Journal of Exercise Physiologyonline

Volume 15 Number 2 April 2012

Official Research Journal of the American Society of Exercise Physiologists

ISSN

JEPonline

Within-Subjects Analysis of the Effects of a Stand-Biased Classroom Intervention on Energy Expenditure

Mark E. Benden[1], Monica L. Wendel[2], Christina E. Jeffrey[2], Hongwei Zhao[1], Megan L. Morales[2]

[1]School of Rural Public Health, Texas A&M Health Science Center, College Station, Texas, [2]Center for Community Health Development, School of Rural Public Health, Texas A&M Health Science Center, College Station, Texas, USA

ABSTRACT

Benden ME, Wendel ML, Jeffrey CE, Zhao H, Morales ML. Within-Subjects Analysis of the Effects of a Stand-Biased Classroom Intervention on Energy Expenditure. **JEPonline** 2012;15(2):9-19. Recent approaches to combating the childhood obesity epidemic emphasize the health consequences of prolonged physical inactivity and sedentary behaviors that occur throughout the school day. The purpose of this study was to determine if Energy Expenditure (EE) is significantly increased in children who use standing height desks throughout the school day versus using traditional school desks. Nine children between the ages of 6 and 8 completed two consecutive five-month trials at a local elementary school. For the first trial, the participants' classroom (19 total children), used traditional sit-down desks for the duration of the fall semester. Over the holiday break, the entire classroom was converted to stand-biased desks. To measure differences in EE, each participant wore a BodyBugg activity monitor (BodyMedia, Inc) during the school day for one week in the fall and one week in the spring. Along with EE, the activity monitors also observed how many steps each participant took throughout the day. Descriptive statistics and a linear mixed effect model were used to determine EE differences within subjects between sitting and standing behaviors. Mean steps from the fall and spring semesters were also compared within subjects. The analysis indicated a statistically significant difference ($P < .0001$) in EE when the children used stand-biased desks versus traditional sit-down desks.

Key Words: Standing Desk, Classroom Furniture, Physical Activity

INTRODUCTION

The prevalence rate for obesity in children residing in the United States is increasing at an alarming rate, and has more than tripled since 1970 (13,18-20). Consequently, the current generation of children is predicted to have shorter life spans than previous generations and may potentially become the most obese generation in history (2,18). According to the National Health and Nutrition Examination Surveys (NHANES), the onset of obesity is occurring in earlier stages of childhood development, with roughly 16.9% of children between the ages of 2 and 19 currently classified as obese (6,14). In addition, increased distress concerning this problem has also been seen in American citizens, with roughly 8 in 10 American voters reporting concern for child health and the increased obesity rates (6,15). Implementing new strategies to reduce the high frequency of childhood obesity are tantamount in preventing poor health consequences in future adulthood, as well as increasing children's quality of life.

Obesity, Physical Activity, and Academia

Obesity in children has been associated with psychosocial disorders, impaired school functioning, increased absenteeism, and lower test scores. Obese children are also twice as likely to be placed in special education and remedial classes (5,7,20). However, direct causality between childhood obesity and academic achievement has yet to be established (3). Diminished academic success in obese children may result from low self-esteem related to unhealthy weight and poor body image (3). Regardless of whether the effects are direct or indirect, obesity influences children's academic performance.

The education system has a profound impact on early stages of psychosocial and physical development as children spend roughly 30 to 40% of their time in school (16,17,21). Schools can potentially provide good nutrition and educational programs to children, but recent focus has shifted away from physical education to an increased emphasis on standardized performance indicators (16). Currently, much of the time children spend in school requires prolonged periods of sedentary behavior, which can result in weight gain and stress on spinal structures (17,21). Research indicates, however, that increased physical activity is related to better attainment in educational settings than inactivity (16).

Energy Expenditure and Standing Behavior

While weight gain is a normal part of child development and growth, excessive weight gain is unhealthy and may result in consequences for poor adult health. Important factors to consider in energy balance include the total daily Energy Expenditure (EE), or EE accumulated over a 24-hr period and Non-Exercise Activity Thermogenesis (NEAT).

