The relationship between physical activity and educational outcomes in adolescents

Submitted by

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Statement of Sources

This thesis contains no material published elsewhere or extracted in whole or in part from a thesis by which I have qualified for or been awarded another degree or diploma. No parts of this thesis have been submitted towards the award of any other degree or diploma in any other tertiary institution. No other person's work has been used without due acknowledgment in the main text of the thesis. All research procedures reported in the thesis received the approval of the relevant Ethics/Safety Committees (where required).

Katherine Owen

Date

Statement of Appreciation

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Abstract

Introduction: Physical activity could promote students' school engagement (i.e., level of active participation in school activities, positive reactions to school, and investment in school) and academic performance. Studies have found that single bouts of physical activity and regular physical activity promote educational outcomes, including school engagement and academic performance. However, as these studies have not objectively measured single bouts of physical activity or regular physical activity across multiple time points, there is uncertainty as to whether physical activity is beneficial. Therefore, the primary objective of this thesis was to examine the relationship between objectively measured physical activity and school engagement. The secondary objective was to examine the relationship between objectively measured physical activity and academic performance.

Methods: The study designs utilised included a systematic review and meta-analysis (Study 1), a cross-sectional study (Study 2), and a longitudinal study (Study 3). The meta-analysis combined the results from 38 studies using a structural equation modelling approach to meta-analysis. The cross-sectional and longitudinal studies recruited a cohort of 2,194 Australian adolescents (M = 13.40 years, SD = .73). In the cross-sectional study, adolescents wore an accelerometer during the hour before a mathatmatics lesson to measure physical activity, and completed a questionnaire after the mathematics lesson to assess mathematics engagement. In the longitudinal study, adolescents wore an accelerometer for seven consecutive days to measure regular physical activity, completed a questionnaire to assess usual mathematics engagement, and participated in a standardised mathematics test to measure academic performance.

Results: The systematic review and meta-analysis combined evidence from 38 studies addressing the relationship between physical activity and school engagement and concluded that promoting physical activity could benefit school engagement. This study also uncovered two major limitations in the existing literature that would direct subsequent studies. The cross-sectional study found that a single bout of moderate-intensity activity could yield benefits for cognitive mathematics engagement. In contrast, the longitudinal study found that regular total physical activity did not improve mathematics engagement, but was nevertheless beneficial for academic performance.

Conclusion: Overall, physical activity could improve school engagement and academic performance. Specifically, single bouts of physical activity could enhance school engagement, while regular total physical activity could improve academic performance.

List of Abbreviations

BMI…………Body mass index

FIML………..Full information maximum likelihood

MET………..Metabolic equivalent

MVPA ……...Moderate-to-vigorous physical activity

NAPLAN...…National Assessment Program- Literacy and Numeracy

PE…………..Physical Education

SEIFA………Socio-Economic Index for Areas

SES…………Socioeconomic status

Chapter 1: Introduction

Overview

The educational benefits of physical activity are not well understood. There is some evidence that physical activity could enhance students' school engagement (that is, their level of participation in school activities, reactions to school, and investment in learning; Fredricks, Blumenfeld, & Paris, 2004) and improve their academic performance (e.g., Singh, Uijtdewilligen, Twisk, Mechelen, & Chinapaw, 2012a).

Some studies have found that single bouts of physical activity promote school engagement. However, as these studies have not objectively measured physical activity, it is unclear whether the physical activity itself is beneficial for school engagement. It is possible that a break from the classroom lesson is sufficient to improve engagement, regardless of any physical activity during the break.

Other cross-sectional studies suggest that the accumulation of single bouts of physical activity over time, that is, regular physical activity, is associated with higher levels of both school engagement and academic performance. However, these studies have not examined whether changes in physical activity influence changes in school engagement or academic performance. Additionally, these studies have not objectively measured physical activity.

The primary objective of this thesis, therefore, was to examine the relationship between objectively measured physical activity and school engagement. The secondary objective was to examine the relationship between objectively measured physical activity and academic performance.

School engagement

School engagement is a critical factor underpinning academic performance (Perry, Liu, & Pabian, 2010; Shernoff, 2010; Wang, M. & Holcombe, 2010) and the successful development of youth in society (Deil-Amen & Lopez Turley, 2007; Hauser, 2010). Students who are actively engaged in school are more likely to perform well academically. They are better prepared for transition into post-school education and occupations, and to achieve economic success (Abbott-Chapman et al., 2014; Suldo, Riley, & Shaffer, 2006). Recent research suggests that school engagement influences educational and occupational success 20 years later in life, over and above academic achievement (Abbott-Chapman et al., 2014). Students who are not engaged in school are more likely to perform poorly academically, drop out of school, become unemployed, and place a burden on the economy (Archambault, Janosz, Morizot, & Pagani, 2009; Glennie, Bonneau, Vandellen, & Dodge, 2012). Promoting school engagement has, therefore, been a priority for parents, policy makers, and society (Department of Education and Early Childhood Development, 2010).

Since the area's emergence as a research priority, three major school engagement constructs have emerged within the literature (Appleton, Christenson, & Furlong, 2008; Fredricks et al., 2004). The first construct arose from dropout prevention theory, which suggested that school engagement was the key to understanding why students drop out of school (Finn, 1989). Second, a more general school reform construct emerged that aimed at understanding the behaviour and achievement of all students (Fredricks et al., 2004; National Research Council and the Institute of Medicine, 2004; Reschly & Christenson, 2012). Third, and most recently, Appleton, Christenson, Kim, and Reschly (2006) built on the school reform construct by taking a motivational perspective and distinguishing between school engagement and motivation – viewing motivation as the intention to act, and engagement as the action.

Finn (1989) originally proposed the participation-identification model, which suggested that school engagement was the key to understanding school completion and dropout. According to this model, school completion results from participation in school activities (behavioural engagement) and school identification (emotional engagement). In contrast, drop out results from non-participation in school activities (behavioural disengagement) and emotional withdrawal (emotional disengagement).

A growing body of evidence was forthcoming that supported the participation-identification model (e.g., Archambault, Janosz, Fallu, & Pagani, 2009; Christenson & Reschly, 2010; Henry, Knight, & Thornberry, 2012; Janosz, Archambault, Morizot, & Pagani, 2008; Reschly & Christenson, 2006); in the meantime, however, a more general interest in school engagement emerged, aimed at a more comprehensive understanding of the behaviour and achievement of all students (Fredricks et al., 2004; National Research Council and the Institute of Medicine, 2004). Similar to the participation-identification model, Fredricks et al. (2004) conceptualised school engagement as a multidimensional construct including behaviour, emotions, and additionally, cognition. Behavioural engagement involves active participation in school activities (operationalised as classroom behaviour, time on-task, and concentration). Emotional engagement encompasses positive reactions to school (e.g., enjoyment and interest). Differing from the participation-identification model, Fredricks et al. included cognitive engagement, which refers to psychological investment in learning (e.g., motivation, developing strategic learning skills, and problem solving). Many aspects of cognitive engagement parallel those used in the intrinsic motivation literature (such as preference for challenging tasks or autonomous work styles). Fredricks et al., therefore, included motivation as an aspect of cognitive engagement, and have been the first to combine these previously separate lines of research: motivation and school engagement. Fredricks et al. view the inclusion of a wide range of constructs (e.g., motivation) as a strength of their construct, but also a weakness, as some aspects of school engagement lack clear differentiation from concepts in earlier literatures.

Appleton et al. (2006) built on Fredricks' et al. (2004) three-dimensional construct of school engagement by distinguishing between school engagement and motivation. Fredricks et al. (2004) viewed motivation as a form of cognitive engagement, whereas Appleton et al. (2008) suggested that motivation and school engagement are related but distinct: motivation is the intention, and engagement the action (Appleton et al., 2008; Reschly & Christenson, 2012). Nevertheless, definitions of cognitive engagement within this line of research are still characterised by motivational constructs, such as goal setting and perceived relevance to the future. The definitions of motivation and school engagement (specifically cognitive engagement) and the relationships between them are not yet fully understood (Appleton et al., 2008; Appleton et al., 2006; Fredricks et al., 2004; Reschly, 2010).

A difference between the general school reform construct and the motivation-perspective construct concerns whether school engagement and disengagement are situated on a single continuum (motivation-perspective construct) or two separate continua (general school reform construct). While examining their school engagement measure, Skinner, E., Kindermann, and Furrer (2009) compared a one-factor model (school engagement) with a two-factor model (school engagement and school disengagement). The model that distinguished between school engagement and school disengagement fit the data significantly better than the one-factor model. Further, Skinner, E. et al. (2009) reported negative correlations between student-rated behavioural engagement and disengagement (r = -.55) and between emotional engagement and disengagement (r = -.60). As these correlations did not approach 1.0, they concluded that school engagement and disengagement are separate though related constructs. More recently, Martin, Anderson, Bobis, Way, and Vellar (2012) argued that it is important to assess both school engagement and disengagement when examining academic processes such as learning and academic achievement. Although school engagement and disengagement are correlated, class-level factors explain unique variance in school engagement and disengagement. Class-level factors explained 4% of the variance in school engagement and 8% of variance in disengagement (Martin et al., 2012). As school engagement and disengagement account for unique variance, they should be examined as separate but related constructs. Further, Wang, M. and Peck (2013) found that it is possible for students to be actively engaged on one dimension (e.g., on task or paying attention), while being disengaged on another (e.g., feeling bored or frustrated). Based on this evidence, this thesis focuses on the general school reform construct of school engagement, as it views school engagement and disengagement as two separate constructs.

Risk factors for low school engagement

Adolescence and transition. Generally, school engagement declines with age; so a student's engagement typically reaches its lowest level in adolescence (Archambault, Janosz, Morizot, et al., 2009; Darr, 2012; Eccles et al., 1993; Janosz et al., 2008; Marks, 2000; Wylie & Hodgen, 2012). However, there is cross-national variation in the exact age at which the steepest decline occurs, perhaps due to the different ages of transition from one level of schooling to another. Darr (2012) compared overall levels of school engagement in a nationally representative sample of 8,500 New Zealand students in years

7–10. The steepest decline occurred between year 8 and year 9, which is when most New Zealand students transition from primary to secondary school. Similarly, Archambault, Janosz, Morizot, et al. (2009) examined 13,330 students in Canada aged 12–16 years and found that the steepest decline in school engagement occurred at 14–16 years of age, coinciding with the transition from middle school to high school. Yazzie-Mintz (2009) found that Unites States students from grade 9 to grade 11 showed little variation in school engagement levels, perhaps because there is no school transition in that period. Combined evidence, therefore, suggests that the steepest decline occurs during school transition periods, and that this could be due to difficulties and challenges faced in moving to a new school environment (Martin, 2009; Wigfield & Tonks, 2002).

Low socioeconomic status. Youth living in areas of low socioeconomic status (SES) tend to be less engaged in school and more likely to drop out, compared to youth living in higher SES areas (Fullarton, 2002; Ladd & Dinella, 2009; Marks, 2000; Wang, M. & Eccles, 2012). Those in low SES areas usually have less access to educational resources, such as intellectually stimulating toys and books (Sirin, 2005; Walker, Greenwood, Hart, & Carta, 1994). They also receive less encouragement and support for educational accomplishments (Hoover-Dempsey et al., 2005; Malecki & Demaray, 2006). Educational resources and support are both critical factors in educational development, school engagement, and school completion.

Given the low levels of school engagement during early adolescence and in youth from low SES areas (Martin, 2009; Reschly, Huebner, Appleton, & Antaramian, 2008), there is a need to examine the antecedents of school engagement, especially modifiable antecedents that can lead to improvement. Factors outside of the school environment that can influence school engagement are relatively fixed, and include the neighbourhood and family (Fullarton, 2002; Ladd & Dinella, 2009; Marks, 2000; Wang, M. & Eccles, 2012). Within a school, relatively non-modifiable antecedents include the size and structure of the school; and modifiable antecedents include the fairness of school rules and the strength of school spirit (Crosnoe, Johnson, & Elder, 2004; Leithwood & Jantzi, 2009; Libbey, 2009; Sullivan, Joshi, & Leonard, 2010). Classes are, of course, nested within schools, and class-level antecedents tend to be modifiable. For example, teacher support, autonomy support, class climate, task characteristics, peers, and ability grouping are relatively modifiable to improve school engagement (Buhs, Ladd, & Herald, 2006; Carbonaro, 2005; Jang, Reeve, & Deci, 2010; Lam, Wong, Yang, & Liu, 2012). Students in turn are nested within classes. Non-modifiable student-level antecedents include age, gender, and ethnicity; while modifiable antecedents include the perception of ability (manifest in self-concept and self-efficacy), psychological needs satisfaction (in competence, autonomy, and relatedness), and health behaviours (sleep, nutrition, and physical activity). Physical activity could be a modifiable antecedent, with beneficial effects both directly on school engagement and extending further to general health and wellbeing.

Physical activity

Physical activity has been defined as “any bodily movement produced by skeletal muscles that requires energy expenditure” (Bonomi & Westerterp, 2011; World Health Organisation, 2010, p. 53). Physical activity is commonly classified by intensity, using metabolic equivalents (METs) as a quantitative reference. The MET value refers to the rate of energy expended during physical activity, and is expressed as a multiple of the resting metabolic rate. Although an adult value for moderate-to-vigorous physical activity (MVPA) is defined as $\geq$ 3 METs (Evenson, Catellier, Gill, Ondrak, & McMurray, 2008; Freedson, Pober, & Janz, 2005; Puyau, Adolph, Vohra, & Butte, 2002), evidence suggests that children and adolescents expend approximately 4 METs during brisk walking (a key indicator of moderate physical activity; Treuth et al., 2004; Trost, Loprinzi, Moore, & Pfeiffer, 2011). Thus, MVPA will be defined as ≥ 4 METs in this thesis. Generally, MVPA is the intensity of physical activity at which most health benefits can be acquired (Lee & Paffenbarger, 2000; Strong et al., 2005). Global guidelines have recommended that children and adolescents accumulate 60 minutes of MVPA each day, to acquire acute and long-term health benefits (Department of Health and Ageing, 2008; World Health Organisation, 2010).

Adequate physical activity has short- and long-term benefits for children and adolescents. Short-term effects may last up to one hour following the bout of activity (Hillman et al., 2009; Joyce, Graydon, McMorris, & Davranche, 2009). Bouts of physical activity have an immediate positive effect on energy expenditure (Gutin, Yin, Humphries, & Barbeau, 2005), mood (Kirkcaldy, Shephard, & Siefen, 2002), cognitive function (Sibley & Etnier, 2003), concentration (Budde, Voelcker-Rehage, Pietrabyk-Kendziorra, Ribeiro, & Tidow, 2008; Etnier et al., 1997), and time on-task during academic lessons (Bartholomew & Jowers, 2011). Accumulation of single bouts of physical activity over time is known as regular physical activity, and can lead to long-term health benefits (Murphy, Blair, & Murtagh, 2009). Regular physical activity reduces the risk for cardiovascular disease, obesity, cancer, and type II diabetes (Australian Institute of Health and Welfare, 2008). It also has a positive relationship with mental health (Biddle & Asare, 2011), can induce changes in brain regions critical to memory and learning (Best, 2010), and may be positively associated with academic performance (Singh et al., 2012a).

Studies suggest that many children and adolescents do not participate in sufficient levels of physical activity and, therefore, fail to receive the acute and long-term health benefits (Department of Health and Ageing, 2008; Troiano et al., 2008). Approximately 37% of Australian adolescents do not meet the recommended daily MVPA guidelines (Hardy, King, Espinel, Cosgrove, & Bauman, 2010); and the steepest decline in physical activity occurs during early adolescence (i.e., 13–15 years old; Sallis, 2000). There is an evident need for physical activity interventions for the positive health benefits, however, the benefits of physical activity could extend beyond health, into education (e.g., Howie, Beets, & Pate, 2014; Vazou, Gavrilou, Mamalaki, Papanastasiou, & Sioumala, 2012).

Physical activity and school engagement

To promote school engagement, its determinants must first be understood; and one such determinant could be physical activity (e.g., Howie et al., 2014; Vazou et al., 2012).

Single bouts versus regular physical activity. Single bouts of physical activity could be beneficial for school engagement. Some studies have found that these bouts may bring measurable benefits – whether in recess breaks (Jarrett et al., 1998), integrated into classroom lessons (Grieco, Jowers, & Bartholomew, 2009; Vazou et al., 2012), or as breaks during classroom lessons (Howie et al., 2014; Mahar et al., 2006). However, these studies have not objectively measured physical activity. Given that youth generally have trouble recalling the relevant activity and tend to overestimate the frequency and duration (Rzewnicki, Auweele, & Bourdeaudhuij, 2003; Troiano, Gabriel, Welk, Owen, & Sternfeld, 2012), objective measurement of physical activity is needed before a positive relationship with school engagement can be established.

Regular physical activity could also have long-term benefits for school engagement. Some studies have found that regular physical activity during recess breaks (Barros, Silver, & Stein, 2009), lunch breaks (Laberge, Bush, & Chagnon, 2012), physical education (PE) lessons (Dwyer, Blizzard, & Dean, 1996), school programs (Bleeker et al., 2012; Telles, Singh, Bhardwaj, Kumar, & Balkrishna, 2013), and also total physical activity (Feldman, Barnett, Shrier, Rossignol, & Abenhaim, 2003; Leatherdale & Wong, 2008) could be beneficial for school engagement. In contrast, a number of studies have found that high levels of regular total physical activity could be harmful for school engagement, specifically time spent on homework (Atkin, Gorely, Biddle, Marshall, & Cameron, 2008; Lazarou & Soteriades, 2009; Yu, Chan, Cheng, Sung, & Hau, 2006). However, this could simply be because time spent in physical activity competes directly with time available for homework. There is an important limitation in most of these studies, because all but one of them used subjective measures of physical activity. One study has examined the relationship between accelerometer-assessed total physical activity and school engagement. In a relatively small study, involving 199 children (mean age = 8.2 years, SD = .30), Martikainen et al. (2012) reported that students engaging in high levels of regular MVPA were no more likely to display attention problems than students at low levels (OR = 0.8, 95% CI = 0.2, 2.5, $p = .70$). However, this study was a cross-sectional design; so it was not possible to determine whether changes in regular physical activity were associated with changes in school engagement.

Intensity of physical activity. The possible relationship between physical activity (single bouts or regular) and school engagement could differ depending on the intensity of the activity. One study has examined the relationship between light-intensity activity and school engagement, measured as time on-task (Metzler & Williams), and reported a positive relationship. Some research suggests that moderate-intensity activity also has a positive relationship with school engagement (Gibson et al., 2008; Hunter, Abbott, Macdonald, Ziviani, & Cuskelly, 2014; Vazou et al., 2012; Whitt-Glover, Ham, & Yancey, 2011). Similarly, a number of studies have found that MVPA has a positive relationship with school engagement, specifically time on-task (Grieco et al., 2009; Howie et al., 2014), but also on attention (Hoza et al., 2014; Smith et al., 2013). Other investigations have found a positive relationship between vigorous-intensity activity and school engagement, specifically behavioural engagement (Dwyer et al., 1996; Ma, Mare, & Gurd, 2014). In addition, compared to moderate- or low-intensity activity, vigorous-intensity activity appears to be the most beneficial for health outcomes (Swain & Franklin, 2006). However, as no single study has comparerd how different intensities of physical activity influence school engagement, it remains unclear which intensity of physical activity is most beneficial for school engagement.

Theoretical perspectives

Several theories have been proposed to explain the effect physical activity may have on school engagement.

Novelty and arousal. The novelty-arousal theory suggests that a shift in normal routine, such as a mere break, by itself improves interest and attention (Berlyne, 1966; Ellis, 1984). The theory also posits that adolescents who are confined for prolonged periods are more likely to become bored, fidgety, or restless, and to experience reduced concentration. (e.g., Jarrett et al., 1998; Mahar et al., 2006). Studies have found that providing breaks between and during classroom lessons, with opportunities for physical activity, increased subsequent time on-task during the following classroom lesson (Bartholomew & Jowers, 2011; Donnelly, J. et al., 2013; Grieco et al., 2009; Metzler & Williams; Riley, Morgan, & Lubans, 2012). Physical activity may provide a change in pace, or a definite break, from classroom lessons, and this by itself may increase interest and attention (emotional and behavioural engagement, respectively).

Neurological changes. Exercise-induced neurological changes are another possible mechanism to explain the association between physical activity and school engagement (Sattelmair & Ratey, 2009). Evidence suggests that physical activity induces acute and chronic changes in the hippocampus, the critical brain region for memory and learning (Best, 2010; Holmes, 2006; Van Praag, Shubert, Zhao, & Gage, 2005). These changes are mediated by an increase in several growth factors, including brain-derived neurotrophic factor (BDNF), essential for the development of new neurons (Best, 2010; Hillman, Erickson, & Kramer, 2008). Studies have reported that physical activity increases BDNF levels, and therefore improves acquisition and retention of learning in adults (Ferris, Williams, & Shen, 2007; Van der Borght, Havekes, Bos, Eggen, & Van der Zee, 2007; Vaynman, Ying, & Gomez-Pinilla, 2003). Increases in students' BDNF levels may explain how physical activity improves school engagement.

Contextual interference. The theory of contextual interference may also explain how physical activity influences school engagement (Best, 2010). It suggests that when students participate in physical activity through games or complex motor skills they must develop an action plan, monitoring and modifying the plan as tasks continually change (Carey, Bhatt, & Nagpal, 2005). It is likely that the processing of information is effortful and complex, leading to increased cognitive function and learning (Best, 2010). A student playing basketball may need to execute a bounce pass in a particular situation, but a lob in another. The required move is rarely predetermined or repeated; instead, the student must evaluate a number of factors simultaneously and decide accordingly. Budde et al. (2008) evaluated the contextual interference theory by incorporating 10 minutes of coordinative exercises (complex motor skills) into adolescents' PE lessons. The experimental group showed significant improvement in attention and concentration scores (Brickenkamp, 1962), compared to the control group ($t(96) = -3.85$, $p < .01$, $\omega 2 = .12$). Physical activity accumulated through games or application of complex motor skills may therefore explain increases in school engagement.

Positive affect. Extensive research suggests that physical activity is associated with higher levels of positive affect, specifically positive emotions and mood (Biddle & Asare, 2011; Ekkekakis, Hall, & Petruzzello, 2005; Gage et al., 2014; Penedo & Dahn, 2005; Reschly et al., 2008). The broaden-and-build theory suggests that positive emotions lead to broadened thoughts and behaviours, and facilitate more adaptive response, such as problem solving and seeking assistance (Ekkekakis et al., 2005; Fredrickson, 1998; Reschly et al., 2008). So positive affect may well be a mechanism by which physical activity leads to increases in school engagement.

Academic performance

Academic performance is important for students' future wellbeing and the strength of the national economy (Department of Education, 2013), making it a priority area for governments in Australia (Department of Education, 2013) and internationally (Resnick, 2010). This importance was highlighted by the introduction of a National Assessment Program – Literacy and Numeracy (NAPLAN; Australian Curriculum, 2012). Each year in May, all Australian students in years 3, 5, 7, and 9 complete standardised tests covering reading, writing, spelling, grammar and punctuation, and numeracy. Policy makers, researchers, and even parents treat academic performance as a major priority, and actively explore ways to improve it.

Physical activity could have a positive relationship with academic performance. Four recent systematic reviews have synthesised evidence concerning the relationship between physical activity and academic performance (Castelli et al., 2014; Lees &

Hopkins, 2013; Martin, Saunders, Shenkin, & Sproule, 2014; Singh et al., 2012a). These reviews included a total of 32 studies, and reported an overall positive association. Castelli et al. (2014) conducted a systematic review and meta-analysis of 20 experimental studies and found that children and adolescents who participated in physical activity significantly improved academic achievement (d = .38, p < .05). In light of the high level of heterogeneity between studies with respect to measurement, study sample, and study designs, the other three systematic reviews did not conduct meta-analyses. Singh et al. (2012a), in a systematic review of 14 studies, found evidence for a positive prospective relationship between physical activity and academic performance in children and adolescents, especially among the highest quality studies (i.e., those with low risk of bias). Lees and Hopkins (2013) examined three randomised controlled trials and found that physical activity had a small positive effect on academic performance in children. Similarly, Martin et al. (2014) synthesised six experimental studies (four multicomponent and two physical activity) and reported that physical activity led to small improvements in academic performance in overweight and obese children.

While those four systematic reviews provide substantial evidence that physical activity can improve academic performance, other studies found opposing evidence. Hattie and Clinton (2012) disagreed specifically with Singh et al.'s (2012a) conclusion that there was strong evidence for a positive prospective relationship between physical activity and academic performance. Hattie and Clinton conducted a meta-analysis of evidence from the 14 studies included in Singh et al.'s review and found that physical activity had little or no effect on grade point average (pooled d = .11), mathematics (pooled d = .01), or reading (pooled d = .00). However, these small effect sizes may be attributed to the high level of study heterogeneity, as the studies differed in terms of sample characteristics, intervention contents, outcome variables, follow-up duration, study design, and measurement instruments. Singh, Uijtdewilligen, Twisk, Mechelen, and Chinapaw (2012b) responded to Hattie and Clinton suggesting that the heterogeneity was too large to combine in a meta-analysis. Instead, these authors performed a methodological-quality assessment, with a best-evidence synthesis to summarise the findings of included studies. This method takes into account the methodological quality and consistency of outcomes of the studies. Singh et al. concluded that the highest quality studies (i.e., those with low risk of bias) provide strong evidence for a positive prospective relationship between physical activity and academic performance.

There is a serious limitation to the majority of evidence for the relationship between physical activity and academic performance. Most studies have used subjective measures of physical activity, and these clearly have lower validity than objective measures, as youth generally have trouble recalling details of their activity and tend to overestimate the amount of activity (Rzewnicki et al., 2003; Troiano et al., 2012). There are currently eight cross-sectional studies that have examined the relationship between accelerometer-assessed physical activity and academic performance. Three of these studies found positive associations (Booth, A., 2011; Donnelly, J. E. et al., 2009; Kwak et al., 2009); another three studies found no association (Harrington, 2013; LeBlanc et al., 2012; Syväoja, H. J., Tammelin, Ahonen, Kankaanpää, & Kantomaa, 2014); and the remaining two studies found a negative association (Esteban-Cornejo et al., 2014; Van Dijk, De Groot, Savelberg, Van Acker, & Kirschner, 2014). Evidence for the relationship between accelerometer-assessed physical activity and academic performance is currently limited in terms of study design (which has been cross-sectional) and is inconsistent (between studies that have used subjective and objective physical activity measures).

Research aims

The primary purpose of this thesis was to examine the relationship between objectively measured physical activity and school engagement. The secondary purpose was to examine the relationship between objectively measured physical activity and academic performance.

Research objectives

To achieve the aims of this thesis, a number of more specific objectives were developed:

- Perform a systematic review and conduct meta-analyses of evidence from studies that report information on the relationship between physical activity and school engagement.
- Determine whether objectively measured single bouts of physical activity have a positive relationship with school engagement, over and above the mere presence or absence of a break before the classroom lesson.
- Compare the relationships between different intensity (low, moderate, and vigorous) single bouts of physical activity before a classroom lesson and school engagement in the following classroom lesson.
- Determine whether longitudinal changes in objectively measured regular MVPA are associated with changes in school engagement.
- Determine whether longitudinal changes in objectively measured regular MVPA are associated with changes in academic performance.

Outline of the thesis

This thesis comprises six chapters and incorporates three distinct studies:

- Chapter 1 (the present chapter) establishes the framework for the thesis by outlining its aims and objectives, by highlighting its originality and significance in relation to current knowledge and research, and by showing the links between its component studies.
- Chapter 2 presents the results of a systematic review and meta-analysis of evidence from studies that have assessed the relationship between physical activity and school engagement in youth (Study 1). This study was published in Educational Psychologist (see Appendix K). Owen, K., Parker, P., Van Zenden, B., MacMillan, F., & Lonsdale, C. (2016). Physical activity and school engagement in youth: A systematic review and meta-analysis. *Educational Psychologist, 51*(2), 129-145. doi:10.1080/00461520.2016.1151793.
- Chapter 3 explores the relationship between single bouts of physical activity and school engagement (Study 2). This study has been submitted to the Journal of Science and Medicine in Sport.
- Chapter 4 explores how changes in physical activity are associated with changes in school engagement and academic performance (Study 3). This study has been submitted to Preventive Medicine.
- Chapter 5 integrates the significant findings of this thesis (all studies), identifies the limitations, and highlights future directions.

Significance of the thesis

- Study 1 will fill a gap in the literature by systematically combining evidence from research that has examined the association between physical activity and school engagement in youth. It will also identify further gaps in the literature that are addressed in Studies 2 and 3.
- Study 2 will be the first study to determine whether objectively measured single bouts of physical activity have a positive relationship with school engagement, over and above the presence or absence of a break before the classroom lesson.
- Study 2 will be the first to compare the relationships between single bouts of physical activity at different intensities and school engagement.
- Study 2 will be the first to examine the relationship between physical activity and school engagement using the three-dimensional measure of school engagement.
- Study 3 will be the first to determine whether longitudinal changes in objectively measured MVPA are associated with changes in school engagement.
- Study 3 will be the first to determine whether longitudinal changes in objectively measured MVPA are associated with changes in academic performance.
- Study 3 will be the first to compare the cross-sectional and longitudinal relationships between objectively assessed physical activity and educational outcomes.
- The results of all three studies will provide evidence and guidance to inform future school policy and assist curriculum developers: for short- and long-term promotion of school engagement and toward improved academic performance.

Chapter 2: The Literature Review: Study 1 – Physical activity and school engagement in children and adolescents: A systematic review and meta-analysis

Abstract

Physical activity is associated with a number of health benefits in youth; however, these benefits could extend further than health, into education. The primary objective was to systematically review and combine in meta-analyses evidence concerning the association between physical activity and the dimensions of school engagement, including behaviour (e.g., time on-task), emotions (e.g., lesson enjoyment), and cognition (e.g., self-regulated learning). Results from 38 studies were combined using a structural equation modelling approach to meta-analysis. Overall, physical activity had a small positive association with school engagement (d = .28, 95% CI = .12, .46, I^2 = .86). This association was moderated by study design, with significant associations shown in randomised controlled trials, but not in studies employing other designs. Risk of bias was also a significant effect moderator, as studies with a low risk of bias showed significant associations, but not high risk of bias studies. Altogether, these results suggest that physical activity could improve school engagement.

Introduction

Physical activity is generally promoted for its numerous physical health benefits in youth, including positive effects on cholesterol and blood lipids, blood pressure, metabolic syndrome, bone mineral density, and weight management and obesity (Janssen, I. & LeBlanc, 2010). Physical activity also has a positive effect on mental health in youth (Biddle & Asare, 2011). Further, there is now substantial evidence that physical activity is positively associated with academic performance (e.g., grades and test scores) in youth (Castelli et al., 2014; Lees & Hopkins, 2013; Martin et al., 2014; Singh et al., 2012a). School engagement is a commonly suggested explanatory mechanism for this relationship (e.g., Donnelly, J. & Lambourne, 2011; Singh et al., 2012a). Evidence is increasing to suggest that students who are physically active are more engaged with their classroom lessons (e.g., Gibson et al., 2008; Whitt-Glover et al., 2011; Zan, 2013), and this increased engagement is a possible mechanism by which physical activity could have a positive influence on achievement.

Definitions of school engagement and disengagement vary in the existing literature. These two constructs are most often defined as multidimensional constructs, including behaviour, emotions, and cognition (Fredricks et al., 2004; Reschly & Christenson, 2012; Upadyaya & Salmela-Aro, 2013). Behavioural engagement refers to the range of actions that reflect involvement in school activities and is most commonly measured by students' classroom behaviour, time on-task, and concentration. Concentration is sometimes considered to be an aspect of cognitive engagement; however, when defined as the action of focusing attention, it is more commonly considered an aspect of behavioural engagement (Fredricks et al., 2004). Behavioural disengagement involves reduced effort and involvement in school activities and is often assessed by students' fidgeting in class, time off-task, and inattention. Emotional engagement and disengagement encompass positive and negative affective reactions to school, such as enjoyment and boredom, respectively. Finally, cognitive engagement refers to investment in learning, which involves motivation, strategic learning skills, and problem solving. Conversely, cognitive disengagement refers to a lack of investment in learning, such as a lack of motivation. This tripartite definition provides a model of the dynamically interrelated dimensions of school engagement and disengagement (Fredricks et al., 2004).

While there is a general consensus that school engagement is a multidimensional construct, there are some aspects of the school engagement construct that scholars do not agree on. Fredricks et al. suggest that school engagement is a metaconstruct, and within this metaconstruct, cognitive engagement subsumes motivation. However, what Fredricks et al. call cognitive engagement other scholars call motivation (e.g., Reschly, 2010). Another group of scholars suggests that motivation represents intention and school engagement is the action (e.g., Russell, Ainley, & Frydenberg, 2005). This review used Fredricks et al.'s conceptualisation of school engagement as it is the most comprehensive, and therefore, allowed a broader range of articles to be included in the review.

A difference among scholars' conceptualisations of school engagement and disengagement is whether school engagement and disengagement should be viewed as a single continuum (ranging from high to low) or two separate continua (one for school engagement and one for school disengagement, both ranging from high to low). Most researchers have viewed school engagement and disengagement on a single continuum, with low levels of school engagement representing disengagement. However, more recently, scholars are starting to view school engagement and disengagement as two separate constructs. Wang, M. and Peck (2013) found that it is possible for students to be actively engaged on one dimension (e.g., on task or paying attention), while being disengaged on another (e.g., feeling bored or frustrated). Further, while examining their school engagement measure, Skinner, E. et al. (2009) compared a model with one factor (school engagement) with a two factor model (school engagement and school disengagement). The model that distinguished between school engagement and school disengagement fitted the data significantly better than the one factor model. Skinner, E. et al. (2009) reported negative correlations between student-rated behavioural engagement and disengagement $r = -.55$) and between emotional engagement and disengagement ($r = -.60$). As these correlations did not approach 1.0, they concluded that school engagement and disengagement are separate, but related, constructs.

Based on this evidence, school engagement and disengagement results are presented separately in this review. Indeed, reverse coding school disengagement effect sizes and combining them with school engagement effect sizes (i.e., placing on a continuum), may not provide a valid school engagement pooled effect size. Therefore, viewing school engagement and disengagement as two separate constructs is a more conservative approach. If later research conclusively establishes that school engagement and disengagement do in fact exist on a continuum, the results of this meta-analysis would remain interpretable.

School engagement is one of the most critical factors underpinning academic performance (Perry et al., 2010; Shernoff, 2010; Wang, M. & Holcombe, 2010) and the successful development of youth in society (Deil-Amen & Lopez Turley, 2007; Hauser, 2010). Students who are actively engaged in school are more likely to perform well academically, successfully transition into post-school education, and to achieve occupational and economic success (Abbott-Chapman et al., 2014; Suldo et al., 2006).

Recent research suggests that school engagement influences occupational and educational success 20 years later in life, over and above academic achievement (Abbott-Chapman et al., 2014). Students who are disengaged from school and perform poorly academically are more likely to drop out of school, become unemployed, and place a burden on the economy (Archambault, Janosz, Morizot, et al., 2009; Glennie et al., 2012). Unfortunately, students' overall level of school engagement often declines with age (Anderman & Maehr, 1994; Archambault, Janosz, Morizot, et al., 2009; Darr, 2012; Eccles et al., 1993; Janosz et al., 2008; Marks, 2000; Wylie & Hodgen, 2012). Thus, promoting school engagement is a priority for parents, policy makers, and society (Department of Education and Early Childhood Development, 2010).

In order to promote school engagement, its antecedents must first be understood. One such antecedent is physical activity (e.g., Howie et al., 2014; Vazou et al., 2012). However, before physical activity interventions can be used to promote school engagement, the most effective type of physical activity (physical activity duration, intensity, and intervention type) for improving school engagement needs to be determined. For which groups of youth (children vs. adolescents, before school transition vs. after school transition) physical activity is most beneficial needs to be determined. Once these potential moderators of the association between physical activity and school engagement have been explored, interventions using physical activity can be designed to effectively promote school engagement.

One potential moderator of the association between physical activity and school engagement is the type of the physical activity (i.e., single bout vs. regular). A single bout of physical activity refers to one session of activity, whereas, regular physical activity refers to successive bouts of activity over time. A number of studies have found that a bout of physical activity immediately before a classroom lesson was beneficial for school engagement in the following classroom lesson (e.g., Mahar et al., 2006; Riley, Lubans, Holmes, & Morgan, 2014; Whitt-Glover et al., 2011). Other studies have found that regular physical activity was beneficial for school engagement (e.g., Barros et al., 2009; Yu et al., 2006). However, a number of studies have found that regular physical activity was harmful for school engagement, specifically time spent on homework (Atkin et al., 2008; Lazarou & Soteriades, 2009; Yu et al., 2006). However, this could be due to time spent participating in physical activity taking time away from homework. It appears that a single bout of physical activity immediately before a classroom lesson could be more beneficial for school engagement, compared to regular physical activity; however, this needs to be confirmed.

Different intensities of physical activity also could have different associations with school engagement. Low (e.g., Metzler & Williams), moderate (e.g., Gibson et al., 2008; Hunter et al., 2014), moderate-to-vigorous (e.g., Grieco et al., 2009; Howie et al., 2014), and vigorous (e.g., Dwyer et al., 1996; Ma et al., 2014) intensity activity have been shown to be beneficial for school engagement, although compared to moderate and low intensity activity, vigorous-intensity activity appears to be the most beneficial for physical and mental health outcomes in youth (Janssen, I. & LeBlanc, 2010; Swain & Franklin, 2006). However, it is unclear which intensity of physical activity is most beneficial for school engagement.

The type of intervention to promote school engagement might also moderate the relationship between physical activity and school engagement. For example, physical activity programs have been implemented before school (e.g., Smith et al., 2013) and during school hours (e.g., Hoza et al., 2014). Other physical activity interventions have involved additional or extended recess (e.g., Jarrett et al., 1998) and lunch breaks (e.g., Laberge et al., 2012). Similarly, some interventions involved additional or extended Physical Education lessons (e.g., Dwyer et al., 1996). During academic classroom lessons, physical activity has been integrated with academic content (e.g., Gibson et al., 2008) or used as breaks from academic content (e.g., Katz et al., 2010). Although all types of interventions may improve school engagement, it is currently unclear which type of intervention is the most effective in this regard.

Finally, the different dimensions of school engagement (i.e., behavioural, emotional, and cognitive) could moderate the association between physical activity and school engagement. Some studies report that physical activity is positively associated with behavioural engagement (e.g., Barros et al., 2009; Bleeker et al., 2012; Dwyer et al., 1996; Whitt-Glover et al., 2011). However, a number of studies have found a negative association between physical activity and behavioural engagement, specifically time spent on homework (Adam, Snell, & Pendry, 2007; Atkin et al., 2008; Ho & Lee, 2001). There is also some evidence that suggests physical activity is positively associated with emotional (e.g., Gibson et al., 2008) and cognitive (e.g., Zan, 2013) engagement. However, one study reported no association between physical activity and cognitive engagement, specifically students' perceived value of classroom lessons (Vazou et al., 2012). While some evidence suggests that physical activity has a positive association with behavioural, emotional, and cognitive engagement, there is contradictory evidence.

There are several hypotheses as to how physical activity influences school engagement. The novelty-arousal theory suggests that a shift in normal routine, such as a break, improves attention and concentration (Berlyne, 1966; Ellis, 1984). The theory of contextual interference posits that the use and constant modification of action plans during physical activity, specifically games or complex motor skills, can be transferred to other settings, such as a classroom (Best, 2010). 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, are another possible explanation (Sattelmair & Ratey, 2009). Finally, physical activity is associated with higher levels of positive affect, specifically positive emotions and mood (Biddle & Asare, 2011; Penedo & Dahn, 2005). The broaden-and-build theory suggests that positive emotions lead to broadened thoughts and behaviours and facilitate more adaptive responses, such as problem solving and seeking assistance (Ekkekakis et al., 2005; Fredrickson, 1998; Reschly et al., 2008). Further, positive affect is associated with a number of successful outcomes including self-regulated learning (Mega, Ronconi, & De Beni, 2014), school engagement (Linnenbrink-Garcia & Pekrun, 2011; Pekrun & Linnenbrink-Garcia, 2012; Reschly et al., 2008), and academic performance (Daniels et al., 2009; Howell, 2009). Therefore, increases in positive affect, specifically positive emotions and mood, may be the mechanism by which physical activity has an effect on school engagement and academic performance.

While the explanatory mechanism for the association between physical activity and school engagement remains unclear, evidence supporting the association is increasing (Gibson et al., 2008; Whitt-Glover et al., 2011; Zan, 2013). However, no attempt has been made to systematically combine evidence from these studies. This type of synthesis could determine whether interventions targeting physical activity are an effective method of promoting school engagement or have the potential to be in the future.

Purpose

The primary objective of this study was to systematically review and conduct meta-analyses of evidence from studies reporting information on the association between physical activity and overall school engagement and disengagement in youth. The overall school engagement effect size consisted of pooling all behavioural, emotional, and cognitive engagement effect sizes. Similarly, the overall school disengagement effect size consisted of pooling all behavioural, emotional, and cognitive disengagement effect sizes. The secondary objective of this study was to explain the heterogeneity in the overall school engagement and overall school disengagement effect sizes by testing potential moderators (Bangert-Drowns, 1986). Moderator analyses can explain some of the heterogeneity in effect sizes, provide direction for future research, and guide intervention efforts. Comparing the study characteristics, such as physical activity duration, intensity, and intervention type, could determine the most effective way to use physical activity in order to promote school engagement. Exploring participants' characteristics (e.g., age) could determine for which groups physical activity is most beneficial and the groups that interventions should target. The first moderator tested was the dimension of school engagement. The associations between physical activity and behavioural, cognitive, and emotional engagement were compared to determine whether physical activity has different associations with the three different, yet dynamically interrelated, dimensions (Fredricks et al., 2004). Secondly, in order to provide direction for future research and guide intervention efforts, the effectiveness of the different types of interventions (before school vs. integrated into classroom lessons vs. classroom lessons breaks vs. during Physical Education vs. during recess or lunch) were compared. Third, because the short-term effects of physical activity tend to last up to one hour (Hillman et al., 2009; Joyce et al., 2009), the types of physical activity (single bout vs. regular) were compared. Next, as school engagement declines with age (Archambault, Janosz, Morizot, et al., 2009; Darr, 2012; Eccles et al., 1993; Janosz et al., 2008; Marks, 2000; Wylie & Hodgen, 2012), children were compared to adolescents. Next, the measurement tools used to assess school engagement and disengagement (objective vs. subjective) were compared to ensure that the overall effect sizes were not inflated due to methodical artefact. To assess risk of bias, studies with a high risk of bias were compared to studies with a low risk of bias. Finally, to examine publication bias, published studies were compared to unpublished studies (Rothstein, Sutton, & Borenstein, 2006).

Methods

Eligibility criteria

To be included in this review, studies were required to:

- Examine youth (i.e., mean age between 5 and 18 or were enrolled in primary or secondary school).
- Not examine special populations (e.g., youth diagnosed with ADHD or autism).
- Quantitatively assess behavioural (e.g., concentration), emotional (e.g., lesson enjoyment), or cognitive (e.g., academic motivation) engagement in schoolwork, either during an academic lesson or in homework. Definitions of the three dimensions of school engagement still vary. A small number of articles defined emotional engagement as interpersonal relationships between students and teachers (Furlong et al., 2003; Jimerson, Campos, & Greif, 2003). However, most definitions do not include interpersonal relationships, instead they examine interpersonal relationships as an antecedent of school engagement (Cavanagh &

Reynolds, 2007; Fredricks et al., 2004; Wang, M. & Holcombe, 2010). In recent years, Roorda, Koomen, Spilt, and Oort (2011) conducted a meta-analysis and reported a moderate correlation between positive student teacher relationships and both behavioural and cognitive engagement ($r = .39$, $p < .01$, $k = 61$). Due to this recent meta-analysis and the varying definitions of emotional engagement, this review excludes studies that defined emotional engagement as interpersonal relationships.

- Quantitatively assess the association between physical activity and school engagement.
- Be experimental (randomised controlled trials and quasi-experimental), cohort and cross-sectional study designs.
- Be full-text in the English language.
- No publication date restrictions were imposed. Published and unpublished studies were included.

Information sources

Searches were conducted in PubMed, Scopus, SportDiscus, Education Resources Information Center (ERIC), and Education Research Complete in December 2014. Combinations of key words were used to identify eligible studies. Reference lists of eligible studies were also examined to identify additional studies. In order to identify any unpublished articles, the authors sent out an invitation on electronic mailing lists (LISTSERVS) for authors to provide information regarding any unpublished articles that met the inclusion criteria.

