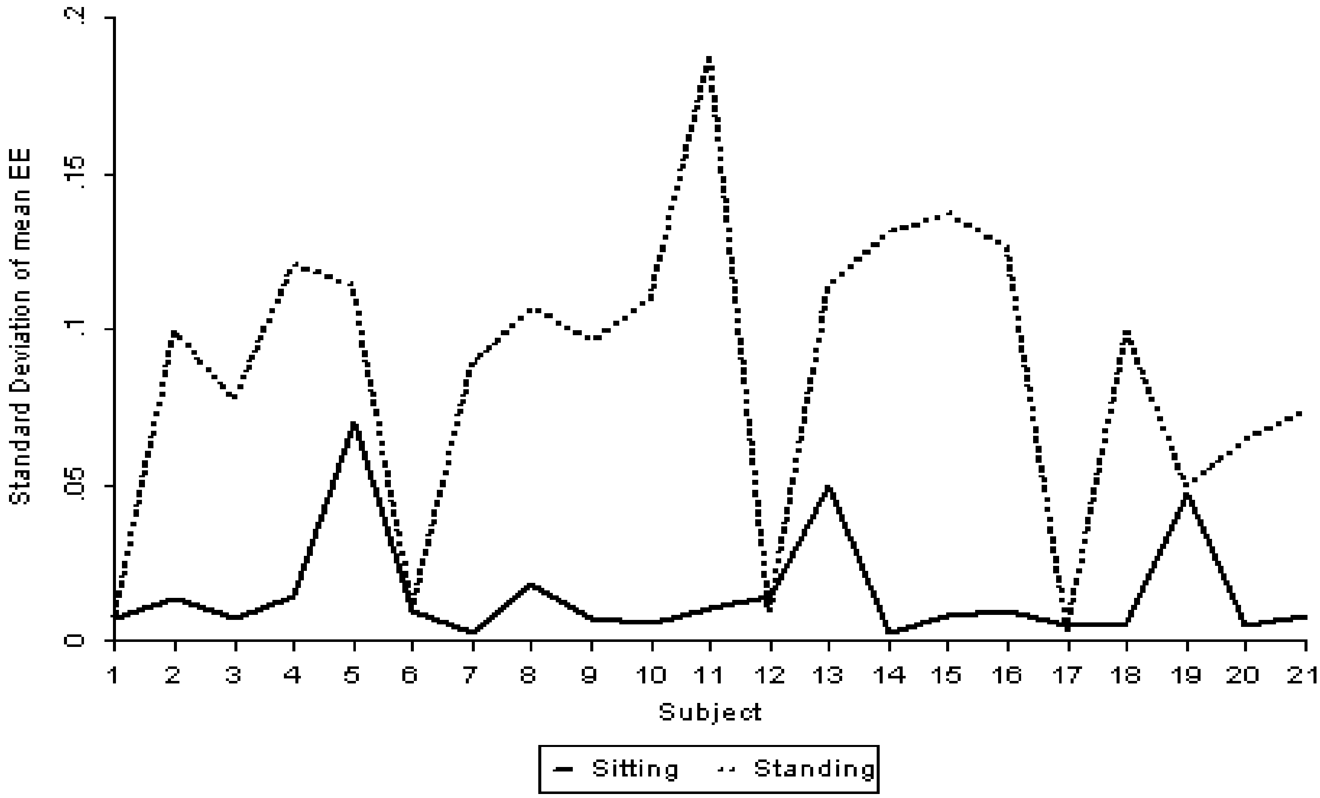

Figure 2. Within-Subject standard deviations of EE (kcal·min^{-1}) over 10 measurements.

