

Children's Enjoyment, Perceived Competency, and Moderate-to-vigorous Physical Activity During High-Intensity Interval Training in Physical Education

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Abstract

Background: Little is known about children's experience with high-intensity interval training (HIIT) during elementary school. Perceptions of enjoyment, perceived competence, and motivation are likely to drive long-term adherence and are, therefore, critical to understanding how HIIT might be implemented in this setting. The purpose of this study was to describe children's physical activity levels, enjoyment, and perceived competency of HIIT activities within a Self-Determination Theory (SDT) framework (autonomy) in elementary school physical education (PE) classes.

Methods: Participants were 402 children from a single, diverse elementary school (49.4% female, 59.6% Non-Hispanic white). Student enjoyment and perceived competency were collected following teacher- (non-autonomous) and student-led (autonomous) conditions. A sub-set of 201 children wore accelerometers to measure percent of time in moderate-to-vigorous physical activity (MVPA). This mixed factorial design was assessed through a series of repeated measures ANOVAs.

Results: While children reported generally positive enjoyment and perceived competence in both condition (rating over 4.0 on a 5-point scale), children significantly enjoyed ($d = 0.44$) and felt more competent ($d = 0.12$) during the autonomous HIIT condition compared to the nonautonomous HIIT condition. In contrast, the percent of time in MPVA ($d=1.09$) was significantly lower in the autonomous condition.

Conclusions: These data illustrate a challenging trade-off with the design of HIIT trials. Increasing autonomy through the inclusion of student choice increased enjoyment and perceived competence of HIIT, which are likely to improve adherence, but lowered physical activity intensity, which is likely to reduce impact.

Background

Physical education (PE) is the only nationally structured period during the school day to promote physical activity (PA) among children [1]. While many look to PE to provide structured moderate-to-vigorous physical activity (MVPA), the primary objectives of PE are pedagogical: i.e. to teach skills, provide knowledge, and increase competence and enjoyment of activities for lifelong PA endeavors [2, 3]. However, while PE has the potential to support children for a lifetime of activity and health, PE instructional time is limited to teach fundamental skills and the levels of accrued PA in PE are insufficient [4–6]. While it is recommended that children engage in MVPA for at least 50% of PE class time, objective data using accelerometry revealed that elementary aged children spent only 32.6% of PE class time in MVPA [7, 8]. While readers of this journal would likely conclude that increased time in high quality PE is a simple solution, the on-going reductions in required time spent in PE suggest the need for other options.

PE time is limited in part due to the passing of the No Child Left Behind Act in 2002. This policy resulted in 62% of elementary schools reallocating time to “core” subjects, with 44% of those schools cutting time specifically from PE, art, music, social studies, and recess [9]. Additionally, there is high variability in states' PE policies, e.g. only 22 states mandate a minimum number of PE minutes, that likely contributes

to PE time restrictions and low physical activity levels during PE [10]. In addition, because teaching is associated with reduced intensity of PA in PE [4], the levels of PA will necessarily be limited by its primary mission: to provide students with the knowledge, skills, competency, and enjoyment to be physically active for life [11].

High-intensity interval training (HIIT) could provide a strategy to increase children's PA without sacrificing the already limited time for teaching the fundamental PE curriculum. HIIT mirrors children's natural tempo of movement. Children tend to follow dynamic flows of activity through short bursts of high-intensity PA followed by intervals of low or moderate intensity PA [12]. As such, it is likely to be familiar and enjoyable to children. Vigorous activity is particularly important for children's health as it is associated with lower body fat and greater improvements in cardiorespiratory fitness [13, 14]. In addition, HIIT is in alignment with the broader goals for PE as improvements in children's fitness have been shown to build self-efficacy for engaging comfortably in lifelong PA [13]. Further, children with the greatest cardiorespiratory fitness were found to be the most physically active [15]. While the potential is clear for HIIT as a potent method for improving children's intensity of activity and the resulting cardiometabolic health benefits [16–18], there remain questions about children's experience with HIIT.