Basal metabolic rate (BMR), physical activity thermogenesis, and thermic effect of food comprise total daily EE. The BMR, defined as the amount of energy required to carry out daily activities and bodily functions, accounts for 50% of the total daily EE. Physical activity thermogenesis accounts for 30% of total daily EE. It includes volitional exercise such as sports, intense workouts, and NEAT (10). The thermic effect of food is characterized by the amount of total daily EE, which is roughly 10% to 15% that results from the biological breakdown of food intake. These factors play a vital role in EE and related weight maintenance.

Non-Exercise Activity Thermogenesis (NEAT) is a primary variable in resistance to weight gain, and is influenced by environmental and biological factors. It accounts for 70% of the physical activity thermogenesis that results from routine activities, including behaviors such as maintaining posture, taking out the trash, shopping, and standing (2,10-12,20).

By increasing physical activity and EE, both obesity and poor school performance may be combated. Ultimately, NEAT and physical activity increase EE, which decreases the likelihood of weight gain (2). In a psychological sense, physical activity also promotes the fostering of social skills, improvement in mental and cognitive functioning, and the reduction of high-risk behaviors. These findings hold promising implications for children since early childhood interventions are likely to decrease the prevalence of adult obesity.

Wingrat and Exner (21) suggest that allowing children to stand in a classroom setting may potentially put them at less risk for weight gain and reduce the probability of attaining repetitive strain injuries, tendonitis, nerve compression syndromes and subsequent musculoskeletal disease from rigid school furniture. In addition, giving children the opportunity to stand throughout the school day can augment NEAT levels. However, research is lacking on the measurement of EE in field conditions with sitting and standing behaviors. The purpose of this study was to determine if a difference exists in EE within children when using traditional classroom sit-down desks compared to using a stand-biased desk.

METHOD

Participants

Following approval by both the Institutional Review Board (IRB) Human Subjects Protection Program at Texas A&M University and the College Station Independent School District Research Review Board (CSISD), 19 potential subjects of a first grade elementary school class received consent forms for the pilot study. Fourteen subjects and their parents consented and assented. Due to attrition and incomplete data sets, 9 subjects comprised the final sample size. Six of the subjects were male (66%) and three were female (33%), with ages ranging from 6 to 8.

Instruments

A Seca stadiometer (HM200P Portstad, Seca Corporation, Hanover MD) was used to quantify the subjects' height in centimeters. A digital scale (BF-679W Scale plus Body Fat Monitor) was used to determine the subjects' weight in kilograms. Both height and weight data were used to calibrate the Bodybugg® Armband (2004-2010 Apex Fitness entitled by BodyMedia Inc., Westlake Village, CA) activity monitors. This motion-type accelerometer worn on the child's arm measured steps, calorie expenditure, heat dissipation, galvanic skin response, and temperature. In addition to height and weight, descriptive characteristics such as age, handedness, and gender were entered into the device as well. An algorithm embedded in the device used the data to compute EE for each subject.

Bodybugg®_200809.msi software was used to import the subject descriptive characteristics, calibrate the Bodybugg® device, and export the collected data. The data were statistically analyzed with SPSS 19.0 and Microsoft Excel 2007®. The traditional classroom environment consisted of a seated desk (Scholar Crafts Products Model 2200 FBBK Series Birmingham, AL) and chair (Chair, 9000 classic series, Virco, Torrance, CA). The intervention setting involved a stand-biased desk (Standing desk with footrest, Archetype, Artco-Bell Inc., Temple, TX) and stool (Model # 0805, Archetype, Artco-Bell Inc., Temple, TX).

Procedures

This study controlled for variation among children by conducting a within-child comparison. This allowed researchers to detect changes in EE and behavioral outcomes in all nine subjects in two different controlled conditions. The first condition occurred during the fall semester of a local elementary school, in which the classroom remained equipped with traditional seated desks and chairs. Over the holiday break, the entire classroom was switched to stand-biased desks for the spring semester. This second condition allowed the subjects to stand or sit at their discretion.

