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Effects of physical activity and breaks on mathematics engagement in adolescents

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ABSTRACT

Objectives: The purpose of this study was to determine whether physical activity has a positive relationship with school engagement regardless of the presence or absence of a recess or lunch break before the classroom lesson.
Design: Data were collected over three ten-week periods: January–April 2014 (Time 1), October–December 2014 (Time 2), and April–June 2015 (Time 3).
Methods: A cohort of 2194 adolescents (mean age = 13.40 years, SD = .73) wore an accelerometer during the hour before a mathematics lesson and completed a questionnaire following the mathematics lesson to assess school engagement in that lesson.
Results: Linear mixed models indicated that moderate-intensity activity before a mathematics lesson had a positive linear relationship with cognitive engagement ($\beta = .40$, $p < .05$). Recess breaks before a mathematics lesson had a negative relationship with overall, behavioural, emotional, and cognitive engagement ($\beta = -.18$, $p < .01$, $\beta = -.19$, $p < .01$, $\beta = -.13$, $p = .03$, and $\beta = -.13$, $p = .04$, respectively).
Conclusions: Promoting moderate-intensity activity prior to mathematics lessons could improve students' cognitive engagement. Educators should be aware that students tend to demonstrate the lowest levels of school engagement after recess breaks.

1. Introduction

Students who are actively engaged with school (i.e., actively participate in school activities, enjoy school, and are psychologically invested in school) are healthier than those who are less engaged.[1,2] Engaged students are more likely to perform well academically,[3] successfully transition into post-school education, and complete post-school education.[1] An individual's level of post-school education is associated with inequities across a number of health outcomes.[4] For example, post-school education is associated with lower levels of health risk behaviours such as tobacco smoking, illicit drug use, and high-risk alcohol consumption. Thus, school engagement could be a modifiable determinant of health in youth. As adolescents from low socioeconomic status (SES) areas tend to display the lowest levels of school engagement,[2] identifying modifiable determinants for this group is a priority for parents, policy makers, and society.

Increasing students' physical activity may be one method of increasing school engagement, including behavioural engagement (e.g., active participation or time on-task), emotional engagement (e.g., enjoyment), and cognitive engagement (e.g., psychological investment). Owen et al.[5] conducted a meta-analysis and concluded that physical activity breaks were an effective method of using physical activity to promote school engagement ($d = .55$, 95% CI = .02, 1.06). A number of studies have reported that physical activity breaks during classroom lessons improved school engagement, specifically time on-task during the following classroom lesson e.g., Refs. 6,7,8. However, one study found that physical activity breaks during classroom lessons had no effect on classroom behaviour.[9] Another study found that physical activity during lunch breaks was positively associated with attention and concentration levels during the following classroom lesson.[10] However, as studies assessing the relationship between physical activity during recess or lunch breaks and school engagement have not objectively measured physical activity, it is currently unclear whether physi-

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cal activity is beneficial for school engagement regardless of the presence or absence of a recess or lunch break.

No previous study has attempted to identify the mechanism underlying the possible relationship between physical activity and school engagement. One possible explanation is the novelty-arousal theory, which suggests that a shift in routine (e.g., recess or lunch break), regardless of any physical activity, allows students to refocus, and improve attention and concentration.[11] An alternate hypothesis relates to exercise-induced neurological changes, such as an increase in brain-derived neurotrophic factor (BDNF), which is responsible for the development of neurons associated with memory and learning.[12] However, it is currently unclear whether the novelty-arousal theory or BDNF provide explanatory mechanisms underlying the relationship between physical activity and school engagement.

Close examination of the relationship between physical activity and school engagement could provide clarity about the underlying mechanism. As the novelty-arousal theory suggests that recess and lunch breaks allow students to refocus their attention,[11] if school engagement levels are highest after recess or lunch breaks, regardless of the amount of physical activity undertaken, the novelty-arousal theory could be an underlying mechanism. Alternatively, vigorous-intensity activity results in higher levels of BDNF production, compared to low and moderate activity.[12] Thus, if vigorous-intensity activity is the most beneficial for school engagement, it is likely that BDNF is an underlying mechanism.

