Quality of process impacts fourth grade students' participation in physically active academic lessons

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Abstract

Background It is important to assess implementation of active learning interventions to maximize their impact. Quality of process, or how well one engages program participants, has been less studied than other implementation components (e.g., dose, fidelity). This cross-sectional study examined associations between teacher engagement behaviors, teacher feedback, and student physical activity outcomes during active classroom lessons.

Methods This study used data from the Texas Initiatives for Children's Activity and Nutrition (I-CAN!) randomized controlled trial. Multivariate analysis of covariance was conducted to compare student physical activity outcomes by teachers' engagement behaviors. Bivariate correlations were conducted to examine associations between teacher feedback and student physical activity outcomes. A latent profile analysis was used to examine whether there were subsets of teachers with similar feedback profiles.

Results The final analytic sample included 82 teachers (N = 100 observations). Teacher-directed changes in physical activity and/or teacher participation in physical activity demonstrated significantly higher ratings for student physical activity intensity, class participation, and how often children were active (all $p < .05$). Physical Activity Reinforcement and Technical Instruction feedback were positively associated with activity intensity (r=-.20, $p < .05$ and $r = .33$, $p < .01$, respectively). Technical Instruction feedback was positively associated with how many (r = .31, $p < .01$) and how often ($r = .44$, $p < .01$) students were active during lessons. Negative feedback was negatively associated with how many (r=-.20, $p < .05$) and how often (r=-.28, $p < .01$) students were active, as well as activity intensity (r=-.27, p < .01). All teachers were represented by relatively high levels of Game Instruction and Classroom Management feedback, moderate levels of Content Reinforcement and Content Instruction feedback, and low levels of Negative, Technical Instruction, and Physical Activity Reinforcement feedback. These data did not indicate the existence of multiple feedback profiles.

Conclusions These findings suggest that teacher engagement and feedback to students during physically active, academic lessons can help promote student engagement in physical activity. Teachers have primary responsibility for implementing school-based interventions, and it is critical to develop strategies that increase teachers' ability to implement them successfully. Opportunities to maximize intervention delivery, such as co-designing with teachers, should be utilized in school-based, physical activity interventions.

Background

There are concerns about the effectiveness of school-based health intervention programs implemented outside of highly controlled research studies or efficacy trials (1–6). Implementation is based on a number of components: dosage (e.g., amount of content / number of lessons delivered), fidelity (e.g., using program content / lessons as intended), and quality of process (e.g., how well teachers engage the students in the program), with a majority of research focused on dosage of and fidelity to programs (2–7). Although dosage is critical to the success of an intervention, it is often limited to a simple count without regard to the quality of the process used to achieve this dosage (2, 8, 9).

Effective school-based interventions are needed to increase physical activity among school-aged children. Physical activity is associated with numerous health benefits for children including lower body fat, stronger muscles and bones, improved cognition, reduced depression, improvements in academic tasks and attention control, and prevention of chronic disease (10–13). Incorporating physically active, academic lessons (active lessons) in the classroom is an innovative approach to increase children's physical activity in schools. Active lessons combine physical activity with academic instruction and are delivered by classroom teachers. Despite efforts to ensure dosage and fidelity of lessons, the impact of active lesson interventions on student physical activity is incongruent, with increases in time spent in moderate-to-vigorous intensity physical activity (MVPA) ranging from 2–16% from pre- to post-intervention (standardized mean difference = 0.40, 95% CI: -0.15,0.95) (14). Thus, research examining how implementation constructs, other than dosage and fidelity, can facilitate optimal program effectiveness is needed. As teachers are the primary implementers of active lesson interventions (15), their ability to engage

students with the lessons (i.e., quality of process) may contribute to variation in children's physical activity outcomes across studies.

Attempts to assess quality of process have typically relied on teacher self-reports which can be biased, rather than more objective measures such as classroom observations (16, 17). Specifically, quality of process can be measured by quantifying behaviors that teachers use to engage students in active lessons. At one level, teachers may engage students in active lessons through manifestations of behaviors intended to structure the lesson, such as modeling, scanning, and moving around the classroom, behaviors which have been shown to be directly associated with students' time spent in MVPA during physical education (PE) lessons (18, 19). Only one known study has objectively examined the association between teachers' ability to engage students during an active lesson intervention and student physical activity, reporting greater physical activity among students whose teachers participated in lessons (i.e., modeling) than those whose teachers did not participate (20). However, only three students per classroom were included in these observations, which likely missed important variations across student physical activity responses. Moreover, there was no consideration of other forms of teacher behaviors that might promote student engagement.

