Regular Physical Activity and Educational Outcomes in Youth: A Longitudinal Study

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Abstract

Purpose. The objectives of this study were to to determine whether longitudinal changes in accelerometer-assessed moderate to vigorous physical activity (MVPA) were associated with changes in educational outcomes (i.e., academic performance and mathematics engagement), and to examine whether the association was non-linear.

Methods. Longitudinal data was collected from 2,194 Australian adolescents (mean age = 13.40 years, SD = .73) at two timepoints (Term 1 2014 and Term 2 2015). 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 performance.

Results. Latent change score models indicated that increases in MVPA had a positive quadratic association with NAPLAN scores in girls (β = .39, p < .001), but not boys. In comparison, cross-sectional regression analyses indicated that MVPA had a positive quadratic association with NAPLAN scores in Grade 7 (β = .92, p = .04) boys and Grade 9 boys (β = .60, p = .06), but not girls. There was a also positive quadratic association between MVPA and school engagement for Grade 9 boys (β = .77, p = .03).

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

Implications and Contribution

The findings of this study suggest that physical activity is associated with academic performance in adolescents. However, adolescents need to participate in physical activity for the health and educational benefits, without compromising time spent on study and homework.

Introduction

Students who are engaged in school, that is, those who actively participate in school activities (behaviorally engaged), enjoy school (emotionally engaged), and are psychologically invested in school (cognitively engaged) are healthier than those who are less engaged with school (1, 2). School engagement is one of the most critical factors underpinning academic performance (3), the successful transition into post-school education, and the completion of post-school education (1, 4). An individual's level of educational attainment is associated with inequities across many health outcomes (5). For example, educational attainment is associated with decreased psychological stress and decreased health risk behaviors (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 socio-economic status (SES) (6) and post transition from one level of schooling to another (this usually occurs during early adolescence; 7). Thus, identifying the modifiable determinants of school engagement, especially for adolescents from areas of low SES, is 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 (8-11). These reviews included a total of 32 studies and reported a positive association between physical activity and academic performance. Castelli, Centeio (8) 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, Uijtdewilligen (11) 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 (9) examined three randomized controlled trials and found that physical activity had a small positive effect on academic performance in children. Similarly, Martin, Saunders (10) synthesized 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. 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 and these few studies have found conflicting results (12-16). Second, most of this evidence is limited to cross-sectional study designs. Only one longitudinal study examined the association between accelerometer-assessed moderate to vigorous physical activity (MVPA) and standardised test scores (17). 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; thus, 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, which could lead to improvements in educational outcomes that may take time to manifest (18).

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) (19). 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 (19), there are limitations to the included studies. First, only one study used accelerometers to measure physical activity (20). 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, specifically mathematics engagement). A secondary objective of this study was to examine whether the association between accelerometer-assessed MVPA and academic performance and achool engagement was non-linear.

Methods

Participants

Year 8 students were recruited from 14 secondary schools located in the Western Sydney region of Australia. Western Sydney is a low socioeconomic area and schools needed to have a Socio-Economic Index for Areas index <6 to be eligible to participate. The index ranges from 1 to 10 and low scores indicate that an area has relative disadvantage in terms of education and income. Within these schools, all Year 8 students without any pre-existing injuries or illnesses were eligible to participate. Of the students, 9% were aboriginal or Torres Strait Islander origin, 27% were born overseas, and 26% spoke a language other than English most of the time at home.

Procedure

A university ethics committee and the New South Wales Department of Education and Communities granted approval for this study. Parents or guardians provided informed written consent, and students provided informed written assent. We collected data at two time points: Time 1 during Term 1 2014 (January-April) when students were in Year 8 and Time 2 during Term 2 2015 (April-June), when students were in Grade 9. Term 1 2014 was 10 weeks in duration and Term 2 2015 was 9 weeks. Data collection for each school was staggered across the term due to equipment constraints. Trained research assistants collected all data. Students were instructed to wear accelerometer (Actigraph GT3X) for seven consecutive days, removing the device only for sleep or if it could get wet (i.e., in the shower or during swimming activities) to assess regular MVPA. During this seven-day period, students responded to a multi-section questionnaire following a mathematics lesson. Following the questionnaire, trained research assistants measured students' height and weight. We then linked this data with students' National Assessment Program- Literacy and Numeracy (NAPLAN) data from Grade 7 and Grade 9.