Search

Systematic review searches should be thorough, objective, reproducible, and identify as many relevant studies as possible (Booth, A., 2011). However, it is important to find a balance between comprehensiveness (sensitivity) and maintaining relevance (precision) in the searches. In order to do this, preliminary searches were conducted using a controlled vocabulary thesaurus for indexing articles (i.e., Medical Subject Headings [MeSH]), the results of preliminary searches were examined, and searches were modified. Emotional engagement terms that are encompassed by positive and negative affect, such as 'interest*', satisf*', 'excite*', 'happiness', 'sadness', and 'anxiety', are low in precision and sensitivity. It is likely that any articles that use these positive and negative affect terms would be identified using the terms 'positive affect' and negative affect'. However, to ensure that excluding these specific affect terms would not exclude any relevant articles, these terms were included and all citations between January 2012 and December 2014 were screened. Of the 3,036 non-duplicate records identified, zero articles met the inclusion criteria. Therefore, to maintain the balance between sensitivity and precision, these specific affect terms were excluded from the final keywords. The final search terms are displayed in Table 1.

Table 1

Search Terms

Physical Activity terms	School Engagement terms	School and youth terms
Physical Activity	General school engagement terms	Adolescen*
Motor activity	School engagement	Teenage
Locomotor activity	School disengagement	Child*
Exercise	Academic engagement	Student
Movement	Behavioural engagement terms	Pupil
Moderate-to-vigorous	Behavio* engagement	Class
MVPA	Classroom behavio*	Youth
Exertion	Academic behavio*	Young people
Recess	Class participation	School
Lunch	Disruptive behavio*	Lesson
Active academic lesson	Academic effort	Classroom
	Extracurricular involvement	Physical Education
	Persistence	Recess
	Concentration	Lunch
	Attention	
	Time on-task	
	On-task behavio*	
	Attention-to-task	
	Truancy	
	Drop out	
	Homework	
	Agentic engagement	
	Emotional engagement terms	
	Emotional engagement	
	Disaffection	
	Affective engagement	
	Positive affect	
	School identification	
	Sense of belonging	
	Enjoy*	
	Bored*	
	Cognitive engagement terms	
	Cognitive engagement	
	Self-regulation	
	Strategy-use	
	Psychological investment	
	Academic motivation	
	Problem solving	

Study selection

All potentially eligible studies identified in the searches were exported into a single Endnote library and duplicate studies were removed. Next, two researchers independently screened titles and abstracts and excluded those that did not meet the eligibility criteria. Finally, full-text versions of the remaining articles were obtained and independently screened for eligibility. Discrepancies regarding whether a study met the inclusion criteria were resolved by discussion between the two researchers and the consultation of a third reviewer.

Data collection process

Two researchers independently extracted data from eligible studies. Extracted data included year of publication, study design, sample size, mean weight status (body mass index [BMI]), mean age, gender of participants, country where the study was set, intervention description (frequency, duration, and intensity of intervention sessions, if applicable), study duration (if applicable), measure of physical activity, measure of school engagement, and the statistical result that examined the association between physical activity and school engagement.

Risk of bias in individual studies

In order to assess the risk of bias in studies employing multiple study designs, the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guide and the CONsolidated Standards of Reporting Trials (CONSORT) statement were adapted. The risk of bias criteria included: a) description of participant eligibility criteria, b) random selection of schools and/or participants (sampling procedures appropriate and adequately described), c) valid assessment of participant physical activity (reliability and validity evidence was reported in the article), d) valid assessment of participant school engagement (reliability and validity evidence was reported in the article), e) power calculation reported and study adequately powered to detect hypothesised relations, and f) confounders adjusted for in analyses (e.g. gender, age). Based on these criteria, two researchers independently assigned a 1 (present and explicitly described) or 0 (absent or inadequately described) and any discrepancies were resolved by discussion between the two researchers and the consultation of a third reviewer. Studies that met less than half of the criteria were considered to have a high risk of bias, implying low confidence that results represent the true effect (Higgins, Altman, & Sterne 2011). Studies that met half or more of the criteria were considered to have a low risk of bias, implying confidence that results represent unbiased estimates of the true effect (e.g., Furlan, Pennick, Bombardier, van Tulder, & the Cochrane Back Review Group, 2009).

Summary measures

Commonly used summary measures include standardised mean differences, correlation coefficients, t-values, log odds ratios, and f-values. All summary measures were converted to Cohen's d using Rosenthal's (1994) and (1991) conversion formulas: Cohen's $d = \frac{2r}{\sqrt{1-r^2}}$, $d = \frac{t}{\sqrt{n-}}$, $d = LogOddsRatio \times \frac{\sqrt{3}}{\pi}$, and $d = \sqrt{F(\frac{(n_t+n_c)}{n_t n_c})(\frac{(n_t+n_c)}{n_t+n_c-2}})$. Effect sizes ($d$) were defined as .2 (small), .5 (medium), and .8 (large) (Cohen, 1988). When studies did not report the information necessary to convert the summary measure to Cohen's *d*, the author was contacted to request the required information[1].

Analysis

Traditionally, researchers used fixed-effects and random-effect models to conduct meta-analyses. Both the fixed- and random-effects models are limited by the assumption of independence (Field, 2003). This means that only one effect size per study can be included in a meta-analysis as multiple effect sizes within a single study are likely to be correlated. Common methods that have been used to address this issue are: a) averaging the effect sizes, b) 'shifting the unit of analysis' (i.e., retaining as many effect sizes as possible from each study, while holding violations of the assumption of independence to a minimum; Cooper, 1989), c) selecting one of the effect sizes or using a combination of the aforementioned methods, and d) not reporting how they handled the issue (Ahn, Ames, & Myers, 2012). These methods have the potential to lose information and therefore, limit the research questions that can be addressed and moderators that can be tested (Cheung, 2014).

Structural equation modelling and multilevel modelling are two approaches to meta-analysis that are not limited by the assumption of independence (Goldstein, 1995; Marsh, Bornmann, Mutz, Daniel, & O'Mara, 2009; Raudenbush & Bryk, 1985; Van Den Noortgate & Onghena, 2003). Another advantage of these two approaches is that covariates and moderator variables can be included in order to explore the heterogeneity in effect sizes (Van Den Noortgate & Onghena, 2003). Multilevel meta-analysis can be

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[1] If the author did not respond, sensitivity analysis was conducted by estimating Cohen's *d* using the reported information, information from similar studies with similar results, and approximation formulas (Higgins & Green, 2011; Irwin, 1997). Results of this sensitivity analysis were compared to the results without these studies. No significant differences were found between results that included and excluded the estimated effect sizes. Therefore, the reported results include the estimated effect sizes and the results that exclude estimated effect sizes are in Appendix B.

integrated into the structural equation modelling approach to meta-analysis providing further methodological advantages (Cheung, 2014). For example, this integrated approach places flexible constraints on parameters, constructs more accurate confidence intervals using the likelihood-based approach, and handles missing covariates using FIML (see Appendix A for futher information; Cheung, 2009; Cheung, 2014).

This meta-analysis took a structural equation modelling approach to multilevel meta-analysis. All analyses were conducted in R Version 3.1.2 (R Core Team, 2014). The package metaSEM, using the meta3 function, was used for meta-analysis (Cheung, 2011). Maximum likelihood estimation was used to fit mixed-effects models. Unconditional mixed-effects models were employed to calculate the overall pooled effect size (pooled *d*). For each pooled effect size, 95% likelihood-based confidence intervals (CIs) were calculated (Cheung, 2009). When the 95% CIs did not encompass zero, a significant effect between variables was said to exist.

The I^2 statistic was used to assess heterogeneity in pooled effect sizes (Higgins, Thompson, Deeks, & Altman, 2003). When effect sizes were heterogeneous (i.e., I^2 exceeded 25%), moderator analyses were conducted to explain some of the heterogeneity in effect sizes. Moderator analyses identify variables that affect the direction or strength of the relations between an independent variable and dependant variable (i.e., physical activity and school engagement; Shadish & Sweeney, 1991). When there were at least four effect sizes per subgroup, conditional models were used to test potential moderators. Although there is no universally accepted minimum number of effect sizes per subgroup required for a moderator analysis, Fu et al. (2011) suggested that at least four effect sizes are required for categorical subgroup variables. For each moderator analysis, the proportion of explained variance of heterogeneity by the inclusion of the potential moderator variable (R^2) and the heterogeneity between effect sizes in each category (I^2) were calculated. Potential moderators included the dimensions of engagement (behavioural vs. cognitive vs. emotional), different types of interventions (physical activity before the classroom lesson commenced vs. incorporating physical activity into classroom lessons vs. physical activity in breaks during the classroom lesson), different types of physical activity (single bouts occurring in the 60-minute period before the classroom lesson vs. regular physical activity), measurement tools used to measure behavioural engagement (objective vs. subjective), and risk of bias within studies.

To examine risk of bias across studies and assess the risk of publication bias, funnel plots (Sterne, Egger, & Moher), which plotted the effect sizes on the x-axes and standard errors on the y-axes were inspected. When bias is absent, the funnel plots resemble a symmetrical inverted funnel. Next, Egger's regression asymmetry tests (Egger, Smith, Schneider, & Minder, 1997) were conducted to quantify the bias visible in the funnel plots. The test regressed the normalised effect estimate (effect size divided by its standard error) against precision (reciprocal of the standard error of the effect size). When the funnel plot is symmetrical (i.e., no bias), the regression line will run through the origin.

Results

Study selection

Study selection results are displayed in Figure 1. Searches of electronic databases, reference lists, and grey literature (i.e., unpublished work) identified 8,195 non-duplicate records. After reviewing the titles and abstracts of these 8,195 records, full-text versions of the 399 potentially relevant records were obtained and reviewed. Of these 399 full-text articles, 40 met the inclusion criteria. However, two of these studies did not provide enough information to be included in the meta-analyses. Thus, 38 studies were included in this systematic review and meta-analyses.

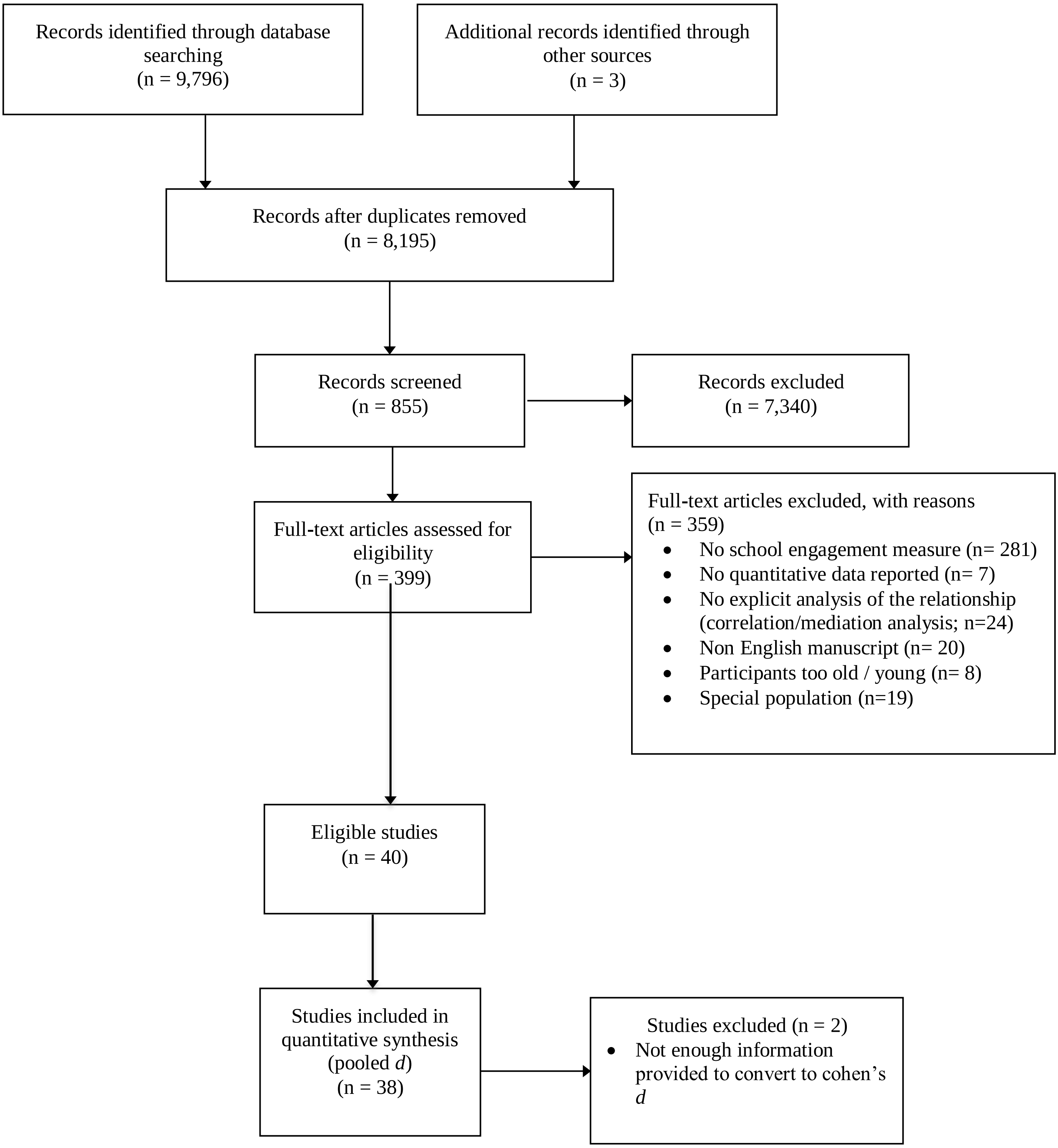

Figure 1. Flow diagram of search results

Study characteristics

Study characteristics are detailed in Table 2. Publication dates ranged from 1993 to 2014. Half of the studies were conducted in either the United States (*k* = 17) or Australia (*k* = 3). Twenty-four studies implemented an intervention, of which, nine were randomised controlled trials and 15 were quasi-experimental study designs. Other study designs include cross-sectional (*k* = 13) and longitudinal (*k* = 1).

Across the 24 intervention studies, there were five types of interventions. One intervention was implemented at school before the school day commenced and four were implemented at school as programs during school hours. Seven interventions involved the academic classroom teachers integrating physical activity into academic classroom lessons, while five interventions involved 10–15 minute physical activity breaks during academic classroom lessons. Six interventions provided additional or extended breaks between academic classroom lessons (e.g., recess or lunch) and the remaining intervention was conducted during Physical Education and involved manipulating the duration and intensity of physical activity. Control conditions involved pre-tests (*k* = 3), no school program (*k* = 2), other activities, such as art (*k* = 1) and yoga (*k* = 1), usual classroom lessons (*k* = 9), usual recess and lunch breaks (*k* = 5), no recess breaks (*k* = 2), and usual PE lessons (*k* = 1).

Across the 38 included studies, 71,433 participants were included. The number of study participants ranged from five (Schnieders-Laber, 2011) to 25,060 (Leatherdale & Wong, 2008). The mean age of participants in each study ranged from 6.7 years (SD = 1.0; Smith et al., 2013) to 15.5 (SD = 1.2; Leatherdale & Wong, 2008).

Of the 38 included studies, the majority examined school engagement (*k* = 28, rather than school disengagement (*k* = 10), while one study examined both engagement and disengagement. Majority of studies examined behavioural engagement (*k* = 25), rather than a combination of cognitive and emotional engagement (k = 2), or a combination of behavioural and emotional engagement (k = 1). Similarly, majority of studies examined behavioural disengagement (k = 8), rather than emotional disengagement (k = 1), cognitive disengagement (k = 0), or a combination of behavioural and emotional disengagement (k = 2). No study examined all three dimensions of school engagement or disengagement.

Behavioural engagement and disengagement were measured using observation of classroom lessons (k = 13), school records (k = 2), teacher reports (k = 11), parent reports (k = 1), and self-reports (k = 11). Cognitive engagement and disengagement were measured using self-reports (k = 2), whereas, emotional engagement and disengagement were measured using teacher reports (k = 1) and self-reports (k = 1).

Table 2

Study characteristics

Author	Study design	Sample size	Mean age (y)	Male/ Female	Country	Intervention description (if applicable)	Physical activity measure	Engagement dimension and measure
Adam 2007	Cross-sectional	2454	Younger group M= 8.9 (SD=1.81), Older group M= 15.2 (SD=1.87)	1203/1251	United States	NA	Week day sport (self-reported time use diary)	Behaviour- Time spent on weekdays doing homework (Time use diary)
Atkin 2008	Cross-sectional (data were collected across 2 waves, 6 months apart)	1484	15.0 (SD = .05)	561/923	United Kingdom (England, North Ireland, Scotland and Wales)	NA	Time use diary of ‘free time’ between 7–9am and 3–11pm (self-reported)	Behaviour- Time spent on homework (Self-report diary of ‘free time’ between 7–9am and 3–11pm)

Barnard 2011	Longitudinal	4391	Kindergarten to Grade 5	Approximately equal number	United States	NA	Frequency and duration of Physical Education (Teacher reported)	Behaviour- ADHD symptoms including: Approaches to learning (teacher rated persistence, flexibility, independence and attentiveness), self-control (teacher rated), externalising behaviour problems (teacher rated arguments and fights), and impulsivity/ over activity (parent rated)
Barros 2009	Cross-sectional (secondary analysis)	11529	8–9	5866/5758	United States	NA	Frequency of recess	Behaviour- Classroom behaviour (teacher-reported)
Bleeker 2012	Randomised controlled trial	2181	1934 Grade 4 and 5 students, 247 teacher	Not reported	United States	Playworks program places full-time coaches in schools in order to provide opportunities for organised physical activity during recess, class time, and after school. The control group did not participate in the Playworks program.	No measure	Behaviour- Student engagement in classroom activities (student rated), attention and lesson participation (teacher rated)

Dwyer 1996	Randomised controlled trial	380	10 (Grade 5)		Australia	The fitness focused group participated in three half hour periods of PE, but focused on high intensity activity. The skills based group participated in 75 minutes of PE each day. The control group participated in the usual three half hour periods of Physical Education.	No measure	Behaviour- Classroom attention (teacher rated on the Child Behaviour Scale)
Feldman 2003	Cross-sectional	743	15.1 (SD = 1.2)	384/359	Canada	NA	Hours per week during the past 6 months (self-reported)	Behaviour- Homework and reading (self-reported hours per week during the past 6 months)
Gibson 2008	Randomised controlled trial	4476	Grade 2–5	2220/2256	United States	The experimental groups participated in Physical Activity Across the Curriculum (PAAC) lessons. These lessons incorporate a brief, classroom-based activity segment one or more times each school day, integrating physical activity with academic content related to health and movement concepts. The control group participated in usual classroom lessons.	System for Observing Fitness Instruction Time (SOFIT)	Emotions- Lesson enjoyment (teacher rated on a Likert scale)

Grieco 2009	Quasi-experimental (Within-subject cross-over design)	97	8.7 (SD= 0.41)	44/53	United States	The Texas I-CAN program was implemented. The program required teacher to integrate 10–15 minutes of moderate-to-vigorous physical activity (MVPA) with the academic curriculum in academic lessons (maths, language arts, science, social studies, and health). The control condition involved usual classroom lessons.	No measure included in analyses- Grieco et al. did use pedometers to measure step counts on school days; however, this data was only used to provide a sense of the sample's activity levels.	Behaviour- Time on-task Observations (1–30s intervals- on/off-task)
Ho 2001	Cross sectional	2110	14.16 (SD = 1.81)	1009/1101	Hong Kong	NA	I-item (self-reported)	Behaviour- Homework (self-reported minutes spend doing homework each day)

Howie 2014	Quasi-experimental (Within-subject cross-over design)	75	Group 1: 11.2 (SD=.39), Group 2: 11.2 (SD=.29), Group 3: 11.1 (SD=.36), Group 4: 10.2 (SD=.34), Group 5: 10.2 (SD=.39)	Not reported	United States	The Brain Bites (Better Ideas Through Exercise) exercise break intervention was implemented. The conditions consisted of 5, 10 and 20 minute physical activity breaks during classroom lessons.	SOFIT (System for Observing Fitness Instruction Time)	Behaviour- Time on-task (15-second intervals)- lessons were video recorded
Hoza 2014	Randomised controlled trial	108	6.83 (SD = .96)	Not reported for typically developing participants specifically	United States	The experimental group participated in continuous activity at a rate that required participants to breathe hard (i.e., MVPA). The control group participated in a classroom-based arts program designed to keep participants sedentary. Both the experimental and control group participated in the program for 31 minutes each school day. The control group participated in art in a sedentary classroom.	No measure	Behaviour- Inattention (teacher rated on the school version of the ADHD-IV Rating Scale)

Huang 2013	Cross sectional	280	Boys M = 11.1 (SD = .9), Girls M = 11.2 (SD = .9)	134/146	Hong Kong	NA	Children's Leisure Activities Study Survey questionnaire (student self-reported)	Behaviour- Homework (yes/no, self-reported)
Hunter 2014	Quasi-experimental (two-group comparison)	107	Year 5	Approximately equal number	Australia	Both the control and experimental group participated in a 30 minute PE lesson once a week and 30 minute Smart Moves sessions on days where there was no PE or sport. The Smart Moves sessions involved 30 minutes of moderate activity. The experimental group received an additional 30 minute AKAM session each day, which involves aerobic activities with little instruction or waiting time.	Pedometer for 5 days and accelerometer for 1 school day (due to logistics, accelerometers could not be used for the 5 days as well).	Behaviour- Classroom behaviour using OneSchool data.

Jarrett 1998	Quasi-experimental (Within-subject cross-over design)	43	Grade 4	18/25	Not reported	The observed classes participated in PE three times per week and no physical activity on the other two days. All observations were conducted on the two days that participants did not have PE. The classes were randomly assigned to have recess on one of these days and no recess on the other.	No measure	Behaviour and emotions- Time on-task Observations (5 second intervals- work, fidgety, listless)
Katz 2010	Randomised controlled trial	1214	Grade 2–4	593/621	United States	The ABC (Activity Bursts in the Classroom) for Fitness program was implemented. The program, led by classroom teachers, provides multiple structured physical activity breaks throughout the school day. The control group participated in usual classroom lessons.	No measure	Behaviour- Classroom behaviour was assessed by the work and social skills component of the school progress report for the school year.
Laberge 2012	Quasi-experimental (two-group comparison)	223	Intervention: M = 13.8 (SD = .7), Control: M = 12.5 (SD = .6)	Intervention: 62/69, Control: 29/63	Canada	The experimental group was offered a variety of 45 min cardiovascular physical activities during their usual lunch breaks. The control condition involved usual lunch activities.	Participation in physical activity during lunch (participation frequency)	Behaviour- Attention and concentration (self-reported)

Lazarou 2009	Cross sectional	670	10.70 (SD = .98)	Does not report regarding the final sample used in analyses.	Cyprus	NA		Physical activity after school on weekdays (self-reported)	Behaviour- Time spent on homework on weekdays and weekend days (self-reported)
Leatherdale 2008	Cross sectional	25060	15.5 (SD = 1.2)	12806/12254	Canada	NA		Kilocalories per kilogram of body weight (students reported time spent in MPA and VPA over the last week)	Behaviour- Time spent on homework (self-reported)

Ma 2014	Quasi-experimental (Within-subject cross-over design)	44	Grade 2 and 4	25/19	Canada	On alternate days, children were exposed to either FUNtervals or no-activity breaks. FUNtervals consisted of a 10 minute break, of which, 4 minutes were spent participating in Tabata (20 seconds of high intensity activity followed by 10 seconds of rest, repeat). The no-activity break group consisted of a 10 minute lecture on the importance of physical activity and nutrition. Following each condition, a 50 minute lesson of Maths was observed.	Participation in the FUNtervals was rated on a scale of 0–3.	Behaviour- Time on-task (BOSS- each lesson 4 observers observed 5–6 students each using 30 second intervals)
Mahar 2006	Randomised controlled trial	62	9.1 (SD=0.9)	Not reported	United States	The experimental group received 10 minute energisers. Energisers are short teacher instructed classroom-based physical activities. The control group was taught as per usual.	Pedometer during school hours. However, there is no association between accelerometer assessed activity and time on-task.	Behaviour- Time on-task Observations (10 second intervals- on-task, motor off-task, noise off-task, or passive/other off-task)

Martikainen 2012	Cross sectional	199	Boys M = 8.2 (SD = .3), Girls M = 8.1 (SD = .3)	92/107	Finland	NA	Weekly activity-accelerometer	Behaviour- Attention (Teachers Report Form)
McWilliams 2013	Cross sectional	424	Boys Median = 10 (IQR= 9–10), Girls Median = 10 (IQR= 9–10)	161/263	England	NA	Physical activity within the previous 24 hours (self-reported, Physical Activity Questionnaire)	Behaviour- Inattention/hyperactivity and conduct disorder (Teacher reported, Strengths and Difficulties Questionnaire)
Metzler unpublished	Quasi-experimental (Single group pre- post test)	38 Classes with a mean of 18.1 students (38 x 18.1 students = approximately 688)	Kindergarten to Grade 5	Not reported	United States	Students participated in TAKE 10! Lessons. These lessons aim to incorporate structured physical activity into classroom lessons, while reinforcing specific learning outcomes.	No measure	Behaviour- Time on-task- observation (2 minute intervals- time on-task and fidgeting)

Pellegrini 1993	Quasi-experimental (Within-subject cross-over design)	23	9.4	14/9	United States	All children participated in 30 minutes of a classroom lesson. Treatment conditions included a short classroom confinement (i.e., 2.5 hours) and a longer classroom confinement (i.e., 3 hours) before being allowed outside for a 30 minute recess break.	Social and non-social physical activity (observation)	Behaviour- Fidgeting and concentration (observation)
Pellegrini 1995	Quasi-experimental (Within-subject cross-over design)	99	Experiment 1: Kindergarten (M=5.6), Grade 2 (M=7.5), and Grade 4 (M=9.7), Experiment 2: not reported	Experiment 1: 34/28 Experiment 2: 17/20	United States	Experiment 1 and 2: Four days a week, the duration of students pre-recess classroom work was manipulated in each grade. Two days students had recess at 10am (short deprivation) and the other two days students had recess at 10:30 (long deprivation).	Observation - coded on a 9 point ordinal scale	Behaviour- Inattention-observation
Ridgeway 2003	Quasi-experimental (Within-subject cross-over design)	9	8	9/0	United States	A 10 minute recess break was introduced on alternate days at a school that did not previously have a recess break. All participants were observed at 8:30am, 9:00am, 9:35am, 10:10am, 10:30am, and 10:50am on recess and non-recess days.	No measure	Behaviour- Time on-task (10-second intervals)-observation by blinded research assistants

Riley unpublished	Randomised controlled trial	54	10.53 (SD=.7)	28/26	Australia	Physical activity was integrated into subjects (maths and English) using movement-based learning experiences. The control group participated in usual classroom lessons.	Objectively measured	Behaviour- Time on-task (Observation)
Schnieders unpublished	Quasi-experimental (Single group pre- post test)	5 children strugglin g with reading	Grade 2	Not reported	Not reported	Students participated in The MINDS in Motion, Maze activities. These activities. These activities use movement to challenge and activate the brain. A 10 minute period before and after the intervention was observed and engagement coded.	No measure	Behaviour and emotions- Disruptions, misbehaviour, time on-task, willingness to respond (Conversation, Help, Activity, Movement, Participation protocol, observation)
Smith 2013	Quasi-experimental (Single group pre- post test)	14 children 'at risk' for ADHD	6.7 (SD = 1.0)	6/8	Not reported	A before school physical activity program was implemented. Each day, the program lasted 26 minutes and participants rotated around four 6 min stations, each with a different game or activity.	No measure	Behaviour- Inattention/over activity and Oppositional/defi ant (Pittsburgh Modified Conners Teacher Rating Scale)

Telles 2013	Randomised controlled trial	98	10.5 (SD = 1.3)	60/38	India	The intervention group participated in 45-minute sessions of physical activity, consisting of jogging, rapid bending, relay races, and games. The control group participated in 45 minute yoga sessions, focusing on awareness, relaxation, and breathing.	No measure	Behaviour- Attention (Teacher rated on Likert scales)
Utter 2003	Cross sectional	4480	14.9	2240/2240	United States	NA	Leisure Time Exercise Questionnaire (self-reported)	Behaviour- Time spent reading/doing homework (self-reported)

Vazou 2012	Quasi-experimental (Within-subject cross-over design)	147	10–12 years (Grages 4 to 6)	64/83	Greece	The intervention lessons were taught by senior education primary education student-teachers. The first two lessons were taught in the traditional format in order to familiarise the students with the student-teacher. The third and fifth lessons were used to implement the intervention, which consisted of physical activity being incorporated into an academic lesson (Language Arts, Math, Geography, or Social Studies). The fourth and sixth lessons were used as control lessons.	No measure	Cognition and emotions-Academic motivation-effort, enjoyment, and value (Intrinsic Motivation Inventory, self-reported)
Wang 2006	Cross sectional	780	12.24 (SD = .47)	285/482	Singapore	NA	Modified Self-administered Physical Activity Checklist- 7 day recall (self-reported)	Behaviour-Homework (self-reported)

Whitt-Glover 2011	Randomised controlled trial	4599	Year 3 to 5	2355/2244	United States	The intervention group participated in Instant Recess. Instant recess involves 10 minute physical activity breaks, focusing on dance, callisthenics, and sport movements. The control group participated in usual classroom lessons.	SOFIT (System for Observing Fitness Instruction Time)	Behaviour- Time on-task (direct observation)
Woehrle 2005	Quasi-experimental (two-group comparison)	Baseline experimental: 1004. Follow up: experimental: 855 control: 788	Junior kindergarten to Grade 6	Not reported	Not reported	The control group followed the traditional school day format, which included two recess breaks and a lunch break. The experimental group followed a balanced school day schedule. School days consisted of 3 x 100 minute blocks of instructional time separated by 2 'nutrition breaks'. Nutrition breaks include 20 minutes for healthy eating and 20 minutes for outdoor time. The breaks are followed by 5 minutes of transition time.	No measure	Behaviour- Concentration (teacher rated) and time on-task (observation)

Yu 2006	Cross sectional	333	Total M = 10.36 (SD = 1.71), Girls M = 10.31 (SD = 1.62), Boys M = 10.40 (SD = 1.78)	189/144	China	NA	Physical Activity Questionnaire for older Children (self-reported)	Behaviour-Conduct in class (teacher rated)
Zan 2013	Quasi-experimental (two-group comparison)	107	10.91 (SD = .72)	49/58	United States	The experimental group participated in 30 minutes of Dance Dance Revolution (DDR) sessions during recess breaks 3 times per week. The DDR sessions involved an interactive dancing video game that required fast-foot movements with energetic music. Participants were able to track how many calories they burn during the DDR session. The control group participated in normal recess breaks.	Physical Activity Questionnaire for Children (self-reported)	Cognition and emotions-Mathematics Value and Interest (6-items, self-reported)

Note. M = mean, SD = standard deviation.

Risk of bias within studies

Complete risk of bias assessments are displayed in the Table 3. The inter-rater agreement for risk of bias ratings was 99.38% and all discrepancies were resolved by discussion between the two researchers and the consultation of a third reviewer. Fifteen studies were rated as having a low risk of bias and twenty-five studies were rated as having a high risk of bias.

Table 3

Risk of bias within studies

Author	Description of participant eligibility criteria	Random selection of schools (sampling procedures appropriate and adequately described)	Random selection of participants (sampling procedures appropriate and adequately described)	Valid assessment of participant physical activity (reliability and validity evidence was reported in the article)	Valid assessment of participant school engagement (reliability and validity evidence was reported in the article)	Power calculation reported and study adequately powered to detect hypothesised relationships	Covariates adjusted for in analyses (e.g. gender, age, weight status)
Adam et al. 2007	1	NA	NA	0	0	0	0
Atkin et al. 2008	1	NA	NA	0	0	0	1
Barnard et al. 2011	0	NA	NA	0	1	0	0
Barros et al. 2009	1	NA	NA	0	0	0	1
Bleeker et al. 2012	0	1	0	0	0	0	1
Dwyer et al. 1996	1	0	1	0	1	0	0
Feldman et al. 2003	1	NA	NA	0	0	0	1
Gibson et al. 2008	0	1	1	1	0	0	0
Grieco et al. 2009	1	0	0	0	1	0	0
Ho et al. 2001	1	NA	NA	1	0	0	0
Howie et al. 2014	1	0	0	1	1	0	1
Hoza et al. 2014	1	0	1	0	1	0	1
Huang et al. 2013	1	NA	NA	1	1	0	1

Hunter et al. 2014	1	0	0	1	1	0	0
Jarrett et al. 1998	1	0	0	0	1	0	0
Katz et al. 2010	1	0	0	0	1	0	0
Laberge et al. 2012	1	0	0	1	1	0	1
Lazarou et al. 2009	1	NA	NA	1	1	0	0
Leatherdale et al. 2008	1	NA	NA	1	1	0	1
Ma et al. 2014	1	0	0	0	1	0	0
Mahar et al. 2006	1	0	0	1	1	0	0
Martikainen et al. 2012	1	NA	NA	1	1	0	1
McWilliams et al. 2013	1	NA	NA	1	1	0	1
Metzler unpublished	0	0	0	0	1	0	0
Pellegrini et al. 1993	1	0	0	1	1	0	1
Pellegrini et al. 1995	1	0	0	1	1	0	0
Ridgeway et al. 2003	1	0	0	0	1	0	0
Riley et al. 2014	1	0	0	1	1	0	1
Schnieders et al. 2011	1	0	0	0	0	0	0
Smith et al. 2013	1	0	0	0	1	0	0
Telles et al. 2013	1	1	0	0	0	1	0
Utter et al. 2003	0	NA	NA	1	1	0	1
Vazou et al. 2012	1	0	0	0	1	0	0
Wang et al. 2006	1	NA	NA	1	1	0	0
Whitt-Glover et al. 2011	0	0	0	1	1	0	0
Woehrle et al. 2005	0	0	0	0	0	0	0
Yu et al. 2006	1	NA	NA	1	0	0	0
Zan et al. 2013	1	0	0	1	1	0	0

Note. 1 = present and explicitly described); 0 = absent or inadequately described; NA = not applicable.

Synthesis of results

Overall school engagement. The unconditional multilevel model focused on the overall pooled effect size of the association between physical activity and school engagement. Overall, physical activity had a small positive association with school engagement (*d* = .28, 95% CI = .12, .46)[2]. The majority of the variation within this pooled effect size was attributable to differences between studies (I^2 = .86), rather than within studies (I^2 = .11). Therefore, moderator analyses were conducted to explain some of the between-study variance.

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[2] One study reported very small standard deviations, and therefore, the converted result to Cohen's *d* appeared unrealistically large (*d* = 5.73). It is possible the authors of that study may have reported the standard errors rather than the standard deviations. The authors were contacted to clarify their reporting; however, they did not respond. In order to determine the influence of this unlikely effect size on the pooled effect size, meta-analyses were conducted in three different ways and the results compared. First, the reported standard deviations from the study in question were treated as standard deviations. The meta-analysis found that physical activity had an overall medium positive association with school engagement (*d* = .51, 95% CI = .05, .98). Next, the reported standard deviations from the study in question were treated as standard errors. This meta-analysis found a small positive association (*d* = .28, 95% CI = .12, .46). Finally, the effect size from the study in question was substituted with the highest effect from another included study. This final meta-analysis found a small positive association (*d* = .33, 95% CI = .14, .54). In order to take the most conservative approach, the standard deviations from the study in question were treated as standard errors.

Overall school disengagement. Physical activity had no significant association with school disengagement (*d* = -.32, 95% CI = -1.00, .36). Variation within the pooled effect size of the association between physical activity and school disengagement was largely due to differences between studies (I^2 = .88), rather than within studies (I^2 = .09). Therefore, moderator analyses were conducted to explain some of the between-study variance.

Moderator analyses

Significant results of moderator analyses are described below. Results of all moderator analyses are presented in Table 4 and Table 5.

Table 4

Results of school engagement meta-analyses and moderator analyses

Variable	*k*	*#ES*	*n*	Coefficient (Υ)	Lower 95% CI	Upper 95% CI	τ _2	τ_3	R^2_2	R^2_3	I^2_2	I^2_3	Q statistic
Overall school engagement	29	59	59,715	0.28	0.12	0.46	0.02	0.14			0.11	0.86	2258.685
Moderator analyses													
Engagement Dimension													
Behavioural engagement	25	55											
Emotional engagement	2	2											
Cognitive engagement	2	2											
Intervention type							0.02	0.14	0.04	0.02			2258.685
Before school	0	0	0										
Classroom integration	5	11	989	0.22	-0.21	0.66	0.01	0.15			0.06	0.91	
Classroom break	4	15	5,950	0.55	0.02	1.06	0.03	0.23			0.12	0.87	
School program	2	2	205										
Physical Education	1	2	497										
Recess/lunch	3	5	1,162	0.26	-0.19	0.73	0.02	0.00			0.00	0.81	
PA type							0.02	0.13	0.01	0.05			2258.685
Regular PA	20	32	53,947	0.24	0.05	0.44	0.02	0.08			0.20	0.77	
Single bout	9	27	5,768	0.43	0.08	0.78	0.01	0.25			0.04	0.95	
PA intensity							0.02	0.10	0.05	0.28			2258.685
Moderate and vigorous	5	21	5,413	0.62	0.26	0.98	0.00	0.16			0.00	0.98	

Low	1	2	688										
Free play	2	3	939										
Not reported	7	11	2,730	0.29	-0.06	0.65	0.02	0.00			0.00	0.85	
Age							0.02	0.13	0.00	0.06			2258.685
Children	22	48	25,400	0.27	0.08	0.47	0.02	0.11			0.16	0.81	
Adolescents	6	10	31,861	0.40	0.06	0.77	0.00	0.26			0.00	0.99	
PA measure							0.02	0.09	0.05	0.34			2258.685
Objective	2	2	253										
Subjective	14	23	48,862	0.23	0.03	0.44	0.02	0.13			0.14	0.83	
Observation	2	13	4,674	0.99	0.33	1.59	0.00	0.00			0.00	0.00	
No measure	11	21	5,926	0.21	-0.04	0.46	0.01	0.06			0.15	0.80	
Study Design							0.02	0.13	0.00	0.06			2258.685
Cross-sectional	13	21	48,731	0.23	-0.01	0.48	0.02	0.15			0.12	0.86	
Quasi-experimental	9	28	2,279	0.27	-0.05	0.59	0.01	0.09			0.10	0.86	
Randomised controlled trial	7	10	8,705	0.40	0.06	0.74	0.02	0.15			0.12	0.85	
Total Risk of bias							0.02	0.13	0.01	0.09			2258.685
Low risk of bias	14	34	31,193	0.37	0.14	0.61	0.02	0.05			0.26	0.69	
High risk of bias	15	25	28,522	0.19	-0.03	0.44	0.01	0.21			0.06	0.93	
Risk of bias 1							0.02	0.14	0.00	0.01			2258.685
Bias 1 = Yes	24	50	49,111	0.27	0.08	0.48	0.02	0.10			0.14	0.83	
Bias 1 = No	5	9	10,604	0.32	-0.05	0.68	0.02	0.24			0.08	0.90	
Risk of bias 2							0.02	0.15	0.03	0.00			2258.685
Bias 2 = Yes	2	4	2,279	0.16	-0.45	0.79	0.01	0.00			0.75	0.00	
Bias 2 = No	14	34	8,705	0.36	0.10	0.63	0.01	0.15			0.06	0.92	
Risk of bias 3							0.02	0.15	0.03	0.00			2258.685

Bias 3 = Yes	1	2	497										
Bias 3 = No	15	36	10,487										
Risk of bias 4							0.02	0.13	0.01	0.08			2258.685
Bias 4 = Yes	15	34	37,640	0.36	0.14	0.59	0.03	0.16			0.14	0.84	
Bias 4 = No	14	25	22,075	0.19	-0.05	0.44	0.01	0.08			0.12	0.84	
Risk of bias 5							0.02	0.11	0.02	0.21			2258.685
Bias 5 = Yes	19	45	37,881	0.38	0.20	0.58	0.02	0.14			0.11	0.86	
Bias 5 = No	10	14	21,834	0.05	-0.22	0.34	0.01	0.02			0.40	0.48	
Risk of bias 6													
Bias 9 = Yes	1	1	98										
Bias 9 = No	28	58	59,617										
Risk of bias 7							0.02	0.13	0.00	0.07			2258.685
Bias 10 = Yes	12	33	44,917	0.42	0.15	0.69	0.03	0.09			0.21	0.76	
Bias 10 = No	17	26	14,798	0.20	-0.01	0.42	0.01	0.16			0.05	0.92	
Publication status							0.02	0.13	0.00	0.09			2258.685
Published	26	54	58,968	0.31	0.14	0.49	0.02	0.14			0.11	0.86	
Unpublished	3	5	747	-0.08	-0.67	0.54	0.03	0.00			0.87	0.00	

Note. τ _2 = variance at level 2; τ _3 = variance at level 3; CI = confidence intervals; I^2_2 = heterogeneity at level 2; I^2_3 = heterogeneity at level 3; *k* = number of studies; *n* = number of participants; PA = Physical activity; R^2_2 = explained variance at level 2; R^2_3 = explained variance at level 3; Risk of bias 1 = Description of participant eligibility criteria; Risk of bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of bias 6 = Power calculation reported and study adequately powered to detect hypothesised relationships; Risk of bias 7 = Covariates adjusted for in analyses (e.g. gender, age, weight status).

Table 5

Results of school disengagement meta-analyses and moderator analyses

Variable	*k*	*#ES*	*n*	Coefficient (Υ)	Lower 95% CI	Upper 95% CI	τ_2	τ_3	R^2_2	R^2_3	I^2_2	I^2_3	Q statistic
Overall school disengagement	11	23	9,260	-0.32	-1.00	0.36	0.08	0.75			0.10	0.88	1948.789
Moderator analyses													
Disengagement Dimension							0.10	0.44	0.00	0.41			1948.789
Behavioural disengagement	10	20	4,741	-0.09	-0.75	0.49	0.04	0.24			0.15	0.79	
Emotional disengagement	2	3	4,519	-1.13	-2.15	0.13	0.08	1.27			0.06	0.93	
Cognitive disengagement	0	0	0										
Intervention type							0.03	0.07	0.65	0.91			1948.789
Before school	1	2	14										
Classroom integration	2	2	4,481										
Classroom break	1	5	44	-0.42	-2.65	1.81	0.00	0.00			0.00	0.00	
School program	2	2	162										
Physical Education	0	0	0										
Recess/lunch	4	11	168	0.83	-1.71	3.38	0.12	0.15			0.42	0.52	
PA type							0.08	0.75	0.00	0.00			1948.789
Regular PA	4	5	4,567	-0.32	-1.34	0.70	0.00	0.05			0.00	0.72	
Single bout	7	18	4,693	-0.33	-1.24	0.59	0.14	1.28			0.10	0.89	
PA intensity							0.09	0.47	0.00	0.37			1948.789
Vigorous and moderate	5	10	4,696	-0.77	-1.53	0.01	0.00	0.83			0.00	0.98	
Low	0	0	0										

Free play	3	9	145	0.49	-0.71	1.69	0.27	0.26			0.49	0.47	
Not reported	1	1	5										
Age													
Children	11	23	9,260										
Adolescents	0	0	0										
PA measure							0.08	0.76	0.03	0.00			1948.789
Objective	1	1	54										
Subjective	2	6	4,435	-0.44	-1.94	1.05	0.00	0.00			0.00	0.00	
Observation	3	5	4,598	-0.36	-1.53	0.82	0.23	2.08			0.10	0.89	
No measure	5	11	173	-0.18	-1.36	1.00	0.00	0.05			0.00	0.74	
Study Design							0.08	0.53	0.00	0.29			1948.789
Cross-sectional	0	0	0										
Quasi-experimental	8	20	285	-0.01	-0.74	0.71	0.06	0.25			0.17	0.77	
Randomised controlled trial	2	2	4,584	-1.17	-2.41	0.10	0.85	0.85			0.49	0.49	
Longitudinal	1	1	4,391										
Total Risk of bias							0.11	0.40	0.00	0.46			1948.789
Low risk of bias	4	31	284	0.31	-0.51	1.10	0.17	0.12			0.56	0.38	
High risk of bias	7	16	8,976	-0.83	-1.55	-0.10	0.00	0.72			0.00	0.97	
Risk of bias 1							0.07	0.37	0.10	0.51			1948.789
Bias 1 = Yes	9	21	393	0.03	-0.56	0.60	0.04	0.20			0.17	0.77	
Bias 1 = No	2	2	8,867	-1.45	-2.50	-0.40	0.98	0.00			0.98	0.00	
Risk of bias 2													
Bias 2 = Yes	1	1	4,476										
Bias 2 = No	9	21	393										
Risk of bias 3							0.08	0.53	0.00	0.29			1948.789

Bias 3 = Yes	2	2	4,584	-1.17	-2.41	0.10	0.85	0.85			0.49	0.49	
Bias 3 = No	8	20	285	-0.01	-0.74	0.71	0.06	0.25			0.17	0.77	
Risk of bias 4							0.08	0.75	0.03	0.00			1948.789
Bias 4 = Yes	4	6	4,652	-0.37	-1.39	0.64	0.22	1.54			0.12	0.86	
Bias 4 = No	7	17	4,608	-0.28	-1.20	0.64	0.05	0.00			0.71	0.00	
Risk of bias 5							0.03	0.17	0.65	0.77			1948.789
Bias 5 = Yes	9	21	4,779	-0.03	-0.43	0.35	0.04	0.20			0.16	0.77	
Bias 5 = No	2	2	4,481	-2.43	-3.47	-1.37	0.00	0.00			0.00	0.00	
Risk of bias 6													
Bias 9 = Yes	0	0	0										
Bias 9 = No	11	23	9,260										
Risk of bias 7							0.08	0.66	0.02	0.12			1948.789
Bias 10 = Yes	2	3	131	0.23	-1.14	1.59	0.00	0.00			0.00	0.00	
Bias 10 = No	9	20	9,129	-0.49	-1.22	0.25	0.16	0.81			0.16	0.82	
Publication status													
Published	10	22	9,255										
Unpublished	1	1	5										

Note. τ _2 = variance at level 2; τ _3 = variance at level 3; CI = confidence intervals; I^2_2 = heterogeneity at level 2; I^2_3 = heterogeneity at level 3; *k* = number of studies; *n* = number of participants; PA = Physical activity; R^2_2 = explained variance at level 2; R^2_3 = explained variance at level 3; Risk of bias 1 = Description of participant eligibility criteria; Risk of bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of bias 6 = Power calculation reported and study adequately powered to detect hypothesised relationships; Risk of bias 7 = Covariates adjusted for in analyses (e.g. gender, age, weight status).