Children's enjoyment of PE is one of the strongest and most consistent correlates of PA outside of school [19, 20]. More recently researchers determined that childhood memories of enjoyment and non-enjoyment during PE are linked with attitudes toward PA, intention, and sedentary behavior into adulthood [21]. Similarly, perceived competence is a significant predictor of children's physical activity and has been found to be positively associated with cardiorespiratory fitness [15].

Thus, it is surprising that the existing literature fails to consider key psychological moderators for children's enjoyment of and perceived competence with HIIT activities. Self-Determination Theory (SDT) could be used as framework to develop a sustainable HIIT intervention for children in PE class [22]. While there are several forms of motivation, intrinsic motivation is distinctly important to foster in children's PA behaviors because it promotes inherent satisfactions with an activity and is regulated by enjoyment [23]. SDT states that there are three essential psychological needs for facilitating intrinsic motivation - autonomy, competency, and relatedness [24]. Considering these constructs would be likely to improve the success of any HIIT program.

Children's enjoyment and perceived competence of HIIT – particularly within a school setting - has been largely understudied. A recent meta-analysis argues for developing interventions that promote children's enjoyment and acceptability of HIIT [25]. Costigan and colleagues [26] piloted an 8-week randomized control trial that incorporated 3 HIIT sessions of 8–10 minutes each week during PE or at lunch. Enjoyment of HIIT was assessed among a sub-group of 9th to 10th grade students during the program evaluation. Students provided reasonably positive reviews of this HIIT protocol (4.2 on a 5-point scale). While intriguing, this finding is limited by small sample size ($n = 31$) and poor generalizability beyond high school. Lambrick and colleagues [27] assessed children's enjoyment of a series of game-based HIIT activities during the school day. While children enjoyed the protocol (4.48 on a 5-point scale), this study

also recruited a small and homogeneous sample ($n = 55$). In addition, the intervention did not use PE teachers, but relied upon highly trained, specialty personnel to implement. This would be challenging to disseminate at scale. None of the existing studies have attempted to measure children's perceived competence of HIIT in a school setting.

While HIIT is a potentially potent training method for children that compliments the time limitations during PE, research is limited in assessing the viability of a theory driven school-based HIIT protocol. To date, no study has included: i) a large, and more diverse sample across the elementary grades; ii) a PE teacher implemented program that can be disseminated at scale; iii) a theoretical model to inform the design. Therefore, the aim of this study was to determine the feasibility of HIIT for the elementary PE classroom. It was designed to describe children's MVPA levels, enjoyment, and perceived competence of HIIT through the manipulation of autonomy within the SDT framework.

Methods

Study design and participants

All procedures and materials were reviewed and approved by an elementary school district located in central Texas. Following district agreement, all study materials were approved by the Institutional Review Board for Human Subjects Research at The University of Texas at Austin (IRB number: 2019-05-0005). Upon district and IRB approval, project staff met with the selected elementary school principal to discuss the project details, who also provided approval to conduct the intervention at the school. Physical education teachers and students were recruited across one academic year (2019–2020). Both parental consent and student assent were required for student participation.

A total of 563, 2nd -5th grade students and 3 PE teachers were recruited. Participants were excluded from the analysis if they did not obtain parental consent and/or did not provide student assent at the time of the study ($n = 160$ [28.4%]). All physical education teachers ($n = 3$ [100%]) consented to participate.

All students participated in a baseline period for 3 weeks prior to the study to familiarize and train the students with the HIIT protocol. This period was teacher-led and a part of their normal PE time. For the remainder of the school year, participants completed HIIT during 2 of 3 regularly scheduled, weekly PE classes. During the high intensity interval, students performed a series of exercises that included: push-ups, jumping jacks, curl ups, star jacks, mountain climbers, high knees, and running in place. During rest periods, students completed flexibility exercises that included cobra stretch, straddle stretch, and child's pose. Post-intervention data were not collected at the end of the school year due to the Coronavirus Disease 2019 (COVID-19) pandemic. As a result, this study was unable to assess change in fitness or other outcomes.

