REVIEW ARTICLE

# Physical Activity and Performance at School

## *A Systematic Review of the Literature Including a Methodological Quality Assessment*

*Amika Singh, PhD; Léonie Uijtdewilligen, MSc; Jos W. R. Twisk, PhD; Willem van Mechelen, PhD, MD; Mai J. M. Chinapaw, PhD*

**Objective:** To describe the prospective relationship between physical activity and academic performance.

**Data Sources:** Prospective studies were identified from searches in PubMed, PsycINFO, Cochrane Central, and Sportdiscus from 1990 through 2010.

**Study Selection:** We screened the titles and abstracts for eligibility, rated the methodological quality of the studies, and extracted data.

**Main Exposure:** Studies had to report at least 1 physical activity or physical fitness measurement during childhood or adolescence.

**Main Outcome Measures:** Studies had to report at least 1 academic performance or cognition measure during childhood or adolescence.

**Results:** We identified 10 observational and 4 intervention studies. The quality score of the studies ranged from 22% to 75%. Two studies were scored as high quality. Methodological quality scores were particularly low for the reliability and validity of the measurement instruments. Based on the results of the best-evidence synthesis, we found evidence of a significant longitudinal positive relationship between physical activity and academic performance.

**Conclusions:** Participation in physical activity is positively related to academic performance in children. Because we found only 2 high-quality studies, future high-quality studies are needed to confirm our findings. These studies should thoroughly examine the dose-response relationship between physical activity and academic performance as well as explanatory mechanisms for this relationship.

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**Author Affiliations:** Department of Public and Occupational Health, EMGO Institute for Health and Care Research (Drs Singh, van Mechelen, and Chinapaw and Ms Uijtdewilligen), and Department of Clinical Epidemiology and Biostatistics (Dr Twisk), Vrije Universiteit (VU) University Medical Center, and Department of Methodology and Applied Biostatistics, Institute of Health Sciences, VU University (Dr Twisk), Amsterdam, the Netherlands.

PHYSICAL ACTIVITY AND SPORTS are generally promoted for their positive effect on children's physical health; regular participation in physical activity in childhood is associated with a decreased cardiovascular risk in youth and adulthood.[1] There is also a growing body of literature suggesting that physical activity has beneficial effects on several mental health outcomes, including health-related quality of life and better mood states.[1]

In addition to the positive physical and mental health impact of physical activity, there is a strong belief that regular participation in physical activity is linked to enhancement of brain function and cognition,[2] thereby positively influencing academic performance. There are several hypothesized mechanisms for why exercise is beneficial for cognition, including (1) increased blood and oxygen flow to the brain[3]; (2) increased levels of norepinephrine and endorphins,[4,5] resulting in a reduction of stress and an improvement of mood[6]; and (3) increased growth factors that help to create new nerve cells and support synaptic plasticity.[7,8] Besides these suggested physiological effects, regular participation in sport activities may improve children's behavior in the classroom, increasing the odds of better concentration on the academic content of these lessons.

Although schools are able to offer unique opportunities for structured physical activity for children, there is a tendency to cut back physical education lessons. The increasing pressures to improve academic scores often lead to additional instructional time for subjects such as mathematics and language at the cost of time for being physically active.

Given the suggested relationship and the ongoing discussions on the replacement of physical education lessons by academic subjects, we aimed to review the evidence on the longitudinal relationship between these 2 variables.

Two previous reviews[9,10] have studied the influence of physical activity on academic performance. Trudeau and Shephard[9] present an overview of the literature on the relationship between physical activity in the school setting and sev-

eral outcome measures, including academic performance. Based on quasi-experimental data, they report that physical education programs demand a substantial reduction in time allocated for academic tuition. Because the children's academic performance did not change, they conclude that learning efficiency had improved. Furthermore, Trudeau and Shephard report that cross-sectional studies generally indicate a positive association between physical activity and academic achievement.

The review by Taras[10] argues that there may be some acute beneficial effects of physical activity, but the long-term improvement of academic achievement is not well established. Taras concludes that the acute cognitive benefits of physical activity may adequately compensate for time spent away from academic areas.

To summarize, the literature provides inconclusive evidence on the positive longitudinal relationship between physical activity and academic performance. However, there is a strong general belief that this relationship is present, and research in this area is ongoing.

No systematic review with the specific focus on the longitudinal relationship between general physical activity and academic performance has been performed. Therefore, we present in this article the results of a systematic review of the literature, examining this longitudinal relationship. We include only prospective data and take into account the methodological quality of the studies.