Measures

Objectively-assessed regular moderate-to-vigorous physical activity

Accelerometers (Actigraph GT3X+) were used to quantify adolescents' regular MVPA. Accelerometers have been shown to provide a valid measure of the frequency, duration, and intensity of physical activity in adolescents (21). Students were asked to wear the accelerometer for seven consecutive days. To increase the weartime compliance, trained research assistants delivered clear and standardised initial instructions during a classroom lesson, students received an SMS text message each morning reminding them to wear the accelerometer, and teachers were asked to provide verbal reminders to students regarding wearing the accelerometer and returning the device on the designated return day.

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 behavior as there is strong between-day intraclass reliability over a seven day period (22). We processed all accelerometer data using ActiLife software (Version 6, ActiGraph, LLC, Fort Walton Beach, FL). First, we filtered out all non-wear time, that is time that the student had removed the accelerometer. We defined non-wear time as blocks of time greater than 30 minutes of consecutive zero counts. Next, due to the differing individual wear times, we calculated the proportion of wear time (%) spent in MVPA. We defined MVPA as ≥ 2296 counts per minute. Counts result from summing accelerometer values (raw data at 30hz) and vary depending on the frequency and intensity of activity. This definition of MVPA has been shown to be the most accurate in adolescents (23).

Mathematics engagement

The School Engagement Scale (24) was used to assess typical engagement towards mathematics, including behavioral (e.g., classroom behavior), emotional (e.g., lesson enjoyment), and cognitive (e.g., problem solving) aspects of engagement. This version of the scale has shown good internal consistency (α.=..75 to..87) . The questionnaire is divided into three subscales that measure typical behavioral (e.g., “When I am in maths I just act as if I am working”), cognitive (e.g., “I check my maths work for mistakes”), and emotional (e.g., “I feel excited by the work during maths lessons”) mathematics engagement, and each item is rated on a five-point Likert scale.

Academic performance

To assess academic performance we obtained Grade 7 (2013) and Grade 9 (2015) NAPLAN numeracy scores from the New South Wales (NSW) Department of Education. NAPLAN is a national standardised test given to all students in Australia in Grades 3, 5, 7, and 9 (25). As NAPLAN is a national standardised test, it is only administered every two years and so the timing of the first NAPLAN assessment (May, 2013) does not exactly align with the first time point of data collection (January-April, 2014). Each year, the median NAPLAN score is 500 across the school population (i.e., all year groups)., and approximately two thirds of student’s scores are within 100 points of the average score for that year. In 2013, the mean NAPLAN score for all Grade 7 students in Australia was 542, and in 2015 the mean NAPLAN score for the same cohort (in Grade 9) was 592.

Covariates

Covariates included age, gender, body mass index (BMI), ethnicity, SES, and seasonality. Students indicated their age, gender, and ethnicity. Weight and height were measured by trained research assistants, using a stadiometer (Surgical and Medical Products No 26SM, Medtone Education Supplies, Melbourne, Australia) and digital scales (UC-321, A&D Company, LTD, Tokyo, Japan). BMI and BMI z-scores were calculated using the Australian Government (26) formula: weight (kg)/height (m^2). Students also responded to an adapted version of the Family Affluence Scale II to assess individual level SES (27). Seasonality was defined as the month that the student wore the accelerometer.

Data Analysis

All analyses were conducted using R software (28). We calculated descriptive statistics and used alpha coefficients to assess the internal consistency of the School Engagement Scale.

As the relationship between physical activity and its outcomes tends to be complicated, [20] we tested for both linear and quadratic relationships. We employed latent change score models to determine whether linear or quadratic changes in MVPA were associated with changes in NAPLAN scores (Figure 1) and mathematics engagement (Figure 2). In latent change score models, change is defined as the time ordered influence of one variable on another variable (29). 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 Grade 7 to Grade 9 and (ii) change in mathematics engagement from Time 1 to Time 2.

Latent change score models were estimates using lavaan (30) in R (28). Models were estimated using the robust maximum likelihood estimator, which is robust to data nonnormality. Due to the clustered nature of the data, all models accounted for classes nested within schools.

To examine the fit of the models, we examined the variance (R^2) of the change in the educational outcomes explained by change in MVPA.