It is important to capture the interactions between students and teachers during lessons at a more granular level and assess the quality of the teacher engagement. Previous studies of PE intervention programs indicate that the nature of teacher-student interactions (i.e., feedback that teachers provide students during programming) is implicated in program success. For example, research suggests that the time teachers spend promoting fitness (i.e. teacher praises/reinforces physical activity) and observing students during PE class is directly associated with percent time students are engaged in MVPA (18, 19). Conversely, students whose PE teachers' feedback focuses on class management and general instruction engage in less MVPA (19).

Quality of process plays an important role in intervention adherence and effectiveness, and assessment of this construct may be crucial in order to understand why a program is successful or ineffective. Overall, quality of process with regard to active lessons has been understudied and the methodology underdeveloped. The purpose of this study was to use an observational tool to 1) Examine the relationship between teacher engagement behaviors (e.g., modeling, moving around classroom) and student physical activity during active lessons; 2) Investigate relationships between quality of teacher engagement (i.e., feedback) variables and student physical activity outcomes; and 3) Explore relationships between quality of teacher engagement variables to determine whether teachers could be organized into groups with homogeneous feedback profiles and examine. Any associations between resulting feedback profiles were examined in relation to student physical activity outcomes.

Methods

Overview

This study used data from the Initiatives for Children's Activity and Nutrition (I-CAN!) randomized controlled trial (RCT), collected across three academic years (i.e., 2012-13, 2013-14, and 2014-15). A complete description of the study design is provided elsewhere (21). Briefly, the overall I-CAN! RCT compared the impact of 10-15 minute active lessons on fourth grade students' physical activity, academic achievement, and time-on-task, compared to standard academic lessons in 28 elementary schools (n=19 intervention and n=9 control) and across 149 fourth-grade teachers (n=99 intervention, n=50 control). Teachers in intervention schools were provided structured active lessons (math or spelling) designed to be easily modified for use across a variety of indoor and outdoor settings (22) that included physical activities such as running, jumping jacks, and push-ups. Both parental consent and student assent were required for student participation. All study protocols were approved by the university's Institutional Review Board. The current study focused only on data from teachers and students in the intervention arm of the I-CAN! study.

Participants

Participants were 94 fourth grade teachers and 1,903 fourth grade students from the 19 schools assigned to the math (n=9) or language arts (n=10) intervention arms of the I-CAN! study. Some schools designated specific teachers on the fourth-grade teaching team to teach math or language arts to all classes, accounting for the disparity between the number of teacher

participants (n=82) and the number of I-CAN! lesson observations (n=100). All fourth-grade students were eligible for inclusion in this study (23). Informed consent was obtained from all teacher participants, and both parental consent and student assent were obtained from all student participants included in the study.

Measures

Demographics. Teachers self-reported reported sex, race/ethnicity, and age. Students' sex, age, race/ethnicity, eligibility for free/reduced lunch (yes/no), and body mass index (BMI) were obtained through school FITNESSGRAM® data and school records (24).

Tool to Observe Classroom Activity. A direct observation tool was developed for the I-CAN! Study to assess teacher engagement behaviors and student physical activity-related outcomes (Supplementary file 1). This tool was developed based on categories derived from the Coaching Behavioral Assessment System (CBAS; 25) and the System for Observing Fitness and Instruction Time (SOFIT; 26) which were developed for use in sports and physical education research, respectively. The I-CAN! observational tool incorporates SOFIT's teacher engagement behaviors such as modeling, visual scanning, and physical movement around the classroom as they have been linked to maintaining or enhancing student physical activity (27-29). Quality of engagement content, specifically teacher feedback related to fitness promotion, class management, and general instruction, were adapted from CBAS and SOFIT. Since active lessons incorporate physical activity into academic lessons, additional teacher feedback categories related to academic content (i.e., instruction, reinforcement) were developed and included in the observational tool. Student physical activity outcomes (e.g., intensity, frequency) were also adapted from SOFIT.