1.1. *Purpose*

The primary objective of this study is to determine whether accelerometer-assessed physical activity had a positive relationship with school engagement regardless of the presence or absence of a recess or lunch break before the classroom lesson. The secondary objective of this study was to investigate whether BDNF or the novelty-arousal theory were mechanisms underlying this possible relationship.

2. Methods

A university Human Research Ethics Committee and Department of Education research application process granted approval for this study. Parents or guardians provided informed written consent, and students provided informed written assent. To increase the sample size, data was collected at three time points: January–April 2014 (Time 1), October–December 2014 (Time 2) when students were in Year 8, and April–June 2015 (Time 3) when students were in Year 9 of the Australian secondary school education system. At each time point, students wore an accelerometer during the hour before a mathematics lesson and responded to a questionnaire assessing their engagement at the end of mathematics lesson.

Year 8 students ($N = 2194$, mean age = 13.40 years, $SD = .73$ years) were recruited from 14 secondary schools located in the western Sydney region, Australia. Schools needed to be of relative socioeconomic disadvantage, as defined by a Socio-Economic Index for Areas (SEIFA) score <6, to be eligible to participate.[13] Within these schools, all Year 8 students without any pre-existing injuries or illnesses were eligible to participate.

Accelerometers (Actigraph GT3X+) were used to measure physical activity during the one-hour period before a mathematics lesson. Accelerometers provide a valid measure of the frequency, duration, and intensity of physical activity in adolescents.[14] Evenson et al.[15] cutpoints were used to define light (101–2295 counts per minute), moderate (2296–4011 counts per minute), vigorous (>4012 counts per minute), and moderate-to-vigorous physical activity (MVPA; >2296 counts per minute). These cutpoints have been shown to be the most accurate in adolescents.[14] ActiLife software (Version 6, ActiGraph, LLC, Fort Walton Beach, FL) was used to filter out the one-hour period before the mathematics lesson. Physical activity during the hour before a mathematics lesson was assessed as the acute effects of physical activity tend to last one hour.[16]

The period before mathematics was determined by the class timetable. Possible periods before mathematics included 'before school', recess breaks, lunch breaks, classroom lessons, and Physical Education lessons. Recess breaks ranged from 20 min to 30 min and lunch breaks ranged from 40 min to 60 min.

Students completed the adapted School Engagement Measure[17] at the end of the mathematics lesson to assess levels of behavioural, emotional, and cognitive mathematics engagement in that particular lesson (rather than usual engagement). The questionnaire was divided into three subscales designed to measure behavioural (e.g., "Today, I followed the rules during the maths lesson"), cognitive (e.g., "Today, if I didn't know what a maths problem meant, I did something to figure it out"), and emotional engagement (e.g., "Today, I was interested by the work in the maths lesson").

Students indicated their age and sex, and responded to an adapted version of the Family Affluence Scale II to assess family level socioeconomic status.[18]

The relationship between physical activity and its outcomes tends to be complicated. e.g., linear or quadratic.[19] In order to capture the potentially complicated relationship between physical activity and school engagement, we tested for linear and quadratic relationships using orthogonal polynomials.

The categories of physical activity during the hour before mathematics were 0–10 min, 10–20 min, 20–30 min, and >30 min of activity. Three systematic reviews indicated that 10–20 min bouts of physical activity appear to be most beneficial for attention scores,[20] 20–30 min bouts appear to be most beneficial for state mood,[21] and bouts greater than 20 min appear to be most beneficial for cognitive performance.[22] Therefore, we tested these two categories of physical activity, as well as less than 10 min and greater than 30 min.