For the repeated measure study design, all 2nd -5th grade PE classes completed both conditions with data collected during two PE classes over the course of one week. Researchers spent a total of three

weeks in the PE classroom. For each class, the order of condition was using a random-number algorithm. The 2 conditions included:

1. *Non-Autonomous Condition (Teacher-Led)*. In the non-autonomous condition, the existing certified PE teachers selected the HIIT activities and led the training. A typical HIIT lesson lasted 5 minutes. The participants performed 7 high intensity or strength exercises for 30 seconds at high intensity with 10 seconds rest and low intensity stretching between each high intensity activity.
2. *Autonomous Condition (Student-Led)*. During the autonomous condition, students were arranged in lines. The student in the front of the line selected an activity to complete, rotating after each activity for another student's turn at the front of their line. Students followed the same format of completing 7 exercises for 30 seconds all-out with 10 second rest before the next activity.

Given the nature of the intervention, it was impossible to blind the research staff or the student and PE teacher participants. Trained members of the research team completed assessments of height and weight, placed the accelerometers, and assisted the students to complete all surveys.

Demographics

The parental informed consent designated the release of demographic data from the school's records. These data included sex, age, race/ethnicity, and eligibility for free/reduced lunch as a proxy for a dichotomous indicator of socioeconomic status.

Fitness

Participant fitness was derived from the school FITNESSGRAM® records [28]. FITNESSGRAM® is considered a valid and reliable measure of physical fitness [28]. Given the nature of the intervention, we were most interested in the tests of: cardiorespiratory fitness assessed through the PACER, a 20-m shuttle run; and muscular endurance as measured by push-ups and curl-ups. Researcher staff completed the body composition component of the FITNESSGRAM® for the PE teachers. Physical assessments were conducted using sensitive methods so that weight and height were measured in a private setting, with only one student measured at a time. No values were called out or given to the student. A handheld display was used for the weight scale and kept away from the sight of the student. If the student requested their values, they were directed to speak with the school nurse who was provided these data. Children's weight was measured in kilograms (kg) using a Health o Meter® 320KL Medical Scale and height was measured in centimeters (cm) using the Portable Adult/Infant Measuring Unit® from Perspective Enterprises, model PE-AIM-101. The school did not report flexibility using the sit-and-reach test. Muscular Strength performance is classified into two areas: the "Healthy Fitness Zone" (HFZ) and the "Needs Improvement" Zone. Body composition and aerobic capacity are classified by: the "Healthy Fitness Zone" (HFZ), the "Needs Improvement" (NI) Zone, and the "Needs Improvement-Health Risk Zone. Researcher dichotomized the fitness components into yes = in HFZ, no = not in HFZ.

Outcome Variables

To achieve a more accurate pre-test assessment, the student participants were blinded to the condition until the PE teacher provided instructions on the day of the PE session. Immediately following the HIIT session, students completed a two-item survey under exam-like conditions assessing enjoyment and perceived competence with the activity type or HIIT condition.

Enjoyment and Perceived Competence

There were single items scored on a 5-point Likert scale: (1) “How did you enjoy the exercise?”: 1 (I did not enjoy it all) to 5 (I enjoyed it a lot), (2) “How do you think you did?”: 1 (I did really poorly) to 5 (I did really well). The enjoyment item was adapted from the validated Physical Activity Enjoyment Scale (PACES) but was condensed to a single question to ease data collection with children [29]. Prochaska et al. [30] found that this single measure of PE enjoyment was positively associated with similar descriptions of PE. To increase the accuracy of response, the Likert-type scale was supplemented with a visual analog displaying a gradient of “happy/sad faces” for each of the 5 possible responses. Research shows that these images improve response accuracy, particularly for youth [31]. The perceived competency item was modelled on this approach and was reviewed by the participating PE teachers to assure wording that was natural to the elementary school context.