Research staff were trained to use the tool prior to field observations by one of the authors of the current study, (VLE), whose ratings were used as the gold standard. Research staff must have obtained an intra-class correlation (ICC) of at least 0.90 with the gold standard to observe teachers in this study. ICCs for continuous variables ranged from 0.89 to 0.98, indicating excellent inter-rater reliability (29). Staff observations of I-CAN! lessons were conducted at least once for each class over the course of the school year.

Teacher Engagement Behaviors. Trained research staff observed whether teachers: 1) moved around the room, 2) scanned the room, 3) directed changes in physical activity performed during lesson (e.g., jumping jacks, push-ups), or 4) participated in physical activity during the I-CAN! lesson. Each item was rated dichotomously (Yes/No).

Quality of Engagement Content. Two trained research staff observed teacher feedback, including: 1) Physical Activity Reinforcement (e.g. "Good high knees!"); 2) Technical Instruction (e.g. "During push-ups, keep your back straight"); 3) Content Instruction (e.g. "72 divided by 9 equals 8"); 4) Content Reinforcement (e.g. "Good answer!"); 5) Game Instruction (e.g. "You should be skipping right now"); 6) Negative Feedback (e.g. "You're doing it wrong"); and 7) Classroom Management (e.g. "Please be quiet"). Research staff tallied the number of times the teacher gave a particular type of feedback to their students. Counts for each feedback category were summed and averaged across observers.

Physical activity. The primary dependent variables were student physical activity-related outcomes, collected using the direct observation tool. Physical activity variables included: 1) how many children were active [(1) less than half of the class to (3) more than half of the class], 2) how often children were active [(1) not at all to (5) most of the time], and 3) the intensity of movement for the lesson [(1) standing still to (5) running]. Observer ratings were averaged for each physical activity variable. ICCs were 0.94 for how many children were active, and 0.93 for how often children were active and intensity of movement variables, indicating excellent inter-rater reliability.

Data Analysis

Descriptive analyses were conducted, including means and frequencies for teacher and student characteristics, teacher behaviors (engagement and quality), and student physical activity outcomes, using the Statistical Package for the Social Sciences (30).

Unadjusted and adjusted multivariate analysis of covariance (MANCOVAs) were conducted to determine whether teachers' engagement behaviors during active lessons impacted student physical activity outcomes. Analysis of variance (ANOVA) was conducted on each dependent variable as a post-hoc test, if necessary. Teacher's age, years teaching fourth grade, years teaching at present school, and years teaching overall were included as covariates in analyses.

Bivariate correlations were run to examine relationships between all teacher quality of content engagement variables and student physical activity. A latent profile analysis (LPA) was conducted using MPlus 7.0 (31) to examine whether there were subsets or classes of teachers who share similar patterns of responses. That is, LPA was used to determine whether relationships between quality engagement can be used to organize teachers into groups with homogeneous category profiles. LPA uses all observations of the continuous dependent variables (i.e. verbal feedback categories) to define classes via maximum likelihood estimation (32). The probability that an individual was properly classified, enabling the individual to be categorized into the best-fitting class, is estimated simultaneously with the overall model (33). Models are estimated with classes added iteratively to determine which model is the best fit to the data. The optimal number of classes for the sample was determined based on several criteria: 1) use of the Lo-Mendell-Rubin Adjusted Likelihood Test (LMRT; 34); 2) the Akaike information criteria (AIC; 35); and 3) the sample size-adjusted Bayesian information criteria (sBIC; 36). The LMRT compares the fit of a target model (e.g. 3 class model) to a comparison model that specifies one less class. If the *p*-value for the LMRT is less than .05, than the solution with more classes is a better fit for the data. The AIC and sBIC are descriptive fit indices where smaller values indicate better model fit. Small classes containing less than 5% of the sample are generally considered spurious, resulting from extracting too many profiles or classes (37). Thus, class size was also considered when determining the optimal number of classes.

Results

Participant characteristics are presented in Table 1 for teachers and Table 2 for students. Teachers were predominantly female (94%), non-Hispanic (89%), white (92%), and had a mean age of 39 years. Students were 51.0% female, non-Hispanic (76%), white (49%), and as a proxy for socioeconomic status (SES), 24% were eligible for free or reduced lunch. A large majority of observed teachers' engagement behaviors included scanning the room (93%) and directing changes in physical activity (69%). Game instruction and classroom management were the most frequently provided forms quality of content engagement. Teachers provided, on average, less than two physical activity reinforcement statements per active lesson.