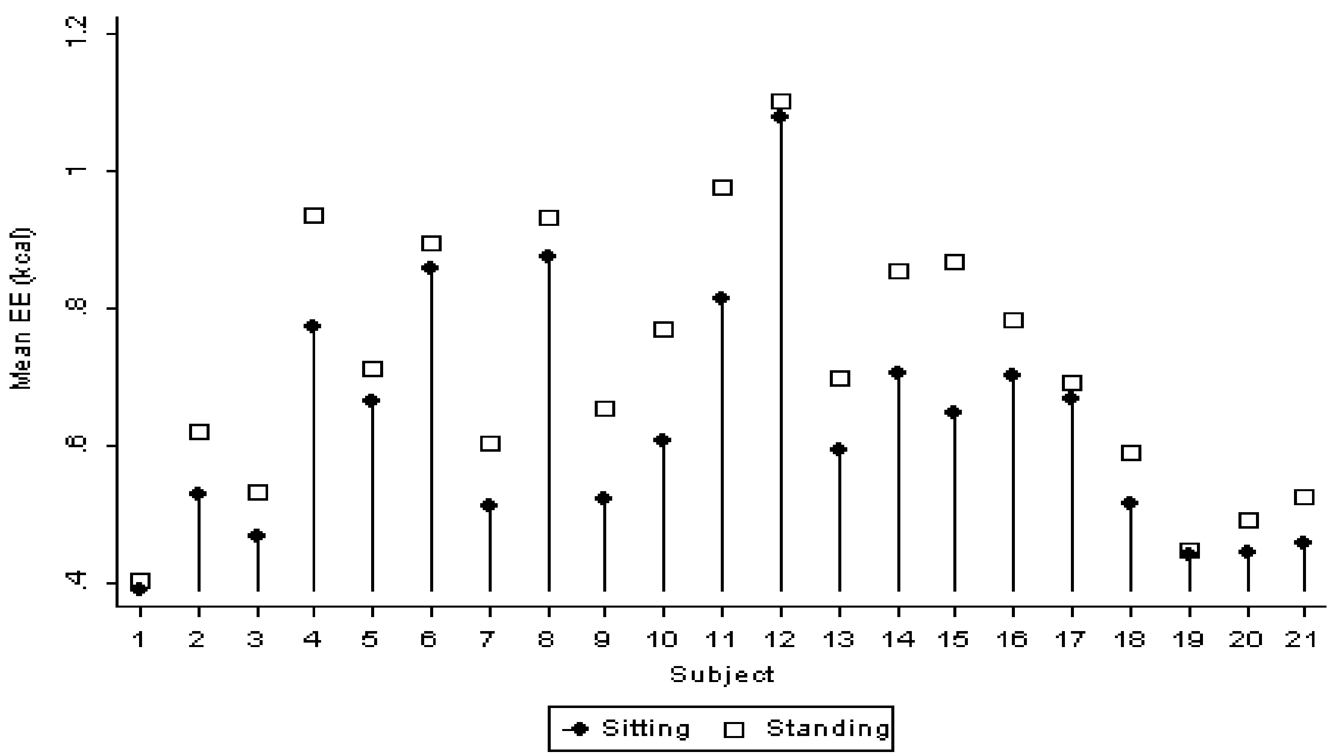

Figure 3. Mean EE over 10 measurements for each subject while standing or sitting.

The difference of EE between standing and sitting for each subject was calculated, and the standard deviation for the difference score was found to be 0.06 kcal·min^{-1}. The distribution of the data was checked using a histogram (Figure 4) and box plot. From the histogram in Figure 5, the differences of the average EE from sitting and standing do not appear normally distributed. However, since the box plot showed that there were no obvious outliers, a paired t-test was performed first, followed by a Wilcoxon signed rank test to ensure that the conclusions were correct. From the paired t-test, the mean difference is 0.08 when comparing sitting and standing. The t-value was 6.73 and the two-sided P-value was less than 0.0001. Therefore, there was found to be a statistically significant difference between EE sitting and EE standing. The Wilcoxon signed rank test also resulted in a P-value less than 0.0001, confirming the statistical significance of the difference in EE between sitting and standing. This significant difference proves that the SWA is sensitive enough to detect a within subjects difference in EE between sitting and standing in 7 to 10 yr old children under controlled conditions in a simulated school environment.