We then conducted linear regression analyses to explore the association between MVPA and academic performance and school engagement. We added a quadratic term for MVPA to the model and adjusted for confounders, including age, BMI, ethnicity,SES, and seasonality.

Missing data was handled using full information maximum likelihood (FIML) so that all available information could be used to estimate parameter values and standard errors. The most common reasons for missing data at each timepoint were students being absent from school during data collection or students not meeting the accelerometer wear time criteria. Of the 1,806 Year 8 students enrolled across the 14 schools, 1,421 (78.7%) gave assent and parental consent. 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. Given that the data used was panel data we have good reason to believe that missing data is largely missing at random (conditioned on the time 1 data) and thus FIML was appropriate. However, even in cases where data are not missing at random FIML provides reasonable estimates {Enders, 2010 #943}. Power analysis indicated that a sample size of 831 would be large enough to detect an effect size of .13 with 80% power and an alpha of 5%. This calculation was conservatively based on result of the meta-analysis with the smallest effect that combined evidence from studies that examined the association between physical activity and an educational outcome (i.e., *d* = .13 for the relationship between MVPA and academic achievement (31).

Results

Descriptive Statistics

The alpha coefficients for the scores derived from the mathematics engagement subscale ranged from .74 to .91. As such, the mathematics engagement subscales were considered to be internally reliable (32).

Means, standard deviations, rank-order consistency, and gender differences are displayed in Table 1. 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 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 (33). Similarly, at Time 2, 76% of adolescents did not meet the global recommendations.

The rank-order consistency of MVPA was moderate, indicating considerable change over the two time points (0.52 for boys and 0.50 for girls). Similarly, the rank-order consistency of mathematics engagement was moderate, indicating considerable change (0.48 for boys and 0.50 for girls). The rank-order consistency of NAPLAN scores was very strong, indicating very little change in relative position over the two time points (0.84 for boys and 0.83 for girls). There were no significant differences in MVPA, academic performance, or mathematics engagement between students who met the accelerometer wear criteria and those who did not meet the criteria at each timepoint.

Main Findings

Longitudinal associations

The longitudinal associations between MVPA and educational outcomes are reported in Table 2. Changes in MVPA had a positive quadratic association with NAPLAN scores in girls ($\beta = .39$, $p < .001$), but not boys. Changes in MVPA had no significant association with changes in mathematics engagement in boys or girls.

Cross-sectional associations

The associations between MVPA and educational outcomes are reported in Table 3. There was a positive quadratic association between MVPA and NAPLAN scores in Grade 7 boys ($\beta = .92$, $p = .04$) and Grade 9 boys ($\beta = .60$, $p = .06$). Similarly, there was a positive quadratic association between MVPA and school engagement for Grade 9 boys ($\beta = .77$, $p = .03$). There were no significant associatons for girls.

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 mathematics engagement). The secondary objective was to examine whether the association between accelerometer-assessed MVPA and academic performance and achool engagement was non-linear. We found that increases in accelerometer-assessed MVPA over time were associated with improvements in academic performance in girls, but not boys. Cross-sectional associations differed from longitudinal associations, as MVPA had a postivie quadratic association with academic performance and mathematics engagement in boys, but not girls.

Longitudinal associations

Our study indicates that changes in MVPA had a positive quadratic association with changes in NAPLAN scores in girls, suggesting that as MVPA increases NAPLAN scores increase at an increasing rate. Increased regular total MVPA leads to improved fitness or cognitive function over time, which have both been linked with academic performance (18, 34). There is some evidence that fitness could mediate the association between MVPA and academic performance, as fitter students tend to perform better academically (34). There is also some evidence that cognitive function could mediate this relationship (18). A systematic review found that physical activity is positively associated with cognitive function, including memory, perceptual skills, and intelligence. There is also substantial evidence that cognitive function is positively associated with academic performance (18). Future research is needed that examines whether fitness or cognitive function mediate the association between regular total MVPA and academic performance that we observed in this study.

Changes in MVPA did not have a positive quadratic assoction with changes in NAPLAN scores in boys. One possible explanation for this finding is that boys had higher initial levels of MVPA, and large increases in MVPA may have taken time away from homework and study. Two previous studies have found that spending large amounts of time participating in MVPA takes time away from studying and homework and can hurt academic performance (12, 13). Future research is needed to determine whether time spent studying and doing homework mediates the negative association between regular physical activity and academic performance.