Table 1. Sociodemographic, engagement behaviors, and quality of engagement of teachers participating in I-CAN! observations

Sociodemographic characteristics[a]	
Age, M±SD	39.11±9.65
Years Teaching Overall, M±SD	9.57±6.48
Years Teaching Present School, M±SD	4.33±3.76
Years Teaching 4th Grade, M±SD	4.58±4.58
Teacher Engagement Behaviors	**%**
Directed Changes in Physical Activities	68.7
Participation in Physical Activities	22.2
Scanned Room	93.0
Moved Around Room	35.0
Quality of Engagement Content	**M±SD**
Game Instruction	8.17±4.62
Classroom Management	6.22±4.08
Content Reinforcement	4.09±4.50
Content Instruction	3.59±3.74
Technical Instruction	2.00±2.26
Physical Activity Reinforcement	1.65±2.31
Negative Feedback	1.43±2.30

[a] Total observations = 100, total teachers observed = 82, Actual n varies due to missing data

Abbreviations: M, mean; SD, standard deviation

Table 2. Sociodemographic and physical activity characteristics of students participating in I-CAN! observations (N=1,903)

Sociodemographic characteristics	%
Free/reduced priced lunch	23.6
Female	51.0
Hispanic	24.0
White	49.2
Body Mass Index (BMI)	
Underweight	4.2
Normal weight	66.7
Overweight/Obese	29.1
Student Physical Activity Outcomes	**M±SD**
Class Participation (range: 0-3)	2.51±0.67
Often Children Active Throughout Lesson (range: 0-5)	3.58±0.96
Intensity of Movement (range: 0-5)	3.62±0.95

Abbreviations: M, mean; SD, standard deviation

Teacher Engagement Behaviors

Results of the unadjusted MANOVAs show that there was a statistically significant difference in outcome characteristics based on teacher-directed changes in physical activity (Wilks' $\Lambda = 0.892$, $F(4,94) = 2.84$, $p = 0.028$) and teacher participation in physical activity (Wilks' $\Lambda = 0.842$, $F(4,94) = 4.40$, $p = 0.003$). Students whose teachers directed changes in physical activity during the I-CAN! lessons and/or students whose teachers participated in physical activity during the I-CAN! lesson demonstrated significantly higher ratings for student physical activity intensity, class participation, and how often students were active throughout the lesson (Table 3). Engagement behaviors such as moving around the classroom (Wilks' $\Lambda = 0.976$, $F(4,95) = 0.59$, $p = 0.674$) and scanning the room (Wilks' $\Lambda = 0.984$, $F(4,95) = 0.05$, $p = 0.818$) during I-CAN! lessons did not impact student physical activity. Table 3 provides the unadjusted means and standard deviations for the child physical activity outcomes by quality of process components.

After adjusting for covariates, MANCOVA results indicated that students whose teachers directed changes in physical activity during I-CAN! lessons had higher ratings for class participation and how often children were active throughout the lesson. However, the relation between teacher-directed changes in physical activity and student physical activity intensity was no longer significant (Table 4).

Table 3. Texas Initiatives for Children's Activity and Nutrition (I-CAN!) unadjusted means and standard deviations for student outcome characteristics by teacher engagement behaviors (N = 100)

Student Physical Activity Outcomes	Teacher Engagement Behaviors											
	Scanned Room			Moved Around Room			Directed Changes in Physical Activities			Participation in Physical Activities		
	Yes	No	p	Yes	No	p	Yes	No	p	Yes	No	p
	M (SD)	M (SD)		M (SD)	M (SD)		M (SD)	M (SD)		M (SD)	M (SD)	
Class Participation (range: 0-3)	2.51 (0.68)	2.50 (0.57)	0.976	2.41 (0.68)	2.56 (0.67)	0.273	2.61 (0.63)	2.27 (0.71)	0.021	2.75 (0.61)	2.43 (0.67)	0.049
Often Children Active Throughout Lesson (range: 0-5)	3.60 (0.96)	3.29 (1.07)	0.411	3.51 (1.00)	3.61 (0.95)	0.629	3.76 (0.91)	3.20 (1.00)	0.007	4.14 (0.96)	3.42 (0.91)	0.002
Intensity of Movement (range: 0-5)	3.62 (0.94)	3.57 (1.13)	0.901	3.54 (1.12)	3.66 (0.85)	0.543	3.73 (0.89)	3.32 (1.00)	0.043	4.05 (0.97)	3.47 (0.90)	0.010