Physical Activity

To determine the intensity of activity during HIIT, four classes from each grade were fitted with GTX3X+ accelerometers, comprising 73.4% ($n = 295$) of the total sample. To ensure a complete collection of school-week PA, accelerometers were distributed at the beginning of the school day by research staff and collected as students left class at the end of each school day. For this measure, children’s PA was assessed with a triaxial accelerometer ActiGraph® Manufacturing Technologies, Inc. model GTX3X+ [32]. The accelerometers were worn throughout the school-day in an elastic belt around the waist, positioned on the right hip [33]. Data were collected in 5-second epochs to best capture children’s activity [34]. Periods of greater than 90 minutes of zero counts were defined as non-wear time [35]. Counts were analyzed with ActiLife v6.13.4 software that applied Evenson cut points [36, 37]. In ActiLife, filters were applied to HIIT times and weekly PE times, validated HIIT and weekly PE PA for each student. Outcomes for PA were: (1) weekly percent time in MVPA (percentage of MVPA during valid wear time), and (2) percent of MVPA spent during HIIT by condition. Students with all zeros counts or improper use ($n = 91$) or outliers likely due to improper use ($n = 3$) were excluded. This resulted in a total of 201 students who wore accelerometers included in the analysis.

Statistical Analysis

Descriptive analyses, including frequencies and percentages, were calculated. The hypotheses were assessed through a series of 3-way ANOVAs; 2 (condition) x 4 (grade) x 2 (sex), with repeated measures on the first factor (condition). When significant interactions occurred, they were decomposed into the simple effects of condition within each level of grade and sex, and post hoc comparisons using the Bonferroni adjustment. All statistical analyses were conducted using IBM SPSS statistics for Macintosh, Version 26.0 (IBM Corp., 2019).

Results

The final sample was fairly diverse being 49.4% female, 59.6% Non-Hispanic white, 6.9% eligible for free/reduced lunch (yes/no), and 80.7% were in the Healthy Fitness Zone (yes/no) for BMI as assessed classified by the FITNESSGRAM® (Table 1) [28].

Table 1
Descriptive Characteristics of Participants (N= 403)

Characteristics	Total Sample (n = 403)	2nd Grade (n = 111)	3rd Grade (n = 104)	4th Grade (n = 88)	5th Grade (n = 100)
Age in years (<i>M ± SD</i>)	8.94 ± 1.24	7.45 ± 0.50	8.38 ± 0.45	9.47 ± 0.50	10.4 ± 0.50
Sex <i>n</i> (%)					
Male	204 (50.6)	61 (55)	51 (49)	48 (54.5)	44 (44)
Female	199 (49.4)	50 (45)	53 (51)	40 (45.5)	56 (56)
Ethnicity <i>n</i> (%)					
Hispanic or Latino	97 (21.1)	20 (18)	22 (21.2)	21 (23.9)	34 (34)
Not Hispanic or Latino	304 (75.4)	90 (81.1)	81 (77.9)	67 (76.1)	66 (66)
Race <i>n</i> (%)					
African American or Black	20 (5.0)	6.0 (5.4)	2.0 (1.9)	7.0 (8.0)	5.0 (5.0)
White	240 (59.6)	69 (62.2)	71 (69.2)	50 (56.8)	49 (49)
Asian	29 (7.2)	10 (9.0)	4.0 (3.8)	7.0 (8.0)	8.0 (8.0)
Hispanic or Latino	96 (23.8)	20 (18)	22 (21.2)	20 (22.7)	34 (34)
Native Hawaiian or other Pacific Islander	1.0 (0.20)	—	1.0 (1.0)	—	—
2 or more races	12 (3.2)	4.0 (3.6)	2.0 (1.9)	3.0 (3.4)	4.0 (4.0)
Eligible for free/reduce lunch <i>n</i> (%)	28 (6.9)	4.0 (3.6)	10 (9.6)	9.0 (10.2)	5.0 (5.0)
Weekly MVPA PE <i>n</i> (<i>M ± SD</i>)	175 (28.2 ± 5.43)	41(29.43 ± 5.61)	47 (27.44 ± 3.03)	41 (30.23 ± 6.0)	46 (25.97 ± 5.76)
FITNESSGRAM <i>n</i> (%)					
BMI in HFZ	251 (80.7)	70 (80.5)	66 (71.7)	50 (62.5)	65 (67.7)
PACER in HFZ	88 (63.3)	—	—	26 (66.7)	62 (62)
Pushups in HFZ	221 (75.9)	—	89 (85.6)	66 (75.9)	66 (66)
Curlups in HFZ	172 (59.1)	—	68 (66)	45 (51.1)	59 (59)
Abbreviations: <i>M</i> , mean; <i>SD</i> , standard deviation					