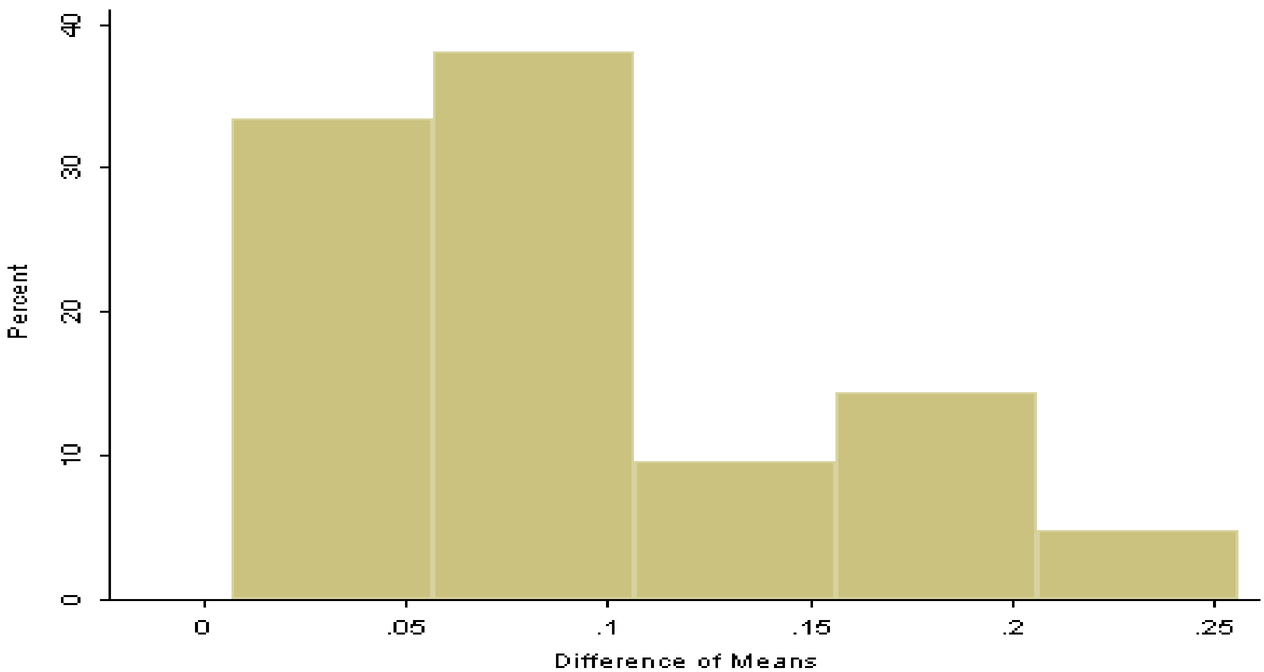

Figure 4. Histogram for differences of mean calorie expenditure (kcal·min^{-1}).

Multiple linear regression analysis was used to determine whether other covariates affected the difference in EE between sitting and standing. Covariates analyzed were: overweight or obese versus normal weight, age >7 versus age = 7 and male versus female. While the males tended to have a larger difference in EE, none of the covariates was statistically significant (P-value = 0.13 to 0.90).