Given the purpose of this study, it was hypothesized that the subjects (students) who had access to the desks that allowed for and promoted standing behaviors would increase their calorie expenditure compared to when confined to a seated desk (1). According to Benden and colleagues, children using standing desks exhibit significant (17%) increases in EE in a pilot study, with the standing group burning roughly 18% more kcal·min^{-1} than a sitting group (1). In addition to measuring EE, behavioral observations determined that the altered environment did not cause distress or impairment in daily functioning of the children.

The subjects' demographic and historical data (height, weight, age, gender, birthdates and race) were collected once in the fall and spring semesters. Height, weight, and body measurements were collected on the stadiometer and a digital scale during the school day. All subjects were individually measured in the hallway outside of their classroom. Descriptive data were entered in a Microsoft Excel 2007® spreadsheet. Body Mass Index (BMI), a screening tool for obesity, was also calculated using height and weight.

Following the descriptive data collection, child activity and EE were measured by the Bodybugg® armband for five consecutive school days between the hours of 8:00 a.m. to 2:30 p.m. in the original classroom setting. The data gathered from the Seca stadiometer and digital scale were synchronized with each Bodybugg® prior to use, so that each child received a Bodybugg® device uploaded with his or her personal data. The Bodybugg® was placed on the back of the subject's left arm with the sensors touching the skin in accordance with the manufacturer's requirements for an accurate measurement. Monitors were placed on each subject at the beginning of each of the five days by the classroom teacher, who was provided with instructions regarding placement of the activity monitor and how to adjust the tightness of the armband. Following placement of the Bodybugg®, the subjects engaged in typical classroom activities. None of the subjects was asked to change their normal behaviors.

Although the subjects wore the activity monitors throughout the school day, data from 8:30 a.m. to 10:30 a.m. were specifically selected for statistical analysis. Beginning the analysis at 8:30 a.m. allowed for an equal start time for all subjects, and ensured that each child had taken a place at their primary workstation and was engaged in similar work tasks by this time. After 10:30 a.m., data were confounded due to variable course periods that dramatically increased activity levels, such as PE, lunch, and recess and were away from the homeroom where the treatment took place. Hence, the design of the study controlled for these potential confounding variables by selecting the 2-hr interval to analyze.

Statistical Analysis

The primary analysis for examining the effect of the stand-biased desk on EE was carried out using a linear mixed effect model (8). The advantage of such a model is that it enabled the researchers to examine not only the effect of the main covariate, but also the day-to-day variations of the EE. In addition, it allowed for using all the subjects in the analysis, including the subjects who did not have complete data. Since there is no reason to suspect that the missing data were related to the outcome measures for this study, the assumption that the missing data was random (which is required for the linear mixed effect model) was acceptable. The dependent variable (average EE) was measured each day for each subject in the study. The fixed covariates include period (Fall Semester *vs.* Spring

Semester), gender, age, and day. The random effect consists of a random intercept for each child. We used the SAS procedure Proc Mixed, version 9.2, to perform the analysis. Empirical variance estimators were used to make the results more robust to misspecifications of the correlation structure. Descriptive statistics were also calculated to observe mean and standard deviation differences in the 9 subjects who completed both the fall and spring periods of the study, as well as the mean differences in the mean number of steps taken in both measurement periods.

RESULTS

Descriptive statistics within the subjects who participated in the study are displayed in Table 1. Differences in height, weight, Body Mass Index (BMI), and BMI percentile are recorded, with changes seen in the overall mean weight and BMI percentile. The mean BMI also exhibited a subtle change from 19.5 $kg \cdot m^{-2}$ to 19.8 $kg \cdot m^{-2}$.

Table 1. Descriptive Data of the Subjects Who Participated in the Fall and Spring Semesters.