Table 1: Descriptive Characteristics of Participants (N = 403)

Three individual 2 (condition) x 4 (grade) x 2 (sex) ANOVAs with repeated measures on condition were performed with percent MPVA, enjoyment, and perceived competence as the outcome variables (Table 2).

Table 2
 MVPA, Enjoyment, Perceived Competence by Grade and Sex in each HIIT Condition (N= 403)

	Between Participant Variables						
	2nd Grade (n = 111)	3rd Grade (n = 104)	4th Grade (n = 88)	5th Grade (n = 100)	Male (n = 204)	Female (n = 199)	Total Sample (N = 403)
Within Participants Variables							
<i>Autonomy</i>							
%MVPA							
M	43.41 ^{a*}	45.27 ^{a*}	33.18 ^{a*}	45.11 ^{a*}	43.35 ^{a*}	54.15 ^{a*}	41.89 ^a
SD	10.40	11.30	9.0	13.4	11.82	11.98	12.2
n	48	52	47	47	101	104	194
Enjoyment							
M	4.60	4.50	4.50	4.50	4.47 ^{b*}	4.21 ^{b*}	4.52 ^b
SD	0.80	1.0	0.90	0.80	0.91	0.82	0.90
n	97	97	86	98	192	19	378
Competence							
M	4.60	4.40	4.50	4.40	4.43	4.39	4.45 ^c
SD	0.80	0.80	0.70	0.60	0.78	0.82	0.70
n	96	98	86	98	191	190	378
<i>No Autonomy</i>							
%MVPA							
M	52.34 ^a	54.9 ^a	56.74 ^a	55.07 ^a	40.37 ^{a*}	55.43 ^{a*}	54.77 ^a
SD	12.90	8.20	12.60	11.90	12.37	11.01	11.50
n	47	51	45	58	93	97	20

* $p < 0.05$ for sex and grade contrasts. Means in the same column sharing the same letter superscript differ at $p < 0.05$.

Abbreviations: *M*, mean; *SD*, standard deviation

Between Participant Variables							
Enjoyment							
M	4.30	4.20	4.0	3.90	4.58 ^{b*}	3.95 ^{b*}	4.08 ^b
SD	1.0	1.10	1.10	1.10	1.07	1.11	1.10
<i>n</i>	98	98	86	98	186	190	380
Competence							
M	4.50	4.30	4.30	4.30	4.49	4.34	4.36 ^c
SD	0.70	0.90	0.80	0.70	0.66	0.75	0.80
<i>n</i>	98	98	86	98	187	190	380
<i>Combined</i>							
%MVPA							
M	47.80	50.10 [*]	45.04 [*]	50.80 [*]	49.14	47.73	—
SD	8.60	8.40	8.40	8.60	8.44	8.54	—
<i>n</i>	95	103	92	105	205	190	—
Enjoyment							
M	4.40	4.40	4.30	4.20	4.33	4.28	—
SD	0.80	0.80	0.80	0.80	0.83	0.84	—
<i>n</i>	195	195	172	196	382	376	—
Competence							
M	4.50	4.30	4.40	4.40	4.40	4.41	—
SD	1.0	1.0	0.90	0.90	0.94	0.95	—
<i>n</i>	194	196	172	196	381	377	—
* <i>p</i> < 0.05 for sex and grade contrasts. Means in the same column sharing the same letter superscript differ at <i>p</i> < 0.05.							
Abbreviations: <i>M</i> , mean; <i>SD</i> , standard deviation							

Table 2: MVPA, Enjoyment, Perceived Competence by Grade and Sex in each HIIT Condition (N = 403)