Abbreviations: M, mean; SD, standard deviation

Table 4. Texas Initiatives for Children's Activity and Nutrition (I-CAN!) adjusted means and standard errors for student outcome characteristics by teacher engagement behaviors (N = 100)

Student Physical Activity Outcomes	Teacher Engagement Behaviors											
	Scanned Room			Moved Around Room			Directed Changes in Physical Activities			Participation in Physical Activities		
	Yes	No	p	Yes	No	p	Yes	No	p	Yes	No	p
	M (SE)	M (SE)		M (SE)	M (SE)		M (SE)	M (SE)		M (SE)	M (SE)	
Class Participation (range: 0-3)	1.97 (0.21)	2.66 (0.14)	0.850	2.35 (0.11)	2.32 (0.27)	0.267	2.74 (0.13)	1.87 (0.22)	0.028	2.48 (0.22)	2.27 (0.15)	0.021
Often Children Active Throughout Lesson (range: 0-5)	3.14 (0.29)	3.62 (0.20)	0.629	3.51 (0.16)	3.21 (0.38)	0.550	3.98 (0.18)	2.72 (0.31)	0.012	3.91 (0.31)	3.11 (0.20)	0.001
Intensity of Movement (range: 0-5)	3.17 (0.29)	3.80 (0.20)	0.728	3.51 (0.16)	3.53 (0.38)	0.531	3.94 (0.18)	3.00 (0.31)	0.071	3.78 (0.31)	3.56 (0.21)	0.009

Abbreviations: M, mean; SE, standard error

Adjusted for teacher's age, years teaching 4th grade, years teaching at present school, and years teaching overall

Quality of Engagement Content

Bivariate correlations (Table 5) revealed that Technical Instruction feedback was significantly and positively associated with Physical Activity Reinforcement ($p < 0.05$) and the student physical activity outcomes – how many students were active, how often students were active, and students' intensity of movement ($p < 0.01$). Conversely, Negative feedback was negatively associated with these three student physical activity variables ($p < 0.05$). Physical Activity Reinforcement was also significantly and positively associated intensity of movement ($p < 0.05$). Content Reinforcement was significantly, positively associated with Content Instruction and Classroom Management ($p < 0.01$). Overall, greater amounts of Technical Instruction and less Negative feedback provided during lessons was related to a greater number of students active during the lesson, a greater amount of time students spent active during the lesson, and a higher intensity of movement during lessons. No significant associations were found between Game Instruction, Content Instruction, or Classroom Management feedback and any of the student physical activity variables.

Table 5. Bivariate correlations between quality of content engagement variables and student physical activity outcomes (N=100)

	1	2	3	4	5	6	7	8	9	10
Quality of Content Engagement										
1. Physical Activity Reinforcement										
2. Game Instruction	-.10									
3. Content Reinforcement	.05	-.02								
4. Technical Instruction	.33**	-.14	-.04							
5. Negative Feedback	-.05	.10	-.01	-.08						
6. Content Instruction	.08	-.03	.51**	-.16	.12					
7. Classroom Management	.06	.06	.31**	.01	.10	.18+				
Student Physical Activity Outcomes										
8. Class Participation in Classroom	.03	-.12	.08	.31**	-.20*	.16	-.01			
9. Often Children Active Throughout Lesson	.05	-.17	-.13	.44**	-.28**	-.10	-.14	.72**		
10. Intensity of Movement	.20*	-.10	-.21	.33**	-.27**	-.01	-.12	.69**	.72**	

Note. * denotes $p \leq 0.05$; ** denotes $p \leq 0.01$; + denotes trend toward significance

Latent profile models containing 2 and 3 classes were fit to the data. The model fit indices for each LPA are available in Supplementary File 2. The LMRT indicated that the 3-class solution was not significantly different from the 2-class solution (p = .19). Moreover, the 3-class solution yielded a class size that was too small to be of substantive value (2 teachers for 2% of the sample). Further, the LMRT revealed that the 2-class solution was not statistically different from the 1-class solution, though it approached significance (p = 0.07). However, the 2-class solution also yielded a class size that was too small to be of substantive value (2 teachers for 2% of the sample). Therefore, a 1-class model was considered the best fit to the data, suggesting that only one homogeneous profile or class represents the data. Teachers in the one class are represented by relatively high levels of Game Instruction and Classroom Management, moderate levels of Content Reinforcement and Content Instruction, and low levels of Negative, Technical Instruction, and Physical Activity Reinforcement.