School engagement dimension. Moderator analyses concerning the association between physical activity and different aspects of engagement or disengagement could not be conducted due to the insufficient number of studies that examined cognitive (k = 2) and emotional (k = 2) engagement, and cognitive (k = 0) and emotional (k = 2) disengagement.

Age. Age explained a small portion of the heterogeneity found between studies that assessed the association between physical activity and school engagement (R^2 = .06). Physical activity had a small to medium positive association with school engagement in adolescents (d = .40, 95% CI = .06, .77, I^2 = .99) and a small positive association with school engagement in children (d = .27, 95% CI = .08, .47, I^2 = .81).

Study design. Study design influenced the association between physical activity and school engagement and accounted for a small portion of the between-study heterogeneity (R^2 = .06). Randomised controlled trials that examined the effect of physical activity on school engagement reported a significant small to medium positive effect (d = .40, 95% CI = .06, .74, I^2 = .85). In contrast, cross-sectional and quasi-experimental studies reported effect sizes that were not different from zero (d = .23, 95% CI = -.01, .48, I^2 = .85 and d = .27, 95% CI = -.05, .59, I^2 = .85, respectively).

Risk of bias within studies. Risk of bias accounted for a portion of the heterogeneity between studies that examined the association between physical activity and school engagement (R^2 = .09). Studies that examined the association between physical activity and school engagement with a low risk of bias reported a small positive effect (d = .37, 95% CI = .14, .61, I^2 = .69), whereas, studies with a high risk of bias reported an effect size not significantly different from zero (d = .19, 95% CI = -.03, .44, I^2 = .93). Studies that assessed the association between physical activity and school disengagement with a low risk of bias reported an effect size not significantly different from zero (d = .31, 95% CI = -.51, 1.10, I^2 = .38), whereas, studies with a high risk of bias reported a large negative effect (*d* = -.83, 95% CI = -1.55, -.10, I^2 = .97).

Intervention type. The type of intervention implemented explained a portion of the between-study heterogeneity (R^2 = .02). Interventions that involved physical activity breaks during academic classroom lessons found that physical activity had a medium positive association with school engagement (*d* = .55, 95% CI = .02, 1.06, I^2 = .87). In contrast, interventions that involved teachers integrating physical activity into classroom lessons and interventions that were implemented during recess or lunch found effect sizes not different from zero (*d* = .22, 95% CI = -.21, .66, I^2 = .91, and *d* = .26, 95% CI = -.19, .73, I^2 = .81, respectively).

Single bouts vs. regular physical activity. Comparing the associations between single bouts and regular physical activity with school engagement accounted for a small portion of the between-study heterogeneity (R^2 = .05). Studies that examined the association between single bouts of physical activity immediately before a classroom lesson and school engagement reported a small to medium positive effect (*d* = .43, 95% CI = .08, .78, I^2 = .95). On the contrary, studies that examined the association between regular physical activity and school engagement found a small positive effect (*d* = .24, 95% CI = .05, .44, I^2 = .77).

Physical activity intensity. The different intensities of physical activity accounted for a portion of the heterogeneity found between studies that examined the association between physical activity and school engagement (R^2 = .28). Moderate- and vigorous intensity activity had a medium positive association with school engagement (*d* = .62, 95% CI = .26, .98, I^2 = .98). In contrast, studies that did not report the intensity of activity found an effect size not significantly different from zero (*d* = .29, 95% CI = -.06, .65, I^2 = .85).

Physical activity measures. The association between physical activity and school engagement differed depending on the measure of physical activity used and this accounted for a portion of the between-study heterogeneity (R^2 = .34). Studies that used observation measures of physical activity (e.g., the System for Observing Fitness Instruction Time) reported that physical activity had a large positive association with school engagement (*d* = .99, 95% CI = .33, 1.59, I^2 = .00). Studies that used subjective measures of physical activity (e.g., the Physical Activity Questionnaire) found that physical activity had a small positive association with school engagement (*d* = .23, 95% CI = .03, .44, I^2 = .83). In contrast, studies that did not measure physical activity, but instead provided additional opportunities for activity, reported that physical activity had no significant association with school engagement (*d* = .21, 95% CI = -.04, .46, I^2 = .80).

Risk of bias across studies

Published studies that examined the association between physical activity and school engagement reported a small positive association (*d* = .31, 95% CI = .14, .49). In contrast, unpublished studies that examined the association between physical activity and school engagement reported an effect size no different from zero (*d* = -.08, 95% CI = -.67, .54). The examination of funnel plots revealed low asymmetry, representing low risk of bias across studies that assessed the association between physical activity and school engagement and disengagement (Figure 2 and Figure 3, respectively). This was confirmed for studies that assessed the association between physical activity and school engagement by a non-significant Egger's test result (*t* =-1.58, *p* = .11). This was also confirmed for studies that examined the effect of physical activity on school disengagement (*t* = -0.03, *p* = .99).

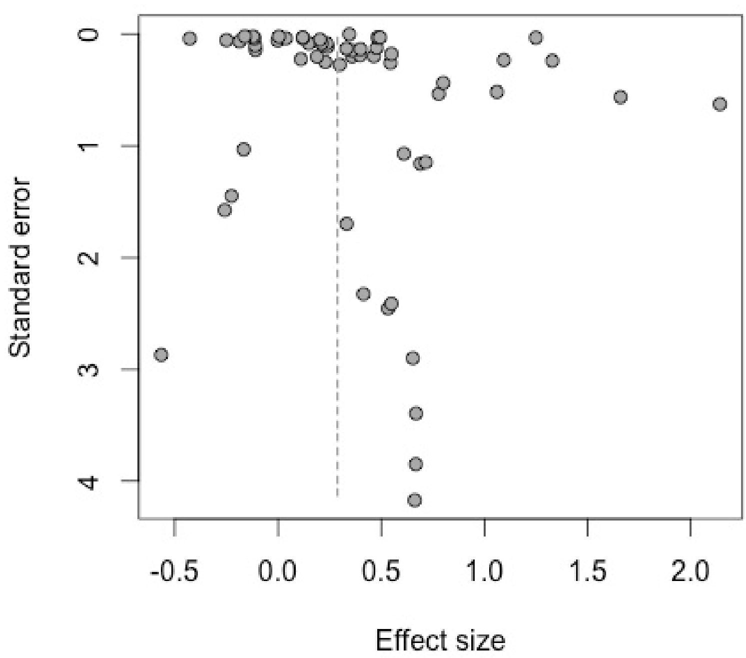


Figure 2. Funnel plot for school engagement

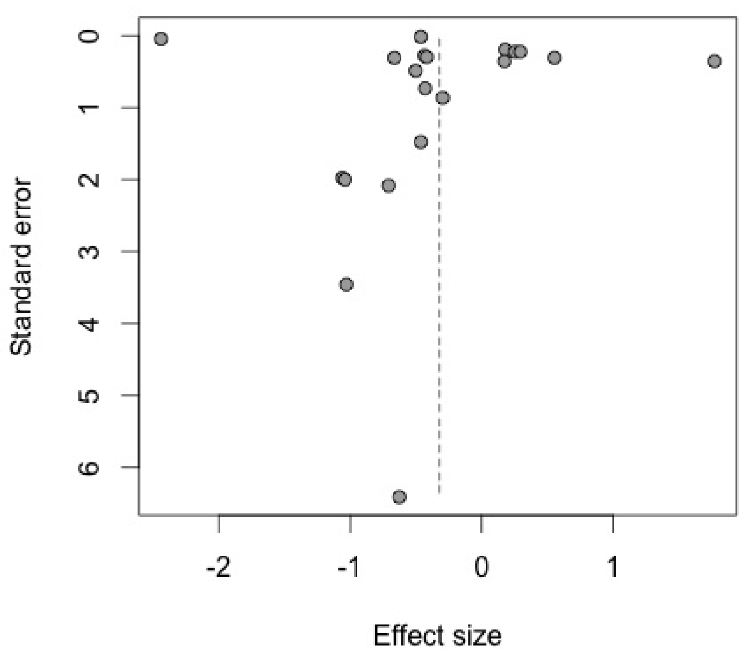


Figure 3. Funnel plot for school disengagement

Discussion

Summary of evidence

The first aim of this study was to systematically review and conduct meta-analyses of evidence from studies reporting information on the association between physical activity and school engagement and disengagement in youth. Overall, physical activity had a small positive association with school engagement, but no association with school disengagement. There was considerable heterogeneity in these effect sizes and the confidence intervals were wide. Therefore, these results should be interpreted with caution.

Interventions that involved physical activity breaks during academic classroom lessons appeared to be the most effective type of intervention for improving school engagement. These results provide potential support for the novelty-arousal theory (Berlyne, 1966; Ellis, 1984). The physical activity breaks could provide a novel distraction from academic classroom tasks and a shift in routine, and may allow students to refocus and improve attention when they return to academic classroom tasks. That said, it is currently unclear whether it is the break or the physical activity that improves school engagement. Future experimental research is needed that compares a sedentary break condition to a physical activity break condition. This design will help determine whether it is the break from academic classroom lessons per se, the physical activity itself, or both physical activity and the break that improve school engagement.

Physical activity was beneficial for both children and adolescents, but more beneficial for adolescents. This is an important finding as school engagement typically declines with age (Archambault, Janosz, Morizot, et al., 2009; Darr, 2012; Eccles et al., 1993; Marks, 2000), and physical activity appears to be most important during adolescence. This importance could be due to the influence of social background (e.g., parental characteristics) becoming less important as students get older and become less economically and socially dependent on their parents (Lucas, 2001). However, this finding could be subject to potential selection bias as not all school systems involve the second transition. Therefore, this finding should be interpreted with caution. Future longitudinal research is needed that follows students from childhood to adolescence to determine at which age physical activity is most important for school engagement.

Study design influenced the association between physical activity and school engagement as studies that employed a randomised controlled trial design were the only studies to report a significant positive effect. This finding suggests that the positive effects exist, as randomised controlled trials represent the highest quality of evidence (Barton, 2000). While five high-quality randomised controlled trials were identified, further high-quality evidence is needed to determine how and for whom interventions should be targeted to effectively improve school engagement.

The type and intensity of physical activity appears to influence the association between physical activity and school engagement. Single bouts before a classroom lesson and regular physical activity had a positive association with school engagement. In terms of intensity, moderate- and vigorous-intensity activity had a medium positive association with school engagement, while studies that did not report the intensity found an effect no different from zero. This suggests that single bouts and regular activity of moderate- and vigorous-intensity could be used to promote school engagement. However, due to the small number of studies that explored the effect of moderate- and vigorous-intensity activity on school engagement, these two subgroups were collapsed. Further research is needed that directly compares the effect of different activity intensities on school engagement.

The measurement tools used to assess physical activity influenced the association between physical activity and school engagement. Studies that used observation and subjective measures of physical activity reported that physical activity had a positive association with school engagement, whereas, studies that did not measure physical activity, but instead provided additional opportunities for activity, indicated that physical activity had no association with school engagement. This could be due to not all students participating in physical activity. When groups of students were provided with an opportunity for physical activity, it is unlikely that all students took the opportunity to be physically active, and without measurement, it is impossible to determine which students were physically active and which students were not. Although studies that used observation and subjective measures found a positive effect, there are also limitations to using these measures. Observation is generally limited to one overall class physical activity score and is subject to participant reactivity (Trost, 2007). While subjective measures provide data at the individual level, they are prone to social desirability bias and youth's inability to accurately recall their physical activity behaviour (Troiano et al., 2012). Objective measures of physical activity, such as accelerometers and pedometers, minimise the potential for respondent bias and provide data at the individual level. Two studies used an objective measure of physical activity; however, further research is needed that employs objective measures to explore the association between physical activity and school engagement.

Unfortunately, moderator analyses concerning the impact of physical activity on different aspects of engagement could not be conducted due to the insufficient number of studies examining emotional (k = 2) and cognitive engagement (k = 2). Fredricks et al. (2004) suggest that the three dimensions of school engagement and disengagement are dynamically interrelated and should be examined all together. However, no single study examined all three dimensions of school engagement or disengagement. Further research is needed that explores the effect of physical activity on the multidimensional constructs of school engagement and disengagement that include behaviour, cognition, and emotions. While there is a general consensus that school engagement is a multidimensional construct, not all scholars agree with Fredricks et al.'s conceptualisation of school engagement, specifically that cognitive engagement subsumes motivation (e.g., Reschly, 2010). Further research is needed to determine whether cognitive engagement subsumes motivation, or whether cognitive engagement and motivation are separate but related constructs. If cognitive engagement does not subsume motivation, further research is needed that examines the effect of physical activity on motivation.

Strengths and limitations

This study has a number of strengths. First, to the authors' knowledge, this is the first systematic review and meta-analysis of the relationship between physical activity and school engagement. These findings are important, as levels of school engagement tend to decline with age and methods that lessen, or reverse, this decline, need to be identified. The evidence reviewed indicates that targeting physical activity could be an effective way to promote school engagement in youth, especially at the highest educational level when school engagement levels tend to be lowest.

There were also limitations to this study. There was a high level of heterogeneity in the pooled effect sizes. This high level of heterogeneity could be due to the large variety of measurement tools used and the variety of contexts in which the studies were conducted. However, some of this heterogeneity was explained by a number of moderating variables. Additionally, although majority of studies employed an experimental design (k = 25), 25 of the 40 included studies were rated as having a high risk of bias. Further, the majority of studies examined behavioural engagement and disengagement, rather than emotional or cognitive engagement and disengagement. As such, behavioural engagement effect sizes made up most of the overall school engagement effect size. Similarly, behavioural disengagement effect sizes made up most of the overall school disengagement effect size. Most studies have been published in Health and Sport Science journals, rather than Educational and Psychological journals. Further research is needed that explores the effect of physical activity on emotional and cognitive engagement and disengagement.

There were also limitations to the moderator analyses. Risk of bias was categorised as high or low within each study. While this method gives a general idea of how risk of bias influences the overall effect, it is limited as each item can influence risk of bias in a different way (Liberati et al., 2009). Thus, total risk of bias was not adjusted for in the moderator analyses. Similarly, although study design was examined as a potential moderating variable, the moderator analyses did not adjust for the quality of the study design. Additionally, studies were divided into categories by age of subjects. Studies examining children were defined as studies with a mean age less than 13 and studies examining adolescents were defined as studies with a mean age of 13 or above. This method of dividing studies is limited, as the mean age does not imply that all participants are that age, it is quite likely that each study has participants in both categories. Therefore, these results should be interpreted with caution.

Implications and conclusions

Despite the limitations of this study, there are also important implications. The health benefits of physical activity are well established; however, the results of this study suggest that the benefits extend further than health, and into education. There is increasing pressure placed on educators to increase academic performance scores, especially standardised test scores, and some educators perceive time spent in the academic classroom to be more beneficial to academic performance, compared to time spent promoting physical activity. Evidence from this study suggests that providing opportunities for physical activity could improve school engagement (Van Dijk et al., 2014; Zhang et al., 2015).

Physical activity declines with age, so the lowest level of participation during the school years tends to occur during adolescence (Blaes, Baquet, Van Praagh, & Berthoin, 2011; Sallis, 2000). Physical activity has the most beneficial effect on school engagement in adolescents. Therefore, promoting physical activity in adolescents, who currently participate in the lowest levels of physical activity, should be a priority for policy makers, teachers, and parents. Teachers could provide adolescents with classroom lesson physical activity breaks in order to improve school engagement. For example, teachers could provide students with 10-minute breaks for physical activity focusing on dance or sport movements (e.g., Whitt-Glover et al., 2011). If policy makers and educators use this evidence and provide more opportunities for physical activity at school, young people could also receive a number of physical and mental health benefits (Biddle & Asare, 2011; Janssen, I. & LeBlanc, 2010).

In conclusion, results from this study suggest that promoting physical activity could provide benefits for school engagement in youth, over and above the well-established physical and mental health benefits. This study provides further evidence to support the promotion of physical activity, especially in schools.

Chapter 3: Study 2 – The effect of physical activity and classroom lesson breaks on school engagement in youth

Abstract

Introduction. Research indicates that single bouts of physical activity during breaks can improve students' school engagement in the following classroom lesson. However, as these studies have not objectively measured physical activity, it is unclear whether the physical activity itself is beneficial for school engagement. It is possible that simply having a break from academic lessons improves engagement regardless of whether or not physical activity takes place in this break. Therefore, the purpose of this study was to determine whether single bouts of physical activity have a positive relationship with school engagement over and above the presence or absence of a break before the classroom lesson.

Methods. Data were collected over three ten-week periods: January–April 2014 (Time 1), October–December 2014 (Time 2), and April–June 2015 (Time 3). A cohort of 2,194 adolescents (mean age = 13.40 years, SD = .73) wore an accelerometer during the hour before a mathematics lesson. Participants also completed a questionnaire following the mathematics lesson to assess school engagement in that particular lesson.

Results. Linear mixed models indicated that moderate-intensity activity before a mathematics lesson had a positive linear relationship with cognitive mathematics engagement ($\beta = .40$, $p < .05$). Recess breaks before a mathematics lesson 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). Similarly, lunch breaks before a mathematics lesson had a negative relationship with cognitive mathematics engagement ($\beta = -.20$, $p < .01$).

Conclusion. Results from this study suggest that promoting single bouts of moderate-intensity activity before mathematics lessons could improve students' cognitive engagement in the following lesson. Educators should also be aware that students tend to demonstrate the lowest levels of school engagement after recess breaks.

Introduction

Students who actively participate in school activities, enjoy school, and are psychologically invested in school are healthier than those who are less engaged (Abbott-Chapman et al., 2014; Carter, McGee, Taylor, & Williams, 2007). Engaged students are more likely to perform well academically, (Wang, M. & Holcombe, 2010), successfully transition into post-school education, and complete post-school education (Abbott-Chapman et al., 2014; Suldo et al., 2006). An individual's level of post-school education is associated with inequities across a number of health outcomes (Australian Bureau of Statistics, 2008b). For example, post-school education is associated with lower levels of psychological stress and health risk behaviours (e.g., 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 SES areas tend to display the lowest levels of school engagement (Fredricks et al., 2004), identifying modifiable determinants for this group is a priority for parents, policy makers, and society.

Physical activity and school engagement

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). Investigations conducted in classrooms have found that before school physical activity promotion programs improved school engagement, specifically time on-task, for up to one hour following the activity (e.g., Grieco et al., 2009; Riley et al., 2014). Further, a number of studies have found that integrating physical activity into classroom lessons increased enjoyment (Gibson et al., 2008; Vazou et al., 2012), effort (Vazou et al., 2012), and time on-task during the classroom lesson (Grieco et al., 2009; Riley et al., 2014). However, an important limitation exists in the majority of these studies. Only one study has used accelerometers to examine the relationship between physical activity and an aspect of school engagement (Riley et al., 2014). This study found that integrating physical activity into mathematics lessons improved students' time on-task (*d* = .41). As there is currently limited evidence that has used accelerometers to assess the relationship between physical activity and school engagement, there is uncertainty about whether physical activity actually is beneficial, when physical activity is beneficial, and how physical activity influences school engagement.

Physical activity breaks from classroom lessons may or may not be beneficial for school engagement. Owen, Parker, Van Zenden, MacMillan, and Lonsdale (2016) concluded that physical activity breaks were the most 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., Howie et al., 2014; Katz et al., 2010; Mahar et al., 2006). However, one study found that physical activity breaks during classroom lessons had no effect on classroom behaviour (d = -.001, p = .86; Katz et al., 2010). Another study found that physical activity during lunch breaks was positively associated with attention and concentration levels during the following classroom lesson (r = .24, p = .008; Laberge et al., 2012). However, as studies assessing the relationship between physical activity during breaks and school engagement have not objectively measured physical activity, it is currently unclear whether physical activity is beneficial for school engagement over and above the presence or absence of a break.

Mechanisms of influence

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, such as a break, allows students to refocus, and improve attention and concentration (Ellis, 1984). In the Australian school system, students receive two breaks from classroom lessons. Recess breaks are usually mid-morning for approximately 15 minutes and lunch breaks are usually around midday for approximately 30 minutes. However, the time and duration may vary from school to school. These breaks provide opportunities for students to be physically active. 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 (Sattelmair & Ratey, 2009). However, it currently unclear whether the novelty-arousal theory or BDNF provides 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. The novelty-arousal theory posits that breaks provide a shift in routine and allow students to refocus, and improve attention and concentration (Ellis, 1984). Therefore, if school engagement levels are highest after breaks, such as recess or lunch, 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 (Knaepen, Goekint, Heyman, & Meeusen, 2010). Thus, if vigorous-intensity activity is the most beneficial for school engagement, it is likely that BDNF is an underlying mechanism. However, it is currently unclear which whether school engagement levels are highest after breaks, and which intensity of activity is the most beneficial for school engagement.

Purpose

The primary objective of this study is to determine whether accelerometer-assessed physical activity had a positive relationship with school engagement over and above the presence or absence of a break before the classroom lesson. The secondary objective of this study was to investigate potential mechanisms underlying this possible relationship. If vigorous-intensity activity is the most beneficial intensity of activity for school engagement, it is likely that BDNF is an underlying mechanism. Additionally, if breaks (e.g., recess and lunch) are beneficial for school engagement, the novelty-arousal theory could be an underlying mechanism.

Methods

Study design and procedure

The Australian Catholic University Human Research Ethics Committee and the Department of Education and Communities granted approval for this study (see Appendix D for the Human Research Ethics Committee approval letter). Parents or guardians provided informed written consent for their student to be involved in this study, and students provided informed written assent to be involved (see Appendix E for consent forms). Data were collected at three time points: Time 1 during Term 1 of 2014 (January–April) and Time 2 during Term 4 of 2014 (October–December) when students were in year 8, and Time 3 during Term 2 of 2015 (April–June), when students were in year 9.

At each Time point of data collection, students wore an accelerometer (Actigraph GT3X+) during the hour before a mathematics lesson. Following the mathematics lesson, students responded to a questionnaire assessing mathematics engagement during the mathematics lesson.

Participants

Year 8 students 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) rank of ≤ 5 (Australian Bureau of

Statistics, 2008a), to be eligible to participate. Within these schools, all year 8 students without any pre-existing injuries or illnesses were eligible to participate (see Appendix A for further information regarding the recruitment process and participants). Of the 2,194 students recruited, 826 students provided complete data 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). Students had a mean age of 13.40 years (SD = .73).

Measures

Physical activity one hour before an academic lesson. Accelerometers (Actigraph GT3X+) were used to measure adolescents' physical activity during the one-hour period before a mathematics lesson. Accelerometers have been shown to accurately classify the frequency, duration, and intensity of physical activity in adolescents (Ridgers & Fairclough, 2011; Snijders, 2005). Evenson et al. (2008) cutpoints were used to define light (101 – 2295 counts per minute), moderate (2296 - 4011 counts per minute), vigorous (> 4012 counts per minute), and MVPA (> 2296 counts per minute). These cutpoints have been shown to be the most accurate in adolescents (Trost et al., 2011). ActiLife software (Version 6, ActiGraph, LLC, Fort Walton Beach, FL) was used to filter out the one-hour period before the mathematics lesson (see Appendix A for further information regarding accelerometer data processing). Physical activity during the hour before a mathematics lesson was assessed as the acute effects of physical activity tend to last one hour (Hillman et al., 2009; Joyce et al., 2009).

Behavioural, cognitive, and emotional mathematics engagement. An adapted version of the School Engagement Measure (Fredricks, Blumenfeld, Friedel, & Paris, 2005; Hyde, 2009) was used to assess current levels of behavioural (e.g., classroom behaviour), emotional (e.g., lesson enjoyment), and cognitive engagement (e.g., problem solving) during the mathematics lesson (see Appendix F for the questionnaire). Hyde (2009) adapted Fredricks' et al. (2005) original 14-item measure of typical school engagement to include 18 items that specifically measure typical school engagement during mathematics. Hyde's version was adapted to include 15 items that specifically measure students' current level of school engagement during mathematics. For example, Hyde adapted Fredricks' original item 'I follow the rules at school' to 'I follow the rules during maths lessons', was adapted to 'Today I followed the rules during the maths lesson'. Fredricks' original measure was internally consistent (α = .55 to .86); however, Hyde's adaptation improved the internal consistency (α = .75 to .87). The current adaptation is divided into three subscales that measure behavioural, cognitive, and emotional engagement, and each item is rated on a five point Likert scale.

Covariates

Covariates included age, gender, and socioeconomic status. Students indicated their age and gender. Students also responded to an adapted version of the Family Affluence Scale II to assess family level socioeconomic status (Currie et al., 2008).

Sample size calculation

Sample size calculations have been based on results of a meta-analysis concerning the effect of physical activity on the dimensions of school engagement, including behaviour, emotions, and cognition (Owen et al., 2016). In that analysis, physical activity had a small positive effect on school engagement (d = .28). To detect an effect of this magnitude, a sample of 398 participants would provide 80% power in a cross-sectional study (α < .05, two-tailed). It is important to adjust for clustering in all study designs that examine adolescents clustered within classes, as these adolescents may be influenced by class-level factors (Reidy et al., 1998), such as teacher support, class climate, and ability grouping. Clustering was adjusted for using the formula $1+(m-1)\rho$, where m is the average cluster size (i.e., number of students per class) and ρ is the intraclass correlation coefficient (ICC) (Campbell, Elbourne, & Altman, 2004). The ICC measures the proportion of variance in the outcome (i.e., school engagement) that lies between students within a classroom (McGraw & Wong, 1996). Based on a class-level ICC for school engagement of .06 reported by a previous study (Reeve, 2013), an adjustment of 2.26 was required: $1+(22-1).06 = 2.26$. Multiplying by the 398 participants required in a cross-sectional study, 899 students will need to participate to achieve 80% power.

Data analysis

All analyses were conducted using R (R Core Team, 2014). Alpha coefficients were used to assess the internal consistency of the adapted version of the Student Engagement in Mathematics Classroom Scale. Descriptive statistics were calculated to examine the skewness and kurtosis of the data.

The relationship between physical activity and its outcomes tends to be complicated. For example, there appears to be a linear relationship between physical activity and self-esteem (e.g., Tremblay, Inman, & Willms, 2000) and a quadratic relationship between physical activity and cognitive function (e.g., Tomporowski, 2003). In order to capture the potentially complicated relationship between physical activity and school engagement, this study tested for linear and quadratic relationships using orthogonal polynomials. To test for these relationships, physical activity was examined in two ways: (i) categories based on previous literature and (ii) evenly distributed quantiles.

Data preparation. The categories of physical activity during the hour before mathematics were 0–10 minutes, 10–20 minutes, 20–30 minutes, and >30 minutes of activity. The results of two reviews supported the use of these categories. First, a recent systematic review that included 12 studies (10 experimental and 2 observational) reported that 10–20 minute bouts of moderate-intensity activity were more effective than 20–45 minute bouts in improving attention scores in youth (Janssen, M., Toussaint, van Mechelen, & Verhagen, 2014). Second, Petruzzello, Landers, Hatfield, Kubitz, and Salazar (1991) conducted a meta-analysis of evidence from studies that examined the effect of physical activity on state mood and found that bouts of activity between 20–30 minutes were the more effective, compared to shorter (<20 minutes). As 10–20 minute bouts of physical activity appear to be most beneficial for attention scores and 20–30 minute bouts appear to be most beneficial for state mood, this study tested these two categories of physical activity, as well as less than 10 minutes and greater than 30 minutes.

In addition to forming categories of physical activity bouts based on previous literature, this study also examined quantiles using sample-specific cut-offs. The quantiles of physical activity were the 10th, 25th, 50th, 75th, and 90th quantiles. This allowed the examination of how the relationship between physical activity and mathematics engagement differs at different parts of the physical activity distribution.

Main analyses. Using both the category and quantile approach, multilevel regression models (see Appendix A for further information regarding multilevel regression models) determined whether physical activity predicted mathematics engagement during the mathematics lesson over and above the presence or absence of a break before the classroom lesson (e.g., recess and lunch). The models consisted of repeated measures 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 break before a classroom lesson predicted mathematics engagement in the following lesson. In Model 3 both activity and having a break before a classroom lesson were included as explanatory variables. The final model (Model 4) controlled for all covariates.

Missing data. The percentage of missing data for covariates ranged from 3% (socioeconomic status) to 5% (age) and resulted from participants missing items and/or absenteeism. Participants who were missing one or more covariates were assigned imputed values using multiple imputation (Graham, Cumsille, & Elek-Fisk, 2003). Five imputed datasets were created using the Amelia II package (Honaker, King, & Blackwell, 2011) in R (R Core Team, 2014). The final estimates and standard errors of the linear mixed effects models were obtained by combining the results from the five datasets (Rubin, 1987).

Results

Descriptive statistics

Descriptive statistics are displayed in Table 6. During the hour before mathematics, adolescents spent on average 1.66 minutes in vigorous-intensity activity, 2.81 minutes in moderate-intensity activity, 7.23 minutes in light-intensity activity, and 48.17 minutes sedentary.

The items within the mathematics engagement questionnaire that students left blank revealed no apparent pattern (< 1% of items were missing). Alpha coefficients for the scores derived from the mathematics engagement subscales ranged from .75 to .91. As such, the mathematics engagement subscales were considered to be internally reliable (Nunnally & Bernstein, 1994).

Table 6

Descriptive statistics of physical activity and school engagement

	Mean	Standard deviation	Skewness	Kurtosis	Class ICC	School ICC	Alpha coefficient
Sedentary minutes	48.17	7.84	-1.33	2.38	0.09	0.04	
Light-intensity minutes	7.23	4.46	1.23	2.25	0.08	0.04	
Moderate-intensity minutes	2.81	2.84	4.00	33.13	0.06	0.02	
Vigorous-intensity minutes	1.66	2.45	3.85	23.31	0.05	0.02	
Moderate-to-vigorous intensity minutes	4.47	4.53	2.56	10.83	0.07	0.02	
Behavioural engagement	4.05	0.73	-0.92	0.60	0.07	0.02	.75
Emotional engagement	3.08	1.13	-0.14	-0.90	0.08	0.02	.91
Cognitive engagement	3.35	1.13	-0.37	-0.69	0.05	0.03	.85
Overall school engagement	3.50	0.81	-0.39	-0.38	0.08	0.03	.91

Note. ICC = Intraclass correlation coefficient.

Main results

Results of linear mixed models (Model 4) examining the relationship between categories of different intensities of physical activity and mathematics engagement can be viewed in Tables 7, 8, 9, and 10. Complete results pertaining to linear mixed models for the relationship between categories of different intensities of physical activity and mathematics engagement can be viewed in Appendix C (see Tables C1–4, which display results of Model 1 for categories of physical activity; see Table C5, which displays results of Model 2 for categories of physical activity; see Tables C6–9, which display results of Model 3 for categories of physical activity). Additionally, results of linear mixed models for the relationship between quantiles of different intensities of physical activity and mathematics engagement can be viewed in Appendix C (see Tables C10–13, which display results of Model 1 for quantiles of physical activity; see Table C14, which displays results of Model 2 for quantiles of physical activity; see Tables C15–18, which display results of Model 3 for quantiles of physical activity; see Tables C19–22, which display results of Model 4 for quantiles of physical activity).

Moderate-to-vigorous physical activity and mathematics engagement. There was no linear or quadratic relationship between MVPA and overall, behavioural, emotional, or cognitive mathematics engagement.

Table 7

The effect of moderate-to-vigorous physical activity on mathematics engagement

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.11 (.45)	-1.55*** (.46)	.17 (.45)	1.04* (.45)
MVPA during the hour before mathematics				
Linear	.06 (.09)	.08 (.12)	.02 (.12)	.02 (.14)
Quadratic	.01 (.10)	-.03 (.11)	.02 (.11)	-.03 (.11)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18*** (.06)	-.19*** (.07)	-.13* (.06)	-.13* (.06)
Lunch	-.06 (.07)	.03 (.08)	.06 (.07)	-.20*** (.07)
Physical Education	-.05 (.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)
Gender (male = 1)	.01 (.05)	-.13** (.05)	.12* (.05)	-.01 (.05)
SES- family level	.03* (.01)	.04*** (.01)	.02 (.01)	.02 (.01)

Different intensities of activity and mathematics engagement. Moderate-intensity activity had a positive linear relationship with cognitive mathematics engagement (β = .40, p < .05), but no significant relationship with overall, behavioural, or emotional mathematics engagement (β = .31, β = .24, and β = .11, respectively). Light and vigorous-intensity activity did not have a positive relationship with overall, behavioural, emotional, or cognitive mathematics engagement.

Table 8

The effect of vigorous physical activity on mathematics engagement

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.12 (.55)	-1.33* (.56)	.10 (.55)	1.02 (.55)
MVPA 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	-.18** (.06)	-.20** (.07)	-.13* (.06)	-.13* (.06)
Lunch	-.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)
Gender (male = 1)	.01 (.05)	-.14** (.05)	.12* (.05)	-.01 (.05)
SES- family level	.03* (.01)	.04** (.01)	.02 (.01)	.02 (.01)

Table 9

The effect of moderate physical activity on mathematics engagement

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.17 (.52)	-1.80** (.53)	-.20 (.52)	1.00 (.52)
MVPA 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	-.18** (.06)	-.20** (.07)	-.13* (.06)	-.13* (.06)
Lunch	-.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)
Gender (male = 1)	.01 (.05)	-.13** (.05)	.12* (.05)	-.01 (.05)
SES- family level	.03* (.01)	.04** (.01)	.02 (.01)	.02 (.01)

Table 10

The effect of light physical activity on mathematics engagement

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.24 (.42)	-1.46** (.43)	.42 (.42)	1.04* (.42)
MVPA 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	-.18** (.06)	-.19** (.07)	-.14* (.06)	-.12* (.06)
Lunch	-.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)
Gender (male = 1)	.01 (.05)	-.13** (.05)	.11* (.05)	-.01 (.05)
SES- family level	.02* (.01)	.04** (.01)	.02 (.01)	.02 (.01)

Breaks and mathematics engagement. Recess breaks had a negative relationship with overall, behavioural, emotional, and cognitive mathematics engagement (β = -.18, $p < .01$, β = -.19, $p < .01$, β = -.13, p = .03, and β = -.13, p = .04, respectively) indicating that students were less engaged in lessons after recess, compared to lessons following other classroom lessons, PE lessons, lunch breaks, or the first lessons of the day. Similarly, lunch breaks had a negative relationship with cognitive mathematics engagement (β = -.20, $p < .01$), but no relationship with overall, behavioural, and emotional mathematics engagement (β = -.06, β = .03, and β = .06, respectively).

Discussion

The primary objective of this study was to determine whether physical activity had a positive relationship with school engagement over and above the presence or absence of a break before the classroom lesson. Overall, the results of this study suggest that moderate-intensity activity had a positive linear relationship with cognitive engagement over and above the presence or absence of a break before the classroom lesson. However, moderate-intensity activity did not have a positive relationship with behavioural, emotional, or overall mathematics engagement over and above the presence or absence of a 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, BDNF was unlikely to be an underlying mechanism. Similarly, as recess breaks had a negative relationship with school engagement, the novelty-arousal theory seems unlikely to be an underlying mechanism.

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 classroom 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 physical activity breaks from classroom lessons improved behavioural engagement (e.g., Howie et al., 2014; Mahar et al., 2006), whereas integrating physical activity into classroom lessons improved emotional engagement (e.g., Gibson et al., 2008; Vazou et al., 2012). Further research is needed that examines whether different types of physical activity have different relationships with different dimensions of school engagement.

Vigorous-intensity activity was not the most beneficial intensity of activity for school engagement, so BDNF was unlikely to be the mechanism underlying the relationship. Low and vigorous-intensity activity had no relationship with cognitive engagement, whereas, moderate-intensity activity had a positive relationship with cognitive engagement (β = .40, $p < .05$). This result suggests that an inverted-U relationship could exist between the intensity of physical activity and cognitive engagement. Yerkes and Dodson (1908) hypothesised that performance increases up to an optimal point, and then deteriorates with further increases of physical arousal. The results support this hypothesis, as when the intensity of physical activity increased, so did cognitive engagement, up to an optimal point (i.e., moderate-intensity), and then deteriorated with further increases in intensity (i.e., when the activity became vigorous). Future research is needed that examines the inverted-U relationship between accelerometer assessed physical activity intensity and cognitive engagement.

It is unlikely that the novelty-arousal theory is a mechanism underlying the relationship between physical activity and school engagement. The results indicated that students demonstrated the lowest levels of school engagement after recess breaks. In contrast to this finding, previous research has found that students are more engaged after recess, compared to before recess (e.g., Jarrett, 2002). While the results of our study suggest that recess and lunch breaks might not beneficial for school engagement in the following classroom lesson, these breaks are still important. Recess and lunch provide a break from the rigours of academic challenges and the unstructured nature of recess contributes to youths' cognitive, social, emotional, and physical functioning (Ramstetter, Murray, & Garner, 2010).

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., Martikainen et al., 2012). Regular MVPA can change the structure and function of the brain by increasing the production of neurotrophins, growth of nerve cells in the hippocampus, development of nerve connections, density of neural network, and brain-tissue volume (Chaddock, Pontifex, Hillman, & Kramer, 2011). These physiological changes are linked to increased attention, information processing, coping strategies, and positive affect. Regular MVPA might therefore 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.

Strengths and limitations

This study has a number of strengths. Firstly, to the authors' knowledge, this is the first study to examine whether physical activity, breaks from classroom lessons, both objectively measured physical activity and breaks, or neither physical activity nor breaks have a positive relationship with school engagement. Secondly, this is the first study to use objective measures of physical activity to examine the relationship between physical activity and school engagement. Unlike subjective measures of physical activity, objective measures 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 (Adams et al., 2005). Thirdly, this is the first study to examine the relationship between physical activity and school engagement using the three-dimensional measure of school engagement.

There are also some limitations to this study. Firstly, although physical activity was accurately measured, the low levels of MVPA (M = 4.47 mins, 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 minutes of physical activity during the hour before the mathematics lesson. Secondly, while the measure of school engagement is internally consistent (alphas ranged from .75 to .91), it is a subjective measure. Subjective measures are subject to biases related to social desirability (Adams et al., 2005). This means that some students tend to respond in a way that they perceive to be more socially acceptable than their “real” response. However, observational measures of school engagement also have problems, as they provide limited information on the quality of effort, participation, or thinking (Fredricks et al., 2004). Additionally, there are no observational measures 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. Thirdly, despite accelerometers providing a measure of the intensity of physical activity, there are also limitations. The standardised cut-off points that accelerometers use to define the intensity of physical activity may not actually represent the same intensity of activity across individuals (Hills, Mokhtar, & Byrne, 2014). In contrast, heart rate monitors use an individualised method (percent of maximum heart rate) to classify activity into six intensity categories, ranging from very light to maximal (Hills et al., 2014). However, heart rate can be influenced by a number of factors not related to physical activity (e.g., age, sex, and level of training). Thus, future research should use heart rate monitors in conjunction with accelerometers to verify that increases in heart rate are due to physical activity.

Implications

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 (Biddle & Asare, 2011; Janssen, I. & LeBlanc, 2010).

Students' levels of school engagement are generally lowest following recess breaks. As such, educators need to be aware of these low levels after recess 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.

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.

Chapter 4: Study 3 – Regular physical activity and educational outcomes in youth: A longitudinal study

Abstract

Introduction. Physical activity could have a number of educational benefits; however, this evidence is currently limited in terms of study design (i.e., cross-sectional) and measurement (i.e., subjective moderate-to-vigorous physical activity measures).Thus, the objective of this study was to determine whether longitudinal changes in accelerometer-assessed moderate-to-vigorous physical activity were associated with changes in educational outcomes (i.e., academic performance and school engagement), and to compare the longitudinal and cross-sectional associations between moderate-to-vigorous physical activity and educational outcomes.

Methods. Longitudinal data were collected from a cohort of 2,194 adolescents (mean age = 13.40 years, SD = .73) over three ten-week periods: Term 1 of 2014 (Time 1), Term 4 of 2014 (Time 2), and Term 2 of 2015 (Time 3). To measure total MVPA, adolescents wore an accelerometer for seven consecutive days. Participants responded to a questionnaire to measure mathematics engagement and completed a nationally administered numeracy test to assess academic achievement.

Results. Longitudinal latent change score models indicated that increases in moderate-to-vigorous physical activity were associated with increases in academic performance (β = .17, p < 001), but not school engagement. In contrast, cross-sectional regression analyses indicated that moderate-to-vigorous physical activity was negatively associated with academic performance (β = -.31, p < .001 and β = -.24, p < .001 at Time 1 and Time 2, respectively) and school engagement (β = -.13, p < .01 at both Time 1 and Time 2).

Conclusion. Spending a large portion of time participating in moderate-to-vigorous physical activity likely takes time away from homework, but has a positive long-term impact on academic performance. These findings provide parents and policy makers with evidence that moderate-to-vigorous physical activity has long-term benefits for academic performance. However, efforts to increase moderate-to-vigorous physical activity need to do so in a way that acknowledges the competing time demands in adolescents' lives (e.g., homework).

Introduction

Students who are engaged with school tend to be healthier than those who are less engaged (Abbott-Chapman et al., 2014; Carter et al., 2007). School engagement is one of the most critical factors underpinning academic performance (Wang, M. & Holcombe, 2010), the successful transition into post-school education, and the completion of post-school education (Abbott-Chapman et al., 2014; Suldo et al., 2006). An individual's level of educational attainment is associated with inequities across many health outcomes (Australian Bureau of Statistics, 2008a). For example, educational attainment is associated with decreased psychological stress and decreased health risk behaviours (e.g., tobacco smoking, illicit drug use, and high-risk alcohol consumption). For these reasons, school engagement may be a modifiable determinant of health in youth. Unfortunately, the lowest levels of school engagement are displayed by youth from areas of low SES (Fredricks et al., 2004) and post transition from one level of schooling to another. Identifying the modifiable determinants of school engagement, especially for adolescents from areas of low SES, is therefore a priority for parents, policy makers, and society.

Physical activity and academic performance

Four recent systematic reviews have concluded that physical activity likely has a positive association with academic performance (Castelli et al., 2014; Lees & Hopkins, 2013; Martin et al., 2014; Singh et al., 2012a). These reviews included 32 studies and reported a positive association between physical activity and academic performance. Castelli et al. (2014) conducted a systematic review and meta-analysis of 20 studies and reported that physical activity has a small to medium positive effect on academic achievement ($d = .38$, $p < .05$) in children and adolescents. Due to the high level of heterogeneity between studies regarding measurement, study sample, and study designs, the other three systematic reviews did not conduct meta-analyses. Singh et al. (2012a) conducted a systematic review of 14 studies and concluded that there was strong evidence for a positive association between physical activity and academic performance in children and adolescents. Lees and Hopkins (2013) reviewed three randomised controlled trials and reported that physical activity led to small improvements in academic performance in children. Similarly, Martin et al. (2014) examined six experimental studies (four multicomponent and two physical activity) and found that physical activity had a small positive effect on academic performance in overweight and obese children. These four systematic reviews provide evidence that physical activity could improve academic performance.

Although these systematic reviews have found that there is a positive association between physical activity and academic performance, there are limitations to the included studies. First, only a small number of studies have used accelerometers to measure physical activity. These few studies have found conflicting results, with one study finding a positive association (Kwak et al., 2009), two studies finding a negative association (Esteban-Cornejo et al., 2014; Van Dijk et al., 2014), and three studies finding no association (Harrington, 2013; LeBlanc et al., 2012; Syväoja, H. et al., 2013). Second, most of this evidence is limited to cross-sectional study designs. Only one longitudinal study examined the association between accelerometer-assessed MVPA and standardised test scores (Booth, J. et al., 2013). Results indicated that MVPA at age 11 positively predicted English (β = .16, p = < .001), mathematics (β = .11, p = .05), and science (β = .12, p = .10) standardised test scores at age 16. However, MVPA was only measured at age 11; so we can only determine how current levels of MVPA are associated with academic performance. Longitudinal data could provide information about how changes in MVPA over time potentially lead to changes in academic performance that would not be uncovered using cross-sectional study designs.