Percent of Time in MVPA During HIIT

The means, standard deviations, and sample sizes are shown in Table 2. For the percent of time spent in MVPA during HIIT, there was a significant main effect of grade, $F(3,176) = 4.34$, $p < 0.05$, $\eta_p^2 = 0.70$. A post hoc comparison revealed that 4th grade students participated in a significantly lower percent of time in MVPA compared to 3rd ($d = 0.60$) and 5th ($d = 0.68$) grade students. There was a significant main effect of condition, $F(1,176) = 131.86$, $p < 0.001$, $\eta_p^2 = 0.49$. Post hoc comparisons revealed that students engaged in significantly less MVPA during the autonomous than during the non-autonomous HIIT condition ($d = 1.09$). These main effects were dependent upon the other, as indicated by a significant interaction between grade and condition, $F(3,176) = 10.76$, $p < 0.001$, $\eta_p^2 = 0.16$. Post hoc comparisons indicated that percent MVPA was significantly higher for 2nd ($d = 1.05$), 3rd ($d = 1.18$), and 5th grade ($d = 1.05$) students in the autonomous HIIT condition compared to 4th grade students. However, percent MVPA across 2nd ($d = 0.76$), 3rd ($d = 0.98$), 4th ($d = 2.15$), and 5th ($d = 0.79$) grades was higher in the non-autonomous HIIT condition compared to the autonomous HIIT condition. There was a significant interaction between condition and sex, $F(1,176) = 5.16$, $p < 0.05$, $\eta_p^2 = 0.03$. Post hoc comparisons indicated that percent MVPA was significantly higher for males compared to females in the autonomous HIIT condition ($d = 0.25$) but no difference in the non-autonomous HIIT condition ($d = 0.11$). Percent MVPA was significantly higher for males ($d = 0.91$) and females ($d = 1.29$) in the non-autonomous HIIT condition compared to the autonomous HIIT condition (Table 2).

Enjoyment

The means, standard deviations, and sample sizes are shown in Table 2. There was a significant, though small main effect of condition $F(1,362) = 63.67$, $p < 0.001$, $\eta_p^2 = 0.15$. A post hoc comparison indicated that participants in the autonomous group enjoyed HIIT significantly more than the non-autonomous group ($d = 0.44$). There was a significant interaction between condition and sex, $F(1,362) = 11.86$, $p < 0.05$, $\eta_p^2 = 0.03$. Post hoc comparisons indicated that enjoyment of HIIT was significantly higher for males ($d = 0.30$) and for females ($d = 0.58$) in the autonomous condition compared the non-autonomous condition. Additionally, during the non-autonomous condition, males enjoyed HIIT significantly more than females ($d = 0.27$), while there was no difference in enjoyment for males and females in the autonomous HIIT condition ($d = 0.11$, Table 2).

Perceived Competence

The means, standard deviations, and sample sizes are shown in Table 2. There was a significant main effect of condition, $F(1, 363) = 5.855$, $p < 0.05$, $\eta_p^2 = 0.02$. A post hoc comparison revealed that perceived competence was significantly increased in the autonomous HIIT condition compared to the non-autonomous HIIT condition ($d = 0.12$, Table 2).

Discussion

The aim of this study was to apply an SDT framework to investigate the effects of HIIT on children's MVPA, enjoyment, and perceived competence during elementary PE classes. We assessed these

relationships during one week of a year-long PE intervention. Overall, children tended to enjoy HIIT in both conditions and to perceive themselves as competent with scores consistently above 4.0 on the 5-point Likert-type scale. Neither enjoyment nor competence were impacted by grade or sex – with 2nd – 5th grade male and female students rating the HIIT conditions largely similarly. Thus, regardless of age and sex, elementary students appear to enjoy HIIT activities as used in this study and to feel competent in executing these activities. However, there were differences as a function of sex based on conditions. Both male and female students rated autonomous HIIT lessons more enjoyable than non-autonomous, and males enjoyed the non-autonomous condition more than female students. Females' enjoyment rating of HIIT in the non-autonomous condition was the only instance with a rating below 4.0 (3.95) on the 5-point Likert-type scale. Students also had significantly higher ratings of perceived competence for HIIT in the autonomous condition compared to the non-autonomous, which was not impacted by gender or sex.