Discussion

This study examined the relation of teachers' engagement behaviors and the quality of their engagement during physically active, academic lessons with student physical activity intensity, class participation, and how often children were active during the lesson. Students whose teachers exhibited engagement by directing changes in physical activity and participating in I-CAN! lessons had higher ratings for physical activity intensity, average class participation, and physical activity frequency. These associations, excluding the relationship between teacher-directed change and physical activity intensity, remained significant even after adjusting for covariates. Scanning the room or moving around the classroom during I-CAN! lessons were not associated with student physical activity outcomes.

The results of this study are similar to those found in the Physical Activity Across the Curriculum (PAAC) intervention in which increased teacher active modeling during lessons was associated with increased student physical activity levels (20). However, the present study indicates that teacher engagement behaviors differentially impact student physical activity. For instance, scanning the room and moving around the room during active lessons were not related to increased student physical activity. These findings suggest that in order to maximize the impact of active lessons on student physical activity, teachers need to participate in the lessons and direct changes in activity during the lessons.

Relationships between quality of teacher engagement and staff-rated, student physical activity during active lessons were also examined to determine which types of verbal feedback were indicative of a greater number of children active, more time spent being active, and higher intensity of activity. It was hypothesized that associations between teacher feedback variables would organize teachers into groups with homogeneous feedback profiles, which would then be examined in relation to student physical activity outcomes. However, these data did not indicate the existence of multiple feedback profiles. All teachers were represented by relatively high levels of Game Instruction and Classroom Management feedback, moderate levels of Content Reinforcement and Content Instruction feedback, and low levels of Negative, Technical Instruction, and Physical Activity Reinforcement feedback.

As Texas elementary students are provided academic instruction and physical activity/physical education instruction from separate instructors (i.e. classroom versus physical education teachers), it is not surprising that classroom teachers provided feedback primarily related to classroom management and academic content during active lessons. In fact, though physical activity-related feedback (i.e. Physical Activity Reinforcement and Technical Instruction) was significantly and positively associated with greater intensity of movement, number of students active, and time spent active, few teachers provided this feedback. Given these findings, it seems reasonable to conclude that most teachers provide similar feedback for active lessons in the classroom. This, however, indicates that their self-selected instructional style may not ideal for achieving high levels of activity when implementing active lessons. Moreover, the high frequency of Classroom Management and Game Instruction feedback indicates that the intervention may have imposed a structure (i.e., active lessons) that teachers are not comfortable with in the classroom.

The present study's findings reveal opportunities to maximize effectiveness of active lessons on child physical activity outcomes. For instance, one strategy to optimize quality of implementation of active lessons in the classroom is to enhance teacher training by emphasizing teacher engagement behaviors, such as participating with children, and providing greater levels of physical activity-related feedback. Teacher trainings should incorporate strategies such as modeling and role play to illustrate the importance of providing Physical Activity Reinforcement and Technical Instruction feedback during active lessons. Additionally, it may be beneficial to provide teachers with mentors, that is, teachers who are successful implementers of active lessons in the classroom. These mentors can provide other teachers with different approaches they can use in the classroom to improve quality of process, and specifically the forms of feedback used during active lessons. It is imperative that future research identify which strategies are most impactful with regard to helping teachers improve quality of process of active lesson implementation.

Another, perhaps more essential strategy, is to incorporate teacher perspectives of classroom-based physical activity when designing active lesson interventions. Teachers are often the primary implementers of school-based physical activity interventions and therefore, successful implementation, adoption, and sustainment of these interventions is highly dependent upon the ability of teachers to deliver them effectively. Unfortunately, teachers are rarely involved in active lesson intervention development (38). Including teachers as collaborators in the development of active lesson interventions will enable researchers to identify facilitators and barriers to implementation and increase the likelihood that teachers can implement these interventions successfully (39).

