Stand-Biased Versus Seated Classrooms and Childhood Obesity: A Randomized Experiment in Texas

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Objectives. To measure changes in body mass index (BMI) percentiles among third- and fourth-grade students in stand-biased classrooms and traditional seated classrooms in 3 Texas elementary schools.

Methods. Research staff recorded the height and weight of 380 students in 24 classrooms across the 3 schools at the beginning (2011–2012) and end (2012–2013) of the 2-year study.

Results. After adjustment for grade, race/ethnicity, and gender, there was a statistically significant decrease in BMI percentile in the group that used stand-biased desks for 2 consecutive years relative to the group that used standard desks during both years. Mean BMI increased by 0.1 and 0.4 kilograms per meter squared in the treatment and control groups, respectively. The between-group difference in BMI percentile change was 5.24 (SE = 2.50; *P* = .037). No other covariates had a statistically significant impact on BMI percentile changes.

Conclusions. Changing a classroom to a stand-biased environment had a significant effect on students' BMI percentile, indicating the need to redesign traditional classroom environments. (*Am J Public Health.* 2016;106:1849–1854. doi:10.2105/AJPH.2016.303323)

See also Galea and Vaughan, p. 1730.

Despite considerable attention, resource investment, and effort, obesity—in particular childhood obesity—remains one of the prominent public health issues in the United States. Although overall obesity rates seem to have stabilized, the prevalence of childhood obesity is still alarmingly high. In their longitudinal analysis of national data, Ogden et al. found that 16.9% of children aged 2 to 19 years were obese in 2012, and another 14.9% were overweight.[1] Obese children are at significantly increased risk for chronic diseases, including diabetes, cardiovascular disease, hypertension, osteoarthritis, stroke, and several types of cancer.[2,3] In addition, children who are overweight or obese are more likely to have low self-esteem, perform worse in school, and be victims of bullying.[4–6] Obese children are more likely than their normal-weight peers to become obese adults, and the long-term implications include increased risk of disease, disability, and early death.[7,8]

At the most basic level, childhood obesity is caused by energy imbalance, or the consumption of more calories than are used by the body over an extended period of time.[9] However, myriad social and environmental factors contribute to childhood obesity, such as poverty, neighborhood safety, and low cost of nutritionally poor foods.[10,11] These factors complicate the development and implementation of effective population-level strategies to combat childhood obesity.

Given that the vast majority of children spend between 7 and 9 hours of their 14 to 16 hours of awake time at school each day, many public health initiatives, such as the National Football League's "Play 60" and Michelle Obama's "Let's Move!" campaign, have focused on schools as a key setting for obesity-related interventions.[12] Many school-based initiatives have primarily aimed to reduce caloric intake through comprehensive school-based nutrition services out of concern that initiatives aimed at increasing physical activity in schools take away from time for academic instruction.[13,14] A greater focus on standardized test scores has created pressure on teachers and administrators and contributed to decreased requirements for students to participate in physical activity during the school day.[14,15] This situation has also led to significant amounts of prolonged sedentary behaviors among students, and these behaviors are associated with a significant risk of chronic disease and measurable metabolic changes.[16,17]

A variety of interventions designed to reduce sitting or sedentary behavior, increase physical activity, or increase passive caloric expenditures have been tested, primarily among office workers. One systematic review showed that standing, stand-biased, and adjustable work stations decreased sitting time and increased caloric expenditures, as well as improving posture and decreasing pain.[18] In addition, the use of stand-biased desks in office settings has been shown to mitigate the biological effects of sitting.[19] Although results among adults are promising, relatively little

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research has been conducted in classroom settings to explore whether stand-biased desks yield similar effects among children. The studies published in the peer-reviewed literature thus far have been limited to pilot investigations.[20–24]

In view of the aforementioned concerns with respect to in-school activity-promoting initiatives, school-based physical activity interventions, if they are to be practical and scalable, must be simple and affordable and must require minimal instructional or staff time. Hence, in this study, we tested the effectiveness of activity-permissive learning environments as a means of meeting academic as well as health goals. The intervention assessed involved changing classroom environments from traditional seated desks to stand-biased desks, which are set at a height at which children can work at their desk while standing but are also outfitted with a stool so that they can sit if they so choose. Changing classroom environments is relatively simple, the equipment is comparable in cost to that of traditional classroom desks, and the intervention requires no instructional time.