Cross sectional associations

There was a positive quadratic association between MVPA and NAPLAN scores in boys, suggesting that as MVPA increases NAPLAN scores increase at an increasing rate. The differening types of MVPA that boys and girls participate in could explain why the positive quadratic association was only found in boys. Boys tend to participate in more team sports such as soccer and football, while girls tend to participate in individual sports such as running and aerobics (35). Team sports have many additional benefits including improving communication, decision making skills, teamwork, self-esteem, and a sense of community (36). These benefits likely extend into the classroom and could explain why MVPA appears to be more beneficial for boys compared to girls. Future research is needed that examines the relationship between different types of activities and educational outcomes.

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 (39). 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 (40). Future research should assess the relationship between physical activity and academic performance across a wider range of academic subjects (e.g., literacy). Second, as the mathematics engagement questionnaire was a subjective measure, it could be subject to social desirability. Third, 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. 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. Third, although accelerometers provide an objective measure of the frequency, duration, and intensity of physical activity, they do not have the ability to measure swimming, cycling, or many strength training activities (23). Fourth, the timing of Time 1 physical activity data collection (January-April 2014) did not line up with the Grade 7 NAPLAN assessment (May 2013). This means that we examined change in physical activity over a 1.5 year period and change in NAPLAN scores over a 2 year period. This was an opportunistic study which meant that 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 (rank order consistency = 0.88), 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 (41, 42). 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

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

References

[1] Abbott-Chapman J, Martin K, Ollington N, et al. The longitudinal association of childhood school engagement with adult educational and occupational achievement: findings from an Australian national study. British Educational Research Journal 2014;40:102-120.
[2] Carter M, McGee R, Taylor B, et al. Health outcomes in adolescence: Associations with family, friends and school engagement. J Adolesc 2007;30:51-62.
[3] Wang M, Holcombe R. Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. American Educational Research Journal 2010;47:633-662.
[4] Suldo SM, Riley KN, Shaffer EJ. Academic correlates of children and adolescents' life satisfaction. School Psychology International 2006;27:567-582.
[5] Australian Bureau of Statistics. Health literacy. Available at: http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/4102.0Main+Features20June+2009.
[6] Fredricks J, Blumenfeld P, Paris A. School engagement: Potential of the concept, state of the evidence. Review of Educational Research 2004;74:59-109.
[7] Martin A. Age appropriateness and motivation, engagement, and performance in high school: Effects of age within cohort, grade retention, and delayed school entry. J Educ Psychol 2009;101:101-114.
[8] Castelli D, Centeio E, Hwang J, et al. The history of physical activity and academic performance research: Informing the future. Monographs of the Society for Research in Child Development 2014;79:119-148.
[9] Lees C, Hopkins J. Effect of aerobic exercise on cognition, academic achievement, and psychosocial function in children: a systematic review of randomized control trials. Prev Chronic Dis 2013;10:E174.
[10] Martin A, Saunders D, Shenkin S, et al. Lifestyle intervention for improving school achievement in overweight or obese children and adolescents. The Cochrane Library 2014;14:1-95.
[11] Singh A, Uijtdewilligen L, Twisk J, et al. Physical activity and performance at school: A systematic review of the literature including a methodological quality assessment. Arch Pediatr Adolesc Med 2012;166:49-55.
[12] Esteban-Cornejo I, Tejero-González C, Martinez-Gomez D, et al. Objectively measured physical activity has a negative but weak association with academic performance in children and adolescents. Acta Paediatrica 2014;103:e501-e506.
[13] Van Dijk ML, De Groot R, Savelberg H, et al. The association between objectively measured physical activity and academic achievement in Dutch adolescents: Findings from the GOALS study. J Sport Exerc Psychol 2014;36:460-473.
[14] Harrington SA. Relationships of objectively measured physical activity and sleep with BMI and academic outcomes in 8-year-old children. Appl Nurs Res 2013;26:63-70.
[15] LeBlanc MM, Martin CK, Han H, et al. Adiposity and physical activity are not related to academic achievement in school-aged children. J Dev Behav Pediatr 2012;33:486-494.
[16] Syväoja H, Kantomaa MT, Ahonen T, et al. Physical Activity, Sedentary Behavior, and Academic Performance in Finnish Children. Med Sci Sports Exerc 2013;45:2098-2104.
[17] Booth J, Leary S, Joinson C, et al. Associations between objectively measured physical activity and academic attainment in adolescents from a UK cohort. Br J Sports Med 2013;6:212-219.
[18] Sibley BA, Etnier JL. The relationship between physical activity and cognition in children: A meta-analysis. Pediatr Exerc Sci 2003;15:243-256.
[19] Owen K, Parker P, Van Zenden B, et al. Physical activity and school engagement in youth: A systematic review and meta-analysis. Educ Psychol 2016;51:129-145.
[20] Martikainen S, Pesonen AK, Lahti J, et al. Physical activity and psychiatric problems in children. J Pediatr 2012;161:160-162.