It is possible that longitudinal evidence could differ from cross-sectional evidence as increases in regular MVPA over a period of time has a number of benefits that could lead to improvements in educational outcomes. For example, regular MVPA improves fitness and cognitive function in youth (Sibley & Etnier, 2003), which could lead to improvements in educational outcomes that may take time to manifest (Castelli, Hillman, Buck, & Erwin, 2007; Chomitz et al., 2009; Hansen, Herrmann, Lambourne, Jaehoon, & Donnelly, 2014; Hillman, Kamijo, & Scudder, 2011; Kwak et al., 2009; Sibley & Etnier, 2003).

Physical activity and school engagement

A recent systematic review and meta-analysis reported that physical activity had a positive association with school engagement (d = .28, 95% CI = .12, .46) (Owen et al., 2016). Of the 29 studies included in this meta-analysis, 20 studies examined the effect of regular physical activity on school engagement (as opposed to studies examining the immediate effects of physical activity). Pooled together, these 20 studies indicated that regular physical activity had a small positive effect on school engagement (d = .24, 95% CI = .05, .44).

Although this systematic review and meta-analysis provides some evidence for the positive association between regular physical activity and school engagement (Owen et al., 2016), there are limitations to the included studies. First, only one study used accelerometers to measure physical activity (Martikainen et al., 2012). This study reported that children who participated in high levels of regular MVPA were no more likely to display attention problems compared to children who participated in low levels of regular MVPA (OR = 0.8, 95% CI = 0.2, 2.5, p = .70). However, as this study was a cross-sectional design, the authors could only determine how current levels of MVPA were associated with current school engagement. Longitudinal data could provide information about how changes in MVPA over time potentially lead to improvements in school engagement that take time to manifest.

Purpose

The primary objective of this study was to determine whether longitudinal changes in accelerometer-assessed MVPA were associated with changes in educational outcomes (i.e., academic performance and school engagement). A secondary objective of this study was to compare the cross-sectional and longitudinal associations between accelerometer-assessed MVPA and educational outcomes.

Methods

Sample size calculation

Conservatively, sample size calculations were based on result of the meta-analysis with the smallest effect that combined evidence from studies that examined the relationship between physical activity and an educational outcome (pooled d = .13; Hattie & Clinton, 2012). To detect a small effect of .13, a sample of 368 participants will provide 80% power in a longitudinal study ($\alpha < .05$, one-tailed). Clustering was adjusted for using the formula $1+(m-1)\rho$, where m is the average cluster size (i.e., number of students per class) and ρ is the ICC (Campbell et al., 2004). Based on a class-level ICC for school engagement (three dimensional) of .06 reported by a previous study (Reeve, 2013), an adjustment of 2.26 was required: $1+(22-1).06 = 2.26$. Multiplying by the 368 participants required in a longitudinal study, 831 students will need to participate to achieve 80% power.

Participants

Year 8 students were recruited from 14 secondary schools located in the Western Sydney region, Australia. Schools needed to have a Socio-Economic Index for Areas (SEIFA) rank of ≤ 5, indicating relative socioeconomic disadvantage (Australian Bureau of Statistics, 2008a), to be eligible to participate. Within these schools, all year 8 students without any pre-existing injuries or illnesses were eligible to participate (see Appendix A for further information regarding the recruitment process and participants).

Procedure

The Australian Catholic University Human Research Ethics Committee and the Department of Education and Communities granted approval for this study (see Appendix D for the Human Research Ethics Committee approval letter). Parents or guardians provided informed written consent, and students provided informed written assent (see Appendix E for consent forms). Data were collected at three time points: Time 1 during Term 1 of 2014 (January–April), Time 2 during Term 4 of 2014 (October–December) when students were in year 8, Time 3 during Term 2 of 2015 (April–June), when students were in year 9.

At each time point, students wore an accelerometer (Actigraph GT3X) for seven consecutive days to assess regular physical activity. During this seven-day period, students responded to a multi-section questionnaire following two mathematics lessons. Following the questionnaire, trained research assistants measured students' height, using a stadiometer (Surgical and Medical Products No 26SM, Medtone Education Supplies, Melbourne, Australia); and weight, using digital scales (UC-321, A&D Company, LTD, Tokyo, Japan). This data was then linked with students' NAPLAN data from Year 7 (May, 2013) and Year 9 (May, 2015). As NAPLAN is a national standardised test, it is only administered every two years. Thus, the timing of the first NAPLAN assessment (May,

2013) does not exactly align with the first time point of data collection (January–April, 2014).

Measures

Objectively assessed regular moderate-to-vigorous physical activity. Accelerometers (Actigraph GT3X+) were used to quantify adolescents' regular physical activity. Accelerometers provide a valid measure of the frequency, duration, and intensity of physical activity in adolescents (Ridgers & Fairclough, 2011; Snijders, 2005). Students were asked to wear the accelerometer for seven consecutive days. Students who wore the accelerometer for at least eight hours on one day were included in analyses. Research has shown that one day of accelerometer data is representative of regular MVPA behaviour as there is strong between-day intraclass reliability over a seven day period (Nader, Bradley, Houts, McRitchie, & O'Brien, 2008).

All accelerometer data processing was conducted using the ActiLife software (Version 6, ActiGraph, LLC, Fort Walton Beach, FL). First, all non-wear time was filtered out, that is time that the student removed the accelerometer. Non-wear time was defined as blocks of time greater than 60 minutes of consecutive zero counts. Next, the proportion of time (%) spent in MVPA was calculated. MVPA was defined as >2296 counts per minute (Evenson et al., 2008). Counts result from summing accelerometer values (raw data at 30hz) and vary depending on the frequency and intensity of activity (see Appendix A for further information regarding accelerometer data processing). This definition of MVPA has been shown to be the most accurate in adolescents (Trost et al., 2011).

Mathematics engagement. The School Engagement Measure (Fredricks et al., 2005; Hyde, 2009) was used to assess typical behavioural (e.g., classroom behaviour), emotional (e.g., lesson enjoyment), and cognitive (e.g., problem solving) engagement towards mathematics (see Appendix G for the questionnaire). Hyde (2009) adapted

Fredricks' et al. (2005) original measure of school engagement to specifically measure mathematics engagement. For example, Hyde adapted Fredricks' original item 'I feel excited by my work at school' to 'I feel excited by my work during maths lessons'. This adaptation was internally consistent (α = .75 to .87). The scale is divided into three subscales that measure typical behavioural, cognitive, and emotional mathematics engagement, and each item is rated on a five-point Likert scale.

Academic performance. To assess academic performance, NAPLAN numeracy scores were obtained from the NSW Department of Education. NAPLAN is a national standardised test given to all students in Australia in Years 3, 5, 7, and 9 (Australian Curriculum, 2012). NAPLAN scores for this study were from students' Year 7 (2013) and Year 9 (2015) tests.

Covariates

Covariates included age, gender, body mass index (BMI), ethnicity, and SES. Students indicated their age, gender, and ethnicity. BMI was calculated using the Australian Government (2009) formula: $\frac{\text{weight (kg)}}{\text{Height(m)}^2}$. Family level SES was also measured using an adapted version of the Family Affluence Scale II (Currie et al., 2008).

Data analysis

All analyses were conducted using R software (R Core Team, 2014). Alpha coefficients were used to assess the internal consistency of the Student Engagement in Mathematics Classroom Scale. The descriptive statistics calculated include means, standard deviations, rank-order consistency, mean-level differences, and gender differences.

Latent change score models determined whether changes in MVPA were associated with changes in NAPLAN scores (Figure 4) and school engagement (Figure 5). In latent change score models, change is defined as the time ordered influence of one variable on another variable (McArdle, John J & Prindle, 2008). Thus, change is examined by defining variables at Time 2 as the sum of the same variable at Time 1 and the unobserved change score. The main advantage of these models is being able to relate change in one variable with change in another variable. The current models examined how change in MVPA from Time 1 to Time 2 was associated with (i) change in NAPLAN scores from Year 7 to Year 9 and (ii) change in school engagement from Time 1 to Time 2.

Latent change score models were estimated using the lavaan program (Rosseel, 2012) in R (R Core Team, 2014). Models were estimated using the robust maximum likelihood estimator, which is robust to data nonnormality (Beauducel & Herzberg, 2006; Yuan & Bentler, 2002). The explained variance (R^2) of the change in the educational outcomes was used to examine the fit of the models (see Appendix A for further information regarding latent change score models).

Linear regression analyses explored the cross-sectional association between MVPA and academic performance. First, Model 1 examined the association between MVPA and NAPLAN scores. Next, Model 2 adjusted for confounders, including age, BMI, ethnicity, and SES.

Missing Data. Missing data was handled using FIML so that all available information could be used to estimate parameter values and standard errors (Enders, 2010). Missing data resulted from students being absent from school during data collection or students not meeting the accelerometer wear time criteria. Of the 2,194 students recruited, at Time 1 1,224 students (n = 629 boys and n = 595 girls) provided accelerometer-assessed total MVPA data, 1,306 students (n = 651 boys and n = 655 girls) provided mathematics engagement data, and 1,206 students (n = 594 boys and n = 612 girls) provided NAPLAN data. At Time 2, 814 students (n = 395 boys and n = 419 girls) provided accelerometer-assessed total MVPA data, 1,222 students (n = 619 boys and n = 603 girls) provided mathematics engagement data, and 1,213 students (n = 600 boys and n = 613 girls) provided NAPLAN data.

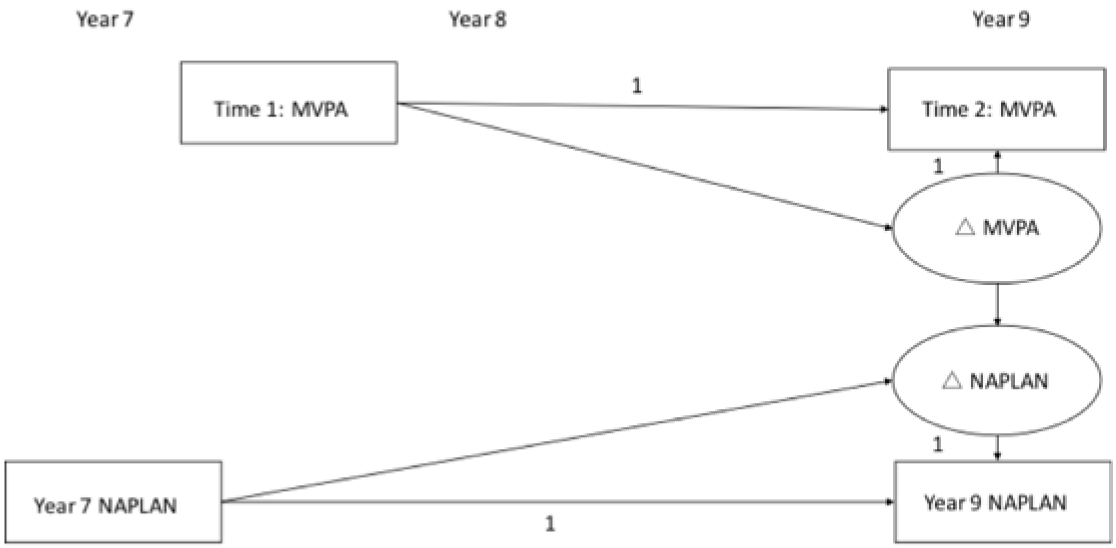


Figure 4. Latent change model: moderate-to-vigorous physical activity and NAPLAN scores

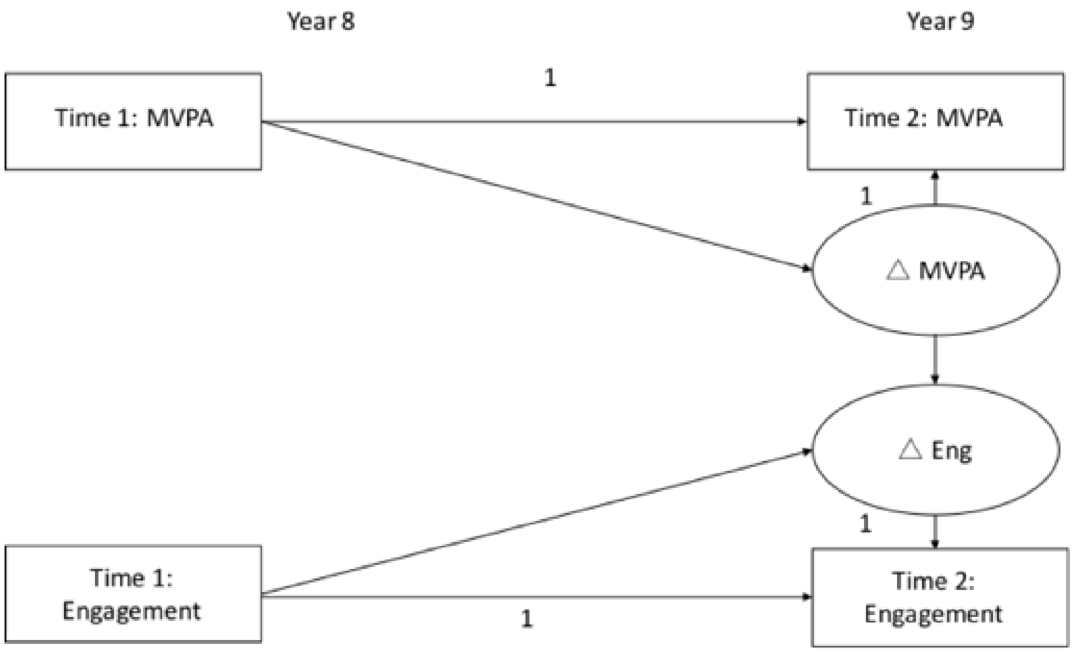


Figure 5. Latent change model: moderate-to-vigorous physical activity and mathematics engagement

Results

Descriptive statistics

Alpha coefficients for the scores derived from the mathematics engagement subscale ranged from .74 to .91. Thus, the mathematics engagement subscales were internally reliable (Nunnally & Bernstein, 1994).

Means, standard deviations, rank-order consistency, and gender differences are displayed in Table 11. At Time 1, average daily minutes in MVPA for boys was 50.94 (SD = 21.39) and girls was 42.16 (SD = 16.88). At Time 2, average daily minutes in MVPA for boys was 51.98 (SD = 22.15) and girls was 42.72 (SD = 18.58). At Time 3, average daily minutes in MVPA for boys was 49.82 (SD = 23.20) and girls was 41.13 (SD = 21.13). At Time 1, 77% of adolescents did not meet the global recommendations of 60 minutes of MPVA each day (Department of Health and Ageing, 2008; World Health Organisation, 2010). Similarly, at Time 2, 76% of adolescents did not meet the global recommendations.

The rank-order consistency of MVPA was strong, indicating little change over the three time points. The rank-order consistency of school engagement was moderate, indicating considerable change over the three time points. The rank-order consistency of NAPLAN was very strong, indicating very little change in relative position over the two time points. There was evidence of gender differences in subjectively and objectively measured MVPA at each of the three time points, with boys participating in higher levels of MVPA, compared to girls. There were no gender differences in school engagement or NAPLAN. There were no significant differences in academic performance or school engagement between students who met the accelerometer wear criteria and those who did not meet the criteria at each time point.

Table 11

Means, standard deviations, rank-order consistency, mean-level differences, gender differences for MVPA, NAPLAN scores, and school engagement

	Time 1 Mean (SD)	Time 2 Mean (SD)	Time 3 Mean (SD)	Mean-level change: Time 1 to Time 2	Mean-level change: Time 2 to Time 3	Rank-order consistency	Gender difference Time 1	Gender difference Time 2	Gender difference Time 3
Objective MVPA	7.29 (3.19)	6.74 (3.72)	7.61 (4.01)	**-.17**	**.23**	**.71**	**.31**	**.54**	**.50**
Subjective MVPA	2.24 (1.11)	1.51 (.90)	1.37 (.82)	**-.66**	**-.16**	.19	**.14**	**.26**	**.32**
School engagement	3.20 (.75)	3.36 (.72)	3.29 (.77)	.21	-.10	**.63**	-.03	.00	.08
NAPLAN	518.11 (74.63)		572.58 (70.03)	**.73**		**.88**	.04		.07

Note. Values in bold indicate statistically significant effects at $p < .01$. [a] Mean-level changes and gender differences are represented by Cohen's d; boys are coded as 1, girls as 0.

Main Results

Longitudinal associations. Increases in MVPA were associated with increases in academic performance (β = .17, p < .001, R^2 = .03). However, changes in MVPA were not associated with changes in school engagement (β = .03, p = .60, R^2 = .01).

Cross-sectional associations. The associations between MVPA and educational outcomes are reported in Table 12. Higher MVPA was associated with poorer NAPLAN scores in Year 7 (β = -.31, p < .001) and Year 9 (β = -.24, p < .001) and lower levels of school engagement at Time 1 (β = -.13, p < .01) and Time 2 (β = -.13, p = .01).

Table 12

Cross-sectional associations between MVPA and educational outcomes

	NAPLAN			School engagement		
	β	SE	P value	β	SE	P value
Time 1						
MVPA in Model 1	-.22	.03	<.001	-.13	.03	<.001
MVPA in Model 2	-.31	.06	<.001	-.13	.05	<.01
Time 3						
MVPA in Model 1	-.19	.04	<.001	-.04	.04	.28
MVPA in Model 2	-.24	.06	<.001	-.13	.05	< .01

Note. Model 1 = no covariates; Model 2 = covariates.

Discussion

The overarching objective of this study was to determine whether longitudinal changes in accelerometer-assessed MVPA were associated with changes in educational outcomes (i.e., academic performance and school engagement). The secondary objective was to compare the cross-sectional and longitudinal associations between accelerometer-assessed MVPA and educational outcomes. Increases in accelerometer-assessed MVPA over time were associated with improvements in academic performance, but not school engagement. Cross-sectional associations differed from longitudinal associations, as MVPA had a negative cross-sectional association with academic performance and school engagement at each time point.

Longitudinal associations

This study indicates that increases in MVPA were positively associated with improvements in academic performance. Increased regular total MVPA leads to improved fitness or cognitive function over time, which have both been linked with academic performance. There is some evidence that fitness could mediate the association between MVPA and academic performance, as fitter students tend to perform better academically (Castelli et al., 2007; Chomitz et al., 2009; Hansen et al., 2014; Kwak et al., 2009). There is also some evidence that cognitive function could mediate this relationship (Hillman et al., 2011; Sibley & Etnier, 2003). A systematic review found that physical activity is positively associated with cognitive function, including memory, perceptual skills, and intelligence (Sibley & Etnier, 2003). There is also substantial evidence that cognitive function is positively associated with academic performance (e.g., Bull, Espy, & Wiebe, 2008; St Clair-Thompson & Gathercole, 2006). Future research is needed that examines whether fitness or cognitive function mediate the association between regular total MVPA and academic performance.

Cross sectional associations

Although increases in MVPA were associated with improvements in academic performance, MVPA had a negative cross-sectional association with academic performance in adolescents. This finding is consistent with two previous studies that examined the cross-sectional association between total physical activity and academic performance in adolescents (Esteban-Cornejo et al., 2014; Van Dijk et al., 2014). It is possible that students who are more physically active experience poorer educational outcomes because participating in physical activity takes time away from studying and doing homework (Adam et al., 2007; Atkin et al., 2008; Ho & Lee, 2001; Lazarou & Soteriades, 2009). But over time this physical activity improves other factors (e.g., cognitive function) that could improve educational outcomes. Future research is needed that examines whether time spent studying and doing homework moderates the association between regular physical activity and academic performance.

Accelerometer-assessed MVPA also had a negative association with school engagement in this study. This finding is inconsistent with the one previous study that found no association between regular accelerometer-assessed MVPA and school engagement in children (Martikainen et al., 2012). As this previous study examined children and the present study recruited adolescents, it is possible that there is no association between regular MVPA and school engagement in children, but a negative association in adolescents. Further research is needed to determine whether the association between regular accelerometer-assessed MVPA and school engagement differs between children and adolescents.

Strengths and limitations

There are a number of strengths to this study. First, this was the first study to examine whether longitudinal changes in accelerometer-assessed MVPA are associated with changes in educational outcomes. Second, this study had a relatively large sample size considering the time and financial costs associated with measurement using accelerometers (Sylvia, Bernstein, Hubbard, Keating, & Anderson, 2014). There are also some limitations. First, although we did not measure academic performance in all school subjects, mathematics test scores have been found to predict academic performance across all school subjects, even more so than literacy skills (Duncan et al., 2007). Future research should assess the relationship between physical activity and academic performance across a wider range of academic subjects (e.g., literacy). Second, while the use of standardised test scores provides an unbiased measure of academic performance, standardised test scores assess a narrow range of knowledge and often assess concepts that have not been taught in class (Freeman et al., 1983). When the tests assess concepts that have not been taught in class, it is likely that the test is actually measuring intellectual ability, rather than academic performance. Another option would be to use school grades to measure academic performance. However, school grades are often influenced by teachers' perceptions. Future research could examine the association between MVPA and standardised test scores in conjunction with school grades. These studies could also assess student engagement and achievement across a wider range of academic subjects (e.g., literacy). Third, the timing of Time 1 physical activity data collection (January-April 2014) did not line up with the Year 7 NAPLAN assessment (May 2013). This means that we examined change in physical ativity over a 1.5 year period and change in NAPLAN scores over a 2 year period. Unfortunately the timing of the NAPLAN test was out of our control as it is a national standardised test and is only administered every two years. However, as NAPLAN scores had very little change over the two timepoints, this lagged measure should not influence the results of this study.

Implications

Despite the limitations of this study, there are also important implications. Increases in physical activity were positively associated with improvements in academic performance, which suggests that the benefits of physical activity could extend further than the physical and mental health benefits, and into education. Interventions should continue to promote physical activity for the physical and mental health benefits, and also assess educational benefits (Resaland et al., 2015; Telford et al., 2013). Although increases in physical activity were positively associated with improvements in academic achievement, the cross-sectional associations between physical activity levels and educational outcomes were negative. Thus, parents need to ensure that students find a balance between physical activity and study and homework. Ideally, increases in physical activity would replace sedentary time not related to educational outcomes (e.g., recreational screen time).

Conclusion

Although cross-sectional evidence indicated that students who were more physically active had poorer educational outcomes than their less active peers, students who increased their regular physical activity showed improvements in academic performance. Students need to increase their physical activity levels for the health and educational benefits, without compromising time spent on study and homework.

Chapter 5: Discussion and Conclusion

The primary purpose of this thesis was to examine the relationship between objectively measured physical activity and school engagement. The secondary purpose was to examine the relationship between objectively measured physical activity and academic performance. To achieve these aims, three distinct but interrelated studies were conducted.

Study 1 (Chapter 2) aimed to perform a systematic review and conduct meta-analyses of evidence from studies addressing the relationship between physical activity and school engagement in youth. The 38 included studies indicated that physical activity had a small positive association with school engagement (d = .28), with single bouts (d = .43) and regular physical activity (d = .24) both yielding benefits. However, two major limitations were uncovered in the existing research. First, although single bouts of physical activity during breaks appear to improve school engagement, these studies have have not objectively measured physical activity. Thus, it is currently unclear whether the physical activity itself is beneficial for school engagement. Second, no previous study has examined how longitudinal changes in accelerometer-assessed regular physical activity influence school engagement. This review concluded that physical activity could improve school engagement, but identified a number of limitations in the existing literature, which directed Study 2 (Chapter 3) and Study 3 (Chapter 4).

Study 2 (Chapter 3) aimed to address the first major limitation in the existing literature identified in Study 1(Chapter 2). This limitation was that it is currently unclear whether physical activity during breaks is beneficial for school engagement as these studies have not measured physical activity objectively. The primary objective was to determine whether physical activity has a positive relationship with school engagement over and above the mere presence or absence of a break before the classroom lesson. Results indicated that moderate-intensity activity before a mathematics lesson had a positive linear relationship with cognitive engagement (β = .40, p < .05) in the following lesson. Recess breaks before a mathematics lesson had a negative relationship with overall engagement (β = -.18, p < .01), behavioural engagement (β = -.19, p < 01), emotional engagement (β = -.13, p = .03), and cognitive engagement (β = -.13, p = .04) in the following lesson. Results from Study 2 suggest that promoting moderate-intensity activity before mathematics lessons could benefit students' cognitive engagement in the following lesson.

Study 3 (Chapter 4) aimed to address the second major limitation in the existing literature identified in Study 1 (Chapter 2). This limitation was that no previous study has examined how longitudinal changes in accelerometer-assessed regular physical activity influence school engagement. The primary objective was to determine whether longitudinal changes in accelerometer-assessed MVPA were associated with changes in educational outcomes (academic performance and school engagement). Increases in MVPA were associated with increases in academic performance (β = .17, p < .001), but not in school engagement. Results from Study 3 suggest that increasing time spent in MVPA has a positive long-term impact on academic performance, but not on school engagement.

Single bouts and regular physical activity

Single bouts and regular physical activity may have different influences on school engagement. Results of the systematic review and meta-analysis in Study 1 indicated that both single bouts and regular physical activity were beneficial for school engagement. But the included studies were limited by not measuring physical activity objectively. Study 2 found that objectively measured single bouts of moderate-intensity activity before a mathematics lesson had a positive relationship with school engagement in the following lesson, while Study 3 found that increases in regular physical activity over time had no association with school engagement.

Given this important difference between single bouts and regular physical activity, it is possible that short-term brain activation could be the underlying mechanism. Physical activity leads to immediate increases in oxygen to the brain, alpha wave activity, and neurochemicals that are associated with learning and memory (Binder et al., 2012; Chapman et al., 2013). Tomporowski (2003) conducted a systematic review of 43 studies and concluded that single bouts of physical activity were linked to improvements in cognitive performance, including problem solving, information processing, memory, reaction time, and creative thinking. As a number of cognitive performance aspects overlap with cognitive engagement (e.g., problem solving and information processing), it is likely that single bouts of physical activity are also beneficial for cognitive engagement through brain activation. Future research is needed to examine whether brain activation is the mechanism underlying the relationship between single bouts of physical activity and cognitive engagement.

Strengths and limitations

This thesis was the first to examine a number of important relationships between physical activity and educational outcomes. Study 1 filled a gap in the literature by systematically combining evidence from investigations that have examined the association between physical activity and school engagement in youth. Study 2 innovated by using objective measures of physical activity to determine whether physical activity has a positive relationship with school engagement, over and above the presence or absence of a break before the classroom lesson. Study 3 was the first study to determine whether longitudinal changes in objectively measured MVPA were associated with changes in academic performance or school engagement. Together, these three studies have made significant contributions to the literature. They can provide valuable empirical evidence to inform future school policy, and to assist curriculum developers in evolving more effective short- and long-term promotion of school engagement and academic performance.

A strength of this thesis was the use of accelerometers to measure physical activity. They provide an accurate measure of the frequency, duration, and intensity of physical activity in adolescents (Ridgers & Fairclough, 2011; Snijders, 2005). Unlike subjective measures of physical activity, accelerometers are not influenced by social desirability, nor do they rely on adolescents to recall their physical activity behaviour and accurately report its frequency and intensity (Troiano et al., 2012). Accelerometers are limited, however, by their inability to measure swimming, cycling, or many strength training activities (Troiano et al., 2012). Another drawback is that when using accelerometers, the intensity of physical activity is defined using standardised cut-off points that may not represent the same intensity of activity across individuals. In contrast, with heart rate monitors the intensity is defined using individualised cut-off points (percent of maximum heart rate). Heart rate monitors are also limited however, as they can be influenced by a number of factors not related to physical activity (e.g., age, gender, and level of training). Future research might therefore use both heart rate monitors and accelerometers, to confirm that the increases in heart rate are indeed due to physical activity. Future research should explore the relationships between heart rate, accelerometer-assessed physical activity, and educational outcomes.

The relatively large sample size (n = 2,194) in Study 2 and Study 3 was a strength of this thesis. Most previous investigations with accelerometers had sample sizes between 50 and 200, due to the time and financial cost of accelerometers. Each accelerometer must be belted, charged, initialised, distributed, collected, downloaded, and have its data processed (ActiLife, 2015). As well as the considerable cost in time, each accelerometer costs more than A$300. The sample in Study 2 and Study 3 was the second largest to date (following Esteban-Cornejo et al., 2014) to have used accelerometers to assess the relationship between physical activity and educational outcomes.

The recruitment of participants from a low SES areas was a strength of this thesis. All participants were enrolled in government-funded secondary schools in the Western Sydney region of Australia, representing one of the lowest SES areas in Sydney (Australian Bureau of Statistics, 2008a). As youth living in low SES areas tend to lack engagement and show poor academic performance (Fullarton, 2002; Ladd & Dinella, 2009; Marks, 2000; Wang, M. & Eccles, 2012), it is likely that youth living in Western Sydney will display particularly low levels of school engagement and academic performance. Thus, it is particularly important to determine the extent to which physical activity determines school engagement and academic performance for youth living in Western Sydney.

The results of this thesis are limited to engagement and performance in mathematics. It is possible that physical activity has different effects for other educational domains. Each school subject is unique and requires different types of thinking and skills. For example, English may require more creativity than mathematics, while mathematics may involve more problem solving than English. Future research is needed to determine whether the results of this thesis can be generalised to other school subjects.

The use of questionnaires to assess school engagement could be considered both a strength and a limitation of this thesis. This is the first research to examine the relationship between physical activity and school engagement using a three-dimensional measure of school engagement. The three-dimensional measure of school engagement has provided valid and reliable scores (Fredricks et al., 2005; Hyde, 2009). However, all questionnaires are subject to perceptions of social desirability (Edwards, 1957). Some students likely respond to items in a way that they consider socially acceptable, rather than giving their "real" response. However, there are also limitations to observational measures of school engagement, which provide limited information regarding the quality of effort, participation, and thinking (Fredricks et al., 2004). For example, if a student is sitting in the classroom staring at the ceiling, observation may fail to determine whether the student is processing information on task or thinking about which sport they want to play during the lunch break. Future research should use subjective measures in conjunction with observational measures of school engagement for a more robust assessment of its relationship with physical activity.

This thesis used standardised tests to measure academic performance, and this too can be viewed as both a strength and a weakness. Standardised tests are consistent across schools, allowing comparisons to be made. However, they only assess a very small portion of the curriculum – often including concepts that have not been taught in class (Kohn, 2000). When the test assesses concepts that have not been taught in class, it is likely that the test is actually measuring intellectual ability rather than academic performance (Kohn, 2000). But the alternative of using school grades to measure academic performance is also limited, since they are often influenced by teachers' perceptions. Future research is needed that more reliably examines the relationship between physical activity and standardised test scores in conjunction with school grades.

Implications

The pressure placed on educators to ensure academic success has increased (especially since each school's standardised test scores are now published), so time and opportunities for physical activity have decreased (Castelli et al., 2014; Mahar et al., 2006). It is understandable that most educators see time spent in the classroom as more beneficial than time spent participating in physical activity. However, this thesis yields evidence that time set aside for physical activity provides benefits for school engagement and academic performance.

The results of this thesis (specifically Study 1 and Study 2) suggest that single bouts of physical activity could be beneficial for school engagement. However, evidence from Study 2 suggests that the intensity of physical activity is important, and that only single bouts of moderate-intensity activity bring benefits for mathematics engagement. Using this evidence, teachers might provide opportunities for moderate-intensity activity before mathematics lessons to promote mathematics engagement in the following mathematics lesson. However, as Study 2 was cross-sectional, causal inferences cannot be made. Future experimental research is needed that compares a moderate-intensity activity condition with other intensities of activity and also a control condition (e.g., no activity). Such a design will determine whether it is actually the moderate-intensity activity that causes improvements in school engagement.

Regular total physical activity could lead to improvements in academic performance (Study 3). This result provides further evidence for the promotion of regular physical activity, especially at school. School provides an ideal context for such promotion as it reaches nearly all youth. Unfortunately, 37% of Australian adolescents do not meet the recommended 60 minutes of physical activity each day (Hardy et al., 2010). Future interventions should continue to aim to increase in regular total physical activity, for the well-established physical and mental health benefits (Biddle & Asare, 2011; Janssen, I. & LeBlanc, 2010), and the additional educational benefits that are the focus of the present research.

Conclusion

The findings of this thesis have contributed to the literature on physical activity and educational outcomes. Study 1 combined all evidence for the relationship between physical activity and school engagement and concluded that promoting physical activity could enhance school engagement in youth. Study 1 also highlighted gaps in the existing literature, some of which were then addressed in Study 2 and Study 3. Study 2 examined single bouts of physical activity and found that single bouts of moderate-intensity activity were positively associated with cognitive mathematics engagement. On the other hand, Study 3 found that increases in regular total physical activity were not associated with improvements in mathematics engagement, but were nevertheless associated with improvements in academic performance. Overall, single bouts of physical activity could enhance school engagement, while regular total physical activity might be beneficial for academic performance.

References

Abbott-Chapman, J., Martin, K., Ollington, N., Venn, A., Dwyer, T., & Gall, S. (2014). The longitudinal association of childhood school engagement with adult educational and occupational achievement: findings from an Australian national study. *British Educational Research Journal, 40*(1), 102-120. doi:10.1002/berj.3031

ActiLife. (2015). Pensacola, FL: ActiGraph.

Adam, E. K., Snell, E. K., & Pendry, P. (2007). Sleep timing and quantity in ecological and family context: A nationally representative time-diary study. *Journal of Family Psychology, 21*(1), 4-19.

Adams, S. A., Matthews, C. E., Ebbeling, C. B., Moore, C. G., Cunningham, J. E., Fulton, J., & Hebert, J. R. (2005). The effect of social desirability and social approval on self-reports of physical activity. *American journal of epidemiology, 161*(4), 389-398.

Ahn, S., Ames, A., & Myers, N. (2012). A review of meta-analyses in education: Methodological strengths and weaknesses. *Review of Educational Research, 82*(4), 436-476. doi:10.3102/0034654312458162

Anderman, E. M., & Maehr, M. L. (1994). Motivation and schooling in the middle grades. *Review of Educational Research, 64*(2), 287-309. doi:10.3102/00346543064002287

Appleton, J., Christenson, S., & Furlong, M. (2008). Student engagement with school: Critical conceptual and methodological issues of the construct. *Psychology in the Schools, 45*(5), 369-386. doi:10.1002/pits.20303

Appleton, J., Christenson, S., Kim, D., & Reschly, A. (2006). Measuring cognitive and psychological engagement: Validation of the Student Engagement Instrument. *Journal of School Psychology, 44*(5), 427-445. doi:10.1016/j.jsp.2006.04.002

Archambault, I., Janosz, M., Fallu, J.-S., & Pagani, L. S. (2009). Student engagement and its relationship with early high school dropout. *Journal of Adolescence, 32*(3), 651-670. doi:10.1016/j.adolescence.2008.06.007

Archambault, I., Janosz, M., Morizot, J., & Pagani, L. (2009). Adolescent behavioral, affective, and cognitive engagement in school: Relationship to dropout. *Journal of School Health, 79*(9), 408-415. doi:10.1111/j.1746-1561.2009.00428.x.

Atkin, A. J., Gorely, T., Biddle, S., Marshall, S. J., & Cameron, N. (2008). Critical hours: physical activity and sedentary behavior of adolescents after school. *Pediatric Exercise Science, 20*(4), 446-456.

Australian Bureau of Statistics. (2008a). *ABS releases measures of socio-economic advantage and disadvantage*. Canberra. Cat. No. 2033.0.55.001.

Australian Bureau of Statistics. (2008b). Health literacy. Retrieved from http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features20June+2009

Australian Curriculum, A. a. R. A. (2012). *National Assessment Program—Literacy and Numeracy: Achievement in reading, writing, language conventions and numeracy. National report for 2010*. Sydney: ACARA.

Australian Government. (2009). *About Overweight and Obesity*. Canberra: Department of Health.

Australian Institute of Health and Welfare. (2008). *Australia's Health*. Canberra: Australian Institute of Health and Welfare.

Bangert-Drowns, R. L. (1986). Review of developments in meta-analytic method. *Psychological Bulletin, 99*(3), 388-399.

Barnard-Brak, L., Davis, T., Sulak, T., & Brak, V. (2011). The association between physical education and symptoms of attention deficit hyperactivity disorder. *Journal of Physical Activity and Health, 8*(7), 964-970.

Barros, R. M., Silver, E. J., & Stein, R. E. (2009). School recess and group classroom behavior. *Pediatrics, 123*(2), 431-436. doi:10.1542/peds.2007-2825

Bartholomew, J. B., & Jowers, E. M. (2011). Physically active academic lessons in elementary children. *Preventive Medicine, 52*, S51-S54. doi:10.1016/j.ypmed.2011.01.017

Barton, S. (2000). Which clinical studies provide the best evidence?: The best RCT still trumps the best observational study. *BMJ: British Medical Journal, 321*(7256), 255-256. doi:10.1136/bmj.321.7256.255

Beauducel, A., & Herzberg, P. Y. (2006). On the performance of maximum likelihood versus means and variance adjusted weighted least squares estimation in CFA. *Structural Equation Modeling, 13*(2), 186-203. doi:10.1207/s15328007sem1302_2

Berlyne, D. E. (1966). Curiosity and exploration. *Science, 153*(3731), 25-33.

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review, 30*(4), 331-351. doi:10.1016/j.dr.2010.08.001

Biddle, S., & Asare, M. (2011). Physical activity and mental health in children and adolescents: a review of reviews. *British Journal of Sports Medicine, 45*(1), 886-895. doi:10.1136/bjsports-2011-090185

Binder, J., Bryant, A., Burcyzk, A., Payant, P., Zorn, K., & Gerner, E. (2012). Effects of moderate exercise on short term memory: An analysis of beta wave forms and heart rate. *Journal of Advanced Student Science, 1*(1), 1-10.

Blaes, A., Baquet, G., Van Praagh, E., & Berthoin, S. (2011). Physical activity patterns in French youth-from childhood to adolescence-monitored with high-frequency accelerometry. *American Journal of Human Biology, 23*(3), 353-358. doi:10.1002/ajhb.21142

Bleeker, M., James-Burdumy, S., Beyler, N., Dodd, A. H., London, R. A., Westrich, L., . . . Castrechini, S. (2012). Findings from a Randomized Experiment of Playworks: Selected Results from Cohort 1. *Mathematica Policy Research, Inc.*

Bonomi, A., & Westerterp, K. (2011). Advances in physical activity monitoring and lifestyle interventions in obesity: A review. *International Journal of Obesity, 36*(2), 167-177. doi:10.1038/ijo.2011.99

Booth, A. (2011). Chapter 3: Searching for Studies. In J. Noyes, A. Booth, K. Hannes, A. Harden, J. Harris, S. Lewin, & C. Lockwood (Eds.), *Supplementary Guidance for Inclusion of Qualitative Research in Cochrane Systematic Reviews of Interventions*. Version 1 (updated August 2011). Cochrane Collaboration Qualitative Methods Group. Available from URL http://cqrmg.cochrane.org/supplemental-handbook-guidance.

Booth, J., Leary, S., Joinson, C., Ness, A., Tomporowski, P., Boyle, J., & Reilly, J. (2013). Associations between objectively measured physical activity and academic attainment in adolescents from a UK cohort. *British Journal of Sports Medicine, 6*(1), 212-219. doi:10.1136/bjsports-2013-092334

Brickenkamp, R. (1962). *Test d2: aufmerksamkeits-belastungs-test*. Göttingen, Germany: Hogrefe.

Brodersen, N. H., Steptoe, A., Boniface, D. R., & Wardle, J. (2007). Trends in physical activity and sedentary behaviour in adolescence: Ethnic and socioeconomic differences. *British Journal of Sports Medicine, 41*(3), 140-144. doi:10.1136/bjsm.2006.031138

Budde, H., Voelcker-Rehage, C., Pietrabyk-Kendziorra, S., Ribeiro, P., & Tidow, G. (2008). Acute coordinative exercise improves attentional performance in adolescents. *Neuroscience Letters, 441*(2), 219-223. doi:10.1016/j.neulet.2008.06.024

Buhs, E. S., Ladd, G. W., & Herald, S. L. (2006). Peer exclusion and victimization: Processes that mediate the relation between peer group rejection and children's classroom engagement and achievement? *Journal of Educational Psychology, 98*(1), 1-13. doi:10.1037/0022-0663.98.1.1

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*(3), 205-228. doi:10.1080/87565640801982312

Campbell, M. K., Elbourne, D. R., & Altman, D. G. (2004). CONSORT statement: Extension to cluster randomised trials. *British Medical Journal, 328,* 702-708.

Carbonaro, W. (2005). Tracking, students' effort, and academic achievement. *Sociology of Education, 78*(1), 27-49. doi:10.1177/003804070507800102

Carey, J. R., Bhatt, E., & Nagpal, A. (2005). Neuroplasticity promoted by task complexity. *Exercise and Sport Sciences Reviews, 33*(1), 24-31.

Carter, M., McGee, R., Taylor, B., & Williams, S. (2007). Health outcomes in adolescence: Associations with family, friends and school engagement. *Journal of Adolescence, 30*(1), 51-62. doi:10.1016/j.adolescence.2005.04.002

Castelli, D., Centeio, E., Hwang, J., Barcelona, J., Glowacki, E., Calvert, H., & Nicksic, H. (2014). The history of physical activity and academic performance research: Informing the future. *Monographs of the Society for Research in Child Development*, *79*(4), 119-148. doi:10.1111/mono.12133

Castelli, D., Hillman, C., Buck, S., & Erwin, H. (2007). Physical fitness and academic achievement in third-and fifth-grade students. *Journal of Sport and Exercise Psychology*, *29*(2), 239.

Cavanagh, R., & Reynolds, P. (2007). *Senior secondary school students' risk of disengagement from further education, employment and training*. Paper presented at the AARE International Research Conference, Fremantle, WA.

Chaddock, L., Pontifex, M., Hillman, C., & Kramer, A. (2011). A review of the relation of aerobic fitness and physical activity to brain structure and function in children. *Journal of the International Neuropsychological Society*, *17*(06), 975-985. doi:10.1017/S1355617711000567

Chapman, S. B., Aslan, S., Spence, J. S., DeFina, L. F., Keebler, M. W., Didehbani, N., & Lu, H. (2013). Shorter term aerobic exercise improves brain, cognition, and cardiovascular fitness in aging. *Frontiers in Aging Neuroscience*, *5*(1), 75. doi:10.3389/fnagi.2013.00075

Cheung, M. (2009). Constructing approximate confidence intervals for parameters with structural equation models. *Structural Equation Modeling*, *16*(2), 267-294. doi:10.1080/10705510902751291

Cheung, M. (2011). metaSEM: meta-analysis: a structural equation modeling approach. *R package version 0.5-3*, http://courses. *nus. edu. sg/course/psycwlm/Internet/metaSEM*.

Cheung, M. (2014). Modeling dependent effect sizes with three-level meta-analyses: A structural equation modeling approach. *Psychological Methods, 19*(2), 211-229. doi:10.1037/a0032968

Chomitz, V. R., Slining, M. M., McGowan, R. J., Mitchell, S. E., Dawson, G. F., & Hacker, K. A. (2009). Is there a relationship between physical fitness and academic achievement? Positive results from public school children in the northeastern United States. *Journal of School Health, 79*(1), 30-37. doi:10.1111/j.1746-1561.2008.00371.x

Christenson, S. L., & Reschly, A. L. (2010). Check & Connect: Enhancing school completion through student engagement. In E. Doll & J. Charvat (Eds.), *Handbook of Prevention Science* (pp. 327–348). New York, NY: Routledge.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cooper, H. M. (1989). *Integrating research: A guide for literature reviews*. Thousand Oaks, CA: Sage Publications, Inc.

Crosnoe, R., Johnson, M., & Elder, G. (2004). School size and the interpersonal side of education: An examination of race/ethnicity and organizational context. *Social Science Quarterly, 85*(5), 1259-1274. doi:10.1111/j.0038-4941.2004.00275.x

Currie, C., Molcho, M., Boyce, W., Holstein, B., Torsheim, T., & Richter, M. (2008). Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. *Social Science & Medicine, 66*(6), 1429-1436. doi:10.1016/j.socscimed.2007.11.024

Daniels, L. M., Stupnisky, R. H., Pekrun, R., Haynes, T. L., Perry, R. P., & Newall, N. E. (2009). A longitudinal analysis of achievement goals: From affective antecedents to emotional effects and achievement outcomes. *Journal of Educational Psychology, 101*(4), 948-963. doi:10.1037/a0016096

Darr, C. W. (2012). Measuring student engagement: The development of a scale for formative use. In S. Christenson, L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 707-723). New York, NY: Springer.

Deil-Amen, R., & Lopez Turley, R. (2007). A review of the transition to college literature in sociology. *The Teachers College Record, 109*(10), 2324-2366.

Department of Education and Early Childhood Development. (2010). *Pathways to re-engagement though flexible learning options*. Victoria: Department of Education and Early Childhood Development.

Department of Education, E. a. W. R. (2013). *National Plan for School Improvement*. Canberra: Australian Government.

Department of Health and Ageing. (2008). *Australian national children's nutrition and physical activity survey*. Canberra: Commonwealth of Australia.