## METHODS

### SELECTION OF THE LITERATURE

We performed a computerized search in 4 electronic bibliographic databases (PubMed, PsycINFO, Cochrane Central, and Sportdiscus) from 1990 through 2010, using search terms suitable to each specific database. The search strategy consisted of 3 elements: (1) physical activity (eg, *physical activity, exercise, physical fitness,* and *sport*); (2) academic achievement (eg, *academic achievement, cognition, academic performance,* and *school learning*); and (3) age (eg, *child, infant, adolescent,* and *0-18 years old*). These terms were used as MeSH (Medical Subject Headings) and free text words in all databases. The full search strategy can be obtained on request.

### INCLUSION CRITERIA

Studies were included if they were prospective studies (observational cohorts and intervention studies) examining the longitudinal relationship between physical activity and academic performance in young people. Eligible studies described (1) at least 1 physical activity or physical fitness measurement during childhood or adolescence and (2) at least 1 academic achievement or cognition measure during childhood or adolescence. We included only full-text articles published after 1990 in English-language peer-reviewed journals.

### SELECTION PROCESS

First, a single reviewer (L.U.) checked all titles and abstracts of articles identified through the search process to identify potentially relevant articles. In case of uncertainty, a second reviewer (A.S.) screened the article. In total, 14 studies fulfilled all inclusion criteria.

### DATA EXTRACTION

The first reviewer (L.U.) extracted data from the identified studies, including (1) the study population, (2) the study design, (3) a measure of physical activity and academic achievement/cognition, and (4) main results.

### METHODOLOGICAL QUALITY ASSESSMENT

Both reviewers (A.S. and L.U.) independently scored the included studies. Disagreements were discussed and resolved.

The methodological quality of the included studies was scored on the basis of a criteria list that was adapted from the criteria lists developed for observational longitudinal studies[11,12] and for prognosis studies in systematic reviews.[13] The criteria list (eTable 1; http://www.archpediatrics.com) included 11 items and assessed the methodological quality in the following 4 dimensions: (1) participation rate (n=1), (2) study attrition (n=3), (3) data collection (n=4), and (4) data analysis (n=3). The criteria answer format included positive, negative, and don't know. We gave a positive score if the publication provided an informative description of the criterion at issue and met the quality criterion. A negative score was given in case of an informative description but an inadequate performance. In case of no or insufficient information, we scored the quality item at issue with a question mark. If the study referred to another publication containing relevant information about the same study, we retrieved the additional publication to score the criterion of concern. In case we were not able to decide on the rating of a criterion based on the information in the publication, we contacted the authors for additional information or clarification. If the information could not be retrieved, a question mark was given.

For each study, we calculated the percentage of items that a study scored positively on methodological quality. A study was considered to be of high methodological quality if the quality score was at least 70%. A score less than 70% was defined as low quality.

### LEVEL OF SCIENTIFIC EVIDENCE

To synthesize the methodological quality of the studies and to be able to draw conclusions regarding the relationship between physical activity and academic achievement, we applied the best-evidence synthesis.[14] This rating system consists of 3 levels and takes into account the number, methodological quality, and consistency of outcomes of the studies, as follows:

- Strong evidence, provided by generally consistent findings in multiple (≥2) high-quality studies;
- Moderate evidence, provided by generally consistent findings in 1 high-quality study and 1 or more low-quality studies, or in multiple low-quality studies;
- Insufficient evidence, when only 1 study was available or findings were inconsistent in multiple (≥2) studies.

We considered results to be consistent when at least 75% of the studies showed results in the same direction, which was defined according to significance ($P<.05$). If 2 or more studies were of high methodological quality, we disregarded the studies of low methodological quality in the evidence synthesis.

**Table. Description of the Studies Reporting on the Relationship Between Physical Activity and Academic Performance in Children and Adolescents**