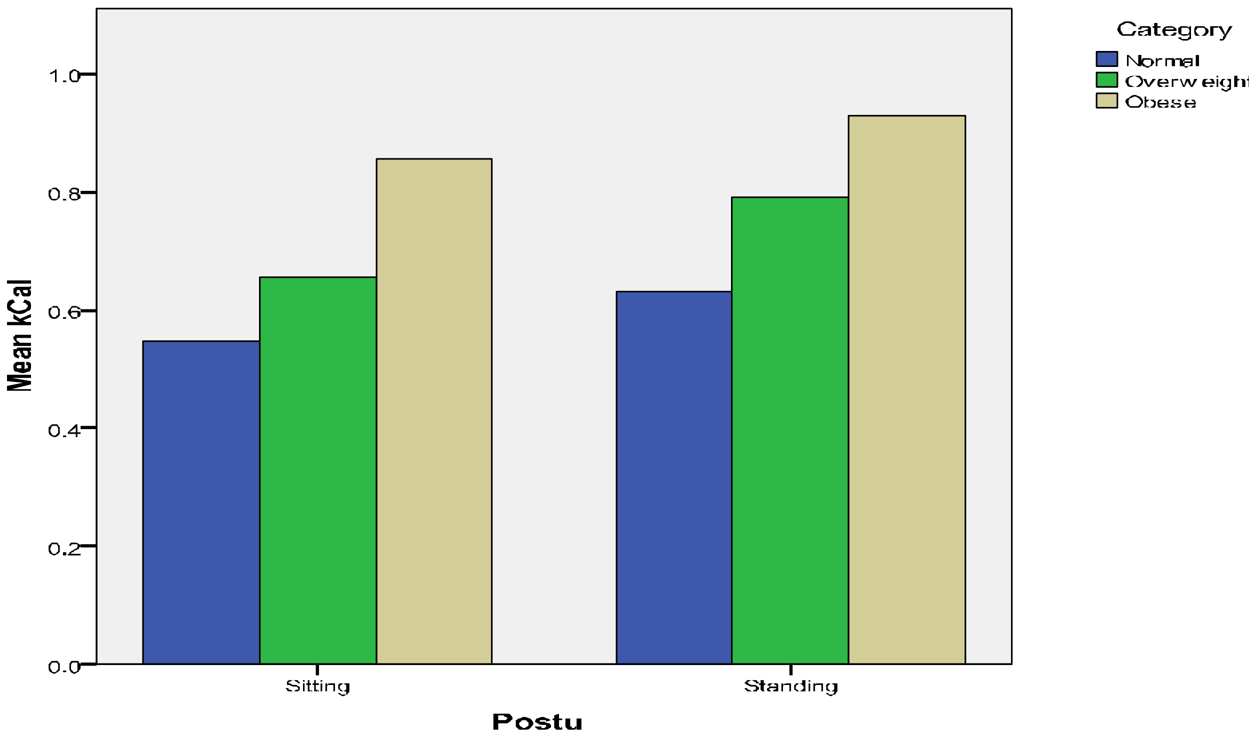

Figure 5. Comparison of Mean EE for BMI classifications and Posture.

DISCUSSION

This study compared average EE levels of sitting to standing in children 7 to 10 years of age. The study was completed in a controlled laboratory environment in order to isolate EE during sitting and standing so that comparisons could be made based on these parameters. Activities performed by the subjects while sitting and standing were controlled. However, other than being asked not to lean on the desks, the subjects were allowed to sit or stand as they naturally would. From past studies on adults (25,38), it was assumed that children would also have an increase in EE when standing compared to sitting; the assumption of the increase in EE was met in the current study. The device being assessed, the SWA, demonstrated a sensitivity level accurate enough to detect a difference in EE when comparing sitting to standing. The results from this study are in agreement with sensitivity based results of the SWA from the Calabro et al. study (7) for EE readings from resting to sitting.

With childhood obesity increasing in the United States (8,31) and childhood obesity likely leading to adult obesity (17), intervention strategies to prevent obesity are necessary for children. Preventive interventions have shown positive potential in averting childhood overweight and obesity (15). Past studies have emphasized the importance of investigating the ability of the SWA to estimate slight increases of EE over resting levels (18, 32), in order to assess EE in sedentary states where people spend much of their time. Following the need expressed in those studies and others, this study focused on the validity of using the SWA for assessments in children during low intensity activities. Since it was found that the device is sensitive enough to detect a difference in slight EE changes in children, it is a promising segue into future studies related to childhood obesity. These types of studies include an inexpensive environmental modification that could potentially contribute positively by reducing and preventing the high prevalence of childhood obesity.