Several earlier investigations established evidence foundational for the current study. In 2009, we conducted a laboratory study confirming that the Sensewear Armband was a sufficiently sensitive device to measure caloric expenditures among elementary school children.[25] In the 2009–2010 academic year, we launched a small pilot study to examine whether use of stand-biased desks in first-grade classrooms increased caloric expenditures. That study's findings not only indicated that caloric expenditures indeed increased in the treatment classrooms but also provided anecdotal evidence that standing improved students' behavioral classroom engagement.[22,26,27]

In 2011, our research team began exploring ideal stand-biased desk designs for classrooms. Partnering with Stand2Learn (a small, ergonomically focused school furniture design company) and supported by a small business innovation research grant from the Centers for Disease Control and Prevention, the team developed desks and tested them to ensure that they were affordable and ergonomically correct, with a small footprint and adequate storage. The purpose of the 2-year study described here was to determine the impact on students' body mass index (BMI) of altering elementary school classroom environments from traditional to stand-biased environments.

METHODS

We approached 24 teachers in 3 Texas schools (8 in each school), informed them of the study's purpose and protocol, and offered them a financial incentive for their participation. All 24 teachers consented to take part in the study, and 4 in each school were randomly assigned to treatment conditions and 4 to control conditions. In August 2011, research staff members attended the parent orientation events held at each of the schools and presented study information to parents.

A total of 480 students were eligible for participation in our 2-year study (which encompassed the 2011–2012 and 2012–2013 school years), and parental consent and child assent were obtained for 380 of them. Two of the sample classrooms used exercise balls as chairs instead of the traditional layout and thus failed to meet the study's inclusion criteria; as a result, 37 students were removed from the initial sample. At the start of the first semester of the study, 6 students dropped out of the study owing to behavioral issues or switching to a different school. Therefore, the final sample at the beginning of the study consisted of 337 students. Parental consent (or child assent) was not obtained for any new children after this time frame.

Because our research was conducted in a school environment, many factors were outside of our control. School administrators and teachers were incredibly helpful and gracious, but they were unable to accommodate all research requests. For example, in the transition from year 1 to year 2 of the study, students were assigned to different classrooms (as is the case at almost all public elementary schools); also, the stand-biased desks had to stay with the original teachers, who typically remained in the same grade. As a result, the student cohorts were not wholly maintained in the transition from year 1 to year 2; that is, some students who were in a control condition in year 1 were assigned to a treatment classroom in year 2, and vice versa. Thus, 4 distinct groups emerged from the final sample: those who remained in treatment conditions for both years of the study (the T-T group), those who remained in a control condition for both years of the study (the C-C group), those who switched from a control to a treatment condition (the C-T group), and those who switched from a treatment to a control condition (the T-C group).

One grade at one of the schools was also excluded from data collection in the second year of the study as a result of students switching to classrooms that were not participating in the study. Thus, the final sample size for our analyses was 193. (Data on overall attrition across the study period are shown in Figure A, available as a supplement to the online version of this article at http://www.ajph.org.)

Intervention

In each of the participating schools, the control classrooms were left unchanged, outfitted identically to the rest of the classrooms in the school, with traditional seated desks (FBBK Series Model 2200, Scholar Craft Products, Birmingham, AL) and accompanying chairs (9000 Classic Series, Virco Inc., Torrance, CA). The treatment classrooms were outfitted completely with Stand2learn LLC (College Station, TX) stand-biased desks and stools (models S2LK04 and S2LS04, respectively). It is important to note that all desks in the treatment classrooms were changed to stand-biased desks, regardless of parental or student consent to participate in the study; consent was relevant solely to data collection.

Data Collection

After completion of the consent process, researchers organized trips to each classroom early in the first semester of the academic year to record students' height, weight, gender, birth date, and age. These data were used to calculate each student's BMI, BMI percentile, and BMI category, according to the Centers for Disease Control and Prevention guidelines (https://nccd.cdc.gov/dnpabmi/calculator.aspx). This process was repeated at the conclusion of the 2-year study, late in the spring semester. Teachers received $50 per semester after data collection as an incentive for their participation. (We also used Sensewear Armbands to collect data on caloric expenditures; these findings are being analyzed and will be reported separately.)