| Source (Quality Score) | Study Design/Country/ Follow-up Duration | Characteristics Study Sample at Baseline | Measure of Physical Activity | Measure of Academic Achievement | Main Results |
|---|---|---|---|---|---|
| Nelson and Gordon-Larsen,[17] 2006 (70%) | Observational/ US/1-2 y | 7th-12th grades (age, 12-18 y) Both sexes[a] (N = 11 957) | Standard 7-day recall questionnaire; self-reported participation in PE, school-based sports, academic clubs, sports with parents, and use of recreation centers | Self-reported score in math or English | Students with high participation in school-based physical activities and students with ≥5 bouts per week MVPA were more likely to earn higher grades |
| Eitle and Eitle,[26] 2002 (60%) | Observational/ US/2 y | 10th grade (age, 15-16 y) Only boys (N = 5018) | Self-reported basketball, football, or "other sports" participation | Math and reading test; self-reported grades | Students who played football or basketball had poorer math and reading scores; white male students who participated in other sports earned higher grades than white male students who played football and basketball and black male students who played football, basketball, or other sports |
| Carlson et al,[18] 2008 (55%) | Observational/ US/5.5 y | Mean (SE) age, 74.9 (0.1) mo 58.9% Boys (N = 5316) | PE participation reported by classroom teachers | Math and reading tests; IRT scale scores | Female students with the highest exposure to PE demonstrated small academic benefits for reading and math |
| Eitle,[27] 2005 (55%) | Observational/ US/2 y | 8th grade (age, 13-14 y) 48.5% Boys (N = 10 087) | Self-reported participation in baseball/softball, basketball, football, or "other team sports" and individual sports | Standardized test scores | Participating in other team sports or individual sports was associated with enhanced achievement; playing baseball/softball, football, or basketball had a negative effect on scores for male students; baseball/softball participation had a negative effect on math scores for black female students; participating in other team sports had a positive effect on math and reading scores for white female students; participating in basketball had a negative effect on math and science scores for black male students |
| Coe et al,[22] 2006 (45%) | Observational/ US/1 school year (11 mo) | Mean (SD) age, 11.5 (0.4) y Both sexes[a] (N = 214) | Self-reported 3-day physical activity recall | Grades; Terra Nova (national standardized test) scores | Students who met or exceeded guidelines for vigorous physical activity earned higher grades |

*(continued)*

## RESULTS

### LITERATURE SEARCH

The systematic literature search yielded 844 publications. After excluding duplicates (n=26) and those that were not published as full-text articles (n=87) or were published before 1990 (n=259), we screened the titles and abstracts of 472 publications, of which 14 articles were identified as relevant. The **Table** provides a summary of the studies included in the present review on their main characteristics, that is, study population, study design, measures of physical activity and academic achievement/cognition, and main results. An extensive description of the studies can be found in eTable 2.

### GENERAL

Twelve of the 14 studies[17-28] were performed in the United States, 1 in Canada,[15] and 1 in South Africa.[16] Four articles described the results of school-based interventions. The sample size ranged from 53 participants[16] to approximately 12 000 participants,[17] aged 6 through 18 years. Follow-up duration varied from 8 weeks[16] to more than 5 years.[18,19]

**Table. Description of the Studies Reporting on the Relationship Between Physical Activity and Academic Performance in Children and Adolescents (continued)**

| Source (Quality Score) | Study Design/Country/ Follow-up Duration | Characteristics of Study Sample at Baseline | Measure of Physical Activity | Measure of Academic Achievement | Main Results |
|---|---|---|---|---|---|
| Miller et al,[24] 2005 (45%) | Observational/ US/2 y | Mean age, 14.4 y<br>45% Boys (N = 586) | Self-reported participation in sports | Self-reported GPA | Female athletes reported higher GPAs than female nonathletes |
| Crosnoe,[23] 2002 (36%) | Observational/ US/3 school years | Freshmen/sophomores (age, 14-16 y)<br>Both sexes[a] (N = 2651) | Self-reported extracurricular activities | Self-reported GPA | Compared with male nonathletes, change in academic achievement was less negative for male athletes, female athletes, and female nonathletes |
| Stevens et al,[19] 2008 (36%) | Observational/ US/5 y | Kindergarten (age, 5-6 y)<br>Math, 49.8% boys (N = 6482)<br>Reading, 49.5% boys (N = 6393) | Parent-reported child's aerobic physical activity, exercise behavior, and participation in sports team or league; report by school administrators on PE participation | Tests on math and reading | PE had a negative effect on math achievement in male students; participation in physical activity had a positive effect on math and reading achievement in both sexes |
| Hanson and Kraus,[28] 1998 (30%) | Observational/ US/2 y | Sophomores (age, 15-16 y)<br>Both sexes[a] (N = 11 683) | Self-reported participation in sports or cheerleading/pep club | Self-reported grades; standardized test scores | For female students, there was a negative effect of participating in cheerleading/pep club on science achievement |
| Silliker and Quirk,[20] 1997 (22%) | Observational/ US/approximately 4 mo | Freshmen to seniors (age, 14-18 y)<br>Both sexes[a] (N = 123) | Self-reported participation in extracurricular activity | Self-reported GPA | Students had higher GPAs in season than out of season |
| Donnelly et al,[21] 2009 (75%) | Cluster RCT/ US/3 school years | Mean (SD) age, 8.2 (0.4) y<br>48.8% Boys (N = 203) | Intervention: additional 90 min of physical activity | WIAT-II-A | Children in experimental group improved their academic achievement scores |
| Ahamed et al,[15] 2007 (50%) | Cluster RCT/Canada/ 16 mo | Mean (SD) age, 10.2 (0.6) y<br>49.7% Boys (N = 288) | Intervention: additional 15 minutes of classroom-based activities | CAT-3 | Academic performance was not different between intervention groups |
| Fredericks et al,[16] 2006 (43%) | RCT/South Africa/8 wks | 1st grade (age, 6-7 y)<br>56.6% Boys (N = 53) | Intervention: participation in a 10-wk sensory-integration developmental movement program | ASB; reading age test; math age test; DAP | All groups performed better after intervention period; the experimental group performed better on spatial, reading, and math skills after 10-wk program |
| Sallis et al,[25] 1999 (38%) | RCT/US/2 y | Mean (SD) age, 9.5 (0.4) y<br>52.2% Boys (N = 754) | Intervention: an additional 30 min of health-fitness and skill-fitness activities | MAT6 and MAT7 | Cohort 1: intervention group showed less decline on language scores and increased reading scores;<br>cohort 2: intervention group showed less decline on reading and basic battery scores but more decline on language scores |