Dong, Y., & Peng, C.-Y. J. (2013). Principled missing data methods for researchers. *SpringerPlus, 2*(1), 222-239. doi:10.1186/2193-1801-2-222

Donnelly, J., Greene, J., Gibson, C., Sullivan, D., Hansen, D., Hillman, C., . . . Washburn, R. (2013). Physical activity and academic achievement across the curriculum (A + PAAC): rationale and design of a 3-year, cluster-randomized trial. *BMC Public Health, 13*(1), 307. doi:10.1186/1471-2458-13-307

Donnelly, J., & Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Preventive Medicine, 52*(1), S36-S42. doi:10.1016/j.ypmed.2011.01.021

Donnelly, J. E., Greene, J. L., Gibson, C. A., Smith, B. K., Washburn, R. A., Sullivan, D. K., . . . Ryan, J. J. (2009). Physical Activity Across the Curriculum (PAAC): a randomized controlled trial to promote physical activity and diminish overweight and obesity in elementary school children. *Preventive Medicine, 49*(4), 336-341. doi:10.1016/j.ypmed.2009.07.022

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., . . . Brooks-Gunn, J. (2007). School readiness and later achievement. *Developmental Psychology, 43*(6), 1428-1462.

Dwyer, T., Blizzard, L., & Dean, K. (1996). Physical activity and performance in children. *Nutrition Reviews, 54*(4), S27-S31. doi:10.1111/j.1753-4887.1996.tb03895.x

Eccles, J., Midgley, C., Wigfield, A., Buchanan, C., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: the impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist, 48*(2), 90-101. doi:10.1037/0003-066X.48.2.90

Edwards, A. L. (1957). *The social desirability variable in personality assessment and research*. New York, NY: Dryden Press

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal, 315*(1), 629–634. doi:10.1136/bmj.315.7109.629

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005). Variation and homogeneity in affective responses to physical activity of varying intensities: An alternative perspective on dose–response based on evolutionary considerations. *Journal of Sports Sciences, 23*(5), 477-500. doi:10.1080/02640410400021492

Ellis, M. J. (1984). Play, novelty, and stimulus seeking. In T. Yawkey & A. D. Pellegrini (Eds.), *Child's Play: Developmental and Applied* (pp. 203-218). Hillsdale, NJ: Erlbaum.

Enders, C. (2010). *Applied missing data analysis*. New York, NY: Guilford Press.

Esteban-Cornejo, I., Tejero-González, C., Martinez-Gomez, D., Cabanas-Sánchez, V., Fernández-Santos, J., Conde-Caveda, J., . . . Veiga, O. (2014). Objectively measured physical activity has a negative but weak association with academic performance in children and adolescents. *Acta Paediatrica, 103*(11), e501-e506. doi:10.1111/apa.12757

Etnier, J. L., Salazar, W., Landers, D. M., Petruzzello, S. J., Han, M., & Nowell, P. (1997). The influence of physical fitness and exercise upon cognitive functioning: A meta-analysis. *Journal of Sport & Exercise Psychology, 19*(1), 249-277. doi:10.1007/s10389-005-0116-z

Evenson, K. R., Catellier, D. J., Gill, K., Ondrak, K. S., & McMurray, R. G. (2008). Calibration of two objective measures of physical activity for children. *Journal of Sports Sciences*, *26*(14), 1557-1565. doi:10.1080/02640410802334196

Feldman, D. E., Barnett, T., Shrier, I., Rossignol, M., & Abenhaim, L. (2003). Is physical activity differentially associated with different types of sedentary pursuits? *Archives of Pediatrics & Adolescent Medicine, 157*(8), 797-802. doi:10.1001/archpedi.157.8.797

Ferris, L., Williams, J., & Shen, C. (2007). The effect of acute exercise on serum brain-derived neurotrophic factor levels and cognitive function. *Medicine & Science in Sports & Exercise, 39*(4), 728-734. doi:10.1249/mss.0b013e31802f04c7

Field, A. P. (2003). The problems in using fixed-effects models of meta-analysis on real-world data. *Understanding Statistics: Statistical Issues in Psychology, Education, and the Social Sciences, 2*(2), 105-124. doi:10.1207/S15328031US0202_02

Finn, J. D. (1989). Withdrawing from school. *Review of Educational Research, 59*(2), 117-142.

Fredricks, J., Blumenfeld, P., Friedel, J., & Paris, A. (2005). School engagement. In K. A. Moore & L. Lippman (Eds.), *What do Children Need to Flourish?: Conceptualizing and Measuring Indicators of Positive Development* (pp. 305-321). New York, NY: Springer Science and Business Media.

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59-109. doi:10.3102/00346543074001059

Fredrickson, B. L. (1998). What good are positive emotions? *Review of General Psychology, 2*(3), 300-319. doi:10.1037/1089-2680.2.3.300

Freedson, P., Pober, D., & Janz, K. (2005). Calibration of accelerometer output for children. *Medicine & Science in Sports & Exercise, 37*(11), 523-530. doi:10.1249/01.mss.0000185658.28284.ba

Freeman, D. J., Kuhs, T. M., Porter, A. C., Floden, R. E., Schmidt, W. H., & Schwille, J. R. (1983). Do textbooks and tests define a national curriculum in elementary school mathematics? *The Elementary School Journal, 83*(5), 501-513.

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., . . . Ismaila, A. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology, 64*(11), 1187-1197.

Fullarton, S. (2002). *Student engagement with school: Individual and school-level influences*. Camberwell, Victoria: Australian Council for Educational Research.

Furlan, A. D., Pennick, V., Bombardier, C., van Tulder, M., & the Cochrane Back Review Group. (2009). Updated method guidelines for systematic reviews in the Cochrane Back Review Group. *Spine 34*, 1929–1941.

Furlong, M. J., Whipple, A. D., Jean, G. S., Simental, J., Soliz, A., & Punthuna, S. (2003). Multiple contexts of school engagement: Moving toward a unifying framework for educational research and practice. *The California School Psychologist, 8*(1), 99-113. doi:10.1007/BF03340899

Gage, H., Egan, B., Williams, P., Gyorei, E., Brands, B., Lopez-Robles, J. C., . . . Raats, M. (2014). Views of parents in four European countries about the effect of food on the mental performance of primary school children. *European Journal of Clinical Nutrition, 68*(1), 32-37. doi:10.1038/ejcn.2013.214

Gibson, C. A., Smith, B. K., DuBose, K. D., Greene, J. L., Bailey, B. W., Williams, S. L., . . . Sullivan, D. K. (2008). Physical activity across the curriculum: year one process evaluation results. *International Journal of Behavioral Nutrition and Physical Activity, 5*(1), 36-47. doi:10.1186/1479-5868-5-36

Gillander Gadin, K., & Hammarstrom, A. (2002). Can school-related factors predict future health behaviour among young adolescents? *Public Health, 116*(1), 22-29. doi:10.1038/sj/ph/1900807

Glennie, E., Bonneau, K., Vandellen, M., & Dodge, K. A. (2012). Addition by subtraction: The relation between dropout rates and school-level academic achievement. *Teachers College Record, 114*(8), 1-26.

Goldstein, H. (1995). *Multilevel Statistical Models*. London: Edward Arnold.

Graham, J. W. (2009). Missing data analysis: Making it work in the real world. *Annual Review of Psychology, 60*(1), 549-576. doi:10.1146/annurev.psych.58.110405.085530

Graham, J. W., Cumsille, P. E., & Elek-Fisk, E. (2003). Methods for handling missing data. *Handbook of Psychology, 4*(1), 87–114. doi:10.1002/0471264385.wei0204

Grieco, L., Jowers, E., & Bartholomew, J. (2009). Physically active academic lessons and time on task: the moderating effect of body mass index. *Medicine & Science in Sports & Exercise, 41*(10), 1921-1926. doi:10.1249/MSS.0b013e3181a61495

Gutin, B., Yin, Z., Humphries, M. C., & Barbeau, P. (2005). Relations of moderate and vigorous physical activity to fitness and fatness in adolescents. *The American Journal of Clinical Nutrition, 81*(4), 746-750.

Hansen, D. M., Herrmann, S. D., Lambourne, K., Jaehoon, L. E. E., & Donnelly, J. E. (2014). Linear/nonlinear relations of activity and fitness with children's academic achievement. *Medicine & Science in Sports & Exercise, 46*(12), 2279-2285. doi:10.1249/MSS.0000000000000362

Hardy, L., King, L., Espinel, P., Cosgrove, C., & Bauman, A. (2010). *NSW Schools Physical Activity and Nutrition Survey (SPANS): Full Report*. Sydney: NSW Ministry of Health.

Harrington, S. A. (2013). Relationships of objectively measured physical activity and sleep with BMI and academic outcomes in 8-year-old children. *Applied Nursing Research, 26*(2), 63-70. doi:10.1016/j.apnr.2013.02.001

Hattie, J., & Clinton, J. (2012). Physical activity is not related to performance at school. *Archives of Pediatrics & Adolescent Medicine, 166*(7), 678-679. doi:10.1001/archpediatrics.2012.334

Hauser, R. M. (2010). Causes and consequences of cognitive functioning across the life course. *Educational Researcher, 39*(2), 95-109. doi:10.3102/0013189X10363171

Hedges, L. V., & Vevea, J. L. (1998). Fixed-and random-effects models in meta-analysis. *Psychological Methods, 3*(4), 486. doi:10.1037/1082-989X.3.4.486

Henry, K. L., Knight, K. E., & Thornberry, T. P. (2012). School disengagement as a predictor of dropout, delinquency, and problem substance use during adolescence and early adulthood. *Journal of Youth and Adolescence, 41*(2), 156-166. doi:10.1007/s10964-011-9665-3

Higgins, J., Altman, D., & Sterne , J. (2011). Chapter 8: Assessing risk of bias in included studies. In J. Higgins & S. Green (Eds.), *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0 (updated March 2011)*. Available from http://www.cochrane-handbook.org.: The Cochrane Collaboration, 2011.

Higgins, J., & Green, S. (2011). Analysing data and undertaking meta-analyses. *In: The Cochrane Library*. Version 5.1.0. 2011. Chichester: Wiley.

Higgins, J., Thompson, S., Deeks, J., & Altman, D. (2003). Measuring inconsistency in meta-analyses. *British Medical Journal, 327*(7414), 557. doi:10.1136/bmj.327.7414.557

Hillman, C., Erickson, K., & Kramer, A. (2008). Be smart, exercise your heart: exercise effects on brain and cognition. *Nature Reviews Neuroscience, 9*(1), 58-65. doi:10.1038/nrn2298

Hillman, C., Kamijo, K., & Scudder, M. (2011). A review of chronic and acute physical activity participation on neuroelectric measures of brain health and cognition during childhood. *Preventive Medicine, 52*, S21-S28.

Hillman, C., Pontifex, M., Raine, L., Castelli, D., Hall, E., & Kramer, A. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience, 159*(3), 1044-1054. doi:10.1016/j.neuroscience.2009.01.057

Hills, A. P., Mokhtar, N., & Byrne, N. M. (2014). Assessment of physical activity and energy expenditure: an overview of objective measures. *Frontiers in Nutrition, 1*(5), 1-16. doi:10.3389/fnut.2014.00005

Ho, S. M., & Lee, T. M. (2001). Computer usage and its relationship with adolescent lifestyle in Hong Kong. *Journal of Adolescent Health, 29*(4), 258-266.

Holmes, P. V. (2006). Curent findings in neurobiological systems' response to exercise. In W. Poon, W. Chodzko-Zajko, & P. Tomporowski (Eds.), *Active Living, Cognitive Functioning, and Aging* (pp. 75-90). Champaign, IL: Human Kinetics.

Honaker, J., King, G., & Blackwell, M. (2011). Amelia II: A program for missing data. *Journal of Statistical Software, 45*(7), 1-47. doi:10.18637/jss.v045.i07

Hoover-Dempsey, K., Walker, J., Sandler, H., Whetsel, D., Green, C., Wilkins, A., & Closson, K. (2005). Why do parents become involved? Research findings and implications. *The Elementary School Journal, 106*(2), 105-130. doi:10.1086/499194

Howell, A. J. (2009). Flourishing: Achievement-related correlates of students' well-being. *The Journal of Positive Psychology, 4*(1), 1-13. doi:10.1080/17439760802043459

Howie, E. K., Beets, M. W., & Pate, R. R. (2014). Acute classroom exercise breaks improve on-task behavior in 4th and 5th grade students: A dose-response. *Mental Health and Physical Activity, 7*(2), 65-71. doi:10.1016/j.mhpa.2014.05.002

Hoza, B., Smith, A. L., Shoulberg, E. K., Linnea, K. S., Dorsch, T. E., Blazo, J. A., . . . McCabe, G. P. (2014). A randomized trial examining the effects of aerobic physical activity on attention-deficit/hyperactivity disorder symptoms in young children. *Journal of Abnormal Child Psychology, 43*(4), 655-667. doi:10.1007/s10802-014-9929-y

Huang, W. Y., Wong, S. H., & Salmon, J. (2013). Correlates of physical activity and screen-based behaviors in Chinese children. *Journal of Science and Medicine in Sport, 16*(6), 509-514. doi:10.1016/j.jsams.2012.12.011

Hunter, L., Abbott, R., Macdonald, D., Ziviani, J., & Cuskelly, M. (2014). Active kids active minds: a physical activity intervention to promote learning? *Asia-Pacific Journal of Health, Sport and Physical Education, 5*(2), 117-131. doi:10.1080/18377122.2014.906057

Hyde, C. E. (2009). *The relationship between teacher assessment practices, student goal orientation, and student engagement in elementary mathematics.* (Doctor of Education), University of Southern California. (ProQuest: 3355464)

Irwin, J. D. (1997). *The industrial electronics handbook*. Boca Raton, FL: CRC Press.

Jang, H., Reeve, J., & Deci, E. (2010). Engaging students in learning activities: It is not autonomy support or structure but autonomy support and structure. *Journal of Educational Psychology, 102*(3), 588-600. doi:10.1037/a0019682

Janosz, M., Archambault, I., Morizot, J., & Pagani, L. S. (2008). School engagement trajectories and their differential predictive relations to dropout. *Journal of Social Issues, 64*(1), 21-40. doi:10.1111/j.1540-4560.2008.00546.x

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity, 7*(40), 1-16. doi:10.1186/1479-5868-7-40

Janssen, M., Toussaint, H. M., van Mechelen, W., & Verhagen, E. A. (2014). Effects of acute bouts of physical activity on children's attention: A systematic review of the literature. *SpringerPlus, 3*(1), 410. doi:10.1186/2193-1801-3-410

Jarrett, O. S. (2002). Recess in Elementary School: What Does the Research Say? *ERIC Digest, ED466331*, 1-7.

Jarrett, O. S., Maxwell, D. M., Dickerson, C., Hoge, P., Davies, G., & Yetley, A. (1998). Impact of recess on classroom behavior: group effects and individual differences.

The Journal of Educational Research, 92(2), 121-126. doi:10.1080/00220679809597584

Jimerson, S. R., Campos, E., & Greif, J. L. (2003). Toward an understanding of definitions and measures of school engagement and related terms. *The California School Psychologist, 8*(1), 7-27. doi:10.1007/BF03340893

Joyce, J., Graydon, J., McMorris, T., & Davranche, K. (2009). The time course effect of moderate intensity exercise on response execution and response inhibition. *Brain and Cognition, 71*(1), 14-19. doi:10.1016/j.bandc.2009.03.004

Katz, D. L., Cushman, D., Reynolds, J., Njike, V., Treu, J. A., Walker, J., . . . Katz, C. (2010). Putting physical activity where it fits in the school day: preliminary results of the ABC (Activity Bursts in the Classroom) for fitness program. *Preventing Chronic Disease, 7*(4), A82.

Kenny, D. A. (2005). *Cross-Lagged Panel Design*: Encyclopedia of Statistics in Behavioral Science. Wiley Online Library.

Kirkcaldy, B., Shephard, R., & Siefen, R. (2002). The relationship between physical activity and self-image and problem behaviour among adolescents. *Social Psychiatry and Psychiatric Epidemiology, 37*(11), 544-550. doi:10.1007/s00127-002-0554-7

Knaepen, K., Goekint, M., Heyman, E. M., & Meeusen, R. (2010). Neuroplasticity-exercise-induced response of peripheral brain-derived neurotrophic factor. *Sports Medicine, 40*(9), 765-801. doi:10.2165/11534530-000000000-00000

Kohn, A. (2000). *The case against standardized testing: Raising the scores, ruining the schools*. Portsmouth, NH: Heinemann.

Kwak, L., Kremers, S. P., Bergman, P., Ruiz, J. R., Rizzo, N. S., & Sjöström, M. (2009). Associations between physical activity, fitness, and academic achievement. *Journal of Pediatrics, 155*(6), 914-918. e911. doi:10.1016/j.jpeds.2009.06.019

Laberge, S., Bush, P. L., & Chagnon, M. (2012). Effects of a culturally tailored physical activity promotion program on selected self-regulation skills and attitudes in adolescents of an underserved, multiethnic milieu. *American Journal of Health Promotion, 26*(4), 105-115. doi:10.4278/ajhp.090625-QUAN-202

Ladd, G. W., & Dinella, L. M. (2009). Continuity and change in early school engagement: Predictive of children's achievement trajectories from first to eighth grade? *Journal of Educational Psychology, 101*(1), 190. doi:10.1037/a0013153

Lam, S.-f., Wong, B. P., Yang, H., & Liu, Y. (2012). Understanding student engagement with a contextual model. In S. Christenson, L. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 403-419). New York, NY: Springer.

Lazarou, C., & Soteriades, E. S. (2009). Physical activity patterns among preadolescent children in Cyprus: the CYKIDS study. *Journal of Physical Activity & Health, 6*(2), 185-194.

Leatherdale, S. T., & Wong, S. L. (2008). Modifiable characteristics associated with sedentary behaviours among youth. *International Journal of Pediatrics Obesity, 3*(2), 93-101. doi:10.1080/17477160701830879

LeBlanc, M. M., Martin, C. K., Han, H., Newton Jr, R., Sothern, M., Webber, L. S., . . . Williamson, D. A. (2012). Adiposity and physical activity are not related to academic achievement in school-aged children. *Journal of Developmental and Behavioral Pediatrics, 33*(6), 486-494. doi:10.1097/DBP.0b013e31825b849e

Lee, I., & Paffenbarger, R. (2000). Associations of light, moderate, and vigorous intensity physical activity with longevity. The Harvard Alumni Health Study. *American Journal of Epidemiology, 151*(3), 293-299. doi:10.1093/oxfordjournals.aje.a010205

Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: a systematic review of randomized control trials. *Preventing Chronic Disease, 10*(1), E174. doi:10.5888/pcd10.130010

Leithwood, K., & Jantzi, D. (2009). A review of empirical evidence about school size effects: A policy perspective. *Review of Educational Research, 79*(1), 464-490. doi:10.3102/0034654308326158

Libbey, H. P. (2009). Measuring student relationships to school: Attachment, bonding, connectedness, and engagement. *Journal of School Health, 74*(7), 274-283. doi:10.1111/j.1746-1561.2004.tb08284.x

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., . . . Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: explanation and elaboration. *Annals of Internal Medicine, 151*(4), 65-94. doi:10.1371/journal.pmed.1000100

Linnenbrink-Garcia, L., & Pekrun, R. (2011). Students’ emotions and academic engagement: Introduction to the special issue. *Contemporary Educational Psychology, 36*(1), 1-3. doi:10.1016/j.cedpsych.2010.11.004

Lucas, S. R. (2001). Effectively maintained inequality: Education transitions, track mobility, and social background effects. *American Journal of Sociology, 106*(6), 1642-1690. doi:10.1086/321300

Lucht, M., & Heidig, S. (2013). Applying HOPSCOTCH as an exer-learning game in English lessons: two exploratory studies. *Educational Technology Research & Development, 61*(5), 767-792. doi:10.1007/s11423-013-9308-3

Ma, J. K., Mare, L. L., & Gurd, B. J. (2014). Classroom-based high-intensity interval activity improves off-task behaviour in primary school students. *Applied Physiology, Nutrition, and Metabolism, 39*(12), 1332-1337. doi:10.1139/apnm-2014-0125

Mahar, M. T., Murphy, S., Rowe, D., Golden, J., Shields, A., & Raedeke, T. (2006). Effects of a classroom-based program on physical activity and on-task behavior. *Medicine & Science in Sports & Exercise, 38*(12), 2086-2094. doi:10.1249/01.mss.0000235359.16685.a3

Malecki, C., & Demaray, M. (2006). Social support as a buffer in the relationship between socioeconomic status and academic performance. *School Psychology Quarterly, 21*(4), 375-395.

Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal, 37*(1), 153-184. doi:10.3102/00028312037001153

Marsh, H. W., Bornmann, L., Mutz, R., Daniel, H.-D., & O'Mara, A. (2009). Gender effects in the peer reviews of grant proposals: A comprehensive meta-analysis comparing traditional and multilevel approaches. *Review of Educational Research, 79*(3), 1290-1326. doi:10.3102/0034654309334143

Martikainen, S., Pesonen, A. K., Lahti, J., Heinonen, K., Tammelin, T., Kajantie, E., . . . Räikkönen, K. (2012). Physical activity and psychiatric problems in children. *Journal of Pediatrics, 161*(1), 160-162. doi:10.1016/j.jpeds.2012.03.037

Martin, A. (2009). Age appropriateness and motivation, engagement, and performance in high school: Effects of age within cohort, grade retention, and delayed school entry. *Journal of Educational Psychology, 101*(1), 101-114. doi:10.1037/a0013100

Martin, A., Anderson, J., Bobis, J., Way, J., & Vellar, R. (2012). Switching on and switching off in mathematics: An ecological study of future intent and disengagement among middle school students. *Journal of Educational Psychology, 104*(1), 1-18. doi:10.1037/a0025988

Martin, A., Saunders, D., Shenkin, S., & Sproule, J. (2014). Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. *The Cochrane Library, 14*(3), 1-95. doi:10.1002/14651858.CD009728.pub2

McArdle, J. J. (2001). A latent difference score approach to longitudinal dynamic structural analyses. In R. Cudeck, S. du Toit, & D. Sörbom (Eds.), *Structural equation modeling: Present and future* (pp. 342–380). Lincolnwood, IL: Scientific Software International.

McArdle, J. J., & Hamagami, F. (2001). Latent difference score structural models for linear dynamic analyses with incomplete longitudinal data. In C. L & A. Sayer (Eds.), *New Methods for the Analysis of Change* (pp. 139–175). Washington, DC: APA Press.

McArdle, J. J., & Prindle, J. J. (2008). A latent change score analysis of a randomized clinical trial in reasoning training. *Psychology and aging, 23*(4), 702.

McGraw, K. O., & Wong, S. (1996). Forming inferences about some intraclass correlation coefficients. *Psychological Methods, 1*(1), 30-46. doi:10.1037/1082-989X.1.1.30

McWilliams, L., Sayal, K., & Glazebrook, C. (2013). Inattention and hyperactivity in children at risk of obesity: A community cross-sectional study. *BMJ Open, 3*(5), 1-9. doi:10.1136/bmjopen-2013-002871

Mega, C., Ronconi, L., & De Beni, R. (2014). What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. *Journal of Educational Psychology, 106*(1), 121-131. doi:10.1037/a0033546

Metzler, M. W., & Williams, S. A classroom-based physical activity and academic content program: more than a “pause that refreshes”. *Unpublished manuscript, International Life Sciences Institute, Atlanta, Georgia*.

Murphy, M. H., Blair, S. N., & Murtagh, E. M. (2009). Accumulated versus continuous exercise for health benefit. *Sports Medicine, 39*(1), 29-43. doi:10.2165/00007256-200939010-00003

Muthén, B. (2001). Second-generation structural equation modeling with a combination of categorical and continuous latent variables: New opportunities for latent class–latent growth modeling. In L. Collins & A. Sayer (Eds.), *New Methods for the Analysis of Change* (pp. 291-322). Washington, DC: US: American Psychological Association.

Nader, P. R., Bradley, R. H., Houts, R. M., McRitchie, S. L., & O’Brien, M. (2008). Moderate-to-vigorous physical activity from ages 9 to 15 years. *Journal of the American Medical Association, 300*(3), 295-305.

National Research Council and the Institute of Medicine. (2004). *Engaging schools: fostering high school students’ motivation to learn*. Washington, DC: The National Academies Press.

Nunnally, J., & Bernstein, I. (1994). *Psychometric theory* (3 ed.). New York, NY: McGraw-Hill.

Osborne, J. W. (2013). *Best practices in data cleaning*. Thousand Oaks, CA: SAGE Publications, Inc.

Owen, K., Parker, P., Van Zenden, B., MacMillan, F., & Lonsdale, C. (2016). Physical activity and school engagement in youth: A systematic review and meta-analysis. *Educational Psychologist, 51*(2), 129-145. doi:10.1080/00461520.2016.1151793

Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. In S. Christenson, A. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 259-282). New York, NY: Springer.

Pellegrini, A. D., Huberty, P. D., & Jones, I. (1995). The effects of recess timing on children's playground and classroom behaviors. *American Educational Research Journal*, *32*(4), 845-864. doi:10.3102/00028312032004845

Pellegrini, A. D., & Smith, P. K. (1993). School recess: Implications for education and development. *Review of Educational Research, 63*(1), 51-67. doi:10.3102/00346543063001051

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: A review of mental and physical health benefits associated with physical activity. *Current Opinion in Psychiatry, 18*(2), 189-193.

Peng, C.-Y. J., & Zhu, J. (2008). Comparison of two approaches for handling missing covariates in logistic regression. *Educational and Psychological Measurement, 68*(1), 58-77. doi:10.1177/0013164407305582

Perry, J. C., Liu, X., & Pabian, Y. (2010). School engagement as a mediator of academic performance among urban youth: The role of career preparation, parental career support, and teacher support. *The Counseling Psychologist, 38*(2), 269-295. doi:10.1177/0011000009349272

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kubitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. *Sports Medicine, 11*(3), 143-182. doi:10.2165/00007256

Puyau, M., Adolph, A., Vohra, F., & Butte, N. (2002). Validation and calibration of physical activity monitors in children. *Obesity Research, 10*(3), 150-157. doi:10.1038/oby.2002.24

Quinn, J. M., Wagner, R. K., Petscher, Y., & Lopez, D. (2015). Developmental relations between vocabulary knowledge and reading comprehension: A latent change score modeling study. *Child Development, 86*(1), 159-175. doi:10.1111/cdev.12292

R Core Team. (2014). A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Ramstetter, C. L., Murray, R., & Garner, A. S. (2010). The crucial role of recess in schools. *Journal of School Health, 80*(11), 517-526. doi:10.1542/peds.2012-2993

Raudenbush, S. W., & Bryk, A. S. (1985). Empirical Bayes meta-analysis. *Journal of Educational and Behavioral Statistics, 10*(2), 75-98.

Reeve, J. (2013). How students create motivationally supportive learning environments for themselves: The concept of agentic engagement. *Journal of Educational Psychology, 105*(3), 579-595. doi:10.1037/a0032690

Reidy, A., Minassian, D., Vafidis, G., Joseph, J., Farrow, S., Wu, J., . . . Connolly, A. (1998). Prevalence of serious eye disease and visual impairment in a north London population: A population based, cross sectional study. *BMJ, 316*(1), 1643-1646. doi:10.1136/bmj.316.7145.1643

Resaland, G. K., Moe, V. F., Aadland, E., Steene-Johannessen, J., Glosvik, Ø., Andersen, J. R., . . . Anderssen, S. A. (2015). Active Smarter Kids (ASK): Rationale and design of a cluster-randomized controlled trial investigating the effects of daily physical activity on children’s academic performance and risk factors for noncommunicable diseases. *BMC public health, 15*(1), 1. doi:10.1186/s12889-015-2049-y

Reschly, A. L. (2010). Reading and school completion: Critical connections and Matthew effects. *Reading & Writing Quarterly, 26*(1), 67-90. doi:10.1080/10573560903397023

Reschly, A. L., & Christenson, S. L. (2006). Prediction of dropout among students with mild disabilities: A case for the inclusion of student engagement variables. *Remedial and Special Education, 27*(5), 276-292. doi:10.1177/07419325060270050301

Reschly, A. L., & Christenson, S. L. (2012). Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct. In S. Christenson, A. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement*. New York, NY: Springer.

Reschly, A. L., Huebner, E. S., Appleton, J. J., & Antaramian, S. (2008). Engagement as flourishing: The contribution of positive emotions and coping to adolescents' engagement at school and with learning. *Psychology in the Schools, 45*(5), 419-431. doi:10.1002/pits.20306

Resnick, L. (2010). Nested learning systems for the thinking curriculum. *Educational Researcher, 39*(3), 183-197. doi:10.3102/0013189X10364671

Ridgers, N., & Fairclough, S. (2011). Assessing free-living physical activity using accelerometry: Practical issues for researchers and practitioners. *European Journal of Sport Science, 11*(3), 205-213. doi:10.1080/17461391.2010.501116

Ridgway, A., Northup, J., Pellegrin, A., LaRue, R., & Hightsoe, A. (2003). Effects of recess on the classroom behavior of children with and without attention-deficit hyperactivity disorder. *School Psychology Quarterly, 18*(3), 253-268. doi:10.1521/scpq.18.3.253.22578

Riley, N., Lubans, D., Holmes, K., & Morgan, P. (2014). Rationale and study protocol of the EASY Minds (Encouraging Activity to Stimulate Young Minds) program: Cluster randomized controlled trial of a primary school-based physical activity integration program for mathematics. *BMC Public Health, 14*(1), 1-10. doi:10.1186/1471-2458-14-816

Riley, N., Morgan, P., & Lubans, D. (2012). Preliminary findings of the EASY (Encouraging Activity to Stimulate Young) Minds feasibility study: A curriculum-based physical activity integration program in the primary school. *Journal of Science and Medicine in Sport, 15*(1), S90. doi:10.1016/j.jsams.2012.11.217

Roorda, D. L., Koomen, H. M., Spilt, J. L., & Oort, F. J. (2011). The influence of affective teacher–student relationships on students' school engagement and achievement: A meta-analytic approach. *Review of Educational Research, 81*(4), 493-529. doi:10.3102/0034654311421793

Rosenthal, R. (1991). *Meta-analytic procedures for social research* (Vol. 6): Sage.

Rosenthal, R. (1994). Parametric measures of effect size. In H. Cooper & L. Hedges (Eds.), *The Handbook of Research Synthesis* (pp. 231-244). New York, NY: Russel Sage Foundation.

Rosseel, Y. (2012). lavaan: An R package for structural equation modeling. *Journal of Statistical Software, 48*(2), 1-36.

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2006). *Publication bias in meta-analysis: Prevention, assessment and adjustments*. Chichester, UK: John Wiley & Sons.

Rubin, D. B. (1987). *Multiple Imputation for Nonresponse in Surveys*. New York, NY: J. Wiley & Sons.

Russell, V. J., Ainley, M., & Frydenberg, E. (2005). *Schooling issues digest: Student motivation and engagement*. Canberra: Department of Education, Science and Training. Retrieved from http://www.dest.gov.au/sectors/school_education/publications_resources/schooling_issues_digest/schooling_issues_digest_motivation_engagement.htm.

Rzewnicki, R., Auweele, Y. V., & Bourdeaudhuij, I. D. (2003). Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample. *Public Health Nutrition, 6*(3), 299-305. doi:10.1079/PHN2002427

Sallis, J. (2000). Age-related decline in physical activity: a synthesis of human and animal studies. *Medicine & Science in Sport & Exercise, 32*(9), 1598-1600.

Satorra, A., & Bentler, P. (1994). Corrections to test statistics and standard errors in covariance structure analysis. In A. Von Eye & C. Clogg (Eds.), *Applications for Latent Variables Analysis: Applications to Developmental Research.* (pp. 399-419). Thousand Oaks, CA: SAGE Publications.

Sattelmair, J., & Ratey, J. J. (2009). Physically active play and cognition. *American Journal of Play, 3*(1), 365-374.

Schnieders-Laber, D. T. (2011). *Exploring second grade student engagement before and after MINDS-In-Motion, MAZE.* (Education Doctorate), Northern Kentucky University, Ohio, United States. Retrieved from http://ezproxy.uws.edu.au/login?url=http://search.ebscohost.com/login.aspxdirect=true&db=eric&AN=ED536399&site=ehost-live&scope=sitehttp://gateway.proquest.com/openurl?url_ver=Z39.88-

2004&rft_val_fmt=info:ofi/fmt:kev:mtx:dissertation&res_dat=xri:pqdiss&rft_dat=xri:pqdiss:3487273

Shadish, W. R., & Sweeney, R. B. (1991). Mediators and moderators in meta-analysis: There's a reason we don't let dodo birds tell us which psychotherapies should have prizes. *Journal of Consulting and Clinical Psychology, 59*(6), 883-893. doi:10.1037/0022-006X.59.6.883

Shernoff, D. (2010). Engagement in after-school programs as a predictor of social competence and academic performance. *American Journal of Community Psychology, 45*(3), 325-337. doi:10.1007/s10464-010-9314-0

Sibley, B. A., & Etnier, J. L. (2003). The relationship between physical activity and cognition in children: A meta-analysis. *Pediatric Exercise Science, 15*(3), 243-256.

Singh, A., Uijtdewilligen, L., Twisk, J., Mechelen, W., & Chinapaw, M. (2012a). Physical activity and performance at school: A systematic review of the literature including a methodological quality assessment. *Archives of Pediatrics and Adolescent Medicine, 166*(1), 49-55. doi:10.1001/archpediatrics.2011.716

Singh, A., Uijtdewilligen, L., Twisk, J., Mechelen, W., & Chinapaw, M. (2012b). Physical activity is not related to performance at school- Reply. *Archives of Pediatrics & Adolescent Medicine, 166*(7), 678-679. doi:10.1001/archpediatrics.2012.337

Sirin, S. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75*(3), 417-453. doi:10.3102/00346543075003417

Skinner, C., Holt, D., & Smith, T. (1989). *Analysis of Complex Surveys*. New York, NY: John Wiley & Sons.

Skinner, E., Kindermann, T., & Furrer, C. (2009). A motivational perspective on engagement and disaffection conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom. *Educational and Psychological Measurement, 69*(3), 493-525. doi:10.1177/0013164408323233

Smith, A. L., Hoza, B., Linnea, K., McQuade, J. D., Tomb, M., Vaughn, A. J., . . . Hook, H. (2013). Pilot physical activity intervention reduces severity of ADHD symptoms in young children. *Journal of Attention Disorders, 17*(1), 70-82. doi:10.1177/1087054711417395

Snijders, T. (2005). Power and sample size in multilevel linear models. In B. S. Everitt & D. C. Howell (Eds.), *Encyclopedia of Statistics in Behavioral Science* (Vol. 3, pp. 1570–1573). Chicester: Wiley.

St Clair-Thompson, H. L., & Gathercole, S. E. (2006). Executive functions and achievements in school: Shifting, updating, inhibition, and working memory. *The Quarterly Journal of Experimental Psychology, 59*(4), 745-759. doi:10.1080/17470210500162854

Sterne, J., Egger, M., & Moher, D. (2011). Chapter 10: Addressing reporting biases. In Higgins J & S. Green (Eds.), *Cochrane Handbook for Systematic Reviews of Intervention. Version 5.1.0 (updated March 2011)*: The Cochrane Collaboration, 2011. Available from http://www.cochrane-handbook.org.

Strong, W. B., Malina, R. M., Blimkie, C. J., Daniels, S. R., Dishman, R. K., Gutin, B., . . . Pivarnik, J. M. (2005). Evidence based physical activity for school-age youth. *The Journal of Pediatrics, 146*(6), 732-737. doi:10.1016/j.jpeds.2005.01.055

Suldo, S. M., Riley, K. N., & Shaffer, E. J. (2006). Academic correlates of children and adolescents' life satisfaction. *School Psychology International, 27*(5), 567-582. doi:10.1177/0143034306073411

Sullivan, A., Joshi, H., & Leonard, D. (2010). Single-sex schooling and academic attainment at school and through the lifecourse. *American Educational Research Journal, 47*(1), 6-36. doi:10.3102/0002831209350106

Swain, D. P., & Franklin, B. A. (2006). Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *The American Journal of Cardiology, 97*(1), 141-147. doi:10.1016/j.amjcard.2005.07.130

Sylvia, L. G., Bernstein, E. E., Hubbard, J. L., Keating, L., & Anderson, E. J. (2014). Practical guide to measuring physical activity. *Journal of the Academy of Nutrition and Dietetics, 114*(2), 199-208. doi:10.1016/j.jand.2013.09.018

Syväoja, H., Kantomaa, M. T., Ahonen, T., Hakonen, H., KankaanpÄÄ, A., & Tammelin, T. H. (2013). Physical Activity, Sedentary Behavior, and Academic Performance in Finnish Children. *Medicine & Science in Sports & Exercise, 45*(11), 2098-2104.

Syväoja, H. J., Tammelin, T. H., Ahonen, T., Kankaanpää, A., & Kantomaa, M. T. (2014). The associations of objectively measured physical activity and sedentary time with cognitive functions in school-aged children. *PloS ONE, 9*(7), e103559. doi:10.1371/journal.pone.0103559

Telford, R. M., Telford, R. D., Cunningham, R. B., Cochrane, T., Davey, R., & Waddington, G. (2013). Longitudinal patterns of physical activity in children aged 8 to 12 years: the LOOK study. *Int J Behav Nutr Phys Act, 10*(1), 81. doi:10.1186/1479-5868-10-81

Telles, S., Singh, N., Bhardwaj, A. K., Kumar, A., & Balkrishna, A. (2013). Effect of yoga or physical exercise on physical, cognitive and emotional measures in children: A randomized controlled trial. *Child and Adolescent Psychiatry and Mental Health, 7*(1), 37-53. doi:10.1186/1753-2000-7-37

Tomporowski, P. D. (2003). Effects of acute bouts of exercise on cognition. *Acta Psychologica, 112*(3), 297-324. doi:10.1016/S0001-6918(02)00134-8

Tremblay, M. S., Inman, J. W., & Willms, J. D. (2000). The relationship between physical activity, self-esteem, and academic achievement in 12-year-old children. *Pediatric Exercise Science, 12*(3), 312-323.

Treuth, M. S., Schmitz, K., Catellier, D. J., McMurray, R. G., Murray, D. M., Almeida, M. J., . . . Pate, R. (2004). Defining accelerometer thresholds for activity intensities in adolescent girls. *Medicine & Science in Sport & Exercise, 36*(7), 1259-1266. doi:10.1249/01.MSS.0000074670.03001.98

Troiano, R., Berrigan, D., Dodd, K., Masse, L., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medicine & Science in Sports & Exercise, 40*(1), 181. doi:10.l249/mss.0b013e31815a5lb3

Troiano, R., Gabriel, K., Welk, G., Owen, N., & Sternfeld, B. (2012). Reported physical activity and sedentary behavior: Why do you ask? *Journal of Physical Activity and Health, 9*(1), 68-75.

Trost, S. (2007). State of the art reviews: Measurement of physical activity in children and adolescents. *American Journal of Lifestyle Medicine, 1*(4), 299-314. doi:10.1177/1559827607301686

Trost, S., Loprinzi, P., Moore, R., & Pfeiffer, K. (2011). Comparison of accelerometer cut points for predicting activity intensity in youth. *Medicine & Science in Sports & Exercise, 43*(7), 1360-1368. doi:10.1249/MSS.0b013e318206476e

Upadyaya, K., & Salmela-Aro, K. (2013). Development of school engagement in association with academic success and well-being in varying social contexts: A review of empirical research. *European Psychologist, 18*(2), 136-147. doi:10.1027/1016-9040/a000143

Utter, J., Neumark-Sztainer, D., Jeffery, R., & Story, M. (2003). Couch potatoes or french fries: Are sedentary behaviors associated with body mass index, physical activity, and dietary behaviors among adolescents? *Journal of the American Dietetic Association, 103*(10), 1298-1305. doi:10.1053/S0002-8223(03)01079-4

Van Den Noortgate, W., & Onghena, P. (2003). Multilevel meta-analysis: A comparison with traditional meta-analytical procedures. *Educational and Psychological Measurement, 63*(5), 765-790. doi:10.1177/0013164403251027

Van der Borght, K., Havekes, R., Bos, T., Eggen, B. J., & Van der Zee, E. A. (2007). Exercise improves memory acquisition and retrieval in the Y-maze task: Relationship with hippocampal neurogenesis. *Behavioral Neuroscience, 121*(2), 324-334. doi:10.1037/0735-7044.121.2.324

Van Dijk, M. L., De Groot, R., Savelberg, H., Van Acker, F., & Kirschner, P. A. (2014). The association between objectively measured physical activity and academic achievement in Dutch adolescents: Findings from the GOALS study. *Journal of Sport and Exercise Psychology, 36*(5), 460-473. doi:10.1123/jsep.2014-0014

Van Praag, H., Shubert, T., Zhao, C., & Gage, F. H. (2005). Exercise enhances learning and hippocampal neurogenesis in aged mice. *The Journal of Neuroscience, 25*(38), 8680-8685. doi:10.1523/JNEUROSCI.1731-05.2005

Vaynman, S., Ying, Z., & Gomez-Pinilla, F. (2003). Interplay between brain-derived neurotrophic factor and signal transduction modulators in the regulation of the effects of exercise on synaptic-plasticity. *Neuroscience, 122*(3), 647-657. doi:10.1016/j.neuroscience.2003.08.001

Vazou, S., Gavrilou, P., Mamalaki, E., Papanastasiou, A., & Sioumala, N. (2012). Does integrating physical activity in the elementary school classroom influence academic motivation? *International Journal of Sport & Exercise Psychology, 10*(4), 251-263. doi:10.1080/1612197X.2012.682368

Walker, D., Greenwood, C., Hart, B., & Carta, J. (1994). Prediction of school outcomes based on early language production and socioeconomic factors. *Child Development, 65*(1), 606-621.

Wang, J., Chia, M., Quek, J., & Liu, W. (2006). Patterns of physical activity, sedentary behaviors, and psychological determinants of physical activity among Singaporean school children. *International Journal of Sport & Exercise Psychology, 4*(3), 227-249. doi:10.1080/1612197X.2006.9671797

Wang, M., & Eccles, J. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence, 22*(1), 31-39. doi:10.1111/j.1532-7795.2011.00753.x

Wang, M., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal, 47*(3), 633-662. doi:10.3102/0002831209361209

Wang, M., & Peck, S. (2013). Adolescent educational success and mental health vary across school engagement profiles. *Developmental Psychology, 49*(7), 1266. doi:10.1037/a0030028

Whitt-Glover, M. C., Ham, S. A., & Yancey, A. K. (2011). Instant Recess: A practical tool for increasing physical activity during the school day. *Prog Community Health Partnersh, 5*(3), 289-297. doi:10.1353/cpr.2011.0031

Wigfield, A., & Tonks, S. (2002). Adolescents' expectancies for success and achievement task values during the middle and high school years. In F. Pajares & T. Urdan

(Eds.), *Academic Motivation of Adolescents* (pp. 53-82). Greenwich, Connecticut: Information Age Publishing Inc.

Woehrle, T., Fox, S., & Hoskin, B. (2005). An examination of the balanced school day schedule. *Ontario Action Researcher, 8*(3), 1-9.

World Health Organisation. (2010). *Global strategy on diet, physical activity and health*. Geneva: World Health Organisation.

Wylie, C., & Hodgen, E. (2012). Trajectories and patterns of student engagement: Evidence from a longitudinal study. In S. Christenson, A. Reschly, & C. Wylie (Eds.), *Handbook of Research on Student Engagement* (pp. 585-599). New York, NY: Springer.

Yazzie-Mintz, E. (2009). *Engaging the voices of students: A report on the 2007 & 2008 High School Survey of Student Engagement*. Retrieved from Bloomington, IN: http://files.eric.ed.gov/fulltext/ED495758.pdf

Yerkes, R. M., & Dodson, J. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology, 18*(1), 459-482. doi:10.1002/cne.920180503

Yu, C. C. W., Chan, S., Cheng, F., Sung, R. Y. T., & Hau, K. T. (2006). Are physical activity and academic performance compatible? Academic achievement, conduct, physical activity and self-esteem of Hong Kong Chinese primary school children. *Educational Studies, 32*(4), 331-341. doi:10.1080/03055690600850016

Yuan, K., & Bentler, P. (2002). On normal theory based inference for multilevel models with distributional violations. *Psychometrika, 67*(4), 539-561. doi:10.1007/BF02295130

Zan, G. (2013). The impact of an exergaming intervention on urban school children's physical activity levels and academic outcomes. *Asian Journal of Exercise & Sports Science, 10*(2), 1-10.

Zhang, Y., Zhang, D., Jiang, Y., Sun, W., Wang, Y., Chen, W., . . . Zhang, J. (2015). Association between physical activity and teacher-reported academic performance among fifth-graders in Shanghai: A quantile regression. *PloS ONE, 10*(3), e0115483. doi:10.1371/journal.pone.0115483

Appendices

Appendix A: Additional Methodology and Design

Study 1

Meta-analysis

There are a number of possible approaches to conducting meta-analyses. Researchers have traditionally used fixed-effects models. This approach assumes that all variance between effect sizes is due to sampling error (within-study), as the samples included in the meta-analysis are assumed to span the entire population relevant to the research question (Field, 2003; Hedges & Vevea, 1998; Marsh et al., 2009). However, this assumption is unrealistic; and in those rare cases where the entire relevant population is covered, the results cannot be generalised to other populations of interest. More recently, researchers have used random-effects models to conduct meta-analyses. This approach assumes that variance is due to both sampling error (within-study) and variability in the population of effects (between-study). This assumption (effectively, that features of the studies such as the context or the instruments contribute to the variability in effect sizes, along with sampling error) makes the random-effects models generalisable to broader populations. It is therefore to be preferred over fixed-effects models.