We employed multilevel regression models to determine whether physical activity predicted mathematics engagement during the mathematics lesson regardless of the presence or absence of a recess or lunch break before the classroom lesson (e.g., recess and lunch breaks). The models consisted of repeated measures of physical activity and school engagement at three timepoints at level one, students at level two, classes at level three, and schools at level four. Model 1 examined the nature of the relationship between different activity intensities (sedentary behaviour, light, MVPA, moderate, or vigorous intensity) and mathematics engagement. Model 2 examined whether having a recess or lunch break before a classroom lesson predicted mathematics engagement in the following lesson. In Model 3 both activity and having a recess or lunch break before a classroom lesson were included as explanatory variables. The final model (Model 4) controlled for all covariates.

The percentage of missing data for covariates ranged from 3% (socioeconomic status) to 5% (age) and resulted from participants missing items and/or absenteeism. For participants who were missing one or more covariates we assigned imputed values using multiple imputation. We created five imputed datasets and combined the results to obtain the final estimates and standard errors of the linear mixed effects models.

Of the 2194 students recruited, 1202 provided physical activity and engagement data from at least one time point. This included 826 students at Time 1 ($n = 449$ boys and $n = 376$ girls), 673 students at Time 2 ($n = 358$ boys and $n = 315$ girls), and 520 students at Time 3 ($n = 277$ boys and $n = 243$ girls). The most common reason for students not providing data at each timepoint was that they did not wear the accelerometer on the day that we measured physical activity and school engagement because they forgot to bring the device to school. Power analysis indicated that a sample size of 899 would be large enough to detect an effect size of .28 with 80% power and an alpha of 5%. This calculation was based on result of a meta-analysis that reported a small positive relationship between physical activity and school engagement.[5]

3. Results

Descriptive statistics are displayed in Table 1. During the hour before mathematics, adolescents spent majority of time sedentary (mean = 48.17 min) and a small amount of time participating in moderate (mean = 2.81 min) or vigorous activity (mean = 1.66 min).

Results of linear mixed models (Model 4) examining the relationship between categories of vigorous and moderate intensity activity and mathematics engagement can be viewed in Tables 2 and 3 , respectively. Complete results pertaining to linear mixed models for the relationship between physical activity and mathematics engagement can be viewed in the Supplementary material (see Supplementary material A, B, C, and D for results of Models 1, 2, 3, and 4, respectively).

There were no linear or quadratic relationships between MVPA and overall, behavioural, emotional, or cognitive mathematics engagement. Moderate-intensity activity had a positive linear relationship with cognitive mathematics engagement, as for every 1% increase in activity, there was a .40 unit increase in the cognitive engagement scale ($\beta = .40$, $p < .05$). However moderate-intensity activity had no significant relationship with overall, behavioural, or emotional mathematics engagement. Neither light- nor vigorous-intensity activity had a positive relationship with overall, behavioural, emotional, or cognitive mathematics engagement.

Recess breaks had a negative relationship with overall, behavioural, emotional, and cognitive mathematics engagement ($\beta = -.18$, $p < .01$, $\beta = -.19$, $p < .01$, $\beta = -.13$, $p = .03$, and $\beta = -.13$, $p = .04$, respectively) indicating that students were less engaged in lessons after recess breaks, compared to lessons following other classroom lessons, PE lessons, lunch breaks, or the first lesson of the day. Similarly, lunch breaks had a negative relationship with cognitive mathematics engagement ($\beta = -.20$, $p < .01$), but no relationship with overall, behavioural, and emotional mathematics engagement.

4. Discussion

The primary objective of this study was to determine whether physical activity had a positive relationship with school engagement. Overall, the results suggest that moderate-intensity activity had a positive linear relationship with cognitive engagement regardless of the presence or absence of a recess or lunch break before the classroom lesson. The secondary objective of this study was to investigate potential mechanisms underlying the relationship between physical activity and school engagement. As vigorous-intensity activity was not the most beneficial intensity of activity for school engagement it is unlikely that BDNF is an underlying mechanism. Furthermore, as recess breaks had a negative relationship with school engagement it seems the novelty-arousal theory also does not explain this relationship.