Conditions	Fall Semester	Spring Semester	Mean ?
Height (cm)	120 ± 10	120 ± 10	0.0
Weight (kg)	27.0 ± 7.9	29.5 ± 8.9	2.5
BMI ($kg \cdot m^{-2}$)	19.5 ± 4.3	19.8 ± 4.3	0.3
BMI Percentile (%)	79.6 ± 20.5	81.6 ± 18.8	2.0

Values are means ± SD

A box plot displaying the level of energy expenditure between Fall Semester and the Spring Semester in the subject sample is displayed in Figure 1. The figure depicts an increase in EE from the Fall Semester to the Spring Semester. Overall, energy expenditure in the fall ranged from 0.79 $kcal \cdot min^{-1}$ to 1.655 $kcal \cdot min^{-1}$, while EE in the spring ranged from 1.06 $kcal \cdot min^{-1}$ to 1.91 $kcal \cdot min^{-1}$.

On average, the difference in EE using the traditional desk and using the stand-biased desk ranged from 0.07 $kcal \cdot min^{-1}$ to 0.47 $kcal \cdot min^{-1}$. The mean difference of means was 0.29 $kcal \cdot min^{-1}$, with the standard deviation of the difference of the means measured at 0.12 $kcal \cdot min^{-1}$. Ultimately, this study found a 25.7% increase in average EE within-subjects using a stand-biased desk compared to the traditional desk. In addition, there was a 17.6% increase in steps within subjects with the use of stand-biased desks. Overall, the mean number of steps from the Fall trial to the Spring trial increased by roughly 836 steps. Figure 2 illustrates the mean steps difference in subjects who completed both study trials, and Figure 3 shows the mean EE difference over the two sample periods within the subjects as well.