Nevertheless, both fixed- and random-effects models are limited by the assumption of independence (Field, 2003). This means that only one effect size per study should be included in a meta-analysis, because the effect sizes within a single study are likely to be correlated. Ahn et al. (2012) reviewed 56 meta-analyses published in education since 2000 and found a variety of strategies to address this issue of multiple effect sizes per study, including: a) averaging the effect sizes (n = 18), b) “shifting the unit of analysis” (i.e., retaining as many effect sizes as possible from each study, while holding violations of the assumption of independence to a minimum; Cooper, 1989) (n = 8), c) selecting one of the effect sizes or using a combination of approaches a and b (n = 7), and d) not reporting how the issue was handled (n = 15). These strategies all have the potential to lose information, and therefore limit the research questions that can be addressed and the moderators that can be tested (Cheung, 2014).

Structural equation modelling and multilevel modelling are two approaches to meta-analysis that are not limited by the assumption of independence (Goldstein, 1995; Marsh et al., 2009; Raudenbush & Bryk, 1985; Van Den Noortgate & Onghena, 2003). Another advantage is that covariates and moderator variables can be included, to explore the heterogeneity in effect sizes (Van Den Noortgate & Onghena, 2003). Multilevel modelling can be integrated with structural equation modelling, providing further methodological advantages (Cheung, 2014). For example, this integrated approach places flexible constraints on parameters, constructs more accurate confidence intervals (with a likelihood-based approach), and handles missing covariates using FIML (Cheung, 2009, 2014). Such a combined approach to meta-analysis was adopted in Study 1.

Study 2 and Study 3

Context

The data for Study 2 and 3 were collected in government-funded secondary schools in the Western Sydney region, Australia. This represents one of the lowest SES areas in metropolitan Sydney (Australian Bureau of Statistics, 2008a). Research has shown that youth living in low SES areas tend to participate in lower levels of physical activity (Brodersen, Steptoe, Boniface, & Wardle, 2007; Hardy et al., 2010) and be less engaged in school and more likely to drop out (Fullarton, 2002; Ladd & Dinella, 2009; Marks, 2000; Wang, M. & Eccles, 2012). It is therefore likely that those living in the Western Sydney region will display particularly low levels of school engagement, and it is especially important to identify the determinants of school engagement for them.

Participants

School inclusion criteria. To be eligible for participation in the data collection for Study 2 and Study 3, schools needed to be located in a low SES area of the Western Sydney region, defined as one with a Socio-Economic Index for Areas (SEIFA) rank of ≤ 5 (Australian Bureau of Statistics, 2008a). Schools needed to be funded by the New South Wales Department of Education and have students enrolled in years 8 in 2014. Finally, schools were deemed eligible if permission was granted by the principal, head teacher of mathematics, and at least one year 8 mathematics teacher.

Student inclusion criteria. Students were eligible to participate if they were enrolled in year 8 in 2014, at a participating school. Parents or guardians provided informed written consent and students provided informed written assent.

Recruitment. Principals from all potentially eligible schools were contacted and provided with information about the study. After principals' expressions of interest had been assembled, schools were selected for participation that would provide a representative sample for the whole Western Sydney region. When selecting schools, school characteristics such as school size and gender composition (i.e., single sex or co-educational) were taken into account.

Ethics

The Australian Catholic University Human Research Ethics Committee (approval # 2014 185N; Appendix D) and the NSW Department of Education (approval # 2013162) granted approval for the collection of data for Study 2 and Study 3.

Data collection

Data were collected at three time points: Time 1 (during term 1 of 2014, January–April) and Time 2 (during term 4 of 2014, October–December) when students were in year 8, and Time 3 (during term 2 of 2015, April–June), when students were in year 9. Trained research assistants and I collected all data. Before data collection began, research assistants attended a training session to familiarise them with standard operating procedure manuals and to ensure quality control during data collection.

At each time point of data collection, a trained research assistant or I attended four lessons for each class. Before the first lesson, accelerometers (Actigraph GT3X+) were initialised to record data over a seven-day period. At the first lesson, students responded to a questionnaire that assessed age, gender, socioeconomic status, ethnicity, and self-reported total physical activity. When students had completed the questionnaire, we measured their height, using a stadiometer (Surgical and Medical Products No. 26SM, Medtone Education Supplies, Melbourne, Australia); and we measured their weight, using digital scales (UC-321, A&D Company, Tokyo, Japan). Next, each student was provided with an accelerometer to assess total weekly physical activity. Students were shown how to fit the accelerometer around their waist, with the arrow pointing up, and instructed to wear the accelerometer for all waking hours of the seven-day period, except during contact sport or if it might get wet.

During the seven-day period, a trained research assistant or I attended two mathematics lessons for each class. For one hour before the first mathematics lesson, students wore the accelerometer to assess their physical activity. After that first mathematics lesson, students responded to a questionnaire that assessed their mathematics engagement during the lesson (for Study 2). Following the second mathematics lessons, students responded to a questionnaire that assessed their usual mathematics engagement (for Study 3). At the end of the seven-day period, a trained research assistant or I attended a lesson to collect the accelerometers.

Accelerometer data processing

Accelerometer data was processed using Actilife (Version 6, ActiGraph, LLC, Fort Walton Beach, FL). The data from each accelerometer were downloaded and converted into AGD files. Each file contained raw counts of acceleration at every 1-second epoch. Any consecutive zero counts greater than 60 minutes likely meant that the student was not wearing the accelerometer and were removed. This process produced a new AGD file for each student that consisted of raw acceleration counts at each 1-second epoch for only the time which it is likely that the student wore the accelerometer.

The new AGD files with raw acceleration counts at each 1-second epoch with non-wear time removed were then converted to the equivelant 60-second epoch count. This allowed the classification of the intensity of activity as the classifications are based on 60-second epoch counts. Each 60-second epoch count was classified as either light (101 – 2295 counts per minute), moderate (2296 - 4011 counts per minute), vigorous (> 4012 counts per minute), or MVPA (> 2296 counts per minute) (Evenson et al., 2008). These classifications of intensity have been shown to be the most accurate in adolescents (Trost et al., 2011). This allowed the calculation of minutes spent in each intensity of activity and the percentage of time spent in each intensity of activity across the wear time period.

The final stage of accelerometer data processing involved isolating the time periods of interest. These periods were isolated using the Actilife date and time filters. As Study 2 assessed activity during the hours before a mathematics lesson, this hour period was isolated. Similarly, as Study 3 examined total weekly activity, this seven day period was isolated.

Data analysis

Study 2 – Linear mixed effects models

Linear mixed effects models are a flexible method for the analysis of clustered data. A hierarchical or clustered structure, such as students nested within classes and classes nested within schools can be an issue due to a lack of independence between measurements. For example, students with similar abilities are often grouped together into a class. Techniques such as linear mixed effects models have evolved for dealing with this clustering (Goldstein, 1995). Linear mixed effects models incorporate both fixed and random effects to examine the relationship between an outcome variable and some covariates in clustered data. Fixed effects parameters are associated with the whole population (e.g., age or physical activity), while random effects parameters are associated with individual units drawn at random from a population (e.g., class and school clustering). Due to the clustered nature of the data collected (students nested within classes within schools, Study 3 used linear mixed effects models.

Study 3 – Latent change score models

Latent change score modelling is a special case of structural equation modelling that provides a dynamic method for assessing change over time (McArdle, J. J, 2001; McArdle, J. J & Hamagami, 2001). Latent change score models combine the strengths of cross-lagged regression models and latent growth curve models (Quinn, Wagner, Petscher, & Lopez, 2015). Cross-lagged regression models divide the developmental period into discrete time intervals allowing causal inference (Kenny, 2005). But these models ignore development or growth. In contrast, the latent growth curve models focus on development and growth (Muthén, 2001). However, these models do not divide the developmental period into discrete time intervals, and so do not allow causal inferences. Latent change score models represent a method of modelling longitudinal data concerning development and growth, and they divide the developmental period into discrete time intervals (McArdle, J. J, 2001; McArdle, J. J & Hamagami, 2001). As the purpose of Study 3 was to examine how the development and growth of physical activity was associated with the development and growth in education outcomes, this study used latent change score models.

Fitting a latent change score model involves solving a number of equations, with some parameters known and others to be estimated. Maximum likelihood estimation is most commonly used; but it assumes normal data distribution. An alternative method is needed for data that are not normally distributed, such as those analysed in Study 3. Therefore, Study 3 used robust maximum likelihood estimation (Beauducel & Herzberg, 2006; Yuan & Bentler, 2002).

Due to the clustered nature of the data collected, Study 3 used complex sampling design modelling. In this approach, the parameter estimates are aggregated over the clusters, and are therefore the same as the parameter estimates that do not adjust for clustering (Skinner, C., Holt, & Smith, 1989). However, the standard errors are adjusted to account for the clustering (Satorra & Bentler, 1994).

Missing data

Missing data is a common issue in almost all research (Graham, 2009). Traditional methods of handling missing data involve deleting any affected cases (listwise), or deleting cases that lack data on the variables selected for a particular analysis (pairwise). Both methods are limited, and can lead to misinterpretation of parameter estimates and a loss of power (Osborne, 2013). Unlike listwise and pairwise deletion, multiple imputation and FIML utilise all available data to provide accurate parameter estimates and retain power (Enders, 2010; Graham, 2009; Graham et al., 2003). Multiple imputation involves replacing each missing datum with a set of imputed values, resulting in several complete datasets. Analyses are then conducted on each dataset and the results pooled (Rubin, 1987). In contrast, the FIML method draws on all available information to estimate parameter values and standard errors in a single model (Enders, 2010).

An advantage of using multiple imputation over FIML when dealing with categorical variables is that multiple imputation uses the distribution of the existing data to estimate values, rather than assuming that the data is normally distributed (Dong & Peng, 2013; Peng & Zhu, 2008). As Study 2 explored different categories and quantiles of physical activity, this study used multiple imputation. However, FIML provides more accurate standard errors when dealing with continuous variables (Dong & Peng, 2013; Peng & Zhu, 2008). Study 3 examined total regular physical activity as a continuous variable and thus, used FIML to handle missing data.

Appendix B: Additional Results for Study 1

Table B1

Results of school engagement meta-analyses and moderator analyses- excluding estimated effect sizes

Variable	*k*	*#ES*	*n*	Coefficient (Υ)	Lower 95% CI	Upper 95% CI	τ _2	τ _3	R^2_2	R^2_3	I^2_2	I^2_3	Q statistic
Overall school engagement	24	47	51,935	0.23	0.06	0.42	0.02	0.11			0.15	0.82	931.58
Engagement Dimension													
Behavioral engagement	23	46	51,828										
Emotional engagement	0	0	0										
Cognitive engagement	1	1	107										
Intervention type							0.02	0.12	0.04	0.00			931.58
Before school	0	0	0										
Classroom integration	3	6	837	0.23	-0.28	0.76	0.03	0.22			0.12	0.81	
Classroom break	3	14	1,351	0.06	-0.61	0.75	0.00	0.00			0.00	0.00	
School program	2	2	205										
Physical Education	1	2	497										
Recess/lunch	3	5	1,162	0.26	-0.64	1.15	0.00	0.00			0.00	0.00	
PA effects							0.02	0.11	0.00	0.00			931.58
Long term	18	26	50,918	0.23	0.04	0.44	0.02	0.10			0.17	0.80	
Short term	6	21	1,017	0.24	-0.18	0.68	0.03	0.17			0.13	0.85	
PA intensity							0.02	0.08	0.05	0.29			931.58
Moderate and vigorous	3	17	667	0.55	0.06	1.03	0.00	0.00			0.00	0.00	
Low	1	2	688										
Free play	2	3	939										

Not reported	5	6	544	0.34	-0.05	0.73	0.00	0.00			0.00	0.00	
HS Transition							0.02	0.08	0.02	0.34			931.58
Before HS transition	14	32	15,901	0.18	-0.02	0.40	0.03	0.08			0.23	0.73	
After transition	6	8	7,795	0.09	-0.19	0.39	0.00	0.03			0.00	0.89	
After 2 transitions	2	4	27,300	0.74	0.27	1.22	0.00	0.17			0.00	0.98	
Age							0.02	0.10	0.01	0.10			931.58
Children	17	36	17,620	0.19	-0.01	0.41	0.02	0.06			0.26	0.69	
Adolescents	6	10	31,861	0.39	0.08	0.73	0.00	0.26			0.00	0.98	
PA measure							0.02	0.11	0.00	0.02			931.58
Objective	2	2	253	0.46	-0.29	1.21	0.00	0.00			0.00	0.00	
Subjective	13	20	48,014	0.22	0.00	0.46	0.02	0.14			0.14	0.84	
Observation	1	12	75	0.05	-1.26	1.37	0.00	0.00			0.00	0.00	
No measure	8	13	3,593	0.22	-0.08	0.55	0.01	0.10			0.13	0.84	
Study Design							0.02	0.11	0.00	0.01			931.58
Cross-sectional	12	18	47,883	0.21	-0.03	0.47	0.02	0.17			0.11	0.86	
Quasi-experimental	7	23	2,127	0.28	-0.05	0.62	0.03	0.11			0.19	0.78	
Randomised controlled trial	5	6	1,925	0.24	-0.16	0.65	0.00	0.03			0.00	0.88	
Total Risk of bias							0.02	0.07	0.07	0.36			931.58
Low risk of bias	13	31	30,345	0.37	0.17	0.58	0.02	0.06			0.25	0.70	
High risk of bias	11	16	21,590	0.04	-0.17	0.29	0.01	0.09			0.12	0.84	
Risk of bias 1							0.02	0.11	0.00	0.04			931.58
Bias 1 = Yes	21	42	48,111	0.26	0.08	0.47	0.02	0.12			0.16	0.82	
Bias 1 = No	3	5	3,824	0.07	-0.36	0.51	0.02	0.07			0.18	0.78	
Risk of bias 2													
Bias 2 = Yes	1	1	98										
Bias 2 = No	11	28	3,954										
Risk of bias 3													

Bias 3 = Yes	1	2	497									
Bias 3 = No	11	27	3,555									
Risk of bias 4							0.02	0.11	0.00	0.04			931.58
Bias 4 = Yes	13	30	32,193	0.27	0.04	0.51	0.03	0.10			0.19	0.78	
Bias 4 = No	11	17	19,742	0.18	-0.07	0.46	0.01	0.11			0.09	0.88	
Risk of bias 5							0.02	0.09	0.02	0.23			931.58
Bias 5 = Yes	16	38	32,287	0.32	0.13	0.53	0.02	0.11			0.17	0.80	
Bias 5 = No	8	9	19,648	0.02	-0.25	0.32	0.00	0.03			0.00	0.86	
Risk of bias 6													
Bias 9 = Yes	1	1	98										
Bias 9 = No	23	46	51,837										
Risk of bias 7							0.02	0.09	0.05	0.24			931.58
Bias 10 = Yes	10	27	41,888	0.45	0.19	0.73	0.03	0.13			0.16	0.81	
Bias 10 = No	14	20	10,047	0.10	-0.10	0.31	0.01	0.07			0.14	0.81	
Publication status							0.02	0.10	0.00	0.12			931.58
Published	22	44	51,193	0.26	0.09	0.45	0.02	0.11			0.15	0.81	
Unpublished	2	3	742	-0.09	-0.64	0.48	0.03	0.00			0.86	0.00	

Note. Risk of bias 1 = Description of participant eligibility criteria; Risk of bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of bias 6 = Power calculation reported and study adequately powered to detect hypothesized relationships; Risk of bias 7 = Covariates adjusted for in analyses (e.g. gender, age, weight status).

Table B2

Results of school disengagement meta-analyses and moderator analyses- excluding estimated effect sizes

Variable	*k*	*#ES*	*n*	Coefficient (Υ)	Lower 95% CI	Upper 95% CI	τ _2	τ _3	R^2_2	R^2_3	I^2_2	I^2_3	Q statistic
Overall school disengagement	7	17	4,765	0.02	-0.46	0.49	0.05	0.21			0.14	0.66	85.75
Disengagement Dimension							0.05	0.22	0.00	0.00			
Behavioral disengagement	6	15	4,722	0.02	-0.51	0.51	0.05	0.25			0.14	0.68	
Emotional disengagement	1	2	43	0.02	-1.14	1.30	0.00	0.00			0.00	0.00	
Cognitive disengagement	0	0	0										
Intervention type							0.00	0.00	0.11	0.61			85.75
Before school	1	2	14										
Classroom integration	0	0	0										
Classroom break	1	5	44	-0.42	-1.72	0.88	0.00	0.00			0.00	0.00	
School program	1	1	108										
Physical Education	0	0	0										
Recess/lunch	3	8	165	0.84	-0.59	2.27	0.12	0.15			0.36	0.45	
PA effects							0.03	0.11	0.35	0.50			85.75
Long term	3	4	4,513	-0.29	-0.85	0.28	0.00	0.07			0.00	0.50	
Short term	4	13	252	0.31	-0.24	0.79	0.10	0.19			0.28	0.54	
PA intensity							0.05	0.12	0.00	0.44			85.75
Vigorous and moderate	3	8	166	-0.24	-0.88	0.38	0.00	0.07			0.00	0.52	
Low													
Free play	2	6	142	0.52	-0.23	1.24	0.27	0.26			0.46	0.43	
Not reported													
HS Transition													
Before HS transition	5	11	4,665										

After 1 transition	0	0	0										
After 2 transitions	0	0	0										
Age													
Children	7	17	4,765										
Adolescents	0	0	0										
PA measure							0.03	0.03	0.44	0.84			85.75
Objective	0	0	0										
Subjective	2	6	4,435	-0.46	-1.02	0.12	0.00	0.00			0.00	0.00	
Observation	2	4	122	0.61	0.16	1.14	0.20	0.04			0.65	0.14	
No measure	3	7	208	-0.17	-0.62	0.25	0.00	0.05			0.00	0.45	
Study Design													
Cross-sectional	0	0	0										
Quasi-experimental	5	15	266										
Randomised controlled trial	1	1	108										
Longitudinal	1	1	4,391										
Total Risk of bias							0.00	0.00	1.00	1.00			85.75
Low risk of bias	3	5	230	0.42	0.20	0.64	0.15	0.04			0.59	0.16	
High risk of bias	4	12	4,492	-0.46	-0.55	-0.27	0.00	0.00			0.00	0.00	
Risk of bias 1													
Bias 1 = Yes	6	16	374										
Bias 1 = No	1	1	4,391										
Risk of bias 2													
Bias 2 = Yes	0	0	0										
Bias 2 = No	6	16	374										
Risk of bias 3													
Bias 3 = Yes	1	1	108										
Bias 3 = No	5	15	266										

Risk of bias 4							0.00	0.00	0.00	0.87			85.75
Bias 4 = Yes	2	4	122	0.63	0.13	1.18	0.20	0.04			0.65	0.14	
Bias 4 = No	5	13	4,643	-0.29	-0.65	0.08	0.05	0.00			0.33	0.00	
Risk of bias 5													
Bias 5 = Yes	7	17	4,765										
Bias 5 = No	0	0	0										
Risk of bias 6													
Bias 9 = Yes	0	0	0										
Bias 9 = No	7	17	4,765										
Risk of bias 7							0.04	0.20	0.10	0.08			85.75
Bias 10 = Yes	2	3	131	0.23	-0.61	1.07	0.00	0.00			0.00	0.00	
Bias 10 = No	5	14	4,634	-0.08	-0.63	0.47	0.13	0.28			0.26	0.60	
Publication status													
Published	7	17	4,765										
Unpublished	0	0	0										

Note. Risk of bias 1 = Description of participant eligibility criteria; Risk of bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of bias 6 = Power calculation reported and study adequately powered to detect hypothesized relationships; Risk of bias 7 = Covariates adjusted for in analyses (e.g. gender, age, weight status).

Appendix C: Additional Results for Study 2

Table C1

Model 1 Categories: *the effect of moderate-to-vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.25 (.20)	-.21 (.21)	-.11 (.20)	-.29 (.20)
Linear	.07 (.09)	.11 (.10)	-.04 (.09)	.10 (.09)
Quadratic	.01 (.10)	-.04 (.10)	.08 (.10)	-.01 (.10)

Table C2

Model 1 Categories : *the effect vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.21 (.35)	.10 (.37)	-.20 (.36)	-.30 (.36)
Linear	.05 (.26)	.11 (.26)	-.08 (.26)	.04 (.26)
Quadratic	.02 (.26)	-.14 (.26)	.15 (.26)	.05 (.26)

Table C3

Model 1 Categories: *the effect moderate physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.15 (.15)	-.21 (.15)	.14 (.15)	-.21 (.15)
Linear	.04 (.08)	-.08 (.09)	.05 (.08)	.06 (.09)
Quadratic	.01 (.09)	.15 (.09)	-.10 (.09)	.00 (.09)

Table C4

Model 1 Categories: *the effect light physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.47 (.32)	-.39 (.34)	-.48 (.33)	-.28 (.33)
Linear	.32 (.18)	.25 (.19)	.11 (.19)	.41* (.19)
Quadratic	-.17 (.19)	-.12 (.20)	.05 (.20)	-.33 (.20)

Table C5

Model 2 Categories: *the effect of the period before mathematics on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.05 (.07)	.04 (.07)	.04 (.06)	.04 (.06)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18*** (.06)	-.17** (.07)	-.13* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.03 (.07)	.07 (.07)	-.19** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.04 (.13)	.01 (.13)
Before school	-.07 (.06)	.01 (.06)	-.05 (.06)	-.10 (.06)

Table C6

Model 3 Categories: *the effect of moderate-to-vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.15 (.21)	-.19 (.22)	-.07 (.21)	-.15 (.21)
Linear	.07 (.09)	.10 (.10)	-.04 (.09)	.09 (.10)
Quadratic	.00 (.10)	-.03 (.11)	.07 (.10)	-.03 (.10)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.17* (.07)	-.13* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.04 (.08)	.07 (.07)	-.18* (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.07 (.06)	.02 (.07)	-.04 (.06)	-.10 (.06)

Table C7

Model 3 Categories: *the effect of vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.15 (.36)	.10 (.37)	-.16 (.36)	-.22 (.36)
Linear	.04 (.26)	.10 (.26)	-.07 (.26)	.03 (.26)
Quadratic	.03 (.26)	-.12 (.26)	.14 (.26)	.06 (.26)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.17* (.07)	-.13* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.03 (.07)	.07 (.07)	-.19** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.00 (.13)
Before school	-.07 (.06)	.01 (.07)	-.04 (.06)	-.10 (.06)

Table C8

Model 3 Categories: *the effect of moderate physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.42 (.33)	-.39 (.34)	-.44 (.33)	-.20 (.33)
Linear	.31 (.18)	.23 (.19)	.11 (.19)	.40* (.19)
Quadratic	-.16 (.19)	-.09 (.20)	.05 (.20)	-.32 (.20)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.17** (.07)	-.14* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.03 (.07)	.07 (.07)	-.18** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.07 (.06)	.02 (.07)	-.05 (.06)	-.11 (.06)

Table C9

Model 3 Categories: *the effect of light physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.05 (.16)	-.18 (.16)	.18 (.16)	-.17 (.16)
Linear	.04 (.08)	-.07 (.09)	.06 (.08)	.06 (.09)
Quadratic	-.01 (.09)	.14 (.09)	-.11 (.09)	.01 (.09)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.16* (.07)	-.14* (.06)	-.13* (.06)
Lunch	-.05 (.07)	.05 (.08)	.06 (.07)	-.17* (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.07 (.06)	.02 (.07)	-.06 (.06)	-.09 (.06)

Table C10

Model 1 Quantiles: *the effect of moderate-to-vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.02 (.11)	.01 (.12)	.00 (.11)	-.05 (.11)
Linear	.00 (.01)	.00 (.01)	.02 (.01)	-.01 (.01)
Quadratic	.00 (.03)	.00 (.03)	-.02 (.03)	.02 (.03)

Table C11

Model 1 Quantiles: *the effect vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.06 (.11)	-.05 (.12)	.11 (.11)	.07 (.11)
Linear	.01 (.01)	.00 (.01)	.02 (.01)	.00 (.01)
Quadratic	-.04 (.03)	.02 (.03)	-.07* (.03)	-.04 (.03)

Table C12

Model 1 Quantiles: *the effect moderate physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.05 (.11)	-.04 (.12)	.01 (.11)	-.10 (.11)
Linear	.00 (.01)	-.01 (.01)	.01 (.01)	-.01 (.01)
Quadratic	.02 (.03)	.03 (.03)	-.01 (.03)	.04 (.03)

Table C13

Model 1 Quantiles: *the effect light physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.09 (.11)	.19 (.12)	.07 (.11)	.01 (.11)
Linear	.00 (.01)	-.02 (.01)	.01 (.01)	-.01 (.01)
Quadratic	-.03 (.03)	-.04 (.03)	-.05 (.03)	.00 (.03)

Table C14

Model 2 Quantiles: *the effect of the period before mathematics on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.05 (.06)	.15 (.07)	.04 (.06)	.04 (.06)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.17** (.07)	-.13* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.03 (.07)	.07 (.07)	-.19** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.04 (.13)	.01 (.13)
Before school	-.07 (.06)	.01 (.06)	-.05 (.06)	-.10 (.06)

Table C15

Model 3 Quantiles: *the effect of moderate-to-vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.03 (.11)	.04 (.12)	.03 (.11)	.00 (.11)
Linear	.01 (.01)	.00 (.01)	.02 (.01)	.00 (.01)
Quadratic	.00 (.03)	.00 (.03)	-.02 (.03)	.02 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.19** (.06)	-.17* (.07)	-.14* (.06)	-.14* (.06)
Lunch	-.06 (.07)	.03 (.08)	.05 (.07)	-.19** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.08 (.06)	.02 (.07)	-.08 (.07)	-.10 (.06)

Table C16

Model 3 Quantiles: *the effect of vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.11 (.11)	-.01 (.12)	.14 (.11)	.13 (.11)
Linear	.01 (.01)	.00 (.01)	.02 (.01)	.01 (.01)
Quadratic	-.04 (.03)	.02 (.03)	-.06* (.03)	-.04 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.17** (.07)	-.14* (.06)	-.14* (.06)
Lunch	-.06 (.07)	.03 (.08)	.05 (.07)	-.19** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.04 (.13)	.01 (.13)
Before school	-.08 (.06)	.01 (.07)	-.07 (.06)	-.10 (.06)

Table C17

Model 3 Quantiles: *the effect of moderate physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	-.01 (.11)	.00 (.12)	.03 (.11)	-.05 (.11)
Linear	.00 (.01)	-.01 (.01)	.01 (.01)	.00 (.01)
Quadratic	.02 (.03)	.03 (.03)	-.01 (.03)	.03 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.16* (.07)	-.14* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.04 (.08)	.06 (.07)	-.18** (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.08 (.06)	.03 (.07)	-.07 (.07)	-.10 (.06)

Table C18

Model 3 Quantiles: *the effect of light physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.13 (.11)	.21 (.12)	.11 (.11)	.06 (.11)
Linear	.00 (.01)	-.02 (.01)	.02 (.01)	.00 (.01)
Quadratic	-.03 (.03)	-.03 (.03)	-.04 (.03)	.00 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.16* (.07)	-.14* (.06)	-.14* (.06)
Lunch	-.05 (.07)	.05 (.08)	.05 (.07)	-.18* (.07)
Physical Education	-.04 (.12)	-.04 (.13)	-.05 (.13)	.01 (.13)
Before school	-.07 (.06)	.03 (.07)	-.07 (.06)	-.10 (.06)

Table C19

Model 4 Quantiles: *the effect of moderate-to-vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.31 (.41)	-1.34** (.42)	.30 (.41)	1.20* (.41)
MVPA during the hour before mathematics				
Linear	.01 (.01)	.00 (.01)	.01 (.01)	.00 (.01)
Quadratic	.00 (.03)	.00 (.03)	-.02 (.03)	.02 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.19** (.06)	-.20** (.07)	-.14* (.06)	-.13* (.06)
Lunch	-.07 (.07)	.02 (.08)	.05 (.07)	-.20** (.07)
Physical Education	-.05 (.12)	.01 (.13)	-.06 (.13)	-.02 (.13)
Before school	-.09 (.06)	-.01 (.07)	-.07 (.07)	-.10 (.06)
Age	-.03 (.03)	.09** (.03)	-.03 (.03)	-.10** (.03)
Gender (male = 1)	.00 (.05)	-.14** (.05)	.11* (.05)	-.01 (.05)
SES- family level	.02* (.01)	.04** (.01)	.01 (.01)	.02 (.01)

Table C20

Model 4 Quantiles: *the effect of vigorous physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.37 (.41)	-1.38** (.42)	.40 (.41)	1.29** (.41)
MVPA during the hour before mathematics				
Linear	.01 (.01)	.00 (.01)	.02 (.01)	.01 (.01)
Quadratic	-.04 (.03)	.02 (.03)	-.06* (.03)	-.04 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.20** (.07)	-.13* (.06)	-.13* (.06)
Lunch	-.07 (.07)	.02 (.08)	.05 (.07)	-.21** (.07)
Physical Education	-.04 (.12)	.01 (.13)	-.05 (.13)	-.02 (.13)
Before school	-.09 (.06)	-.01 (.07)	-.07 (.06)	-.10 (.06)
Age	-.03 (.03)	.09** (.03)	-.03 (.03)	-.10* (.04)
Gender (male = 1)	.00 (.05)	-.14** (.05)	.11* (.05)	-.06 (.05)
SES- family level	.03* (.01)	.04** (.01)	.02 (.01)	.01 (.04)

Table C21

Model 4 Quantiles: *the effect of moderate physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.27 (.41)	-1.38** (.42)	.30 (.42)	1.14* (.41)
MVPA during the hour before mathematics				
Linear	.00 (.01)	-.01 (.01)	.01 (.01)	.00 (.01)
Quadratic	.02 (.03)	.03 (.03)	-.01 (.03)	.03 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.19** (.07)	-.14* (.06)	-.13* (.06)
Lunch	-.06 (.07)	.03 (.08)	.05 (.07)	-.20** (.07)
Physical Education	-.04 (.12)	.02 (.13)	-.05 (.13)	-.03 (.13)
Before school	-.08 (.06)	.00 (.07)	-.07 (.07)	-.10 (.06)
Age	-.03 (.03)	.09** (.03)	-.03 (.03)	-.10** (.03)
Gender (male = 1)	.01 (.05)	-.13** (.05)	.12* (.05)	-.01 (.05)
SES- family level	.03* (.01)	.04** (.01)	.01 (.01)	.02 (.01)

Table C22

Model 4 Quantiles: *the effect of light physical activity on mathematics engagement*

	Overall engagement	Behavioural engagement	Emotional engagement	Cognitive engagement
	Estimate (SE)	Estimate (SE)	Estimate (SE)	Estimate (SE)
Intercept	.41 (.41)	-1.15* (.42)	.37 (.41)	1.25** (.41)
MVPA during the hour before mathematics				
Linear	.00 (.01)	-.02 (.01)	.01 (.01)	.00 (.01)
Quadratic	-.03 (.03)	-.03 (.03)	-.04 (.03)	.00 (.03)
Period before Mathematics				
Classroom lesson	Reference	Reference	Reference	Reference
Recess	-.18** (.06)	-.18** (.07)	-.13* (.06)	-.13* (.06)
Lunch	-.07 (.07)	.04 (.08)	.05 (.07)	-.20** (.07)
Physical Education	-.04 (.12)	.01 (.13)	-.06 (.13)	-.03 (.13)
Before school	-.08 (.06)	.00 (.07)	-.07 (.06)	-.10 (.06)
Age	-.03 (.03)	.09** (.03)	-.03 (.03)	-.10** (.03)
Gender (male = 1)	.01 (.05)	-.13** (.05)	.11* (.05)	-.01 (.05)
SES- family level	.02* (.01)	.03** (.01)	.01 (.01)	.02 (.01)

Appendix D: Ethics Approval from the Human Research Ethics Committee

AUSTRALIAN CATHOLIC UNIVERSITY

Human Research Ethics Committee

Committee Approval Form

Principal Investigator/Supervisor: Associate Professor Chris Lonsdale

Co-Investigators: Dr Louisa Peralta, Prof Anthony Maeder, Prof Jennifer Gore, A/Prof Nikolaos Ntoumanis, A/Prof Ester Cerin (Partner Investigator), A/Prof David Lubans, Prof Gregory Kolt, Mr Ian Moyes (Project Officer)

Student Researcher: : Ms Katherine Owen, Mr Aidan Lester, Ms Rhiannon White (HDR students)

Ethics approval has been granted for the following project:

A Cluster Randomised Controlled Trial of a School-based Physical Activity Intervention in At-risk Communities

for the period: 06/06/2014 - 31/12/2016

Human Research Ethics Committee (HREC) Register Number: 2014 185N

Special Condition/s of Approval

Prior to commencement of your research, the following permissions are required to be submitted to the ACU HREC:

Permissions from governing bodies eg: Catholic Education Office and Principal permissions (where and as required). If NSW state schools - SERAP approval / permission is required.

The following standard conditions as stipulated in the *National Statement on Ethical Conduct in Research Involving Humans* (2007) apply:

(i) that Principal Investigators / Supervisors provide, on the form supplied by the Human Research Ethics Committee, annual reports on matters such as:

- security of records
- compliance with approved consent procedures and documentation
- compliance with special conditions, and

(ii) that researchers report to the HREC immediately any matter that might affect the ethical acceptability of the protocol, such as:

- proposed changes to the protocol
- unforeseen circumstances or events
- adverse effects on participants

The HREC will conduct an audit each year of all projects deemed to be of more than low risk. There will also be random audits of a sample of projects considered to be of negligible risk and low risk on all campuses each year. Within one month of the conclusion of the project, researchers are required to complete a *Final Report Form* and submit it to the local Research Services Officer.

If the project continues for more than one year, researchers are required to complete an *Annual Progress Report Form* and submit it to the local Research Services Officer within one month of the anniversary date of the ethics approval.

K. Pashley.

Signed: Date: .... 06/06/2014.....

Appendix E: Parent/Guardian and Student Consent Form

Dr. Chris Lonsdale
Institute for Positive Psychology and Education
Faculty of Health Sciences
Australian Catholic University
25A Barker Road, Locked Bag 2002,
Strathfield NSW 2135.
Phone: (02) 9701 4642

!
!
!
!

Research!Project!!

Adolescent!Motivation!in!Physical!Education:!The!AMPED!Project!!

STUDENT!&!PARENT/CAREGIVER!INFORMATION!STATEMENT!

Dear Student,

Year 8 students in your school are invited to participate in the project identified above.

Who!is!carrying!out!the!study?

The research is being conducted by Dr Chris Lonsdale (Chief Investigator) Australian Catholic University, Professor Gregory Kolt, and Professor Anthony Maeder from the University of Western Sydney (UWS), Associate Professor David Lubans and Professor Jenny Gore from the University of Newcastle, and Dr Louisa Peralta from the University of Sydney. Mr Ian Moyes will be the project manager and research students, Aidan Lester, Rhiannon White, and Katherine Owen, all from ACU, will also be part of the research team.

What!is!the!study!about?!

This project will evaluate the effectiveness of a professional development training course for Personal Development, Health and Physical Education (PDHPE) teachers. The training course is designed to help PDHPE teachers motivate and engage their students in lessons. The project will also examine the impact that physical activity habits have on students' engagement (i.e., concentration, interest, and motivation) in their academic lessons, as well as their self-concept and mental well-being.

What!does!the!study!involve?!

In Term 1, 2014, students will complete a 15-20 minute questionnaire during a theory lesson in their PDHPE class. This questionnaire is designed to measure students' motivation towards PDHPE and their perceptions of their teacher's behaviour during lessons. Questions designed to measure students' motivation towards physical activity outside school, as well as their self-concept and mental well-being, will be included. Personal information will also be collected at this time, including home address, mobile phone number, method of transport to and from school, gender, and birthdate. Each student's height and weight will also be measured.

During three practical PDHPE lessons, students will wear an accelerometer, which is a small, light-weight device that attaches to a belt placed around the waist and measures physical activity. These three lessons will be video recorded, so that teachers can review their teaching practice and the research team can evaluate the teachers' implementation of strategies from the training course.

Also, students will be asked to wear the accelerometer over a one week period in their own time. During this week, students will receive a text message each morning to remind them to put on their accelerometers.

Finally, the research team will video record two Mathematics lessons involving each student. At the end of each lesson, students will complete a 5-minute questionnaire measuring their perceptions of their engagement during the lesson.

This process will be repeated in Term 4 of 2014 and again in Term 2 or 3 of 2015.

At the end of the study, students' physical activity and Mathematics engagement data will be linked to their standardised scores on the Mathematics portion of the Years 7 and 9 NAPLAN (provided by the NSW Board of Studies).

How!much!time!will!the!study!take?

Questionnaires will be completed during class time and will require a total of 15-20 minutes of PDHPE class time at each time point, plus 5-10 minutes of Mathematics class time (60-90 minutes total). The only requirement in students' own time will be to wear the accelerometers across one week at each time point. !

Will!the!study!benefit!me?!

The professional development training course is designed to help teachers create a more stimulating learning environment. As a result, students may benefit from higher quality teaching, resulting in more enjoyable PDHPE lessons.

!

Will!the!study!involve!any!discomfort!for!me?!

Little discomfort is expected. Students will participate in PDHPE lessons in the usual way. The only difference will be to complete the questionnaires and wear the accelerometers in the PDHPE lesson, and for a one week period, which is a minor inconvenience.

How is this study being paid for?

The study is funded by the Australian Research Council.

Will anyone else know the results? How will the results be disseminated?

The researchers will keep confidential any personal information provided by students. Once the data has been collected, de-identified using a coding system and entered into an electronic data file, questionnaires and other data collection sheets will be destroyed. The electronic data files will be retained for at least 5 years, but no individual will be identifiable in published reports.

Video recordings of PE lessons will be uploaded to a secure server located at UWS. This server is only accessible via the UWS network accessed through the project website. This website will utilise access control procedures consistent with UWS policies. The research team will be able to access all videos in order to collect data, but PDHPE teachers will only have access to videos recorded during their own lessons (for the purpose of self-reflection). Video recordings of Mathematics lessons will be uploaded to a secure server located at UWS. The research team will be able to access all videos in order to collect data. Mathematics teachers will not have access to videos as a matter of course, but will be able to view videos of their own lessons upon request. No image recorded in this study will be made public under any circumstances. No image recorded in this study will be made public under any circumstances.

Video recordings will not be undertaken in a class for which a parent has previously indicated to the school that images of his or her child are not to be recorded. Video recordings will also not be undertaken in a class for which a principal, teacher, parent, or student has indicated on the consent form that he/she does not agree to video recording. A decision to refuse video or audio recording will not influence the ability of the school, teacher or student to take part in other aspects of the study.

At the end of the study, each principal and teacher will be sent a report describing the main results. Principals will not be provided with any information that could identify the results of their school (or any teacher or student) within the overall study. Teachers who make a request will be provided with summary feedback related to their teaching; no individual student's response will be provided to a teacher. Individual results will not be provided to all students, but will be available upon request by a parent or student.

Scholarly reports, such as journal articles, will also be published. All reports will be published in general terms and will not allow the identification of individual students or schools.

Can I withdraw from the study?

The school principal has agreed to your school being involved in the study. However, participation in the study is entirely your choice. If you agree to participate you can choose to withdraw from the study at any time and will be free to stop participation at any time. If you choose to withdraw from the study, you will continue to participate in the lesson, but you will not complete any of the questionnaires, nor will you wear an accelerometer. A decision not to participate or end involvement in the study will not jeopardise your relationship with the Universities of Western Sydney, Newcastle or Sydney, or your school. Withdrawal from this task will not result in any disciplinary action, nor will it affect your academic grades; this is a purely voluntary research task.

Can I tell other people about the study?

Students and parents are welcome to discuss the study with others.

What if I require further information?

If you would like further information please do not hesitate to contact Dr Chris Lonsdale. Thank you for considering this invitation.

What if I have a complaint?

This study has been approved by the Australian Catholic University Human Research Ethics Committee. The approval number is: H9171. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Manager, Ethics c/o Office of the Deputy Vice Chancellor (Research)

Dr. Chris Lonsdale
Institute for Positive Psychology and Education
Faculty of Health Sciences
Australian Catholic University
25A Barker Road, Locked Bag 2002,
Strathfield NSW 2135.
Phone: (02) 9701 4642

Participant Consent Form for Parents/Caregivers

I,[print name]……………………......……………………….., give consent for my child,

[print name]…………………....……………………………,to participate in the research project titled:

Adolescent Motivation in Physical Education: The AMPED Project

Chief Investigators: Dr Chris Lonsdale, Prof Gregory Kolt, Prof Anthony Maeder, Assoc Prof David Lubans, Prof Jenny Gore, and Dr Louisa Peralta

I acknowledge that:

I have read (or had read to me) the participant information sheet and have been given the opportunity to discuss the information and my child's involvement in the project with the researchers via telephone or email.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I have discussed participation in the project with my child and my child agrees to his/her participation in the project.

I understand that my child's involvement is confidential and that the information gained during the study may be published but no information about my child will be used in any way that reveals my child's identity.

I understand that my child's participation in this project is voluntary. I can withdraw my child from the study at any time, without affecting their academic standing or relationship with the school and they are free to withdraw their participation at any time.

I consent to my child being involved in the:
1. Video recording of 15 physical education lessons.
2. Video recording of 6 Mathematics lessons.
3. Wearing of an accelerometer during PDHPE lessons and across one week.
4. Answering of questionnaires.
5. NSW Board of Studies providing my child's Years 7 and 9 NAPLAN Mathematics scores to the research team.

Please cross out any activity for which you do not provide consent for your child to complete.

Signed:... (Parent/caregiver)

Name: ....

Signed:... (Child)

Name: ....

Dr. Chris Lonsdale
Institute for Positive Psychology and Education
Faculty of Health Sciences
Australian Catholic University
25A Barker Road, Locked Bag 2002,
Strathfield NSW 2135.
Phone: (02) 9701 4642

STUDENT ASSENT FORM

I,……………………………………………, agree to participate in the research project titled:

Adolescent Motivation in Physical EDucation: The AMPED Project

Chief Investigators: Dr Chris Lonsdale, Prof Gregory Kolt, Prof Anthony Maeder, Assoc Prof David Lubans, Prof Jenny Gore, and Dr Louisa Peralta

I acknowledge that:

I have read (or had read to me) the participant information sheet and have been given the opportunity to discuss the information and my involvement in the project with the researcher/s.

The procedures required for the project and the time involved have been explained to me, and any questions I have about the project have been answered to my satisfaction.

I agree to the:
1. Video recording of 15 physical education lessons.
2. Video recording of 6 Mathematics lessons.
3. Wearing of an accelerometer during PDHPE lessons and across one week.
4. Answering of questionnaires.
5. NSW Board of Studies providing my Years 7 and 9 NAPLAN Mathematics scores to the research team.

Please cross out any activity which you do not agree to complete.

I have had an opportunity to ask a member of the research team questions about the research. I understand that my participation in this research is voluntary and I am free to withdraw from the research project at any time. My refusal to participate or withdrawal of consent will not affect my relationship with the University of Western Sydney, Newcastle or Sydney, or my school. Withdrawal from this task will not result in any disciplinary action against me, nor will it affect my academic grades, given that this is a purely voluntary research task.

By signing below I am indicating my consent to participate in this research project conducted by Dr Chris Lonsdale, as it has been described to us in the Information Statement, a copy of which I have retained.

I understand that my involvement is confidential and that the information gained during the study may be published but no information about me will be used in any way that reveals my identity.

Student name: ....

Signature: ....   Date: ....

Please sign the consent sheet and return to your Physical Education teacher

This study has been approved by the University of Western Sydney Human Research Ethics Committee. The approval number is: H9171.

This study has been approved by the Australian Catholic University Human Research Ethics Committee. The approval number is: H9171. Manager, Ethics c/o Office of the Deputy Vice Chancellor (Research), Australian Catholic University, North Sydney Campus PO Box 968. NORTH SYDNEY, NSW 2059 Ph.: 02 9739 2519 Fax: 02 9739 2870Email: res.ethics@acu.edu.au
Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.

Appendix F: The School Engagement Scale – Current Engagement

My full name is ________________________________The number on my desk is __________

My Maths Engagement Today

Please fill in the circle (●) that best describes you.

	Never	On Occasion	Some of the Time	Most of Time	All of the Time
1. Today, I followed the rules during the maths lesson.	①	②	③	④	⑤
2. Today, I got in trouble during the maths lesson.	①	②	③	④	⑤
3. Today, during the maths lesson, I just acted as if I was working.	①	②	③	④	⑤
4. Today, I paid attention during the maths lesson.	①	②	③	④	⑤
5. Today, I completed my maths work on time.	①	②	③	④	⑤
6. Today, I liked the maths lesson.	①	②	③	④	⑤
7. Today, I felt excited by my work during the maths lesson.	①	②	③	④	⑤
8. Today, my classroom was a fun place to be during the maths lesson.	①	②	③	④	⑤
9. Today, I was interested by the work in the maths lesson.	①	②	③	④	⑤
10. Today, I felt happy during the maths lesson.	①	②	③	④	⑤
11. Today, I felt bored during the maths lesson.	①	②	③	④	⑤
12. Today, I checked my maths work for mistakes.	①	②	③	④	⑤
13. Today, when I read a maths problem, I asked myself questions or used strategies to make sure I understood what it was about.	①	②	③	④	⑤
14. Today, if I didn't know what a maths problem meant, I did something to figure it out.	①	②	③	④	⑤
15. Today, if I didn't understand a maths problem that I read, I went back and read it over again.	①	②	③	④	⑤

Appendix G: The School Engagement Scale – Usual Engagement

My full name is ___________________________________The number on my desk is __________

My Usual Mathematics Engagement

Please fill in the circle (●) that best describes you.