[21] Ridgers N, Fairclough S. Assessing free-living physical activity using accelerometry: Practical issues for researchers and practitioners. European Journal of Sport Science 2011;11:205-213.
[22] Nader PR, Bradley RH, Houts RM, et al. Moderate-to-vigorous physical activity from ages 9 to 15 years. J Am Med Assoc 2008;300:295-305.
[23] Trost S, Loprinzi P, Moore R, et al. Comparison of accelerometer cut points for predicting activity intensity in youth. Med Sci Sports Exerc 2011;43:1360-1368.
[24] Fredricks J, Blumenfeld P, Friedel J, et al. School engagement. In: Moore KA, Lippman L, eds. What do Children Need to Flourish?: Conceptualizing and Measuring Indicators of Positive Development. New York, NY: Springer Science and Business Media, 2005:305-321.
[25] Australian Curriculum AaRA. National Assessment Program—Literacy and Numeracy: Achievement in reading, writing, language conventions and numeracy. National report for 2010. Sydney: ACARA, 2012.
[26] Australian Government. About Overweight and Obesity. In: Health Do, ed. Canberra: Department of Health, 2009.
[27] Currie C, Molcho M, Boyce W, et al. Researching health inequalities in adolescents: the development of the Health Behaviour in School-Aged Children (HBSC) family affluence scale. Soc Sci Med 2008;66:1429-1436.
[28] R Core Team. A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing, 2014.
[29] McArdle JJ, Prindle JJ. A latent change score analysis of a randomized clinical trial in reasoning training. Psychol Aging 2008;23:702.
[30] Rosseel Y. lavaan: An R package for structural equation modeling. Journal of Statistical Software 2012;48:1-36.
[31] Hattie J, Clinton J. Physical activity is not related to performance at school. Arch Pediatr Adolesc Med 2012;166:678-679.
[32] Nunnally J, Bernstein I. Psychometric theory 3'edition'. New York, NY: McGraw-Hill, 1994.
[33] World Health Organisation. Global strategy on diet, physical activity and health. Geneva: World Health Organisation, 2010.
[34] Kwak L, Kremers SP, Bergman P, et al. Associations between physical activity, fitness, and academic achievement. J Pediatr 2009;155:914-918. e911.
[35] Aaron DJ, Storti KL, Robertson RJ, et al. Longitudinal study of the number and choice of leisure time physical activities from mid to late adolescence: implications for school curricula and community recreation programs. Archives of Pediatrics & Adolescent Medicine 2002;156:1075-1080.
[36] Eime RM, Young JA, Harvey JT, et al. A systematic review of the psychological and social benefits of participation in sport for children and adolescents: informing development of a conceptual model of health through sport. International Journal of Behavioral Nutrition and Physical Activity 2013;10:98.
[37] Atkin AJ, Gorely T, Biddle S, et al. Critical hours: physical activity and sedentary behavior of adolescents after school. Pediatr Exerc Sci 2008;20:446-456.
[38] Lazarou C, Soteriades ES. Physical activity patterns among preadolescent children in Cyprus: the CYKIDS study. Journal of Physical Activity & Health 2009;6:185-194.
[39] Sylvia LG, Bernstein EE, Hubbard JL, et al. Practical guide to measuring physical activity. Journal of the Academy of Nutrition and Dietetics 2014;114:199-208.
[40] Duncan GJ, Dowsett CJ, Claessens A, et al. School readiness and later achievement. Developmental Psychology 2007;43:1428-1462.
[41] Telford RM, Telford RD, Cunningham RB, et al. Longitudinal patterns of physical activity in children aged 8 to 12 years: the LOOK study. Int J Behav Nutr Phys Act 2013;10:81.
[42] Resaland GK, Moe VF, Aadland E, et al. 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 non-communicable diseases. BMC public health 2015;15:1.