Concerning EE, it is beneficial to stand because people are more likely to fidget while standing, hence increasing their EE (26). Based on our observation, the subjects involved in this study followed this expectation and many of them fidgeted more while standing. Other than being asked not to lean on the desk, the subjects were allowed to fidget as they normally would and not encouraged to do so or discouraged from doing so. The fidgeting observed in the current study included shifting weight from one foot to another, propping one foot on the footrest and changing the foot propped on the footrest.

With the proven sensitivity of this device, it could also be used in studies working to understand the benefits of NEAT. These aforementioned slight changes in the environment can increase NEAT. With such a large part of EE consisting of NEAT, these changes can help prevent obesity (23,24,26). Since the principle factor to determine the level of NEAT in adults is their occupation (23,27), it could be beneficial to create an expectation of a stand/sit environment in the workplace from a young age. It has been shown that children are accepting of such environmental changes (22). It is hoped that these changes in the classroom will lead to a more active environment being the norm as children grow into adulthood, rather than the chair-based environment that exists today.

The use of the SWA in this study has proven to be feasible for use with children. The children were very accepting of the device and willingly agreed to wear it. The device met the expectations of being non-invasive, comfortable, and unobtrusive to natural body movement. Also, data transfer from the device was simple along with the manipulation of the software and straightforward exportation of the data for quick analysis. After the use of the SWA in this study and with proof of validation from this study and previous studies on children (1,2,7) and adults (18,20,29,33,38), the SWA is recommended for use in future studies.

A limitation of this study is that more subjects are needed to assess whether covariates such as age, gender, CDC BMI category, race, nutrition, and ADD/ADHD status affect the difference of EE across subjects rather than only within individual subjects. Figure 5 shows one of those relative distributions of participants along CDC BMI categories, but due to sample size, actionable conclusions are not available. Another limitation is that participation in this study required the parents of the subjects to have a means of transportation to come to the study location and that both the child and parent must speak English. Therefore, socioeconomically advantaged children were more likely to participate than socioeconomically disadvantaged children. Lastly, this study compared a snapshot of a 10-min period of sitting and standing. The conclusions made are assuming that the data is reflective of a 6 to 8 hr school day. Therefore, the amount of time the subjects performed the study is a limitation. From pilot work in school settings, it is clear that elementary children spend less than one-third of their day at their primary workstation. By High School, students spend three-fourths of their day at a desk working or listening to lecture and, therefore, the opportunity for exposure to this intervention does increase with grade level.

CONCLUSIONS

This device proved to be sensitive enough to detect a difference between EE with sitting and standing, in 7 to 10 yr old children in a controlled environment. The average EE increased when subjects were standing compared to sitting. Other covariates such as age, gender, whether the children were used to using a standing desk, and CDC BMI category did not significantly affect the sitting and standing differences of EE. These results support the use of this device in the future with children to assess changes in EE. The ultimate question of whether slight environmental changes to school environments can make a difference in EE over the course of a full day is yet to be determined.

ACKNOWLEDGMENTS

Special thanks to the CSISD parents, teachers, and students who offered their time and insights into this research.

Address for correspondence: Benden, ME, PhD, CPE, 114 SRPH Admin Bldg. College Station Texas 77843-1266 mbenden@srph.tamhsc.edu

REFERENCES

1. 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.

2. Arvidsson D, Slinde F, Hulthen L. Free-living energy expenditure in children using multi-sensor activity monitors. ***Clin Nutr*** 2009;28(3):305-312.

3. Arvidsson D, Slinde F, Larsson S, Hulthen L. Energy cost of physical activities in children: validation of SenseWear Armband. ***Med Sci Sports Exerc*** 2007;39(11):2076-2084.

4. Arvidsson D, Slinde F, Larsson S, Hulthen L. Energy cost in children assessed by multisensor activity monitors. ***Med Sci Sports Exerc*** 2009;41(3):603-611.

5. Barlow SE. Expert committee recommendations regarding the prevention, assessment, and treatment of child and adolescent overweight and obesity: summary report. ***Pediatrics*** 2007;120 Suppl 4:S164-92.