Statistical Analyses

At the beginning of the study, treatment group randomization (traditional desks vs stand-biased desks) was performed at the classroom level in each of the 3 schools. However, the classroom formation could not be maintained in the second study year because students had different classroom assignments as they transitioned to the next grade level. Thus, although desirable, a multilevel analysis with classrooms as the units of analysis was not possible. Another study feature is that weight and height measurements were made at the beginning of the study, before stand-biased desks were in use, and later toward the end of the study, after these desks had been in use for about 2 academic years. As a result, the most appropriate strategy involved data analysis of changes in BMI percentiles in the 4 treatment groups (T-T, T-C, C-T, and C-C) described earlier.

Initially, box plots were used to identify obvious outliers. Next, we examined descriptive statistics with respect to the characteristics of students in each treatment group. We conducted χ^2 comparison tests (for categorical variables) to ensure that the 4 treatment groups were similar in terms of baseline characteristics. For each treatment group, raw BMI measures, BMI percentiles, and BMI categories (normal or underweight, overweight, obese) were used to summarize BMI measurements taken at the beginning and end of the study and BMI changes over the study period. Because the percentage of students with changes in BMI categories over the 2-year study period was quite small, we decided to use BMI percentile (which involves more information than BMI category and takes into consideration natural increases in BMI among growing children) as the primary outcome variable.

The main focus of our analysis was the impact of stand-biased desks on BMI percentile changes over the 2-year period. We first calculated students' BMI percentile change scores. We then fit an ordinary linear regression model to the data with BMI percentile change score as the dependent variable and treatment, grade, gender, and race/ethnicity as the covariates. The C-C group served as the reference group in comparisons of each of the other 3 treatment types. We also considered interactions between covariates (grade, gender, and race/ethnicity) and treatment types. The statistical significance level was set at .05. In addition, because students from 3 different schools were enrolled in the study, we fit a multilevel linear mixed-effect model to the data with the same covariates just mentioned as fixed effects and school as a random effect. A likelihood ratio test (assessing whether the variance of the random effect was equal to zero) was conducted to examine the necessity of including school as a random effect.

RESULTS

In general, the sample was almost equally made up of male and female students, with a mean age of 8.8 years. The majority of participating students were White (75%); approximately 8% were Hispanic, 7% were African American, and roughly 10% were of Asian or Native American descent. According to the weight percentiles for children set forth by the Centers for Disease Control and Prevention, approximately 79% of the students were in the normal-weight category, 12% were overweight, and 9% were obese at the start of the study.[28] Table 1 shows descriptive statistics for participants in each treatment group.

As a result of the aforementioned attrition and participant exclusion, treatment and control group sample sizes were disproportionate across schools and grades. Despite these discrepancies, there were no significant differences in baseline characteristics such as race/ethnicity, gender, and BMI category (Table 1). Table 2 shows BMI and BMI percentile means and standard deviations for all of the treatment groups during each study year, as well as changes during the 2 years of the study in BMI, BMI percentile, and BMI category. The largest decrease in BMI percentile across both years occurred in the T-T group; there was also an increase in BMI percentile in the C-C group.

To evaluate the effects of stand-biased desks on students' body weight, we fit a linear regression model with BMI percentile changes over the 2 study years as the outcome variable and grade, race/ethnicity, gender, and their treatment group interactions as the covariates. None of the interaction terms were statistically significant, and these terms were consequently removed from the final model. The results are summarized in Table 3.

After adjustment for grade, race/ethnicity, and gender, there was a statistically significant decrease in BMI percentile in the group that used stand-biased desks for 2 consecutive years relative to the group that used standard desks during both years. The estimated difference in BMI percentile change between these groups was 5.24 (SD = 2.50, $P = .037$). There were no significant differences between the group that used stand-biased desks for 2 consecutive years and the 2 other groups that used stand-biased desks for only 1 year of the study (P values not shown). No other covariates had a significant impact on changes in BMI percentiles.

We also fit a multilevel linear mixed-effect model to the data with treatment group, grade, race/ethnicity, and gender as fixed effects and school as a random effect. The treatment effect for the T-T group relative to the C-C group was reduced, with an estimated difference of 3.89 ($P = .075$). The effects for the other 2 treatment groups (T-C and C-T) were similar to the effects obtained with the linear regression model. The likelihood ratio test assessing the variance of the random effect produced a nonsignificant result, indicating that it was not necessary to include school as a random effect.