Table 1: Descriptive Characteristics

Characteristic	Time 1 M (SD)	Time 2 M (SD)
Age		
Male	12.98 (0.53)	14.12 (0.46)
Female	12.86 (0.54)	14.00 (0.46)
Height (cm)		
Male	160.96 (8.49)	164.69 (8.22)
Female	158.22 (6.81)	158.82 (6.72)
Weight (kg)		
Male	57.78 (15.10)	61.81 (16.02)
Female	55.71 (14.84)	57.60 (13.90)
BMI		
Male	22.14 (4.78)	22.63 (4.95)
Female	22.12 (4.94)	22.74 (4.54)
Physical activity minutes		
Moderate-to-vigorous intensity		
Male	52.08 (20.84)	50.51 (22.84)
Female	41.39 (16.03)	39.54 (17.10)
Vigorous intensity		
Male	21.96 (12.22)	21.51 (14.26)
Female	14.99 (7.98)	13.84 (8.86)
Moderate intensity		
Male	30.12 (11.25)	28.99 (11.57)
Female	26.39 (10.10)	25.70 (10.46)
Light intensity		
Male	84.83 (28.00)	75.00 (24.97)
Female	81.27 (24.70)	73.23 (24.50)
Sedentary		
Male	518.20 (131.73)	486.58 (137.93)
Female	573.74 (117.95)	560.62 (134.71)
School engagement		
Male	3.24 (0.76)	3.32 (0.76)
Female	3.24 (0.71)	3.27 (0.74)
NAPLAN		
Male	520.39 (76.06)	576.04 (70.55)
Female	518.72 (75.88)	572.16 (71.02)

Table 2

Cross-sectional associations between MVPA and educational outcomes in adolescents living in low socioeconomic areas in Western Sydney, Australia

	NAPLAN			Mathematics engagement		
	β	SE	*p* value	β	SE	*p* value
Time 1						
Males						
Linear	-1.19	.39	< .01	-.30	.34	.38
Quadratic	.92	.45	.04	.21	.40	.59
Females						
Linear	-.46	.57	.91	.51	.38	.18
Quadratic	-.46	.57	.42	-.75	.47	.11
Time 2						
Males						
Linear	-.82	.31	< .01	-.82	.33	.01
Quadratic	.60	.32	.06	.77	.36	.03
Females						
Linear	-.39	.29	.18	.17	.27	.53
Quadratic	.12	.31	.69	-.35	.33	.29

Note. Models adjusted for age, BMI, ethnicity, SES and seasonality.

Table 2

Longitudinal associations between MVPA and educational outcomes in adolescents living in low socioeconomic areas in Western Sydney, Australia

	NAPLAN			Mathematics engagement		
	β	SE	*p* value	β	SE	*p* value
Males						
Linear	.00	.20	.99	-.29	.20	.13
Quadratic	.22	.18	.24	.21	.18	.24
Females						
Linear	-.30	.11	<.01	.11	.22	.62
Quadratic	.39	.09	<.001	-.09	.22	.67
Overall						
Linear	-.10	.05	.03	-.09	.04	.03
Quadratic	.27	.02	<.001	.03	.03	.30

Note. Models adjusted for age, BMI, ethnicity, SES and seasonality.