In contrast to children's experience with and perceptions of HIIT, percent of time in MPVA was significantly lower in the autonomous condition compared to the non-autonomous condition, which was affected by grade and sex. While all sexes and grades revealed higher percent MVPA during HIIT in the non-autonomous condition compared to the autonomous, 4th grade students had lower percent MVPA in the autonomous condition compared to all other grades. Females across grades also had lower percent MVPA during HIIT in the autonomous condition compared to males. This pattern of effects suggests a trade-off between psychological outcomes (enjoyment and perceived competence) and health-related outcomes (intensity of PA) within a HIIT protocol.

While children tended to enjoy and feel competence during both HIIT conditions, the preference for the autonomous protocol aligned with the principals of SDT [23], which is consistent with a long history of PE research. PE teachers are fundamental to facilitating autonomy and competency experiences for children that ultimately support students' intrinsic motivation towards PA [38]. Teachers who support autonomy in their classroom have been associated with students who demonstrate increased motivation, classroom engagement, skill development, future intention to exercise, and academic achievement [39]. It is not surprising that children expressed more enjoyment and perceived competence during the lessons that provided a sense of choice. When PE teachers led the lessons, children had little control over the class. Rather than an intrinsic set of self-determined motives, this creates a setting that emphasizes other-determined (teacher) controlled motives for each activity [40]. Other-determined extrinsic motivators include fear, guilt, and obligation that are not autonomous because participants perceive an external source controlling their behavior [40]. Such perceptions have been found to lower motivation and adherence [40]. While the current study was unable to assess behavior over a long-course of time, it would be important to examine how PE teacher-controlled movements impact intentions to be active.

In contrast, the results revealed that intensity of activity significantly decreased with increased enjoyment and perceived competence in the autonomous condition compared to the non-autonomous condition. While enjoyment and perceived competence are important outcomes for promoting children's lifelong PA participation [20], higher levels of MVPA in children are associated with better cardiometabolic risk factors outcomes including waist circumference, fasting insulin levels, BMI, and body fat [41, 42]. There is

preliminary evidence suggesting that the more time children spend in activity in general – and vigorous activity in particular - the greater the reduction in several cardiovascular disease risk factors including BMI and waist circumference, and the greater improvements in cardiorespiratory fitness [43, 44]. Given these data, it is not surprising that HIIT, when offered at a sufficient dose, results in meaningful improvements in cardiorespiratory fitness, systolic blood pressure, vascular function, and resting metabolic rate compared to moderate intensity PA in children and adolescents [16–18]. According to our results, while fostering autonomous experiences increases children’s enjoyment, it seems to undermine intensity of activity – especially for female students. Therefore, both PE teachers and researchers face a challenge when attempting to balance enjoyment of HIIT and sufficient MVPA needed to improve fitness and other cardiovascular disease risks factors. This balance must be considered with future large-scale HIIT interventions designed for children especially in the school setting.

While this study was not designed to assess teacher preferences, it is interesting that the PE teachers expressed their concern with disruptive classroom behavior when providing autonomy and student choice during PE. The teachers explained that large class sizes within a small gym environment were not conducive to an autonomous HIIT protocol if sufficient intensity, form, and time-efficiency were to be achieved. As a result, the PE teachers only allowed students to participate in the non-autonomous HIIT condition during the PE warm-up for the remainder of the school year. Thus, while promoting autonomy is clearly beneficial for children’s motivation and experiences with PA [38], more research is required to better understand the challenge in managing the modern PE classroom and ensuring the needs of PE teachers are met within any intervention in the PE classroom.