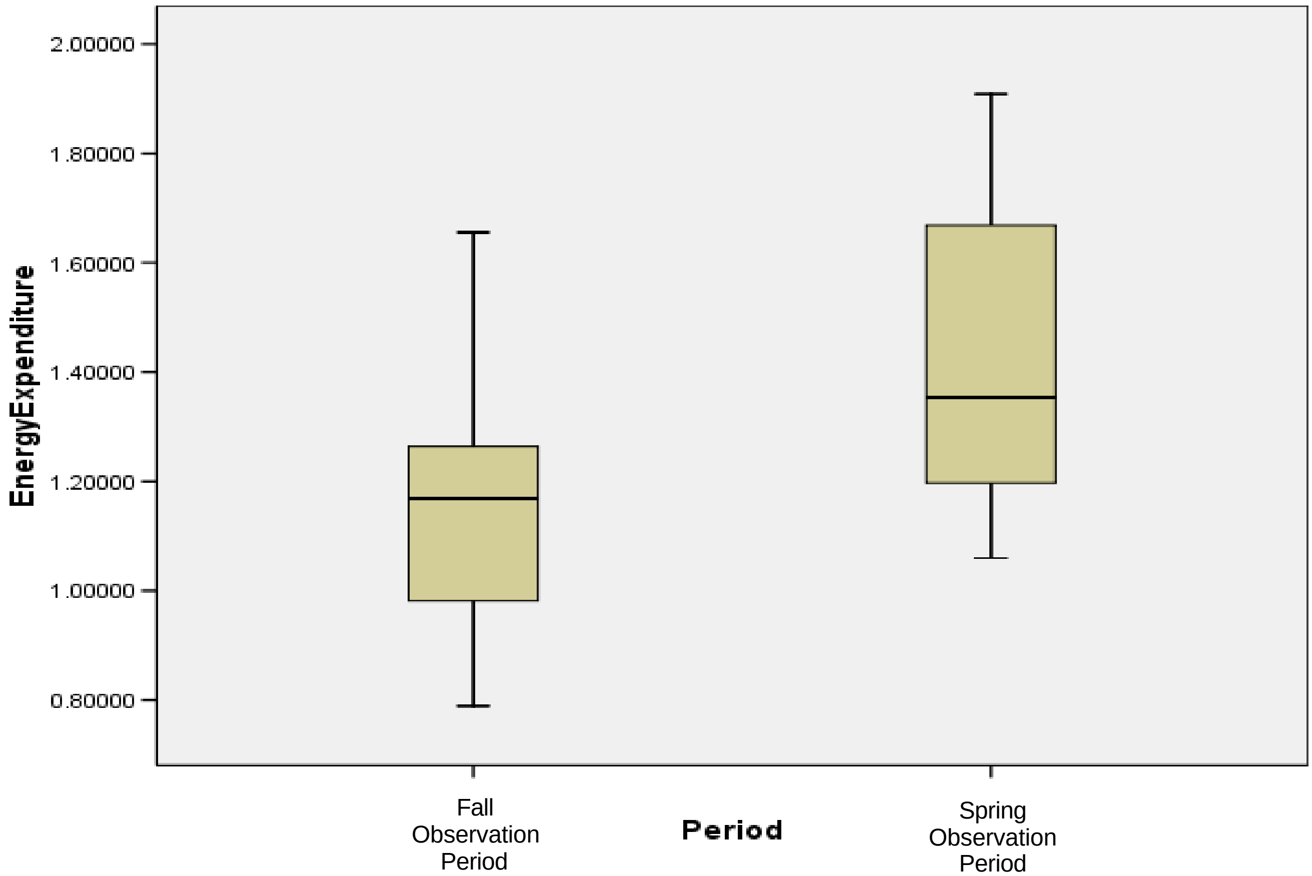

Figure 1. Box Plot of Energy Expenditure in Fall and Spring Observation Periods.