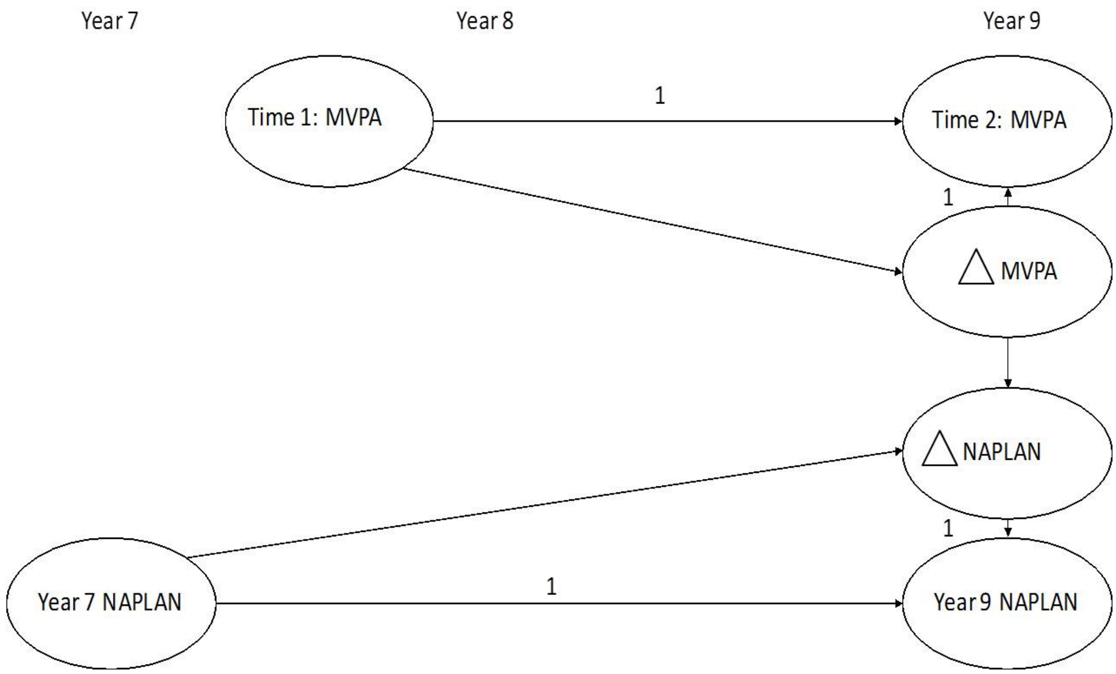

Figure 1. Latent change model: Moderate-to-vigorous physical activity and NAPLAN scores

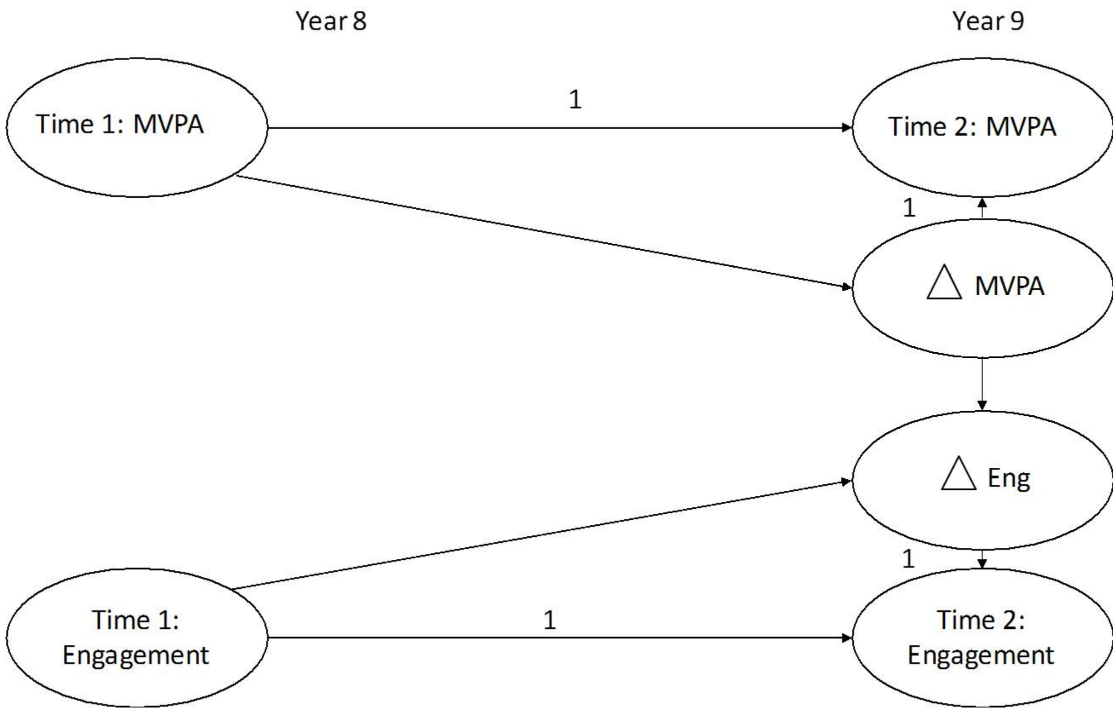

Figure 2. Latent change model: Moderate-to-vigorous physical activity and mathematics engagement