	Never	On Occasion	Some of the Time	Most of Time	All of the Time
1. I follow the rules during maths lessons.	①	②	③	④	⑤
2. I get in trouble during maths lessons.	①	②	③	④	⑤
3. During maths lessons, I just act as if I am working.	①	②	③	④	⑤
4. I pay attention during maths lessons.	①	②	③	④	⑤
5. I complete my maths work on time.	①	②	③	④	⑤
6. I like maths lessons.	①	②	③	④	⑤
7. I feel excited by my work during maths lessons.	①	②	③	④	⑤
8. My classroom is a fun place to be during maths lessons.	①	②	③	④	⑤
9. I am interested by the work in maths lessons.	①	②	③	④	⑤
10. I feel happy during maths lessons.	①	②	③	④	⑤
11. I feel bored during maths lessons.	①	②	③	④	⑤
12. I check my maths work for mistakes.	①	②	③	④	⑤
13. I study at home for maths test even when I don't have a test.	①	②	③	④	⑤
14. When I read a maths problem, I ask myself questions or use strategies to make sure I understand what it is about.	①	②	③	④	⑤
15. I use extra maths resources (such as the internet, tv or books) to learn more about the things we do in maths lessons.	①	②	③	④	⑤
16. If I don't know what a maths problem means, I do something to figure it out.	①	②	③	④	⑤
17. If I don't understand a maths problem that I read, I go back and read it over again.	①	②	③	④	⑤
18. I talk with people outside of school about what I am learning in maths lessons.	①	②	③	④	⑤

Appendix H: Publications

Accepted

Owen, K., Parker, P., Van Zandan, B., Macmillan, F., Astell-Burt, T., Lonsdale, C., (2016) Physical Activity on School Engagement, including Behavior, Emotions, and Cognition in Youth: A Systematic Review and Meta-analysis. *Educational Psychologist*, *51*(2), 129-145. doi:10.1080/00461520.2016.1151793

Submitted

Owen, K., Parker, P., Astell-Burt, T., & Lonsdale, C., (submitted) The effect of physical activity and classroom lesson breaks on school engagement in youth. *Journal of Science and Medicine in Sport.*

Owen, K., Parker, P., Astell-Burt, T., & Lonsdale, C., (submitted) Regular physical activity and educational outcomes in youth: A longitudinal study. *Preventive Medicine*.

Appendix I: Statement of Contribution of Others

Statement of Contributions for Study 1

Study 1 - Physical activity and school engagement in children and adolescents: A systematic review and meta-analysis

I, Katherine Owen, conducted this study and acknowledge that my contribution to the above study is 70%.

Associate Professor Chris Lonsdale, Dr Philip Parker, and Associate Professor Thomas Astell-Burt supervised this study. Associate Professor Chris Lonsdale contributed expertise in the topic area, and drafting and editing the manuscript. Dr Philip Parker provided expertise in the methodology, and drafting and editing the manuscript. Associate Professor Thomas Astell-Burt was involved of the initial development of the study and provided comments on the final version of the manuscript. Therefore, Associate Professor Chris Lonsdale contributed 10%, Dr Philip Parker contributed 8%, and Associate Professor Thomas Astell-Burt contributed 2% to the above study.

Brooke Van Zanden and Dr Freya MacMillan were involved in the article screening, data extraction, and rating the risk of bias for this study. They also provided comments on the final version of the study. Therefore, Brooke Van Zanden and Dr Freya MacMillan each contributed 5% to the above study.

Signatures:

Associate Professor Chris Lonsdale Chris Lonsdale Digitally signed by Chris Lonsdale DN: cn=Chris Lonsdale, o=Australian Catholic University, ou=Institute for Positive Psychology and Education, email=chris.lonsdale@acu.edu.au, c=AU Date: 2016.06.07 13:41:19 +10'00'

Dr Philip Parker Philip Parker Digitally signed by Philip Parker DN: cn=Philip Parker, o=ACU, ou=IPPE, email=philip.parker@acu.edu.au, c=US Date: 2016.06.06 20:55:23 +10'00'

Brooke Van Zanden

Dr Freya MacMillan

Associate Professor Thomas Astell-Burt

Statement of Contributions for Study 2

Study 2- The effect of physical activity and classroom lesson breaks on school engagement in youth

I, Katherine Owen, conducted this study and acknowledge that my contribution tc above study is 80%.

Associate Professor Chris Lonsdale, Dr Philip Parker, and Associate Professor Thomas Astell-Burt supervised this study. Associate Professor Chris Lonsdale contributed expertise in the topic area, and drafting and editing the manuscript. Dı Philip Parker provided expertise in the methodology, and drafting and editing the manuscript. Associate Professor Thomas Astell-Burt was involved of the initial development of the study. Therefore, Associate Professor Chris Lonsdale contribu 10%, Dr Philip Parker contributed 8%, and Associate Professor Thomas Astell-Bı contributed 2% to the above study.

Signatures:

Chris Lonsdale
Digitally signed by Chris Lonsdale
DN: cn=Chris Lonsdale, o=Australian Catholic University, ou=Institute for Positive Psychology and Education, email=chris.lonsdale@acu.edu.au, c=AU
Date: 2016.06.07 13:41:50 +10'00'

Associate Professor Chris Lonsdale ______________________________

Philip Parker
Digitally signed by Philip Parker
DN: cn=Philip Parker, o=ACU, ou=IPPE, email=philip.parker@acu.edu.au, c=US
Date: 2016.06.08 20:35:38 +10'00'

Dr Philip Parker ______________________________

Associate Professor Thomas Astell-Burt ______________________________

Statement of Contributions for Study 3

Study 3- Regular physical activity and educational outcomes in youth: A longitud study

I, Katherine Owen, conducted this study and acknowledge that my contribution tc above study is 80%.

Associate Professor Chris Lonsdale, Dr Philip Parker, and Associate Professor Thomas Astell-Burt supervised this study. Associate Professor Chris Lonsdale contributed expertise in the topic area, and drafting and editing the manuscript. Dı Philip Parker provided expertise in the methodology, and drafting and editing the manuscript. Associate Professor Thomas Astell-Burt was involved of the initial development of the study and provided comments on the final version of the study Therefore, Associate Professor Chris Lonsdale contributed 10%, Dr Philip Parker contributed 8%, and Associate Professor Thomas Astell-Burt contributed 2% to tl above study.

Signatures:

Associate Professor Chris Lonsdale Chris Lonsdale
Digitally signed by Chris Lonsdale
DN: cn=Chris Lonsdale, o=Australian Catholic University, ou=Institute for Positive Psychology and Education, email=chris.lonsdale@acu.edu.au, c=AU
Date: 2016.06.07 13:42:20 +10'00'

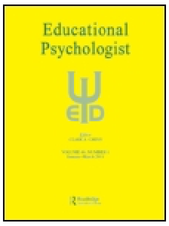
Dr Philip Parker Philip Parker
Digitally signed by Philip Parker
DN: cn=Philip Parker, o=ACU, ou=IPPE, email=philip.parker@acu.edu.au, c=US
Date: 2016.06.06 20:56:37 +10'00'

Associate Professor Thomas Astell-Burt

Appendix J: Additional Publications

Owen, K., Parker, P., Van Zandan, B., MacMillan, F., Lonsdale, C., (2015) Physical activity and school engagement in youth: A systematic review. Eighth SELF Biennial International Conference, Kiel, Germany, Aug 20-24, 2015.

Appendix K: Individual Papers



Educational Psychologist

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Physical Activity and School Engagement in Youth: A Systematic Review and Meta-Analysis

Katherine B. Owen, Philip D. Parker, Brooke Van Zanden, Freya MacMillan, Thomas Astell-Burt & Chris Lonsdale

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DOI: 10.1080/00461520.2016.1151793

Routledge
Taylor & Francis Group

Physical Activity and School Engagement in Youth: A Systematic Review and Meta-Analysis

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Physical activity is associated with numerous health benefits in youth; however, these benefits could extend further than health, into education. Our aim was to systematically review and combine in meta-analyses evidence concerning the association between physical activity and the dimensions of school engagement, including behavior (e.g., time-on-task), emotions (e.g., lesson enjoyment), and cognition (e.g., self-regulated learning). We conducted meta-analyses using structural equation modeling on results from 38 studies. Overall, physical activity had a small, positive association with school engagement ($d = .28$, $I^2 = .86$), 95% confidence interval [.12, .46]. This association was moderated by study design, with significant associations shown in randomized controlled trials but not in studies employing other designs. Risk of bias was also a significant effect moderator, as studies with a low risk of bias showed significant associations but not high risk of bias studies. Altogether, these results suggest that physical activity could improve school engagement.

Physical activity is generally promoted for its numerous physical health benefits in youth, including positive effects on cholesterol and blood lipids, blood pressure, metabolic syndrome, bone mineral density, and weight management and obesity (Janssen & LeBlanc, 2010). Physical activity also has a positive effect on mental health in youth (Biddle & Asare, 2011). Further, there is now substantial evidence that physical activity is positively associated with academic performance (e.g., grades and test scores) in youth (Castelli et al., 2014; Lees & Hopkins, 2013; Martin, Saunders, Shenkin, & Sproule, 2014; Singh, Uijtdewilligen, Twisk, Mechelen, & Chinapaw, 2012). School engagement is a commonly suggested explanatory mechanism for this relation (e.g., Donnelly & Lambourne, 2011; Singh et al., 2012). Evidence is increasing to suggest that students who are physically active are more engaged with their classroom lessons (e.g., Gibson

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et al., 2008; Whitt-Glover, Ham, & Yancey, 2011; Zan, 2013) and this increased engagement is a possible mechanism by which physical activity could have a positive influence on achievement.

DEFINING SCHOOL ENGAGEMENT

Definitions of school engagement and disengagement vary in the existing literature. These two constructs are most often defined as multidimensional constructs, including behavior, emotions, and cognition (Fredricks, Blumenfeld, & Paris, 2004; Reschly & Christenson, 2012; Upadyaya & Salmela-Aro, 2013). Behavioral engagement refers to the range of actions that reflect involvement in school activities and is most commonly measured by students' classroom behavior, time on-task, and concentration. Concentration is sometimes considered to be an aspect of cognitive engagement; however, defined as the action of focusing attention, it is more commonly considered an aspect of behavioral engagement (Fredricks et al., 2004). Behavioral disengagement involves reduced effort and involvement in school activities and is often assessed by students' fidgeting in class, time off-task, and inattention. Emotional engagement and disengagement encompass positive and negative affective reactions to school, such as enjoyment and boredom, respectively. Finally, cognitive engagement refers to investment in learning, which involves motivation, strategic learning skills, and problem solving. Conversely, cognitive disengagement refers to a lack of investment in learning, such as a lack of motivation. This tripartite definition provides a model of the dynamically interrelated dimensions of school engagement and disengagement (Fredricks et al., 2004).

Although there is a general consensus that school engagement is a multidimensional construct, there are some aspects of the school engagement construct that scholars do not agree on. Fredricks et al. (2004) suggested that school engagement is a metaconstruct, and within this metaconstruct cognitive engagement subsumes motivation. However, what Fredricks et al. called cognitive engagement other scholars call motivation (e.g., Reschly, 2010). Another group of scholars suggests that motivation represents intention and school engagement is the action (e.g., Russell, Ainley, & Frydenberg, 2005). In this review we used Fredricks et al.'s conceptualization of school engagement, as it is the most comprehensive and therefore allowed us to include a broader range of articles in our review.

A difference among scholars' conceptualizations of school engagement and disengagement is whether school engagement and disengagement should be viewed as a single continuum (ranging from high to low engagement) or two separate continua (one for school engagement and one for school disengagement, both ranging from high to low). Most researchers have viewed school engagement and disengagement on a single continuum, with low levels of school engagement representing disengagement. However, more recently, scholars are starting to view school engagement and disengagement as two separate constructs. M. Wang and Peck (2013) found that it is possible for students to be actively engaged on one dimension (e.g., on task or paying attention) while being disengaged on another (e.g., feeling bored or frustrated). Further, while examining their school engagement measure, Skinner, Kindermann, and Furrer (2009) compared a model with one factor (school engagement) with a two-factor model (school engagement and school disengagement). The model that distinguished between school engagement and school disengagement fit the data significantly better than the one-factor model. Skinner et al. reported negative correlations between student-rated behavioral engagement and disengagement ($r = -.55$) and between emotional engagement and disengagement ($r = -.60$). As these correlations did not approach 1.0, they concluded that school engagement and disengagement are separate, but related, constructs.

Based on this evidence, we considered school engagement and disengagement results separately in our review. Indeed, reverse coding school disengagement effect sizes and combining them with school engagement effect sizes (i.e., placing on a continuum) may not provide a valid school engagement pooled effect size. Therefore, by viewing school engagement and disengagement as two separate constructs, we adopted a more conservative approach. If later research conclusively establishes that school engagement and disengagement do in fact exist on a continuum, the results of our meta-analysis would remain interpretable.

School engagement is one of the most critical factors underpinning academic performance (Perry, Liu, & Pabian, 2010; Shernoff, 2010; M. Wang & Holcombe, 2010) and the successful development of youth in society (Deil-Amen & Lopez Turley, 2007; Hauser, 2010). Students who are actively engaged in school are more likely to perform well academically, successfully transition into postschool education, and achieve occupational and economic success (Abbott-Chapman et al., 2014; Suldo, Riley, & Shaffer, 2006). Recent research suggests that school engagement influences occupational and educational success 20 years later in life, over and above academic achievement (Abbott-Chapman et al., 2014). Students who are disengaged from school and perform poorly academically are more likely to drop out of school, become unemployed, and place a burden on the economy (Archambault, Janosz, Morizot, & Pagani, 2009; Glennie, Bonneau, Vandellen, & Dodge, 2012). Unfortunately, students' overall level of school engagement often declines with age (Anderman & Maehr, 1994; Archambault et al., 2009; Darr, 2012; Eccles et al., 1993; Janosz, Archambault, Morizot, & Pagani, 2008; Marks, 2000; Wylie & Hodgen, 2012). Thus, promoting school engagement is a priority for parents, policymakers, and society (Department of Education and Early Childhood Development, 2010).

MECHANISMS OF INFLUENCE

To promote school engagement, its antecedents must first be understood. One such antecedent is physical activity (e.g., Howie, Beets, & Pate, 2014; Vazou, Gavrilou, Mamalaki, Papanastasiou, & Sioumala, 2012). However, before physical activity interventions can be used to promote school engagement, the most effective type of physical activity (physical activity duration, intensity, and intervention type) for improving school engagement needs to be determined. We also need to determine for which groups of youth (children vs. adolescents) physical activity is most beneficial. Once these potential moderators of the association between physical activity and school engagement have been explored, interventions using physical activity can be designed to effectively promote school engagement.

One potential moderator of the association between physical activity and school engagement is the incidence of the physical activity (i.e., single bout vs. regular). A single bout of physical activity refers to one session of activity, whereas regular physical activity refers to successive bouts of activity over time. A number of studies have found that a single bout of physical activity immediately before a classroom lesson was beneficial for school engagement in the following classroom lesson (e.g., Mahar et al., 2006; Riley, Lubans, Holmes, & Morgan, 2014; Whitt-Glover et al., 2011). Other studies have found that regular physical activity was beneficial for school engagement (e.g., Barros, Silver, & Stein, 2009; Yu, Chan, Cheng, Sung, & Hau, 2006). However, a number of studies have found that regular physical activity was harmful for school engagement, specifically time spent on homework (Atkin, Gorely, Biddle, Marshall, & Cameron, 2008; Lazarou & Soteriades, 2009; Yu et al., 2006). This negative relation could be due to time spent participating in physical activity, reducing the amount of available time to spend on homework. It appears that a single bout of physical activity immediately before a classroom lesson could be more beneficial for school engagement, compared to regular physical activity; however, this needs to be confirmed.

Different intensities of physical activity also could have different associations with school engagement. Low (e.g., Metzler & Williams, 2006), moderate (e.g., Gibson et al., 2008; Hunter, Abbott, Macdonald, Ziviani, & Cuskelly, 2014), moderate-to-vigorous (e.g., Grieco, Jowers, & Bartholomew, 2009; Howie et al., 2014), and vigorous (e.g., Dwyer, Blizzard, & Dean, 1996; Ma, Mare, & Gurd, 2014) intensity activity have been shown to be beneficial for school engagement. Although compared to moderate and low intensity activity, vigorous intensity activity appears to be the most beneficial for physical and mental health outcomes in youth (Janssen & LeBlanc, 2010; Swain & Franklin, 2006), it is unclear which intensity of physical activity is most beneficial for school engagement.

The type of intervention to promote school engagement might also moderate the relation between physical activity and school engagement. For example, physical activity programs have been implemented before school (e.g., Smith et al., 2013) and during school hours (e.g., Hoza et al., 2014). Some physical activity interventions have taken place during additional or extended recess (e.g., Jarrett et al., 1998) and lunch breaks (e.g., Laberge, Bush, & Chagnon, 2012), whereas other interventions involved additional or extended Physical Education lessons (e.g., Dwyer et al., 1996). During academic classroom lessons, physical activity has been integrated with academic content (e.g., Gibson et al., 2008) or used as breaks from academic content (e.g., Katz et al., 2010). Although all types of interventions may improve school engagement, it is currently unclear which type of intervention is the most effective in this regard.

Finally, the different dimensions of school engagement (i.e., behavioral, emotional, and cognitive) could moderate the association between physical activity and school engagement. Some studies report that physical activity is positively associated with behavioral engagement (e.g., Barros et al., 2009; Bleeker et al., 2012; Dwyer et al., 1996; Whitt-Glover et al., 2011). However, a number of studies have found a negative association between physical activity and behavioral engagement, specifically time spent on homework (Adam, Snell, & Pendry, 2007; Atkin et al., 2008; Ho & Lee, 2001). There is also some evidence suggesting that physical activity is positively associated with emotional (e.g., Gibson et al., 2008) and cognitive (e.g., Zan, 2013) engagement. However, one study reported no association between physical activity and cognitive engagement, specifically students' perceived value of classroom lessons (Vazou et al., 2012). Although some evidence suggests that physical activity has a positive association with behavioral, emotional, and cognitive engagement, there is contradictory evidence.

THEORETICAL PERSPECTIVES

There are several hypotheses as to how physical activity influences school engagement. The novelty-arousal theory suggests that a shift in normal routine, such as a break, improves attention and concentration (Berlyne, 1966; Ellis, 1984). The theory of contextual interference posits that the use and constant modification of action plans during physical activity, specifically games or activities requiring complex motor skills, can be transferred to other settings, such as a classroom (Best, 2010). Exercise-induced neurological changes such as an increase in brain-derived neurotrophic factor, which is responsible for the development of neurons associated with memory and learning, are another possible explanation (Sattelmair & Ratey, 2009). Finally, physical activity is associated with higher levels of positive affect, specifically positive emotions and mood (Biddle & Asare, 2011; Penedo & Dahn, 2005). The broaden-and-build theory suggests that positive emotions lead to broadened thoughts and behaviors and facilitate more adaptive responses, such as problem solving and seeking assistance (Ekkekakis, Hall, & Petruzzello, 2005; Fredrickson, 1998; Reschly, Huebner, Appleton, & Antaramian, 2008). Further, positive affect is associated with a number of successful outcomes, including self-regulated learning (Mega, Ronconi, & De Beni, 2014), school engagement (Linnenbrink-Garcia & Pekrun, 2011; Pekrun & Linnenbrink-Garcia, 2012; Reschly et al., 2008), and academic performance (Daniels et al., 2009; Howell, 2009). Therefore, increases in positive affect, specifically positive emotions and mood, may be the mechanism by which physical activity has an effect on school engagement and academic performance.

Although the explanatory mechanism for the association between physical activity and school engagement remains unclear, evidence supporting the association is increasing (Gibson et al., 2008; Whitt-Glover et al., 2011; Zan, 2013). However, no attempt has been made to systematically combine evidence from these studies. This type of synthesis could determine whether interventions targeting physical activity are an effective method of promoting school engagement or have the potential to be in the future.

PURPOSE

In this study, we aimed to systematically review and conduct meta-analyses of evidence from studies reporting information on the association between physical activity and overall school engagement and disengagement in youth. The overall school engagement effect size consisted of pooling all behavioral, emotional, and cognitive engagement effect sizes. Similarly, the overall school disengagement effect size consisted of pooling all behavioral, emotional, and cognitive disengagement effect sizes. In addition, we aimed to explain the heterogeneity in the overall school engagement and overall school disengagement effect sizes by testing potential moderators (Bangert-Drowns, 1986). Moderator analyses can explain some of the heterogeneity in effect sizes, provide direction for future research, and guide intervention efforts. Comparing the study characteristics, such as physical activity duration, intensity, and intervention type, could allow us to determine the most effective way to use physical activity in order to promote school engagement. Exploring participants' characteristics (e.g., age) allows us to determine for which groups physical activity is most beneficial and the groups that interventions should target.

The first moderator we tested was the dimension of school engagement. We compared the associations between physical activity and behavioral, cognitive, and emotional engagement to determine whether physical activity has different associations with the three different, yet dynamically interrelated, dimensions (Fredricks et al., 2004). Second, to provide direction for future research and guide intervention efforts, we compared the effectiveness of the different types of interventions (before school vs. integrated into classroom lessons vs. classroom lessons breaks vs. during Physical Education vs. during recess or lunch). Third, due to the short-term effects of physical activity tending to last up to 1 hr (Hillman et al., 2009; Joyce, Graydon, McMorris, & Davranche, 2009), we compared incidence of physical activity (single bout vs. regular) as a moderator. Fourth, as school engagement declines with age (Archambault et al., 2009; Darr, 2012; Eccles et al., 1993; Janosz et al., 2008; Marks, 2000; Wylie & Hodgen, 2012), we compared children and adolescents. Fifth, we compared the measurement tools used to assess school engagement and disengagement (objective vs. subjective) to ensure that the overall effect sizes were not inflated due to methodical artifact. Then, to assess risk of bias, we compared studies with a high risk of bias to studies with a low risk of bias. Finally, to examine publication bias, we compared published studies with unpublished studies (Rothstein, Sutton, & Borenstein, 2006).

METHODS

Eligibility Criteria

To be included in this review, studies were required to

- examine youth (i.e., mean age between 5 and 18 or were enrolled in primary or secondary school);
- not examine special populations (e.g., youth diagnosed with ADHD or autism);
- quantitatively assess behavioral (e.g., concentration), emotional (e.g., lesson enjoyment), or cognitive (e.g., academic motivation) school engagement in schoolwork, either during an academic lesson or at home (i.e., homework). Definitions of the three dimensions of school engagement still vary. A small number of articles defined emotional engagement as interpersonal relationships between students and teachers (Furlong et al., 2003; Jimerson, Campos, & Greif, 2003). However, most definitions did not include

interpersonal relationships; instead, the studies examined interpersonal relationships as an antecedent of school engagement (Cavanagh & Reynolds, 2007; Fredricks et al., 2004; M. Wang & Holcombe, 2010). In recent years, Roorda, Koomen, Spilt, and Oort (2011) conducted a meta-analysis and reported a moderate correlation between positive student teacher relationships and both behavioral and cognitive engagement ($r = .39$, $p < .01$, $k = 61$). Due to this recent meta-analysis and the varying definitions of emotional engagement, we have decided to exclude studies that defined emotional engagement as interpersonal relationships;

- quantitatively assess the association between physical activity and school engagement;
- involve an experimental (randomized controlled trials and quasi-experimental), cohort, or cross-sectional study design; and
- provide full-text in the English language.

No publication date restrictions were imposed. We included published and unpublished studies.

Information Sources

Searches were conducted within PubMed, Scopus, SportDiscus, Education Resources Information Center, and Education Research Complete in December 2014. Combinations of keywords were used to identify eligible studies. Reference lists of eligible studies were also reviewed to identify additional studies. To identify any unpublished articles, the authors sent out an invitation on electronic mailing lists (LISTSERVS) for authors to provide information regarding any unpublished articles that met the inclusion criteria.

Search

Systematic review searches should be thorough, objective, reproducible, and identify as many relevant studies as possible (Booth, 2011). However, it is important to find a balance between comprehensiveness (sensitivity) and maintaining relevance (precision) in the searches. To do this, we conducted preliminary searches using a controlled vocabulary thesaurus for indexing articles (i.e., Medical Subject Headings), examined the results of preliminary searches, and modified searches. Emotional engagement terms that are encompassed by positive and negative affect, such as "interest*," "satisf*," "excite*," "happiness," "sadness," and "anxiety" are low in precision and sensitivity. It is likely that any articles that use these positive and negative affect terms would be identified using the terms "positive affect" and "negative affect." However, to ensure that excluding these specific affect terms would not exclude any relevant articles, we included these terms and screened all citations between January 2012 and December 2014. We identified 3,036 nonduplicate records. After reviewing titles, abstracts, and full-text articles, zero articles met the inclusion criteria. Therefore, to maintain the balance between sensitivity and precision, these specific affect terms were excluded from the final keywords. The final search terms are available as supplementary material.

Study Selection

All potentially eligible studies identified in the searches were exported into a single Endnote library, and duplicate studies were removed. Next, two researchers independently screened titles and abstracts and excluded those that did not meet the eligibility criteria. Finally, full-text versions of the remaining articles were obtained and independently screened for eligibility. Discrepancies regarding inclusion criteria fulfillment were resolved by discussion between the two researchers and the consultation of a third reviewer.

Data Collection Process

Two researchers independently extracted data from eligible studies. Extracted data included year of publication, study design, sample size, mean weight status, mean age, gender of participants, country in which the study was set, intervention description (frequency, duration, and intensity of intervention sessions, if applicable), study duration (if applicable), measure of physical activity, measure of school engagement, and the statistical result that examined the association between physical activity and school engagement.

Risk of Bias in Individual Studies

To assess the risk of bias in studies employing multiple study designs, the Strengthening the Reporting of Observational Studies in Epidemiology guide and the CONsolidated Standards of Reporting Trials, or CONSORT, statement were adapted. The risk of bias criteria included (a) description of participant eligibility criteria, (b) random selection of schools and/or participants (sampling procedures appropriate and adequately described), (c) valid assessment of participant physical activity (reliability and validity evidence was reported in the article), (d) valid assessment of participant school engagement (reliability and validity evidence was reported in the article), (e) power calculation reported and study adequately powered to detect hypothesized relations, and (f) confounders adjusted for in analyses (e.g., gender, age). For each of these criteria, two researchers independently assigned a 1 (present and explicitly described) or 0 (absent or inadequately described), and any discrepancies were resolved by discussion between the two researchers and the consultation of a third reviewer. Studies that met less than half of the criteria were considered to have a high risk of bias implying low confidence that results represent the true effect (Higgins, Altman, & Sterne, 2011). Studies that met at least half of the criteria were considered to have a low risk of bias implying confidence that results represent unbiased estimates of the true effect (e.g., Furlan, Pennick, Bombardier, van Tulder, & the Cochrane Back Review Group, 2009).

Summary Measures

Commonly used summary measures include standardized mean differences, correlation coefficients, t values, log odds ratios, and f values. All summary measures were converted to Cohen's d using Rosenthal's (1994) and (1991) conversion formulas: Cohen's $d = \frac{2r}{\sqrt{1 - r^2}}$, $d = \frac{t}{\sqrt{n-}}$, $d = Log\ Odds\ Ratio \times \frac{\sqrt{3}}{\pi}$, and $d = \sqrt{F\left(\frac{(n_t + n_c)}{n_t n_c}\right)\left(\frac{(n_t + n_c)}{n_t + n_c - 2}\right)}$. Effect sizes ($d$) were defined as .2 (small), .5 (medium), and .8 (large; Cohen, 1988). When studies did not report the information necessary to convert the summary measure to Cohen's d, we contacted the author to request the required information.[1]

Analysis

Traditionally, researchers used fixed-effects and random-effect models to conduct meta-analyses. Both the fixed- and random-effects models are limited by the assumption of independence (Field, 2003). This means that only one effect size per study can be included in a meta-analysis, as multiple effect sizes within a single study are likely to be correlated. Common methods that have been used to address this issue are (a) averaging the effect sizes, (b) "shifting the unit of analysis" (i.e., retaining as many effect sizes as possible from each study while holding violations of the assumption of independence to a minimum; Cooper, 1989), (c) selecting one of the effect sizes or using a combination of the aforementioned methods, and (d) not reporting how they handled the issue (Ahn, Ames, & Myers, 2012). These methods have the potential to lose information and therefore limit the research questions that can be addressed and moderators that can be tested (Cheung, 2014).

Structural equation modeling and multilevel modeling are two approaches to meta-analysis that are not limited by the assumption of independence (Goldstein, 1995; Marsh, Bornmann, Mutz, Daniel, & O'Mara, 2009; Raudenbush & Bryk, 1985; Van Den Noortgate & Onghena, 2003). Another advantage of these two approaches is that covariates and moderator variables can be included in order to explore the heterogeneity in effect sizes (Van Den Noortgate & Onghena, 2003). Multilevel meta-analysis can be integrated into the structural equation modeling approach to meta-analysis, providing further methodological advantages (Cheung, 2014). For example, this integrated approach places flexible constraints on parameters, constructs more accurate confidence intervals using the likelihood-based approach, and handles missing covariates using full information maximum likelihood (Cheung, 2009, 2014).

In this meta-analysis, we took a structural equation modeling approach to multilevel meta-analysis. We conducted all analyses in R Version 3.1.2 (R Core Team, 2014). The package metaSEM, using the meta3 function, was used for meta-analysis (Cheung, 2011). We used maximum likelihood estimation to fit mixed-effects models. Unconditional mixed-effects models were employed to calculate the overall pooled effect size (pooled d). For each pooled effect size, 95% likelihood-based confidence intervals (CIs) were calculated (Cheung, 2009). When the 95% CIs did not encompass zero, a significant effect between variables was said to exist.

The I^2 statistic was used to assess heterogeneity in pooled effect sizes (Higgins, Thompson, Deeks, & Altman, 2003). When effect sizes were heterogeneous (i.e., I^2 exceeded 25%), moderator analyses were conducted to explain some of the heterogeneity in effect sizes. Moderator analyses allow us to identify variables that affect the direction or strength of the relations between an independent variable and dependant variable (i.e., physical activity and school engagement; Shadish & Sweeney, 1991). When there were at least four effect sizes per subgroup, we conducted conditional models to test potential moderators. Although there is no universally accepted minimum number of effect sizes per subgroup required for a moderator analysis, Fu et al. (2011) suggested that at least four effect sizes are required for categorical subgroup variables. For each moderator analysis, we calculated the proportion of explained variance of heterogeneity by the inclusion of the potential moderator variable (R^2) and the heterogeneity between effect sizes in each category (I^2). Potential moderators included the dimensions of engagement (behavioral vs. cognitive vs. emotional), different types of interventions (physical activity before the classroom lesson commenced vs. incorporating physical activity into classroom lessons vs. physical activity in breaks during the classroom lesson), different incidences of physical activity (single bouts occurring in the 60-min period before the classroom lesson vs. regular physical activity), measurement tools used to measure behavioral engagement (objective vs. subjective), and risk of bias within studies.

[1]If the author did not respond, sensitivity analysis was conducted by estimating Cohen's d using the reported information, information from similar studies with similar results, and approximation formulas (Higgins & Green, 2011; Irwin, 1997). Results of this sensitivity analysis were compared to the results without these studies. No significant differences were found between results that included and excluded the estimated effect sizes. Therefore, we have reported results that include the estimated effect sizes and have presented results that exclude estimated effect sizes in the Supplementary File.

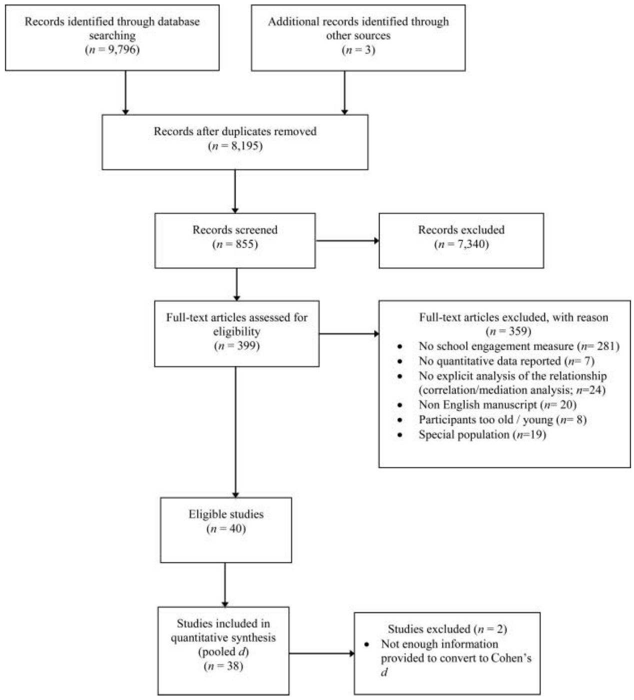

FIGURE 1 Flow diagram of search results.

To examine risk of bias across studies and assess the risk of publication bias, first we inspected funnel plots (Sterne, Egger, & Moher, 2011), which plotted the effect sizes on the x-axes and standard errors on the y-axes. When bias is absent, the funnel plots resemble a symmetrical inverted funnel. Next, to quantify the bias visible in the funnel plots, we conducted Egger's regression asymmetry tests (Egger, Smith, Schneider, & Minder, 1997), by regressing the normalized effect estimate (effect size divided by its standard error) against precision (reciprocal of the standard error of the effect size). When the funnel plot is symmetrical (i.e., no bias), the regression line will run through the origin.

RESULTS

Study Selection

Study selection results are displayed in Figure 1. Through searches of electronic databases, reference lists, and gray literature (i.e., unpublished work), we identified 8,195 non-duplicate records. After reviewing the titles and abstracts of these 8,195 records, we obtained and reviewed full-text versions of 399 potentially relevant records. Of these 399 full-text articles, 40 met the inclusion criteria. However, two of these studies did not provide enough information to be included in the meta-analyses. Thus, 38 studies were included in this systematic review and meta-analyses.

Study Characteristics

Study characteristics are detailed in the supplementary material file. Publication dates ranged from 1993 to 2014. Half of the studies were conducted in either the United States ($k = 17$) or Australia ($k = 3$). Twenty-four studies implemented an intervention of which nine were randomized controlled trials and 15 were quasi-experimental study designs. Other study designs include cross-sectional ($k = 13$) and longitudinal ($k = 1$).

Across the 24 intervention studies, we identified five types of interventions. One intervention was implemented at school before the school day commenced and four were implemented at school as programs during school hours. Seven interventions involved the academic classroom teachers integrating physical activity into academic classroom lessons, whereas five interventions involved 10- to 15-min physical activity breaks during academic classroom lessons. Six interventions provided additional or extended breaks between academic classroom lessons (e.g., recess or lunch), and the remaining intervention was conducted during Physical Education and involved manipulating the duration and intensity of physical activity. Control conditions involved pretests ($k = 3$), no school program ($k = 2$), other activities such as art ($k = 1$) and yoga ($k = 1$), usual classroom lessons ($k = 9$), usual recess and lunch breaks ($k = 5$), no recess breaks ($k = 2$), and usual Physical Education lessons ($k = 1$).

Across the 38 included studies, 71,433 participants were included. The number of study participants ranged from 5 (Schnieders-Laber, 2011) to 25,060 (Leatherdale & Wong, 2008). The mean age of participants in each study ranged from 6.7 years ($SD = 1.0$; Smith et al., 2013) to 15.5 ($SD = 1.2$; Leatherdale & Wong, 2008).

Of the 38 included studies, the majority examined school engagement ($k = 28$) rather than school disengagement ($k = 10$), whereas one study examined both engagement and disengagement. The majority of studies examined behavioral engagement ($k = 25$) rather than a combination of cognitive and emotional engagement ($k = 2$) or a combination of behavioral and emotional engagement ($k = 1$). Similarly, majority of studies examined behavioral disengagement ($k = 8$) rather than emotional disengagement ($k = 1$), cognitive disengagement ($k = 0$), or a combination of behavioral and emotional disengagement ($k = 2$). No study examined all three dimensions of school engagement or disengagement.

Behavioral engagement and disengagement were measured using observation of classroom lessons ($k = 13$), school records ($k = 2$), teacher reports ($k = 11$), parent reports ($k = 1$), and self-reports ($k = 11$). Cognitive engagement and disengagement were measured using self-reports ($k = 2$), whereas emotional engagement and disengagement were measured using teacher reports ($k = 1$) and self-reports ($k = 1$).

Risk of Bias Within Studies

Complete risk of bias assessments are displayed in the supplementary material file. The interrater agreement for risk of bias ratings was 99.38%, and all discrepancies were resolved by discussion between the two researchers and the consultation of a third reviewer. Fifteen studies were rated as having a low risk of bias, and 25 studies were rated as having a high risk of bias.

Synthesis of Results

Overall school engagement. The unconditional multilevel model focused on the overall pooled effect size of the association between physical activity and school engagement. Overall, physical activity had a small positive association with school engagement ($d = .28$), 95% CI [.12, .46]. The majority of the variation within this pooled effect size was attributable to differences between studies ($I^2 = .86$) rather than within studies ($I^2 = .11$). Therefore, we conducted moderator analyses to explain some of the between-study variance.

Overall school disengagement. Physical activity had no significant association with school disengagement ($d = -.32$), 95% CI [−1.00, .36]. Variation within the pooled effect size of the association between physical activity and school disengagement was largely due to differences between studies ($I^2 = .88$) rather than within studies ($I^2 = .09$). Therefore, moderator analyses were conducted to explain some of the between-study variance.

Moderator Analyses

Significant results of moderator analyses are described next. Results of all moderator analyses are presented in Tables 1 and 2.

School engagement dimension. Due to the insufficient number of studies that examined cognitive ($k = 2$) and emotional ($k = 2$) engagement, and cognitive ($k = 0$) and emotional ($k = 2$) disengagement, we did not conduct moderator analyses concerning the association between physical activity and different aspects of engagement or disengagement.

Age. Age explained a small portion of the heterogeneity found between studies that assessed the association between physical activity and school engagement ($R^2 = .06$). Physical activity had a small-to-medium positive association with school engagement in adolescents ($d = .40$, $I^2 = .99$), 95% CI [.06, .77] and a small positive association with school engagement in children ($d = .27$, $I^2 = .81$), 95% CI [.08, .47].

Study design. Study design influenced the association between physical activity and school engagement and accounted for a small portion of the between-study heterogeneity ($R^2 = .06$). Randomized controlled trials that examined the effect of physical activity on school engagement reported a significant small-to-medium positive effect ($d = .40$, $I^2 = .85$), 95% CI [.06, .74]. In contrast, cross-sectional and quasi-experimental studies reported effect sizes that were not different from zero ($d = .23$, $I^2 = .85$), 95% CI [−.01, .48], and ($d = .27$, $I^2 = .85$), 95% CI [−.05, .59], respectively.

TABLE 1
Results of School Engagement Meta-Analyses and Moderator Analyses

Variable	*k*	*#ES*	*n*	*Coefficient (r)*	*Lower 95% CI*	*Upper 95% CI*	τ_2	τ_3	R^2_2	R^2_3	I^2_2	I^2_3	*Q Statistic*
Overall school engagement	29	59	59,715	0.28	0.12	0.46	0.02	0.14			0.11	0.86	2258.685
Moderator analyses													
Engagement dimension													
Behavioral	25	55											
Emotional	2	2											
Cognitive	2	2											
Intervention type							0.02	0.14	0.04	0.02			2258.685
Before school	0	0	0										
Classroom integration	5	11	989	0.22	−0.21	0.66	0.01	0.15			0.06	0.91	
Classroom break	4	15	5,950	0.55	0.02	1.06	0.03	0.23			0.12	0.87	
School program	2	2	205										
Physical Education	1	2	497										
Recess/Lunch	3	5	1,162	0.26	−0.19	0.73	0.02	0.00			0.00	0.81	
PA type							0.02	0.13	0.01	0.05			2258.685
Regular PA	20	32	53,947	0.24	0.05	0.44	0.02	0.08			0.20	0.77	
Single bout	9	27	5,768	0.43	0.08	0.78	0.01	0.25			0.04	0.95	
PA intensity							0.02	0.10	0.05	0.28			2258.685
Moderate and vigorous	5	21	5,413	0.62	0.26	0.98	0.00	0.16			0.00	0.98	
Low	1	2	688										
Free play	2	3	939										
Not reported	7	11	2,730	0.29	−0.06	0.65	0.02	0.00			0.00	0.85	
Age							0.02	0.13	0.00	0.06			2258.685
Children	22	48	25,400	0.27	0.08	0.47	0.02	0.11			0.16	0.81	
Adolescents	6	10	31,861	0.40	0.06	0.77	0.00	0.26			0.00	0.99	
PA measure							0.02	0.09	0.05	0.34			2258.685
Objective	2	2	253										
Subjective	14	23	48,862	0.23	0.03	0.44	0.02	0.13			0.14	0.83	
Observation	2	13	4,674	0.99	0.33	1.59	0.00	0.00			0.00	0.00	
No measure	11	21	5,926	0.21	−0.04	0.46	0.01	0.06			0.15	0.80	
Study design							0.02	0.13	0.00	0.06			2258.685
Cross-sectional	13	21	48,731	0.23	−0.01	0.48	0.02	0.15			0.12	0.86	
Quasi-experimental	9	28	2,279	0.27	−0.05	0.59	0.01	0.09			0.10	0.86	
Randomized controlled trial	7	10	8,705	0.40	0.06	0.74	0.02	0.15			0.12	0.85	
Total risk of bias							0.02	0.13	0.01	0.09			2258.685
Low	14	34	31,193	0.37	0.14	0.61	0.02	0.05			0.26	0.69	
High	15	25	28,522	0.19	−0.03	0.44	0.01	0.21			0.06	0.93	
Risk of Bias 1							0.02	0.14	0.00	0.01			2258.685
Yes	24	50	49,111	0.27	0.08	0.48	0.02	0.10			0.14	0.83	
No	5	9	10,604	0.32	−0.05	0.68	0.02	0.24			0.08	0.90	
Risk of Bias 2							0.02	0.15	0.03	0.00			2258.685
Yes	2	4	2,279	0.16	−0.45	0.79	0.01	0.00			0.75	0.00	
No	14	34	8,705	0.36	0.10	0.63	0.01	0.15			0.06	0.92	
Risk of Bias 3							0.02	0.15	0.03	0.00			2258.685
Yes	1	2	497										
No	15	36	10,487										
Risk of Bias 4							0.02	0.13	0.01	0.08			2258.685
Yes	15	34	37,640	0.36	0.14	0.59	0.03	0.16			0.14	0.84	
No	14	25	22,075	0.19	−0.05	0.44	0.01	0.08			0.12	0.84	
Risk of Bias 5							0.02	0.11	0.02	0.21			2258.685
Yes	19	45	37,881	0.38	0.20	0.58	0.02	0.14			0.11	0.86	
No	10	14	21,834	0.05	−0.22	0.34	0.01	0.02			0.40	0.48	
Risk of Bias 6													
Yes	1	1	98										
No	28	58	59,617										
Risk of Bias 7							0.02	0.13	0.00	0.07			2258.685
Yes	12	33	44,917	0.42	0.15	0.69	0.03	0.09			0.21	0.76	
No	17	26	14,798	0.20	−0.01	0.42	0.01	0.16			0.05	0.92	
Publication status							0.02	0.13	0.00	0.09			2258.685
Published	26	54	58,968	0.31	0.14	0.49	0.02	0.14			0.11	0.86	
Unpublished	3	5	747	−0.08	−0.67	0.54	0.03	0.00			0.87	0.00	

Note. CI = confidence interval; τ _2 = variance at Level 2; τ _3 = variance at Level 3; I^2_2 = heterogeneity at Level 2; I^2_3 = heterogeneity at Level 3; k = number of studies; PA = physical activity; R^2_2 = explained variance at Level 2; R^2_3 = explained variance at Level 3; PA = physical activity; Risk of Bias 1 = Description of participant eligibility criteria; Risk of Bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of Bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of Bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of Bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of Bias 6 = Power calculation reported and study adequately powered to detect hypothesized relationships; Risk of Bias 7 = Covariates adjusted for in analyses (e.g., gender, age, weight status).