6. Benden, M., Blake, J., “Wendel, M, Huber C., “The impact of stand-biased desks in classrooms on calorie expenditure in children” accepted for publication Nov 2010 ***AJPH.***

7. Blake, J., Benden, M., Wendel, M., "Using stand/sit workstations in classrooms: Lessons learned from a pilot study in Texas" accepted for publication, Dec 2010 in the ***Journal of Public Health Management and Practice.***

8. Calabro MA, Welk GJ, Carriquiry AL, Nusser SM, Beyler NK, Mathews CE. Validation of a computerized 24-hour physical activity recall (24PAR) instrument with pattern-recognition activity monitors. ***J Phys Act Health*** 2009;6(2):211-220.

9. Calabro MA, Welk GJ, Eisenmann JC. Validation of the SenseWear Pro Armband algorithms in children. ***Med Sci Sports Exerc*** 2009;41(9):1714-720.

10. CDC National Center for Health Statisitics, Health E-Stat. Prevalence of overweight Among children and adolescents: United States, 2003–2006. [cited 2010 Jan 23]. Available from: http://cdc.gov/nchs/data/hestat/overweight/overwght_child_03.htm.

11. CDC National Center for Health Statisitics, Health E-Stat. Prevalence of overweight, obesity and extreme obesity among adults: United States, trends 1976-80 through 2005-2006. [cited 2010 Jan 23]. Available from: http://cdc.gov/nchs/data/hestat/overweight/overweight_adult.pdf.

12. Centers for Disease Control and Prevention. Overweight and obesity. [cited 2010 Jan 23]. Available from: http://www.cdc.gov/obesity/index.html.

13. Chengalur SN, Rodgers SH, and Bernard TE. ***Ergonomic Design for People at Work.*** 2nd Edition. Hoboken, NJ: John Wiley & Sons, Inc.; 2004, 704 p.

14. Dietz WH. Health consequences of obesity in youth: childhood predictors of adult disease. ***Pediatrics*** 1998;101(3 Pt 2):518-525.

15. Dorminy CA, Choi L, Akohoue SA, Chen KY, Buchowski MS. Validity of a multisensor armband in estimating 24-h energy expenditure in children. ***Med Sci Sports Exerc*** 2008;40(4):699-706.

16. Dwyer TJ, Alison JA, McKeough ZJ, Elkins MR, Bye PT. Evaluation of the SenseWear activity monitor during exercise in cystic fibrosis and in health. ***Respir Med*** 2009;103(10):1511-147.

17. Flodmark CE, Marcus C, Britton M. Interventions to prevent obesity in children and adolescents: a systematic literature review. ***Int J Obes*** *(Lond)* 2006;30(4):579-589.

18. Freedman DS, Khan LK, Dietz WH, Srinivasan SR, Berenson GS. Relationship of childhood obesity to coronary heart disease risk factors in adulthood: the Bogalusa Heart Study. ***Pediatrics*** 2001;108(3):712-718.

19. Freedman DS, Mei Z, Srinivasan SR, Berenson GS, Dietz WH. Cardiovascular risk factors and excess adiposity among overweight children and adolescents: the Bogalusa Heart Study. ***J Pediatr*** 2007;150(1):12-7 e2.

20. Fruin ML, Rankin JW. Validity of a multi-sensor armband in estimating rest and exercise energy expenditure. ***Med Sci Sports Exerc*** 2004;36(6):1063-1069.

21. Hill JO, Wyatt HR, Reed GW, and Peters JC. Obesity and the environment: where do we go from here? ***Science*** 2003;299(5608):853-855.

22. Jakicic JM, Marcus M, Gallagher KI, Randall C, Thomas E, Goss FL, Robertson RJ. Evaluation of the SenseWear Pro Armband to assess energy expenditure during exercise. ***Med Sci Sports Exerc*** 2004;36(5):897-904.