Moderate-intensity activity had a positive linear relationship with cognitive engagement, but not with overall, behavioural, or emotional engagement. This suggests that moderate-intensity activity is positively associated with investment in learning and strategic learning skills, such as problem solving, but not with active participation in classroom activities and enjoyment of class-

Table 1
Descriptive statistics of physical activity during the hour before mathematics and mathematics engagement (N = 2194).

	Overall M (SD)	Classroom lesson M (SD)	Recess break M (SD)	Lunch break M (SD)	Physical Education M (SD)	Before school M (SD)	Class ICC	School ICC	Alpha coefficient
Sedentary minutes	48.17 (7.84)	50.61 (7.15)	48.34 (8.13)	45.63 (7.43)	49.47 (6.36)	44.99 (7.80)	.09	.04	
Light intensity minutes	7.23 (4.46)	6.01 (4.06)	7.48 (5.02)	9.03 (4.38)	6.55 (3.65)	7.91 (4.06)	.08	.04	
Moderate intensity minutes	2.81 (2.84)	1.96 (2.28)	2.61 (2.16)	3.31 (2.06)	2.28 (1.74)	4.46 (4.25)	.06	.02	
Vigorous intensity minutes	1.66 (2.45)	1.08 (1.94)	1.57 (2.01)	2.03 (2.20)	1.70 (1.89)	2.64 (3.59)	.05	.02	
Moderate-to-vigorous intensity minutes	4.47 (4.53)	3.04 (3.68)	4.18 (3.84)	5.34 (3.86)	3.98 (3.17)	7.10 (6.14)	.07	.02	
Behavioural engagement	4.05 (.73)	4.08 (.72)	3.96 (.76)	4.06 (.69)	4.12 (.52)	4.08 (.80)	.07	.02	.75
Emotional engagement	3.08 (1.13)	3.09 (1.11)	3.04 (1.13)	3.13 (1.14)	3.13 (1.05)	3.07 (1.18)	.08	.02	.91
Cognitive engagement	3.35 (1.13)	3.42 (1.14)	3.27 (1.10)	3.24 (1.13)	3.65 (1.19)	3.34 (1.11)	.05	.03	.85
Overall school engagement	3.50 (.81)	3.53 (.81)	3.42 (.82)	3.47 (.79)	3.63 (.70)	3.50 (.84)	.08	.03	.91

ICC = Intraclass correlation coefficient.

Table 2
The effect of vigorous, moderate, and light physical activity during the hour before mathematics on mathematics engagement (N = 2194)