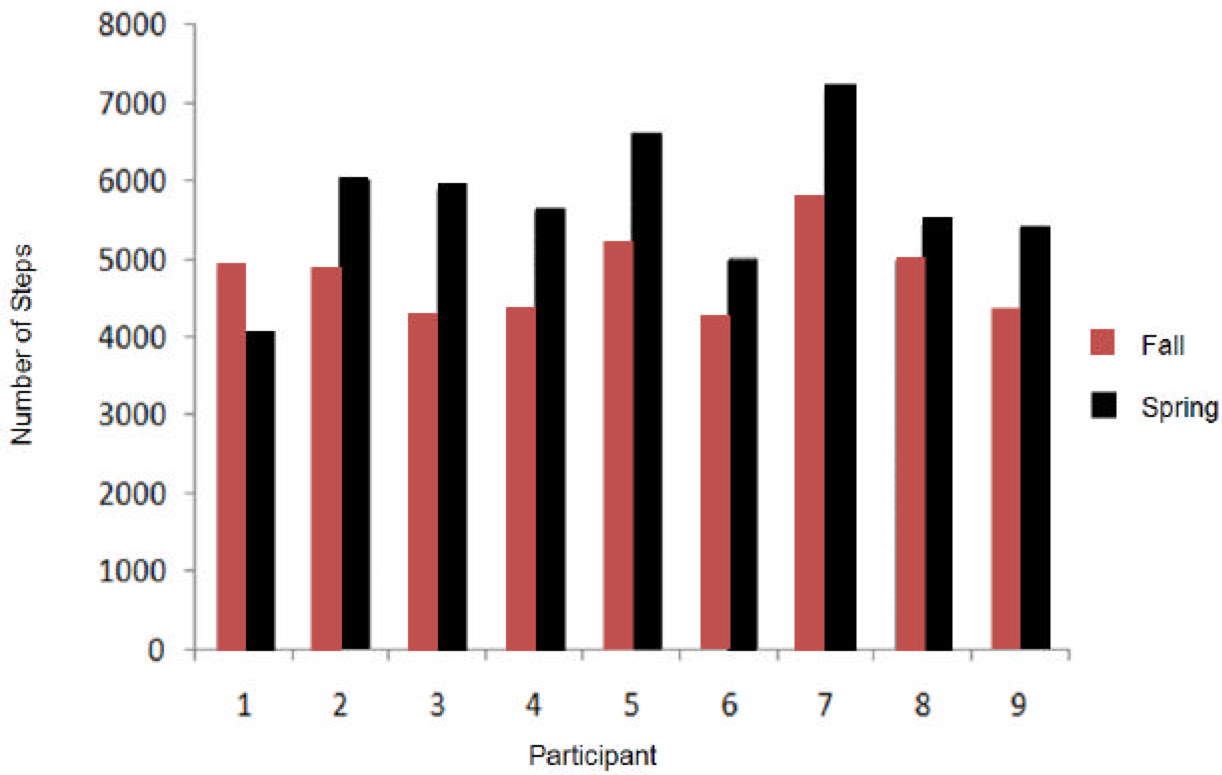

Figure 2. Mean Steps Within-Subjects in the Fall and Spring Observation Periods

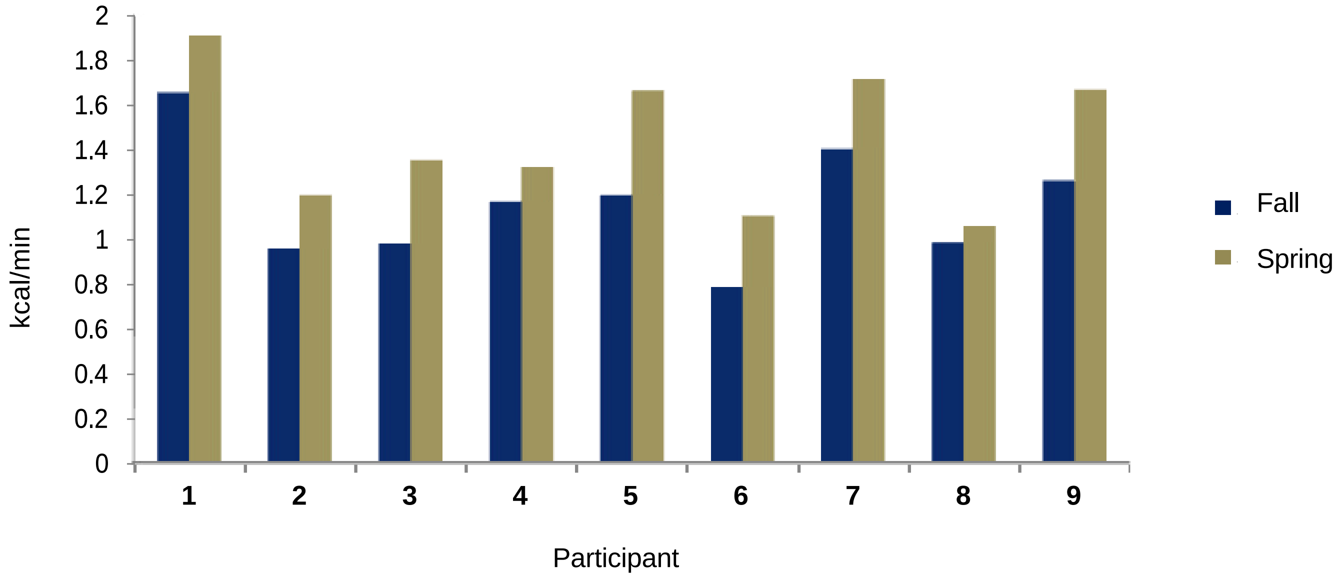

Figure 3. Mean EE Within-Subjects in the Fall and Spring Observation Periods.

The results from fitting a linear mixed effect model to the data are summarized in Table 2. After adjusting for other covariates, the use of a standing desk has a significant effect of increasing the mean EE by 0.29 kcal·min^{-1} ($P < 0.0001$). The mean EE also shows a significant day-to-day variation with a lower EE on days 3 and 4. There was no significant effect for gender and age on EE. Since the sample size is small, it was difficult to detect any significant between-subject effects.

Table 2. Results from Fitting a Linear Mixed Effect Model to the Data.

Parameter	Estimate	Standard Error	P value
Intercept	1.7609	0.7091	0.0379*
Day 5	-0.1727	0.0511	0.0011*
Day 4	-0.2968	0.0446	<.0001*
Day 3	-0.2048	0.0297	<.0001*
Day 2	-0.0976	0.0316	0.0027*
Gender	-0.1380	0.1279	0.2838
Age	-0.0627	0.0950	0.5113
Period	0.2923	0.0400	<.0001*

*Significant within-subjects effect (P<0.05).