23. King GA, Torres N, Potter C, Brooks TJ, Coleman KJ. Comparison of activity monitors to estimate energy cost of treadmill exercise. ***Med Sci Sports Exerc*** 2004;36(7):1244-1251.

24. Lanningham-Foster L, Foster RC, McCrady SK, Manohar CU, Jensen TB, Mitre NG, Hill JO, Levine JA. Changing the school environment to increase physical activity in children. ***Obesity*** *(Silver Spring)* 2008;16(8):1849-1853.

25. Levine JA. Nonexercise activity thermogenesis--liberating the life-force. ***J Intern Med*** 2007;262(3):273-287.

26. Levine JA, Eberhardt NL, Jensen MD. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. ***Science*** 1999;283(5399):212-214.

27. Levine JA, Miller JM. The energy expenditure of using a "walk-and-work" desk for office workers with obesity. ***Br J Sports Med*** 2007;41(9):558-561.

28. Levine JA, Schleusner SJ, Jensen MD. Energy expenditure of nonexercise activity. ***Am J Clin Nutr*** 2000;72(6):1451-1454.

29. Levine JA, Vander Weg MW, Hill JO, Klesges RC. Non-exercise activity thermogenesis: the crouching tiger hidden dragon of societal weight gain. ***Arterioscler Thromb Vasc Biol*** 2006;26(4):729-736.

30. Lloyd-Jones D, Adams RJ, Brown TM, et al. Heart disease and stroke statistics--2010 update: a report from the american heart association. ***Circulation*** 2010;121(7):e46-e215.

31. Malavolti M, Pietrobelli A, Dugoni M, Poli M, Romagnoli E, De Cristofaro P, Battistini NC. A new device for measuring resting energy expenditure (REE) in healthy subjects. ***Nutr Metab Cardiovasc Dis*** 2007;17(5):338-343.

32. Ogden CL, Carroll MD, Curtin LR, Lamb MM, Flegal KM. Prevalence of high body mass index in US children and adolescents, 2007-2008. ***JAMA*** 2010;303(3):242-249.

33. Ogden CL, Carroll MD, Flegal KM. High body mass index for age among US children and adolescents, 2003-2006. ***JAMA*** 2008;299(20):2401-2405.

34. Papazoglou D, Augello G, Tagliaferri M, Savia G, Marzullo P, Maltezos E, Liuzzi A. Evaluation of a multisensor armband in estimating energy expenditure in obese individuals. ***Obesity*** *(Silver Spring)*. 2006;14(12):2217-2223.

35. Patel SA, Benzo RP, Slivka WA, Sciurba FC. Activity monitoring and energy expenditure in COPD patients: a validation study. ***COPD*** 2007;4(2):107-112.

36. Serdula MK, Ivery D, Coates RJ, Freedman DS, Williamson DF, Byers T. Do obese children become obese adults? A review of the literature**.** ***Prev Med*** 1993;22(2):167-177.

37. Soric M, Misigoj-Durakovic M. Physical activity levels and estimated energy expenditure in overweight and normal-weight 11-year-old children. ***Acta Paediatr*** 2009;99(2):244-250.

38. St-Onge M, Mignault D, Allison DB, Rabasa-Lhoret R. Evaluation of a portable device to measure daily energy expenditure in free-living adults. ***Am J Clin Nutr*** 2007;85(3):742-749.

39. Teller A. A platform for wearable physiological computing. ***Interacting with Computers*** 2004;16(5):917-937.

40. Welk GJ, McClain JJ, Eisenmann JC, Wickel EE. Field validation of the MTI Actigraph and BodyMedia armband monitor using the IDEEA monitor. ***Obesity*** *(Silver Spring)*. 2007;15(4):918-928.

41. Whitaker RC, Wright JA, Pepe MS, Seidel KD, Dietz WH. Predicting obesity in young adulthood from childhood and parental obesity. ***N Engl J Med*** 1997;337(13):869-873.

Disclaimer

The opinions expressed in **JEPonline** are those of the authors and are not attributable to **JEPonline**, the editorial staff or the ASEP organization.