	Overall engagement Estimate (SE)	Behavioural engagement Estimate (SE)	Emotional engagement Estimate (SE)	Cognitive engagement Estimate (SE)
VPA				
Intercept	.12 (.55)	−1.33* (.56)	.10 (.55)	1.02 (.55)
VPA during the hour before mathematics				
Linear	.04 (.26)	.13 (.26)	−.09 (.26)	.02 (.26)
Quadratic	.03 (.26)	−.13 (.26)	.16 (.26)	.05 (.26)
Period before mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess break	−.18** (.06)	−.20** (.07)	−.13* (.06)	−.13* (.06)
Lunch break	−.07 (.07)	.02 (.07)	.06 (.07)	−.21** (.07)
Physical Education	−.04 (.12)	.02 (.13)	−.05 (.13)	−.03 (.13)
Before school	−.08 (.06)	−.01 (.07)	−.06 (.06)	−.10 (.06)
Age	−.03 (.03)	.09** (.03)	−.03 (.03)	−.10** (.03)
Sex (male = 1)	.01 (.05)	−.14** (.05)	.12* (.05)	−.01 (.05)
SES- family level	.03* (.01)	.04** (.01)	.02 (.01)	.02 (.01)
MPA				
Intercept	−.17 (.52)	−1.80** (.53)	−.20 (.52)	1.00 (.52)
MPA during the hour before mathematics				
Linear	.31 (.18)	.24 (.19)	.11 (.19)	.40* (.19)
Quadratic	−.15 (.19)	−.09 (.20)	.06 (.20)	−.33 (.20)
Period before mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess break	−.18** (.06)	−.20** (.07)	−.13* (.06)	−.13* (.06)
Lunch break	−.07 (.07)	.03 (.07)	.06 (.07)	−.21** (.07)
Physical Education	−.04 (.12)	.01 (.13)	−.05 (.13)	−.03 (.13)
Before school	−.07 (.06)	.00 (.07)	−.05 (.06)	−.09 (.06)
Age	−.03 (.03)	.09** (.03)	−.03 (.03)	−.10** (.03)
Sex (male = 1)	.01 (.05)	−.13** (.05)	.12* (.05)	−.01 (.05)
SES- family level	.03* (.01)	.04** (.01)	.02 (.01)	.02 (.01)
LPA				
Intercept	.24 (.42)	−1.46** (.43)	.42 (.42)	1.04* (.42)
LPA during the hour before mathematics				
Linear	.03 (.08)	−.07 (.09)	.06 (.08)	.04 (.09)
Quadratic	.00 (.09)	.13 (.09)	−.10 (.09)	.03 (.09)
Period before mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess break	−.18** (.06)	−.19** (.07)	−.14* (.06)	−.12* (.06)
Lunch break	−.06 (.07)	.04 (.08)	.04 (.07)	−.19* (.07)
Physical Education	−.04 (.12)	.02 (.13)	−.06 (.13)	−.02 (.13)
Before school	−.08 (.06)	.00 (.07)	−.07 (.06)	−.09 (.06)
Age	−.03 (.03)	.09** (.03)	−.03 (.03)	−.10** (.03)
Sex (male = 1)	.01 (.05)	−.13** (.05)	.11* (.05)	−.01 (.05)
SES- family level	.02* (.01)	.04** (.01)	.02 (.01)	.02 (.01)

Note: SE = standard error; VPA = vigorous physical activity. MPA = moderate physical activity. LPA = light physical activity.
* $p < .05$.
** $p = < .01$.

room lessons. Although the dimensions of school engagement are interrelated, they are separate constructs and it is possible that different types of physical activity are beneficial for different dimensions of school engagement. The majority of previous studies have found that recess or lunch breaks from classroom lessons improved behavioural engagement e.g., Refs. 6,7, whereas, integrating physical activity into classroom lessons improved emotional engagement e.g., Ref. 23. Further research is needed that examines whether different types of physical activity have different relationships with different dimensions of school engagement.

It is improbable that BDNF or the novelty-arousal theory were mechanisms underlying the relationship between physical activity and school engagement. While vigorous-intensity activity was not the most beneficial intensity of activity for school engagement, it is still crucial for a number of physical and mental health benefits.[24] Although students demonstrated the lowest levels of school engagement after recess breaks, these breaks are still important as they provide a break from the rigours of academic challenges and contribute to cognitive, social, emotional, and physical functioning.[25] The previous studies, all of which used subjective measures of physical activity, have found conflicting results regarding physical activity during recess breaks and school engagement.[5] One theory for the possible negative relationship is that physical activity contributes to physiological arousal which interferes with concentration.[26] However, as the duration and intensity of physical activity during recess did not differ from the other types of breaks, this unlikely explains the low levels of engagement found in our study. Future research is needed that explores possible mechanisms for the low levels of school engagement immediately following recess breaks, but not following other breaks (e.g., PE lessons). An alternate mechanism to BDNF or the novelty-arousal theory could be positive affect or self-esteem.[27] Research suggests that physical activity has a positive influence on positive affect and self-esteem, which could lead to broadened cognitive and behavioural coping strategies, such as problem solving.[27] Future research is needed that examines whether positive affect or self-esteem is the mechanism underlying the relationship.