DISCUSSION

This study compared the mean EE levels in school children using a traditional desk versus a stand-biased desk with the purpose of determining if energy expenditure (EE) is increased with standing behaviors resulting from the use of stand-biased desks. The use of stand-biased desks allowed the subjects to voluntarily change their posture and readily transition from standing to sitting throughout the school day, which resulted in an increase in mean EE within-subjects (Figure 1). This finding shows that children who were measured using the stand-biased desks in a classroom setting had higher rates of EE on average than when sitting in the same classroom setting.

This finding also highlights the fact that the intervention group burned more $kcal \cdot min^{-1}$ than the control group. Within-subjects mean number of steps, displayed in Figure 2, increased in 8 of the 9 subjects completing both trials. This indicates that the majority (89%) of the subjects (children) exhibited an increased physical activity at their workstations when placed at stand-biased desks. The individual average EE within-subjects (shown in Figure 3) also increased within all 9 children from the Fall Semester to the Spring Semester. This increase in individual EE supports the group mean increase in EE displayed in Figure 1. The descriptive data shows promising implications for future replication studies. Overall, gender and age were not significant factors in the changes in EE within-subjects.

This study followed a strict protocol in applying the intervention (stand-biased desks) as practically as possible. The subjects in this study were not *required* to stand or sit at any scheduled time, but were instead given the opportunity to change positions at their discretion. The subjects' freedom maintained the integrity of the study, which promoted an unbiased intervention necessary for future comparisons to other school environments.

A change in body weight was found in the subjects over the course of the study, which was generally attributed to the subjects' natural growth cycles. Increased energy expenditure is expected as children grow and as physical activity increases. Due to the design of the study, it is not logical that an effort would have been made to control the subjects' growth. However, using a mathematical algorithm in the BodyBugg device, the elevated EE was approximated through the calculation of each subject's body measurements and age at the time of the Fall and Spring data collections. In addition, the step data are not affected by growth changes and represent unbiased physical activity increase.

Several limitations may have included the following. While the focus on one elementary school facilitated the gathering of data and result analysis, it may have been beneficial to target multiple elementary schools. In addition, the study was limited in location. Conducting the study in an urban, metropolitan setting rather than in a rural town would likely have allowed for greater access to more subjects and classroom settings. A larger sample size would no doubt allow for increased data and further interpretation.

Several additional potential confounders of this study include short time measurement and the limited amount of time that the students spent at their workstation. By examining only a 2-hr period at a child's workstation, the subjects' EE levels during the afterschool activities were not measured. Also, since children of this grade level do not spend as much time at their desk as a middle or high school student, future studies should collect 24-hr data at various grade levels. It stands to reason that, if a measurable difference is detected in children who spend only 2 hrs at their desks, the effects would be magnified in older students who spend up to 6-hrs each day at their desks.

Despite these limitations, positive behavioral factors were found in relation to the stand-biased desks in addition to the beneficial increase in EE and number of steps. Specifically, the teacher involved with the intervention reported that when the children used stand-biased desks, they exhibited more focus in their school activities and they demonstrated an increase in positive in-class behavior. The intervention teacher said: "I notice myself scolding the children less and that we are both able to focus more on academic material. I am in deep favor of using the stand-biased desks and want to keep them. I cannot see myself ever using traditional desks again."

Research has shown that parental involvement and increased adult supervision lead to a higher child response rate to the intervention than less supervised children (9). This highlights increased parental interaction with future studies in order to promote increased standing behavior in children (9). This study should be conducted over a 13-yr period, ranging from kindergarten to the twelfth grade. Since obesity tracks strongly from childhood to adulthood, it is imperative to understand how physical activity and sedentary behavior may influence the risk of obesity and health outcomes among children (4). More research on this topic should be carried out in hopes of decreasing the prevalence of obesity and sedentary related diseases.

CONCLUSIONS

The stand-biased workstation intervention showed an increase in physical activity and EE for the child participants. Hence, the results suggest that the stand-biased desks have the potential to decrease sedentary behaviors and, as a result, may possibly help in decreasing the risk for childhood obesity. This study provides valuable information for schools considering adoption of this intervention, as it offers evidence that providing a child with an option to stand during class time can be an effective method to increase physical activity during the school day.