There were key differences as a function of method of delivery. Because the conditions differed in who was selecting the activity (students vs teachers), there were observed variations in the activities selected. When the students selected the HIIT activities they tended to select aerobic and lower intensity activities like high knees, jumping jacks, straddle stretch, and child’s pose. In contrast, when teachers selected the HIIT activities they emphasized a routine of 7 high-intensity and strength based exercises interspersed with lower-intensity exercises. This different pattern of selection is sufficient to explain the observed differences in intensity between the autonomous and non-autonomous HIIT conditions. We do not have data to assess why children made these selections, e.g. due to differences in enjoyment of these activities or their perceived competence / ability across different tasks, or some other variable. Higher intensity activity has consistently shown to be associated with negative affect in adults [45] but there is less existing research with youth. Costigan and colleagues [46] recently found that higher levels of vigorous activity were associated with more positive affect and less negative affect in a large sample of adolescents – which appear in contrast to the data for adults. However, affect and intensity have yet to be explored in elementary-aged children. Such data may help to explain the preference for HIIT activities. Further, we know of no work that has assessed differences in perceived competence at activities of different intensities among children. It is reasonable to expect that the physiological response to intense activity might be associated with perceptions of poor performance, especially for those who are less experienced with high intensity activity or have lower cardiorespiratory fitness [15]. It may be that more exposure to and training in higher intensity activities perhaps with an impact on fitness, would serve to

reduce the differences in the selection of these activities when given choice. This is clearly an area ripe for future study.

Limitations

The current study has several shortcomings. While the sample was large and fairly diverse, this study took place at one school with the 3 PE teachers, limiting generalizability to other schools. We also did not have the measures to establish that the participant's heart rate and/or $VO_{2\max}$ to ensure the HIIT stimulus classification of greater than or equal to 70% $VO_{2\text{peak}}$ or the equivalent of HR_{\max} was achieved [25]. Our measure of intensity was limited to those participants who wore GTX3X + accelerometers. These data indicated that we did not achieve true high intensity PA during HIIT, reducing the potential benefit of the selected HIIT intervention. This is in part due to the challenge of working with a class of over 100 students – as made clear by the PE teachers. It is also a function of the activities selected by the students. Future research must consider how to achieve a more acceptable dose of HIIT within the constraints of the PE classroom and considering children's preferences. Additionally, as data collection only took place over the course of 1 week per grade, the repeated measures design is subject to carry over effects from previous condition. However, limiting data collection to 1 week per grade likely helped prevent differential attrition and fatigue of participants. Lastly, neither students nor PE teachers were not able to be blinded to condition, which may have resulted in information bias.

Conclusions

This is the largest study to date to assess HIIT in the elementary setting and one of the few to incorporate objective measures of PA and embed itself in a broader, psychological theory. Findings from this study highlight both the potential of HIIT interventions in the elementary school setting and the challenge in designing interventions to achieve higher intensity PA with children while simultaneously striving to promote an enjoyable PA experience. Autonomy significantly improved children's enjoyment and perceived competency during HIIT but was resisted by PE teachers and resulted in less percent of time spent in MVPA. As a result, children's ability to achieve sufficient intensity of HIIT might be compromised with a more positive experience of choice and autonomous PA. It is precisely this kind of tradeoff that makes the translation of physical activity research to the school setting challenging and we hope that these data will inform the design of these efforts.

Abbreviations

PA

Physical activity; MVPA; Moderate-to-vigorous physical activity; PE:Physical education; SDT:Self-Determination Theory; HIIT:High-intensity interval training; HFZ:Healthy Fitness Zone; PACES:Physical Activity Enjoyment Scale; M:Mean; SD:Standard deviation

Declarations

Ethics approval and consent to participate

This study was approved by the Institutional Review Board for Human Subjects Research at The University of Texas at Austin (IRB number: 2019-05-0005). All participants in this study received written and oral information about the study, requirements and risks of participation, and the possibility of withdrawal at any given time. The participants who agreed to participate gave a written consent and assent to participate in the study and use of the data for research studies.

Consent for publication

Not applicable

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

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Authors' Contributions

KB was responsible for the development and management of this study. KB completed the analysis and drafted, edited, and revised the manuscript. KG contributed significantly to data collection and analysis. JB was key to the development of this study and was a major contributor to writing and editing the final manuscript. EJ contributed to the management of data collection and editing of the manuscript. All authors read and approved of the final manuscript.

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