DISCUSSION

The results of this study indicate that simply changing a classroom to a stand-biased environment had a significant effect on students' BMI percentile. The greatest impact occurred among students who were in treatment classrooms (T-T) in both study years. However, the other 2 groups that had stand-biased desks for least 1 year (T-C and C-T) experienced smaller (nonsignificant) BMI percentile changes than the group that was in a control classroom (C-C) during both years. In addition, there were no statistically significant interactions according to gender or race/ethnicity, suggesting that this 2-year intervention benefitted our elementary school study population equivalently across demographic groups. Consistent with our pilot

TABLE 1—Baseline Characteristics of Participating Students: 3 Texas Schools, 2011–2013

Characteristic	T-T Group (n = 62), %	T-C Group (n = 59), %	C-T Group (n = 23), %	C-C Group (n = 49), %	Total (n = 193), %	P[a]
School						< .001
School 1 (n = 35)	33.9	23.7	0.0	0.0	18.1	
School 2 (n = 107)	35.5	57.6	47.8	81.6	55.4	
School 3 (n = 51)	30.7	18.6	52.2	18.4	26.4	
Gender						.88
Female (n = 97)	46.8	50.9	56.5	51.0	50.3	
Male (n = 96)	53.2	49.2	43.5	49.0	49.7	
Grade						.005
Grade 2 (n = 103)	59.7	37.3	78.3	53.1	53.4	
Grade 3 (n = 90)	40.3	62.7	21.7	46.9	46.6	
Race/ethnicity						.42
White (n = 144)	77.4	76.3	82.6	65.3	74.6	
Hispanic (n = 15)	8.1	8.5	8.7	6.1	7.8	
Black (n = 14)	4.8	10.2	0.0	10.2	7.3	
Other (n = 20)	9.7	5.1	8.7	18.4	10.4	
Body mass index category[b]						.07
Normal or underweight (n = 153)	82.3	72.9	82.6	81.6	79.3	
Overweight (n = 23)	14.5	8.5	8.7	14.3	11.9	
Obese (n = 17)	3.2	18.6	8.7	4.1	8.8	

Note. Treatment groups are as follows: students who remained in a treatment condition for both years of the study (T-T), students who remained in a control condition for both years of the study (C-C), students who switched from a control to a treatment condition (C-T), and students who switched from a treatment to a control condition (T-C).

[a]*P* values determined by Pearson χ^2 test.

[b]Body mass index category was determined according to the Centers for Disease Control and Prevention guidelines (https://nccd.cdc.gov/dnpabmi/calculator.aspx).

study findings among first graders, an age group in which many habits are being formed, the intervention resulted in a marked decrease in students' BMI percentiles. Our findings are also consistent with what has been found among adults using stand-biased desks in workplaces.

As noted by Dunstan et al., "prolonged sitting has been engineered into our lives across many settings."[16(p368)] The norm for

TABLE 2—Body Mass Index (BMI) Measures for Participating Students: 3 Texas Schools, 2011–2013

Variable	T-T Group (n = 62), % or Mean (SD)	T-C Group (n = 59), % or Mean (SD)	C-T Group (n = 23), % or Mean (SD)	C-C Group (n = 49), % or Mean (SD)
BMI category status[a]				
Moved down 1 category	6.5	0.0	8.7	2.0
Maintained category	88.7	94.9	87.0	85.7
Moved up 1 category	4.8	5.1	4.4	12.2
BMI				
Year 1	16.9 (2.2)	18.0 (3.5)	16.9 (3.2)	17.3 (2.9)
Year 2	17.0 (2.5)	18.3 (4.1)	17.0 (3.5)	17.7 (3.0)
Change	0.1 (1.2)	0.3 (1.0)	0.1 (0.7)	0.4 (1.1)
BMI percentile				
Year 1	52.7 (27.4)	54.8 (30.4)	45.9 (32.1)	55.6 (26.6)
Year 2	49.7 (29.5)	53.3 (34.9)	44.9 (32.5)	57.4 (27.8)
Change	−3.1 (14.5)	−1.5 (10.0)	−1.0 (10.3)	1.8 (14.6)

Note. Treatment groups are as follows: students who remained in a treatment condition for both years of the study (T-T), students who remained in a control condition for both years of the study (C-C), students who switched from a control to a treatment condition (C-T), and students who switched from a treatment to a control condition (T-C). BMI, BMI percentile, and BMI category were determined according to the Centers for Disease Control and Prevention guidelines (https://nccd.cdc.gov/dnpabmi/calculator.aspx).

[a]Indicates whether children moved up from, moved down from, or maintained their original BMI category.