TABLE 2
Results of School Disengagement Meta-Analyses and Moderator Analyses

Variable	*k*	*#ES*	*n*	*Coefficient (r)*	*Lower 95% CI*	*Upper 95% CI*	τ _2	τ_3	R^2_2	R^2_3	I^2_2	I^2_3	*Q Statistic*
Overall school disengagement	11	23	9,260	−0.32	−1.00	0.36	0.08	0.75			0.10	0.88	1948.789
Moderator analyses													
Disengagement dimension							0.10	0.44	0.00	0.41			1948.789
Behavioral	10	20	4,741	−0.09	−0.75	0.49	0.04	0.24			0.15	0.79	
Emotional	2	3	4,519	−1.13	−2.15	0.13	0.08	1.27			0.06	0.93	
Cognitive	0	0	0										
Intervention type							0.03	0.07	0.65	0.91			1948.789
Before school	1	2	14										
Classroom integration	2	2	4,481										
Classroom break	1	5	44	−0.42	−2.65	1.81	0.00	0.00			0.00	0.00	
School program	2	2	162										
Physical Education	0	0	0										
Recess/lunch	4	11	168	0.83	−1.71	3.38	0.12	0.15			0.42	0.52	
PA type							0.08	0.75	0.00	0.00			1948.789
Regular PA	4	5	4,567	−0.32	−1.34	0.70	0.00	0.05			0.00	0.72	
Single bout	7	18	4,693	−0.33	−1.24	0.59	0.14	1.28			0.10	0.89	
PA intensity							0.09	0.47	0.00	0.37			1948.789
Vigorous and moderate	5	10	4,696	−0.77	−1.53	0.01	0.00	0.83			0.00	0.98	
Low	0	0	0										
Free play	3	9	145	0.49	−0.71	1.69	0.27	0.26			0.49	0.47	
Not reported	1	1	5										
Age													
Children	11	23	9,260										
Adolescents	0	0	0										
PA measure							0.08	0.76	0.03	0.00			1948.789
Objective	1	1	54										
Subjective	2	6	4,435	−0.44	−1.94	1.05	0.00	0.00			0.00	0.00	
Observation	3	5	4,598	−0.36	−1.53	0.82	0.23	2.08			0.10	0.89	
No measure	5	11	173	−0.18	−1.36	1.00	0.00	0.05			0.00	0.74	
Study design							0.08	0.53	0.00	0.29			1948.789
Cross-sectional	0	0	0										
Quasi-experimental	8	20	285	−0.01	−0.74	0.71	0.06	0.25			0.17	0.77	
Randomized controlled trial	2	2	4,584	−1.17	−2.41	0.10	0.85	0.85			0.49	0.49	
Longitudinal	1	1	4,391										
Total risk of bias							0.11	0.40	0.00	0.46			1948.789
Low	4	31	284	0.31	−0.51	1.10	0.17	0.12			0.56	0.38	
High	7	16	8,976	−0.83	−1.55	−0.10	0.00	0.72			0.00	0.97	
Risk of Bias 1							0.07	0.37	0.10	0.51			1948.789
Yes	9	21	393	0.03	−0.56	0.60	0.04	0.20			0.17	0.77	
No	2	2	8,867	−1.45	−2.50	−0.40	0.98	0.00			0.98	0.00	
Risk of Bias 2													
Yes	1	1	4,476										
No	9	21	393										
Risk of Bias 3							0.08	0.53	0.00	0.29			1948.789
Yes	2	2	4,584	−1.17	−2.41	0.10	0.85	0.85			0.49	0.49	
No	8	20	285	−0.01	−0.74	0.71	0.06	0.25			0.17	0.77	
Risk of Bias 4							0.08	0.75	0.03	0.00			1948.789
Yes	4	6	4,652	−0.37	−1.39	0.64	0.22	1.54			0.12	0.86	
No	7	17	4,608	−0.28	−1.20	0.64	0.05	0.00			0.71	0.00	
Risk of Bias 5							0.03	0.17	0.65	0.77			1948.789
Yes	9	21	4,779	−0.03	−0.43	0.35	0.04	0.20			0.16	0.77	
No	2	2	4,481	−2.43	−3.47	−1.37	0.00	0.00			0.00	0.00	
Risk of Bias 6													
Yes	0	0	0										
No	11	23	9,260										
Risk of Bias 7							0.08	0.66	0.02	0.12			1948.789
Yes	2	3	131	0.23	−1.14	1.59	0.00	0.00			0.00	0.00	
No	9	20	9,129	−0.49	−1.22	0.25	0.16	0.81			0.16	0.82	
Publication status													
Published	10	22	9,255										
Unpublished	1	1	5										

Note. CI = confidence intervals; τ _2 = variance at Level 2; τ _3 = variance at Level 3; I^2_2 = heterogeneity at Level 2; I^2_3 = heterogeneity at Level 3; *k* = number of studies; R^2_2 = explained variance at Level 2; R^2_3 = explained variance at Level 3; PA = physical activity; Risk of Bias 1 = Description of participant eligibility criteria; Risk of Bias 2 = Random selection of schools (sampling procedures appropriate and adequately described); Risk of Bias 3 = Random selection of participants (sampling procedures appropriate and adequately described); Risk of Bias 4 = Valid assessment of participant physical activity (reliability and validity evidence was reported in the article); Risk of Bias 5 = Valid assessment of participant school engagement (reliability and validity evidence was reported in the article); Risk of Bias 6 = Power calculation reported and study adequately powered to detect hypothesized relationships; Risk of Bias 7 = Covariates adjusted for in analyses (e.g., gender, age, weight status).

Risk of bias within studies. Risk of bias accounted for a portion of the heterogeneity between studies that examined the association between physical activity and school engagement ($R^2 = .09$). Studies that examined the association between physical activity and school engagement with a low risk of bias reported a small positive effect ($d = .37$, $I^2 = .69$), 95% CI [.14, .61], whereas studies with a high risk of bias reported an effect size not significantly different from zero ($d = .19$, $I^2 = .93$), 95% CI [–.03, .44]. Studies that assessed the association between physical activity and school disengagement with a low risk of bias reported an effect size not significantly different from zero ($d = .31$, $I^2 = .38$), 95% CI [–.51, 1.10], whereas studies with a high risk of bias reported a large negative effect ($d = –.83$, $I^2 = .97$), 95% CI [–1.55, –.10].

Intervention type. The type of intervention implemented explained a portion of the between-study heterogeneity ($R^2 = .02$). Interventions that involved physical activity breaks during academic classroom lessons found that physical activity had a medium positive association with school engagement ($d = .55$, $I^2 = .87$), 95% CI [.02, 1.06]. In contrast, interventions that involved teachers integrating physical activity into classroom lessons and interventions that were implemented during recess or lunch found effect sizes not different from zero ($d = .22$, $I^2 = .91$), 95% CI [–.21, .66], and ($d = .26$, $I^2 = .81$), 95% CI [–.19, .73], respectively.

Single bouts versus regular physical activity. Comparing the associations between single bouts and regular physical activity with school engagement accounted for a small portion of the between-study heterogeneity ($R^2 = .05$). Studies that examined the association between single bouts of physical activity immediately before a classroom lesson and school engagement reported a small-to-medium positive effect ($d = .43$, $I^2 = .95$), 95% CI [.08, .78]. On the contrary, studies that examined the association between regular physical activity and school engagement found a small positive effect ($d = .24$, $I^2 = .77$), 95% CI [.05, .44].

Physical activity intensity. The different intensities of physical activity accounted for a portion of the heterogeneity found between studies that examined the association between physical activity and school engagement ($R^2 = .28$). Moderate and vigorous intensity activity had a medium positive association with school engagement ($d = .62$, $I^2 = .98$), 95% CI [.26, .98]. In contrast, studies that did not report the intensity of activity found an effect size not significantly different from zero ($d = .29$, $I^2 = .85$), 95% CI [–.06, .65].

Physical activity measures. The association between physical activity and school engagement differed depending on the measure of physical activity used and this accounted for a portion of the between-study heterogeneity ($R^2 = .34$). Studies that used observation measures of physical activity (e.g., the System for Observing Fitness Instruction Time) reported that physical activity had a large positive association with school engagement ($d = .99$, $I^2 = .00$), 95% CI [.33, 1.59]. Studies that used subjective measures of physical activity (e.g., the Physical Activity Questionnaire) found that physical activity had a small positive association with school engagement ($d = .23$, $I^2 = .83$), 95% CI [.03, .44]. In contrast, studies that did not measure physical activity but instead provided additional opportunities for activity reported that physical activity had no significant association with school engagement ($d = .21$, $I^2 = .80$), 95% CI [–.04, .46].

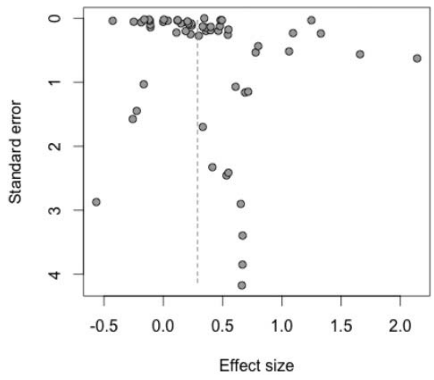

FIGURE 2 Funnel plot for school engagement.

Risk of Bias Across Studies

Published studies that examined the association between physical activity and school engagement reported a small positive association ($d = .31$), 95% CI [.14, .49]. In contrast, unpublished studies that examined the association between physical activity and school engagement reported an effect size no different from zero ($d = –.08$), 95% CI [–.67, .54]. The examination of funnel plots revealed low asymmetry, representing low risk of bias across studies that assessed the association between physical activity and school engagement and disengagement (Figures 2 and 3, respectively). This was confirmed for studies that assessed the association between physical activity and school engagement by a nonsignificant Egger's test result ($t = -1.58$, $p = .11$). This was also confirmed for studies that examined the effect of physical activity on school disengagement ($t = -0.03$, $p = .99$).

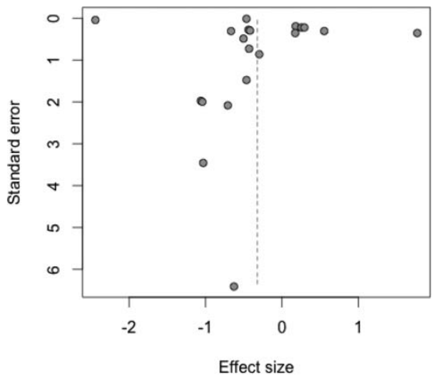

FIGURE 3 Funnel plot for school disengagement.

DISCUSSION

Summary of Evidence

The first aim of this study was to systematically review and conduct meta-analyses of evidence from studies reporting information on the association between physical activity and school engagement and disengagement in youth. Overall, physical activity had a small positive association with school engagement but no association with school disengagement. There was considerable heterogeneity in these effect sizes and the confidence intervals were wide. Therefore, our results should be interpreted with caution.

Interventions that involved physical activity breaks during academic classroom lessons appeared to be the most effective type of intervention for improving school engagement. These results provide potential support for novelty arousal theory (Berlyne, 1966; Ellis, 1984). The physical activity breaks could provide a novel distraction from academic classroom tasks and a shift in routine and may allow students to refocus and improve attention when they return to academic classroom tasks. That said, it is currently unclear whether it is the break or the physical activity that improves school engagement. Future experimental research is needed that compares a sedentary break condition to a physical activity break condition. This design will help determine whether it is the break from academic classroom lessons per se, the physical activity itself, or both physical activity and the break that improve school engagement.

Physical activity was beneficial for both children and adolescents, but more beneficial for adolescents. This is an important finding, as school engagement typically declines with age (Archambault et al., 2009; Darr, 2012; Eccles et al., 1993; Marks, 2000), and physical activity appears to be most important during adolescence. This importance could be due to the influence of social background (e.g., parental characteristics) becoming less important as students get older and become less economically and socially dependent on their parents (Lucas, 2001). Therefore, this finding should be interpreted with caution. Future longitudinal research is needed that follows students from childhood to adolescence to determine at which age physical activity is most important for school engagement.

Study design influenced the association between physical activity and school engagement, as studies that employed a randomized controlled trial design were the only studies to report a significant positive effect. This finding suggests that the positive effects exist, as randomized controlled trials represent the highest quality of evidence (Barton, 2000). Although five high-quality randomized controlled trials were identified, further high-quality evidence is needed to determine how and for whom interventions should be targeted in order to effectively improve school engagement.

The frequency and intensity of physical activity appeared to influence the association between physical activity and school engagement. Single bouts before a classroom lesson and regular physical activity had a positive association with school engagement. In terms of intensity, moderate and vigorous intensity activity had a medium positive association with school engagement, whereas studies that did not report the intensity found an effect no different from zero. This suggests that single bouts and regular activity of moderate and vigorous intensity could be used to promote school engagement. However, due to the small number of studies that explored the effect of moderate and vigorous intensity activity on school engagement, we collapsed these two subgroups. Further research is needed that directly compares the effect of different activity intensities on school engagement.

The measurement tools used to assess physical activity influenced the association between physical activity and school engagement. Studies that used observation and subjective measures of physical activity reported that physical activity had a positive association with school engagement, whereas studies that did not measure physical activity, but instead provided additional opportunities for activity, indicated that physical activity had no association with school engagement. This could be due to not all students participating in physical activity. When groups of students were provided with an opportunity for physical activity, it is unlikely that all students took the opportunity to be physically active, and without measurement, it is impossible to determine which students were physically active and which students were not. Although studies that used observation and subjective measures found a positive effect, there are also limitations to using these measures. Observation is generally limited to one overall class physical activity score and is subject to participant reactivity (Trost, 2007). Although subjective measures provide data at the individual level, they are prone to social desirability bias and youths' inability to accurately recall their physical activity behavior (Troiano, Gabriel, Welk, Owen, & Sternfeld, 2012). Objective measures of physical activity, such as accelerometers and pedometers, minimize the potential for respondent bias and provide data at the individual level. Two studies used an objective measure of physical activity; however, further research is needed that employs objective measures to explore the association between physical activity and school engagement.

Unfortunately, due to the insufficient number of studies examining emotional ($k = 2$) and cognitive ($k = 2$) engagement, we did not conduct moderator analyses concerning the impact of physical activity on different aspects of engagement. Fredricks et al. (2004) suggested that the three dimensions of school engagement and disengagement are dynamically interrelated and should be examined all together. However, no single study examined all three dimensions of school engagement or disengagement. Further research is needed that explores the effect of physical activity on the multidimensional constructs of school engagement and disengagement that include behavior, cognition, and emotions. Although there is a general consensus that school engagement is a multidimensional construct, not all scholars agree with Fredricks et al.'s conceptualization of school engagement, specifically that cognitive engagement subsumes motivation (e.g., Reschly, 2010). Further research is needed to determine whether cognitive engagement subsumes motivation, or whether cognitive engagement and motivation are separate but related constructs. If cognitive engagement does not subsume motivation, further research is needed that examines the effect of physical activity on motivation.

Strengths and Limitations

This study has a number of strengths. First, to the authors' knowledge, this is the first systematic review and meta-analysis of the relation between physical activity and school engagement. Our findings are important, as levels of school engagement tend to decline with age, and methods that lessen or reverse this decline need to be identified. The evidence we reviewed indicates that targeting physical activity could be an effective way to promote school engagement in youth, especially during adolescence when school engagement levels tend to be lowest.

There were also limitations to our study. There was a high level of heterogeneity in the pooled effect sizes. This high level of heterogeneity could be attributed to the large variety of measurement tools used and the variety of contexts in which the studies were conducted. However, some of this heterogeneity was explained by a number of moderating variables. In addition, although the majority of studies employed an experimental design ($k = 25$), 25 of the 40 included studies were rated as having a high risk of bias. Further, the majority of studies examined behavioral engagement and disengagement, rather than emotional or cognitive engagement and disengagement. As such, behavioral engagement effect sizes made up most of the overall school engagement effect size. Similarly, behavioral disengagement effect sizes made up most of the overall school disengagement effect size. The majority of studies have been published in health and sport science journals, rather than educational and psychological journals. Further research is needed that explores the effect of physical activity on emotional and cognitive engagement and disengagement.

There were also limitations to our moderator analyses. When we examined risk of bias as a potential moderator, we categorized each study as having a high or low risk of bias. Although this method can give us a general idea of how risk of bias influences the overall effect, it is limited as each item can influence risk of bias in a different way (Liberati et al., 2009). Thus, we did not adjust or account for total risk of bias in the moderator analyses. Similarly, although we examined study design as a potential moderating variable, we did not adjust for the quality of the study design in the moderator analyses. In addition, when we examined age as a moderator we divided studies into categories. We classified studies examining children as studies with a mean age younger than 13 and studies examining adolescents as studies with a mean age of 13 or older. This method of dividing studies is limited, as the mean age does not imply that all participants are that age; it is quite likely that each study has participants in both categories. Therefore, these results should be interpreted with caution.

Implications and Conclusions

Despite the limitations of this study, there are also important implications. The health benefits of physical activity are well established; however, our results suggest that the benefits extend further than health and into education. There is increasing pressure placed on educators to increase academic performance scores, especially standardized test scores, and some educators perceive time spent in the academic classroom to be more beneficial to academic performance, compared to time spent promoting physical activity. Evidence from this study suggests that providing opportunities for physical activity could improve school engagement (Van Dijk, De Groot, Savelberg, Van Acker, & Kirschner, 2014; Zhang et al., 2015).

Physical activity declines with age, and thus, the lowest level of participation during the school years tends to occur during adolescence (Blaes, Baquet, Van Praagh, & Berthoin, 2011; Sallis, 2000). Physical activity has the most beneficial effect on school engagement in adolescents. Therefore, promoting physical activity in adolescents, who currently participate in the lowest levels of physical activity, should be a priority for policymakers, teachers, and parents. Teachers could provide adolescents with classroom lesson physical activity breaks in order to improve school engagement. For example, teachers could provide students with 10-min breaks for physical activity focusing on dance or sport movements (e.g., Whitt-Glover et al., 2011). If policymakers and educators use this evidence and provide more opportunities for physical activity at school, young people could also receive a number of physical and mental health benefits (Biddle & Asare, 2011; Janssen & LeBlanc, 2010).

In conclusion, results from this study suggest that promoting physical activity could provide benefits for school engagement in youth, over and above the well-established physical and mental health benefits. This study provides further evidence to support the promotion of physical activity, especially in schools.

SUPPLEMENTAL MATERIAL

Supplemental data for this article can be accessed on the publisher's website.

REFERENCES

*References marked with an asterisk indicate studies included in the meta-analysis.

Abbott-Chapman, J., Martin, K., Ollington, N., Venn, A., Dwyer, T., & Gall, S. (2014). The longitudinal association of childhood school engagement with adult educational and occupational achievement: findings from an Australian national study. *British Educational Research Journal*, *40*, 102–120.

*Adam, E. K., Snell, E. K., & Pendry, P. (2007). Sleep timing and quantity in ecological and family context: A nationally representative time-diary study. *Journal of Family Psychology*, *21*, 4–19. Retrieved from http://www.scopus.com/

Ahn, S., Ames, A., & Myers, N. (2012). A review of meta-analyses in education: Methodological strengths and weaknesses. *Review of Educational Research*, *82*, 436–476. doi:10.3102/0034654312458162

Anderman, E. M., & Maehr, M. L. (1994). Motivation and schooling in the middle grades. *Review of Educational Research*, *64*, 287–309.

Archambault, I., Janosz, M., Morizot, J., & Pagani, L. (2009). Adolescent behavioral, affective, and cognitive engagement in school: Relationship to dropout. *Journal of School Health*, *79*, 408–415. doi:10.1111/j.1746-1561.2009.00428.x

*Atkin, A. J., Gorely, T., Biddle, S., Marshall, S. J., & Cameron, N. (2008). Critical hours: Physical activity and sedentary behavior of adolescents after school. *Pediatric Exercise Science*, *20*, 446–456.

Bangert-Drowns, R. L. (1986). Review of developments in meta-analytic method. *Psychological Bulletin*, *99*, 388–399.

*Barnard-Brak, L., Davis, T., Sulak, T., & Brak, V. (2011). The association between physical education and symptoms of attention deficit hyperactivity disorder. *Journal of Physical Activity and Health*, *8*, 964–970.

*Barros, R. M., Silver, E. J., & Stein, R. E. (2009). School recess and group classroom behavior. *Pediatrics*, *123*, 431–436. doi:10.1542/peds.2007-2825

Barton, S. (2000). Which clinical studies provide the best evidence?: The best RCT still trumps the best observational study. *British Medical Journal*, *321*, 255.

Berlyne, D. E. (1966). Curiosity and exploration. *Science*, *153*, 25–33.

Best, J. R. (2010). Effects of physical activity on children's executive function: Contributions of experimental research on aerobic exercise. *Developmental Review*, *30*, 331–351. doi:10.1016/j.dr.2010.08.001

Biddle, S., & Asare, M. (2011). Physical activity and mental health in children and adolescents: A review of reviews. *British Journal of Sports Medicine*, *45*, 886–895. doi:10.1136/bjsports-2011-090185

Blaes, A., Baquet, G., Van Praagh, E., & Berthoin, S. (2011). Physical activity patterns in French youth-from childhood to adolescence-monitored with high-frequency accelerometry. *American Journal of Human Biology*, *23*, 353–358. doi:10.1002/ajhb.21142

*Bleeker, M., James-Burdumy, S., Beyler, N., Dodd, A. H., London, R. A., Westrich, L., . . . Castrechini, S. (2012, April). *Findings from a randomized experiment of playworks: Selected results from Cohort 1* (Evaluation report). Princeton, NJ: Mathematica Policy Research, John W. Gardner Center, and Robert Woods Johnson Foundation.

Booth, A. (2011). Chapter 3: Searching for studies In J. Noyes, A. Booth, K. Hannes, A. Harden, J. Harris, S. Lewin, & C. Lockwood (Eds.), *Supplementary guidance for inclusion of qualitative research in cochrane systematic reviews of interventions*. London, UK: Cochrane. Retrieved from http://cqrmg.cochrane.org/supplemental-handbook-guidance

Castelli, D. M., Centeio, E. E., Hwang, J., Barcelona, J. M., Glowacki, E. M., Calvert, H. G., & Nicksic, H. M. (2014). The history of physical activity and academic performance research: Informing the future. *Monographs of the Society for Research in Child Development*, *79*, 119–148. doi:10.1111/mono.12133

Cavanagh, R., & Reynolds, P. (2007, November). *Senior secondary school students' risk of disengagement from further education, employment and training*. Paper presented at the AARE 2007 International Research Conference, Fremantle, WA.

Cheung, M. (2009). Constructing approximate confidence intervals for parameters with structural equation models. *Structural Equation Modeling*, *16*, 267–294. doi:10.1080/10705510902751291

Cheung, M. (2011). metaSEM: meta-analysis: A structural equation modeling approach. *R package version 0.5-3*. Retrieved from http://courses.nus.edu.sg/course/psycwlm/Internet/metaSEM

Cheung, M. (2014). Modeling dependent effect sizes with three-level meta-analyses: A structural equation modeling approach. *Psychological Methods*, *19*, 211–229.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Erlbaum.

Cooper, H. M. (1989). *Integrating research: A guide for literature reviews*. Thousand Oaks, CA: Sage.

Daniels, L. M., Stupnisky, R. H., Pekrun, R., Haynes, T. L., Perry, R. P., & Newall, N. E. (2009). A longitudinal analysis of achievement goals: From affective antecedents to emotional effects and achievement outcomes. *Journal of Educational Psychology*, *101*, 948–963. doi:10.1037/a0016096

Darr, C. W. (2012). Measuring student engagement: The development of a scale for formative use. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 707–723). New York, NY: Springer.

Deil-Amen, R., & Lopez Turley, R. (2007). A review of the transition to college literature in sociology. *The Teachers College Record*, *109*, 2324–2366.

Department of Education and Early Childhood Development. (2010). *Pathways to re-engagement though flexible learning options*. Victoria, Australia: Department of Education and Early Childhood Development.

Donnelly, J. E., & Lambourne, K. (2011). Classroom-based physical activity, cognition, and academic achievement. *Preventive Medicine*, *52*, S36–S42. doi:10.1016/j.ypmed.2011.01.021

*Dwyer, T., Blizzard, L., & Dean, K. (1996). Physical activity and performance in children. *Nutrition Reviews*, *54*, S27–S31. doi:10.1111/j.1753-4887.1996.tb03895.x

Eccles, J., Midgley, C., Wigfield, A., Buchanan, C., Reuman, D., Flanagan, C., & Mac Iver, D. (1993). Development during adolescence: The impact of stage-environment fit on young adolescents' experiences in schools and in families. *American Psychologist*, *48*(2), 90–101.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *British Medical Journal*, *315*, 629–634.

Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (2005). Variation and homogeneity in affective responses to physical activity of varying intensities: An alternative perspective on dose–response based on evolutionary considerations. *Journal of Sports Sciences*, *23*, 477–500. doi:10.1080/02640410400021492

Ellis, M. J. (1984). Play, novelty, and stimulus seeking. In T. Yawkey & A. D. Pellegrini (Eds.), *Child's play: Developmental and applied* (pp. 203–218). Hillsdale, NJ: Erlbaum.

*Feldman, D. E., Barnett, T., Shrier, I., Rossignol, M., & Abenhaim, L. (2003). Is physical activity differentially associated with different types of sedentary pursuits? *Archives of Pediatrics & Adolescent Medicine*, *157*, 797–802.

Field, A. P. (2003). The problems in using fixed-effects models of meta-analysis on real-world data. *Understanding Statistics: Statistical Issues in Psychology, Education, and the Social Sciences*, *2*, 105–124. doi:10.1207/S15328031US0202_02

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, *74*, 59–109. doi:10.3102/00346543074001059

Fredrickson, B. L. (1998). What good are positive emotions? *Review of General Psychology*, *2*, 300–319.

Fu, R., Gartlehner, G., Grant, M., Shamliyan, T., Sedrakyan, A., Wilt, T. J., . . . Ismaila, A. (2011). Conducting quantitative synthesis when comparing medical interventions: AHRQ and the Effective Health Care Program. *Journal of Clinical Epidemiology*, *64*, 1187–1197.

Furlan, A. D., Pennick, V., Bombardier, C., van Tulder, M., & the Cochrane Back Review Group. (2009). 2009 updated method guidelines for systematic reviews in the Cochrane Back Review Group. *Spine*, *34*, 1929–1941.

Furlong, M. J., Whipple, A. D., Jean, G. S., Simental, J., Soliz, A., & Punthuna, S. (2003). Multiple contexts of school engagement: Moving toward a unifying framework for educational research and practice. *The California School Psychologist*, *8*, 99–113.

*Gibson, C. A., Smith, B. K., DuBose, K. D., Greene, J. L., Bailey, B. W., Williams, S. L., . . . Sullivan, D. K. (2008). Physical activity across the curriculum: Year one process evaluation results. *International Journal of Behavioral Nutrition and Physical Activity*, *5*, 36. doi:10.1186/1479-5868-5-36

Glennie, E., Bonneau, K., Vandellen, M., & Dodge, K. A. (2012). Addition by subtraction: The relation between dropout rates and school-level academic achievement. *Teachers College Record*, *114*(8), 1–26.

Goldstein, H. (1995). *Multilevel statistical models*. London, UK: Edward Arnold.

*Grieco, L., Jowers, E., & Bartholomew, J. (2009). Physically active academic lessons and time on task: the moderating effect of body mass index. *Medicine and Science in Sport and Exercise*, *41*, 1921–1926. doi:10.1249/MSS.0b013e3181a61495

Hauser, R. M. (2010). Causes and consequences of cognitive functioning across the life course. *Educational Researcher*, *39*, 95–109.

Higgins, J., Altman, D., & Sterne, J. (2011). Chapter 8: Assessing risk of bias in included studies. In J. Higgins & S. Green (Eds.), *Cochrane handbook for systematic reviews of interventions, Version 5.1.0*. Available from http://www.cochrane-handbook.org

Higgins, J., & Green, S. (2011). Analysing data and undertaking meta-analyses. *The Cochrane Library* (Version 5.1.0). Chichester, UK: Wiley.

Higgins, J., Thompson, S., Deeks, J., & Altman, D. (2003). Measuring inconsistency in meta-analyses. *British Medical Journal*, *327*, 557–560. doi:10.1136/bmj.327.7414.557

Hillman, C. H., Pontifex, M. B., Raine, L. B., Castelli, D. M., Hall, E. E., & Kramer, A. F. (2009). The effect of acute treadmill walking on cognitive control and academic achievement in preadolescent children. *Neuroscience*, *159*, 1044–1054. doi:10.1016/j.neuroscience.2009.01.057

*Ho, S. M., & Lee, T. M. (2001). Computer usage and its relationship with adolescent lifestyle in Hong Kong. *Journal of Adolescent Health*, *29*, 258–266.

Howell, A. J. (2009). Flourishing: Achievement-related correlates of students' well-being. *The Journal of Positive Psychology*, *4*, 1–13. doi:10.1080/17439760802043459

*Howie, E. K., Beets, M. W., & Pate, R. R. (2014). Acute classroom exercise breaks improve on-task behavior in 4th and 5th grade students: A dose-response. *Mental Health and Physical Activity*, *7*(2), 65–71. doi:10.1016/j.mhpa.2014.05.002

*Hoza, B., Smith, A. L., Shoulberg, E. K., Linnea, K. S., Dorsch, T. E., Blazo, J. A., . . . McCabe, G. P. (2014). A randomized trial examining the effects of aerobic physical activity on attention-deficit/hyperactivity disorder symptoms in young children. *Journal of Abnormal Child Psychology*, *43*, 655–667. doi:10.1007/s10802-014-9929-y

*Huang, W. Y., Wong, S. H., & Salmon, J. (2013). Correlates of physical activity and screen-based behaviors in Chinese children. *Journal of Science and Medicine in Sport*, *16*, 509–514. doi:10.1016/j.jsams.2012.12.011

*Hunter, L., Abbott, R., Macdonald, D., Ziviani, J., & Cuskelly, M. (2014). Active kids active minds: A physical activity intervention to promote learning? *Asia-Pacific Journal of Health, Sport and Physical Education*, *5*, 117–131. doi:10.1080/18377122.2014.906057

Irwin, J. D. (1997). *The industrial electronics handbook*. Boca Raton, FL: CRC Press.

Janosz, M., Archambault, I., Morizot, J., & Pagani, L. S. (2008). School engagement trajectories and their differential predictive relations to dropout. *Journal of Social Issues*, *64*, 21–40.

Janssen, I., & LeBlanc, A. G. (2010). Systematic review of the health benefits of physical activity and fitness in school-aged children and youth. *International Journal of Behavioral Nutrition and Physical Activity*, *7* (40), 1–16. doi:10.1186/1479-5868-7-40

*Jarrett, O. S., Maxwell, D. M., Dickerson, C., Hoge, P., Davies, G., & Yetley, A. (1998). Impact of recess on classroom behavior: Group effects and individual differences. *The Journal of Educational Research*, *92*, 121–126. doi:10.1080/00220679809597584

Jimerson, S. R., Campos, E., & Greif, J. L. (2003). Toward an understanding of definitions and measures of school engagement and related terms. *The California School Psychologist*, *8*, 7–27.

Joyce, J., Graydon, J., McMorris, T., & Davranche, K. (2009). The time course effect of moderate intensity exercise on response execution and response inhibition. *Brain and Cognition*, *71*, 14–19. doi:10.1016/j.bandc.2009.03.004

*Katz, D. L., Cushman, D., Reynolds, J., Njike, V., Treu, J. A., Walker, J., . . . Katz, C. (2010). Putting physical activity where it fits in the school day: Preliminary results of the ABC (Activity Bursts in the Classroom) for fitness program. *Preventing Chronic Disease*, *7*(4), A82.

*Laberge, S., Bush, P. L., & Chagnon, M. (2012). Effects of a culturally tailored physical activity promotion program on selected self-regulation skills and attitudes in adolescents of an underserved, multiethnic milieu. *American Journal of Health Promotion*, *26*(4), e105–115. doi:10.4278/ajhp.090625-QUAN-202

*Lazarou, C., & Soteriades, E. S. (2009). Physical activity patterns among preadolescent children in Cyprus: The CYKIDS study. *Journal of Physical Activity and Health*, *6*, 185–194.

*Leatherdale, S. T., & Wong, S. L. (2008). Modifiable characteristics associated with sedentary behaviours among youth. *International Journal of Pediatric Obesity*, *3*, 93–101. doi:10.1080/17477160701830879

Lees, C., & Hopkins, J. (2013). Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: A systematic review of randomized control trials. *Preventing Chronic Disease*, *10*, E174. doi:10.5888/pcd10.130010

Liberati, A., Altman, D. G., Tetzlaff, J., Mulrow, C., Gøtzsche, P. C., Ioannidis, J. P., . . . Moher, D. (2009). The PRISMA statement for reporting systematic reviews and meta-analyses of studies that evaluate health care interventions: Explanation and elaboration. *Annals of Internal Medicine*, *151*, W-65–W-94. doi:10.1371/journal.pmed.1000100

Linnenbrink-Garcia, L., & Pekrun, R. (2011). Students' emotions and academic engagement: Introduction to the special issue. *Contemporary Educational Psychology*, *36*, 1–3. doi:10.1016/j.cedpsych.2010.11.004

Lucas, S. R. (2001). Effectively maintained inequality: Education transitions, rrack mobility, and social background effects. *American Journal of Sociology*, *106*, 1642–1690.

*Ma, J. K., Mare, L. L., & Gurd, B. J. (2014). Classroom-based high-intensity interval activity improves off-task behaviour in primary school students. *Applied Physiology, Nutrition, and Metabolism*, *39*(999), 1–6. doi:10.1139/apnm-2014-0125

*Mahar, M. T., Murphy, S., Rowe, D., Golden, J., Shields, A., & Raedeke, T. (2006). Effects of a classroom-based program on physical activity and on-task behavior. *Medicine and Science in Sports and Exercise*, *38*, 2086–2094. doi:10.1249/01.mss.0000235359.16685.a3

Marks, H. M. (2000). Student engagement in instructional activity: Patterns in the elementary, middle, and high school years. *American Educational Research Journal*, *37*, 153–184. doi:10.3102/00028312037001153

Marsh, H. W., Bornmann, L., Mutz, R., Daniel, H.-D., & O'Mara, A. (2009). Gender effects in the peer reviews of grant proposals: A comprehensive meta-analysis comparing traditional and multilevel approaches. *Review of Educational Research*, *79*, 1290–1326. doi:10.3102/0034654309334143

*Martikainen, S., Pesonen, A. K., Lahti, J., Heinonen, K., Tammelin, T., Kajantie, E., . . . Räikkönen, K. (2012). Physical activity and psychiatric problems in children. *Journal of Pediatrics*, *161*, 160–162.e161. Retrieved from http://www.scopus.com/

Martin, A., Saunders, D., Shenkin, S., & Sproule, J. (2014, March). Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. *Cochrane Database System Review*. doi:10.1002/14651858.CD009728.pub2

*McWilliams, L., Sayal, K., & Glazebrook, C. (2013). Inattention and hyperactivity in children at risk of obesity: A community cross-sectional study. *BMJ Open*, *3*(5). doi:10.1136/bmjopen-2013-002871

Mega, C., Ronconi, L., & De Beni, R. (2014). What makes a good student? How emotions, self-regulated learning, and motivation contribute to academic achievement. *Journal of Educational Psychology*, *106*, 121. doi:10.1037/a0033546

*Metzler, M. W., & Williams, S. (2006). *A classroom-based physical activity and academic content program: More than a "pause that refreshes*." Unpublished manuscript, International Life Sciences Institute, Atlanta, GA.

Pekrun, R., & Linnenbrink-Garcia, L. (2012). Academic emotions and student engagement. S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 259–282). New York, NY: Springer.

*Pellegrini, A. D., Huberty, P. D., & Jones, I. (1995). The effects of recess timing on children's playground and classroom behaviors. *American Educational Research Journal*, *32*, 845–864. doi:10.3102/00028312032004845

*Pellegrini, A. D., & Smith, P. K. (1993). School recess: Implications for education and development. *Review of Educational Research*, *63*, 51–67.

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: A review of mental and physical health benefits associated with physical activity. *Current Opinion in Psychiatry*, *18*, 189–193.

Perry, J. C., Liu, X., & Pabian, Y. (2010). School engagement as a mediator of academic performance among urban youth: The role of career preparation, parental career support, and teacher support. *The Counseling Psychologist*, *38*, 269–295. doi:10.1177/0011000009349272

Raudenbush, S. W., & Bryk, A. S. (1985). Empirical Bayes meta-analysis. *Journal of Educational and Behavioral Statistics*, *10*, 75–98.

R Core Team. (2014). *A language and environment for statistical computing*. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from http://www.R-project.org/

Reschly, A. L. (2010). Reading and school completion: Critical connections and Matthew effects. *Reading & Writing Quarterly*, *26*, 67–90. doi:10.1080/10573560903397023

Reschly, A. L., & Christenson, S. L. (2012). Jingle, jangle, and conceptual haziness: Evolution and future directions of the engagement construct. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 3–19). New York, NY: Springer.

Reschly, A. L., Huebner, E. S., Appleton, J. J., & Antaramian, S. (2008). Engagement as flourishing: The contribution of positive emotions and coping to adolescents' engagement at school and with learning. *Psychology in the Schools*, *45*, 419–431. doi:10.1002/pits.20306

*Ridgway, A., Northup, J., Pellegrin, A., LaRue, R., & Hightsoe, A. (2003). Effects of recess on the classroom behavior of children with and without Attention-Deficit Hyperactivity Disorder. *School Psychology Quarterly*, *18*, 253–268.

*Riley, N., Lubans, D., Holmes, K., & Morgan, P. (2014). Rationale and study protocol of the EASY Minds (Encouraging Activity to Stimulate Young Minds) program: Cluster randomized controlled trial of a primary school-based physical activity integration program for mathematics. *BMC Public Health*, *14*, 816.

Roorda, D. L., Koomen, H. M., Spilt, J. L., & Oort, F. J. (2011). The influence of affective teacher–student relationships on students' school engagement and achievement a meta-analytic approach. *Review of Educational Research*, *81*, 493–529. doi:10.3102/0034654311421793

Rosenthal, R. (1991). *Meta-analytic procedures for social research* (Vol. 6). Newbury Park, CA: Sage.

Rosenthal, R. (1994). Parametric measures of effect size. In H. Cooper & L. Hedges (Eds.), *The handbook of research synthesis* (pp. 231–244). New York, NY: Russell Sage Foundation.

Rothstein, H. R., Sutton, A. J., & Borenstein, M. (2006). *Publication bias in meta-analysis: Prevention, assessment and adjustments*. Chichester, UK: Wiley & Sons.

Russell, V. J., Ainley, M., & Frydenberg, E. (2005). *Schooling issues digest: Student motivation and engagement*. Canberra, Australia: Retrieved from http://www.dest.gov.au/sectors/school_education/publications_resources/schooling_issues_digest/schooling_issues_digest_motivation_engagement.htm

Sallis, J. (2000). Age-related decline in physical activity: A synthesis of human and animal studies. *Medicine & Science in Sports & Exercise*, *32*, 1598–1600.

Sattelmair, J., & Ratey, J. J. (2009). Physically active play and cognition. *American Journal of Play*, *3*, 365–374.

*Schnieders-Laber, D. T. (2011). *Exploring second grade student engagement before and after MINDS-In-Motion, MAZE* (Doctoral dissertation). Available from ProQuest Dissertations and Theses database. (UMI No. 3487273)

Shadish, W. R., & Sweeney, R. B. (1991). Mediators and moderators in meta-analysis: There's a reason we don't let dodo birds tell us which psychotherapies should have prizes. *Journal of Consulting and Clinical Psychology*, *59*, 883–893.

Shernoff, D. (2010). Engagement in after-school programs as a predictor of social competence and academic performance. *American Journal of Community Psychology*, *45*, 325–337. doi:10.1007/s10464-010-9314-0

Singh, A., Uijtdewilligen, L., Twisk, J., Mechelen, W., & Chinapaw, M. (2012). Physical activity and performance at school: A systematic review of the literature including a methodological quality assessment. *Archives of Pediatrics and Adolescent Medicine*, *166*, 49–55. doi:10.1001/archpediatrics.2011.716

Skinner, E., Kindermann, T., & Furrer, C. (2009). A motivational perspective on engagement and disaffection conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom. *Educational and Psychological Measurement*, *69*, 493–525. doi:10.1177/0013164408323233

*Smith, A. L., Hoza, B., Linnea, K., McQuade, J. D., Tomb, M., Vaughn, A. J., . . . Hook, H. (2013). Pilot physical activity intervention reduces severity of ADHD symptoms in young children. *Journal of Attention Disorders*, *17*, 70–82. doi:10.1177/1087054711417395

Sterne, J., Egger, M., & Moher, D. (2011). Chapter 10: Addressing reporting biases. In J. Higgins & S. Green (Eds.), *Cochrane handbook for systematic reviews of intervention. Version 5.1.0 (updated March 2011)*. The Cochrane Collaboration. Available from http://www.cochrane-handbook.org.

Suldo, S. M., Riley, K. N., & Shaffer, E. J. (2006). Academic correlates of children and adolescents' life satisfaction. *School Psychology International*, *27*, 567–582. doi:10.1177/0143034306073411

Swain, D. P., & Franklin, B. A. (2006). Comparison of cardioprotective benefits of vigorous versus moderate intensity aerobic exercise. *The American Journal of Cardiology*, *97*, 141–147. doi:10.1016/j.amjcard.2005.07.130

*Telles, S., Singh, N., Bhardwaj, A. K., Kumar, A., & Balkrishna, A. (2013). Effect of yoga or physical exercise on physical, cognitive and emotional measures in children: A randomized controlled trial. *Child and Adolescent Psychiatry and Mental Health*, *7*, 37. doi:10.1186/1753-2000-7-37

Troiano, R., Gabriel, K., Welk, G., Owen, N., & Sternfeld, B. (2012). Reported physical activity and sedentary behavior: Why do you ask? *Journal of Physical Activity and Health*, *9*, 68–75.

Trost, S. (2007). State of the art reviews: Measurement of physical activity in children and adolescents. *American Journal of Lifestyle Medicine*, *1*, 299–314. doi:10.1177/1559827607301686

Upadyaya, K., & Salmela-Aro, K. (2013). Development of school engagement in association with academic success and well-being in varying social contexts: A review of empirical research. *European Psychologist*, *18*, 136–147. doi:10.1027/1016-9040/a000143

*Utter, J., Neumark-Sztainer, D., Jeffery, R., & Story, M. (2003). Couch potatoes or french fries: Are sedentary behaviors associated with body mass index, physical activity, and dietary behaviors among adolescents? *Journal of the American Dietetic Association*, *103*, 1298–1305. doi:10.1053/S0002-8223(03)01079-4

Van Den Noortgate, W., & Onghena, P. (2003). Multilevel meta-analysis: A comparison with traditional meta-analytical procedures. *Educational and Psychological Measurement*, *63*, 765–790. doi:10.1177/0013164403251027

Van Dijk, M. L., De Groot, R., Savelberg, H., Van Acker, F., & Kirschner, P. A. (2014). The association between objectively measured physical activity and academic achievement in Dutch adolescents: Findings from the GOALS study. *Journal of Sport & Exercise Psychology*, *36*, 460–473. doi:10.1123/jsep.2014-0014

*Vazou, S., Gavrilou, P., Mamalaki, E., Papanastasiou, A., & Sioumala, N. (2012). Does integrating physical activity in the elementary school classroom influence academic motivation? *International Journal of Sport & Exercise Psychology*, *10*(4), 251–263. doi:10.1080/1612197X.2012.682368

*Wang, C. K. J., Chia, Y. H. M., Quek, J. J., & Liu, W. C. (2006). Patterns of physical activity, sedentary behaviors, and psychological determinants of physical activity among Singaporean school children. *International Journal of Sport & Exercise Psychology*, *4*, 227–249. doi:10.1080/1612197X.2006.9671797

Wang, M., & Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal*, *47*, 633–662. doi:10.3102/0002831209361209

Wang, M., & Peck, S. (2013). Adolescent educational success and mental health vary across school engagement profiles. *Developmental Psychology*, *49*, 1266–1276. doi:10.1037/a0030028

*Whitt-Glover, M. C., Ham, S. A., & Yancey, A. K. (2011). Instant Recess (R): A practical tool for increasing physical activity during the school day. *Progress in Community Health Partnerships*, *5*, 289–297. doi:10.1353/cpr.2011.0031

*Woehrle, T., Fox, S., & Hoskin, B. (2005). An examination of the balanced school day schedule. *Ontario Action Researcher*, *8* (3).

Wylie, C., & Hodgen, E. (2012). Trajectories and patterns of student engagement: Evidence from a longitudinal study. In S. L. Christenson, A. L. Reschly, & C. Wylie (Eds.), *Handbook of research on student engagement* (pp. 585–599). New York, NY: Springer.

*Yu, C. C. W., Chan, S., Cheng, F., Sung, R. Y. T., & Hau, K. T. (2006). Are physical activity and academic performance compatible? Academic achievement, conduct, physical activity and self-esteem of Hong Kong Chinese primary school children. *Educational Studies*, *32*, 331–341. doi:10.1080/03055690600850016

*Zan, G. (2013). The impact of an exergaming intervention on urban school children's physical activity levels and academic outcomes. *Asian Journal of Exercise & Sports Science*, *10*(2), 1–10.

Zhang, Y., Zhang, D., Jiang, Y., Sun, W., Wang, Y., Chen, W., . . . Zhang, J. (2015). Association between physical activity and teacher-reported academic performance among fifth-graders in Shanghai: A quantile regression. *PloS One*, *10*(3), e0115483.