ACKNOWLEDGMENTS

The authors wish to thank and acknowledge the funders that made this study possible: the United Way of the Brazos Valley, the Texas A&M School of Rural Public Health, and Artco-Bell. This study was also made possible, in part, by the Prevention Research Centers Program at the Centers for Disease Control and Prevention through cooperative agreement U48DP000045.

Note. The conclusions of this article are those of the authors and do not represent the official position of the Centers for Disease Control and Prevention.

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

REFERENCES

1. Benden ME, Blake JJ, Wendel ML, Huber JC. The impact of stand-biased classrooms on calorie expenditure in children. ***Am J Public Health***. 2011;101(8):1433-1436.

2. Caprio S. Treating child obesity and associated medical conditions. ***Future Child***. 2006;16(1):209-224.

3. Childhood obesity and academic outcomes: A brief review of research. ***James B. Hunt Jr. Institute for Educational Leadership and Policy***. Durham, NC: Author, 2008.

4. Cleland V, Venn A. Encouraging physical activity and discouraging sedentary behavior in children and adolescents. ***J Adolesc Health***. 2010;47(3):221-222.

5. Daniels SR. The consequences of childhood overweight and obesity. ***Future Child***. 2006;16(1):47-67.

6. Hassink SG, Hill KS, Biddinger S. Introduction: Pediatric obesity and the role of children's hospitals. ***Pediatrics***. 2011;128:45-46.

7. Hill JO, Peters JC. Environmental contributions to the obesity epidemic. ***Science***. 1998;280(5368):1371-1374.

8. Laird NM, Ware JH. Random effects models for longitudinal data. ***Biometrics***.1982;38:963-974.

9. Leung MM, Agaronov A, Grytsenko K, Yeh M. Intervening to reduce sedentary behaviors and childhood obesity among school-age youth: A systematic review of randomized trials. ***J Obes***. 2012;2012:1-14.

10. Levine JA. Role of nonexercise activity thermogenesis in resistance to fat gain in humans. ***Science***. 1999;283(5399):212-214

11. Levine JA. Non-exercise activity thermogenesis (NEAT). ***Nutr Rev***. 2004;62:82-97.

12. Levine JA, Kotz CM. NEAT – non-exercise activity thermogenesis – egocentric & geocentric environmental factors vs. biological regulation. ***Acta Physiol Scand***. 2005;184(4):309-318.

13. McKenzie TL, Kahan D. Physical activity, public health, and elementary schools. ***Elem School J***. 2008;108(3):171-180.

14. Ogden C, Carroll M. Prevalence of obesity among children and adolescents: United States, trends 1963-1965 through 2007-2008. ***NCHS Health E-Stat***. 2010.

15. Quinlan A, Lieberman D, Ferguson G. American voters support investment in preventing childhood obesity. **Greenberg Quinlan Rosner Research and American Viewpoint**. 2010.

16. Reid, EM. Genes load the gun, the environment pulls the trigger: Obesity among children and adolescents in U.S. schools. ***The Free Library****.* 2008.

17. Saarni L, Nygård CH, Kaukiainen A, Rimpelä A. Are the desks and chairs at school appropriate? ***Ergonomics.*** 2007;50(10):1561–1570.

18. Schwartz MB, Brownell KD. Actions necessary to prevent childhood obesity: creating the climate for change. ***J Law Med Ethics***. 2007;35(1):78-89.

19. Singh GK, Kogan MD, Van Dyck PC. Changes in state-specific childhood obesity and overweight prevalence in the United States from 2003 to 2007. ***Arch Pediatr Adolesc Med***. 2010;164(7):598-607.

20. Story M. The role of child care settings in obesity prevention. ***Future Child***. 2006;16(1):143-168.

21. Wingrat JK, Exner CE. The impact of school furniture on fourth grade children's on-task and sitting behavior in the classroom: A pilot study. ***Work***. 2005;25(3):263-272.

Disclaimer

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