The limitations of this study should be noted. Although the parent I-CAN! study was a RCT, data for the present analyses were collected using a cross-sectional design during one day of a typical I-CAN! lesson, limiting the ability to make causal inferences. In addition, teachers were not blinded to observations from the researchers and may be subject to social desirability bias, particularly in regards to lesson delivery and involvement. Use of multiple observations over the school year, or multiple video

recordings, could help further limit teacher reactance to observation and help determine whether teacher feedback during lessons is consistent across time. Moreover, teacher engagement behavior (e.g., participating in lessons, moving around classroom) was observed using a binary (yes/no) response, which does not allow for detection of different levels of teacher participation or finer exploration of the direct impact of the teacher behavior on student activity levels. Finally, given the magnitude of Texas I-CAN!, device-based measures of activity during lessons could not be correlated with observer-rated physical activity. Future studies should explore the relationship between teacher engagement and accelerometry-assessed physical activity outcomes.

In spite of these limitations, this study has numerous strengths. This study observed a large number of teachers relative to other studies in this area as well as a large, diverse population of fourth grade students, which increases generalizability of results. Additionally, at least two observers were present per lesson to assess physical activity outcomes. Observers demonstrated excellent inter-rater reliability for these variables, limiting the likelihood of observer bias. Further, direct observation is considered an important tool for assessing lesson and teacher effectiveness (23).

This study also addresses limitations of previous work examining observing teachers' behaviors as an indicator of quality of process by considering a wider variety of teacher feedback during active lessons. For example in the coaching literature, technical instruction, where the coach instructs the player in a specific technique (i.e. keep your head down through the swing), has been linked to positive player outcomes, such as greater self-esteem and enjoyment of sport experience (40, 41) and higher perceived ability and competence (42, 43). It is important to more granularly assess teacher feedback during active lessons and its relation to student physical activity.

Conclusions

Increasing physical activity participation among youth is paramount as activity levels decline from childhood into adolescence (44, 45). Texas I-CAN! has been shown to provide up to 20% of the recommended physical activity for children, with participation in the physically active, academic lessons occurring regardless of demographic subgroup (i.e., SES, race, ethnicity, BMI, fitness level; 23). This suggests the inclusiveness and benefit of active lessons for all children. Results from school-based, physical activity intervention studies help to inform public health and public policy decisions. It is important to assess the quality of implementation of such interventions, so as to maximize their impact. The findings of this study suggest opportunities to maximize intervention delivery such as co-designing active lesson interventions with teachers and training teachers to engage in specific types of teacher behaviors during active lessons to help promote student engagement in physical activity. As teachers are primarily responsible for implementing school-based interventions, it is critical to develop strategies that increase teachers' ability to implement them successfully.

Abbreviations

Children's Activity and Nutrition (I-CAN!)

Moderate-to-vigorous intensity physical activity (MVPA)

Physical education (PE)

Randomized controlled trial (RCT).

Body mass index (BMI)

Coaching Behavioral Assessment System (CBAS)

System for Observing Fitness and Instruction Time (SOFIT)

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Intra-class correlation (ICC)

Multivariate analysis of covariance (MANCOVAs)

Analysis of variance (ANOVA)

Latent profile analysis (LPA)

Lo-Mendell-Rubin Adjusted Likelihood Test (LMRT)

Akaike information criteria (AIC)

Sample size-adjusted Bayesian information criteria (sBIC)

Socioeconomic status (SES)

Physical Activity Across the Curriculum (PAAC)

Declarations

Ethics approval and consent to participate. All procedures were approved by the Institutional Review Board for Human Subjects Research at the University of Texas at Austin (2011-01-0014). All procedures were reviewed and approved by each of the participating school districts and school principals. Consent was obtained from fourth grade teachers and consent and assent were obtained from participating fourth grade students and parents.

Consent for publication. Not applicable.

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Author's contributions

VE, ED, and JB conceived the study and/or contributed to the planning and design of the study. VE and ED contributed to data analyses and interpretation. VE, KB, ED, AJ, and JB drafted the full manuscript. EJ was involved in the design and management of the study and data. JB was the PI of the original RCT. All authors made substantial contributions to the acquisition of data and/or were involved in revising the manuscript. All authors read and approved the final manuscript.

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Not applicable

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