TABLE 3—Changes in Body Mass Index Percentiles Associated With Stand-Biased vs Seated Classrooms: Students in 3 Texas Schools, 2011–2013

Variable	b (95% CI)	SE
Intercept	3.93 (−0.89, 8.75)	2.44
Treatment group		
T-T	−5.24 (−10.16, −0.31)	2.50
T-C	−2.96 (−7.97, 2.05)	2.54
C-T	−3.94 (−10.56, 2.68)	3.35
Male gender	−1.08 (−4.81, 2.65)	1.89
Grade 3	−2.41 (−6.27, 1.46)	1.96
Race/ethnicity		
Black	−4.52 (−11.86, 2.82)	3.72
Hispanic	0.14 (−6.80, 7.08)	3.52
Asian	0.04 (−6.29, 6.37)	3.21

Note. CI = confidence interval. Treatment groups are as follows: students who remained in a treatment condition for both years of the study (T-T), students who remained in a control condition for both years of the study (C-C), students who switched from a control to a treatment condition (C-T), and students who switched from a treatment to a control condition (T-C). Data were derived from a linear regression model with the C-C group as the referent.

general public school classrooms is seated instruction; they were designed that way. However, with a growing body of evidence that prolonged sitting greatly increases one's risk not only for obesity but also for metabolic issues and chronic diseases, is it time to reengineer classrooms? Our society is ripe with examples of using scientific findings to shape policy.[29] Perhaps the more important question is can we choose not to redesign the classroom environment, knowing that we are doing long-term harm to children by conditioning them to prolonged sitting?

Limitations

A few limitations of our study warrant attention. First, measuring children's BMIs is complex; because BMI is based on height and weight, both of which are expected to increase as children grow and develop, child BMI results must be interpreted carefully and in light of what is developmentally normal. Examining changes in BMI percentile is one way of balancing this issue, because growth charts account for anticipated increases in height and weight. In addition, our measurements were taken over a 2-year period, thus allowing time to balance out fluctuations related to episodic growth spurts.

A second limitation is that, although our intervention was provided to all of the students in treatment classrooms, we were able to collect data only for those children who assented and whose parents provided consent. Thus, our results do not include everyone who was treated. We did not observe specific differences between children who did and did not participate, but it is possible that small differences existed.

Finally, our research was challenged by its implementation in real school environments, where many factors were out of our control. For example, some teachers themselves stood more than others and consequently influenced classroom dynamics; although our total of 24 classroom interventions is not sufficient to thoroughly examine teacher effects, it is sufficient to account for classroom variations. Ultimately, implementation in actual school settings was a benefit of the study, as the results suggest what effects might be expected if the intervention were replicated.

Public Health Implications

Changing classroom environments to stand-biased environments has the potential to affect millions of children; according to the National Center for Education Statistics, 49.8 million students were enrolled in public schools in fall 2014.[30] Stand-biased classrooms can interrupt sedentary behavior patterns among students in kindergarten through grade 12 (and beyond) during the hours they spend at school, and this can be done simply, at a low cost, and without disrupting classroom instruction time.

Research solely based on 2 hours of instructional time each day indicates that stand-biased classrooms have measurable effects on elementary school students. Considering the increase in seated instructional time as students move to higher grade levels, the potential impact could be even greater among secondary school students. Additional research should examine actual effects on older students as their instructional contexts change and they progress with respect to physiological development. AJPH

CONTRIBUTORS

M. L. Wendel was the co–principal investigator of the study, contributed to the study design and data analysis, and led the writing of the article. M. E. Benden was the principal investigator of the study, led the study design, and contributed to the writing of the article. H. Zhao led the statistical design and analysis of data and contributed to the results section of the article. C. Jeffrey led the data collection for the study and contributed to the background and methods sections of the article.

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M. E. Benden declares a financial conflict of interest associated with this research since his US patented designs for standing height school desks have been licensed by Texas A&M University to Stand2Learn LLC, a faculty led startup company, of which he owns stock and whose desks were included in the treatment groups used in this study. M. E. Benden's COI is managed by a TAMU approved plan and his involvement was at the experimental design stage and not the data collection or analysis phases.

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Note. The conclusions presented are those of the authors and do not necessarily represent the official position of the National Institutes of Health.

HUMAN PARTICIPANT PROTECTION

This study was approved by the institutional review boards of Texas A&M University and the College Station Independent School District. Written informed consent was obtained from parents or guardians, and verbal assent was obtained from students, prior to data collection.

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