While it appears that only bouts of moderate-intensity activity have a positive relationship with school engagement in a subsequent lesson, it is possible that regular MVPA has a positive long-term relationship with school engagement. A number of studies have found that regular, subjectively-measured MVPA has a positive relationship with school engagement e.g., Ref. 28. Regular MVPA changes the structure and function of the brain by increasing the growth of nerve cells in the hippocampus, development of nerve connections, density of neural network, and brain tissue volume.[29] These physiological changes are linked to increased attention, information processing, coping strategies, and positive affect. Thus, regular MVPA could have a positive long-term relationship with school engagement. Future research is needed that examines the long-term relationship between regular accelerometer-assessed MVPA and school engagement.

This study has a number of strengths. Firstly, to the authors' knowledge, this is the first study to examine whether physical activity had a positive relationship with school engagement regardless of the presence or absence of a recess or lunch break before the classroom lesson. Secondly, this is the first study to use objective measures of physical activity to examine the relationship between physical activity and school engagement. Objective measures of physical activity are not influenced by social desirability and do not rely on youths' abilities to recall behaviour and accurately estimate the frequency and intensity of physical activity.

There are also some limitations to this study. Firstly, although physical activity was measured using an objective method, the low levels of MVPA (M = 4.47 min, SD = 4.53) during the hour before mathematics made it difficult to detect whether physical activity had a positive relationship with school engagement. At each time point, only 1% of students participated in more than 20 min of physical activity during the hour before the mathematics lesson. Secondly, although we determined the type of period before the mathematics lesson and the amount and intensity of PA during this period, we did not examine the specific activities that each student participated in. For example, we identified that students had a lunch break before the mathematics lesson; however, we did not identify what activities students participated in (the student could played basketball or been in detention). Future research is needed that examines whether the type of activities before the mathematics lesson influence mathematics engagement in the following lesson. Thirdly, while the measure of school engagement produced internally consistent scores, it is a subjective measure, which could be subject to social desirability. However, observational measures of school engagement also have problems, as they provide limited information on the quality of effort, participation, or thinking.[30] There are no observational measues of emotional engagement as it is an internal construct. Future research is needed that combines subjective and objective measures of school engagement to assess the relationship between physical activity and school engagement. Fourthly, despite accelerometers providing a measure of the intensity of physical activity, there are also limitations. Accelerometers do not have the ability to measure swimming, cycling, or many strength training activities.[14]

Despite the limitations of this study, there are also important implications. The results suggest that moderate-intensity activity is beneficial for cognitive mathematics engagement. Providing opportunities for moderate-intensity activity during the hour before a mathematics lesson could improve cognitive mathematics engagement in the following mathematics lesson. If policy makers and educators use this evidence and provide more opportunities for moderate-intensity activity during the hour before a mathematics lesson, young people could also receive a number of physical and mental health benefits.[24]

Students' levels of school engagement are generally lowest following recess breaks. As such, educators need to be aware of these low levels after recess breaks when constructing school subject timetables. Teachers also need to be aware that they might have trouble engaging students after recess breaks. Thus, teachers could plan the weekly lessons so that the most engaging lessons take place in the period after a recess break. This knowledge and lesson planning could reduce the need for teachers to manage troublesome classroom behaviour and punish students, thus improving the student-teacher relationship and subsequently, improving school engagement.

5. Conclusion

Results from this study suggest that promoting moderate-intensity activity could provide benefits for cognitive mathematics engagement. Educators should be aware that students tend to demonstrate the lowest levels of school engagement after recess breaks.

Practical implications

- Moderate intensity activity before a mathematics lesson was beneficial for cognitive mathematics engagement in the following mathematics lesson.
- Physical activity interventions should consider the intensity of physical activity that they promote. Moderate intensity activity appears to be the most beneficial intensity for mathematics engagement.
- Educators and teachers need to be aware that levels of school engagement are generally lowest following recess breaks.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jsams.2017.07.002.

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