Abbreviations: ASB, Aptitude Test for School Beginners; CAT-3, Canadian Achievement Test; DAP, Draw-a-Person Test; GPA, grade point average; IRT, item response theory; MAT6/MAT7, Metropolitan Achievement Tests, 6th and 7th Editions; MVPA, moderate and vigorous physical activity; PE, physical education; RCT, randomized controlled trial; US, United States; WIAT-II-A, Wechsler Individual Achievement Test–Second Edition.

[a] No further descriptive data were available on the baseline sample.

## METHODOLOGICAL QUALITY

In eTable 3, we present the methodological scoring of the included studies, which ranged from 22%[20] to 75%.[21] Two studies had a score of at least 70% and thus were considered to be of high methodological quality.

About one-third of the studies[15,22-25] examined whether dropouts from the study were comparable to the study

sample at the follow-up measurements. Three of these[23-25] reported that the dropouts significantly differed from the study sample at follow-up.

Six of 10 observational studies[17,18,23,24,26,27] included in the present review controlled for confounding by socioeconomic status by including proxy measures for socioeconomic status, such as parental educational level.

## MEASUREMENT OF PHYSICAL ACTIVITY

Eight studies[17,20,22-24,26-28] examined self-reported athletic participation (eg, being a member of a sports club and the total number of athletic activities) as a measure of physical activity. Two studies[18,19] assessed participation in physical education classes using the reports by significant others; Carlson et al[18] relied on teacher report, and Stevens et al,[19] reports by school administrators.[19] Stevens et al[19] also had parents report their child's aerobic physical activity, exercise behavior, and participation in a sports team or league.

Two studies[17,22] used self-reported physical activity questionnaires or recalls to assess physical activity beyond athletic participation. The same 2 studies reported the use of a valid (criteria 5) and reliable (criteria 7) measurement instrument of physical activity.

The 4 intervention studies[15,16,21,25] did not measure physical activity or sports participation but increased the amount of physical activity offered within the school setting.

No study included in this systematic review used an objective measure of physical activity.

## MEASUREMENT OF ACADEMIC ACHIEVEMENT

Four studies assessed academic achievement by self-reported grades[17,20,23,24]; 7, by cognitive test scores[15,16,18,19,21,25,27]; and 3, by both measures.[22,26,28] All intervention studies[15,16,21,25] used cognitive tests to assess academic performance. Test batteries and self-reported grades took into account a large variety of academic performance skills, including reading, mathematics, world studies, and history.

## PRINCIPAL FINDINGS: RELATIONSHIP BETWEEN PHYSICAL ACTIVITY AND ACADEMIC ACHIEVEMENT

### Observational Studies

Nine observational studies[17-20,23,24,26-28] compared subgroups on the basis of their participation in sports (ie, athletes with nonathletes or students who participated in physical education or organized sports in the school setting) instead of measuring actual levels of physical activity. The results of these studies were inconsistent with regard to the relationship between sports participation and academic performance.

Three studies,[17,19,22] including one of high methodological quality,[17] assessed time spent in physical activity (moderate or vigorous physical activity). Two of these studies[17,19] assessed leisure time physical activity and sports/physical education participation. All 3 studies reported a positive relationship with academic performance.

### Intervention Studies

All intervention studies used a (cluster) randomized controlled trial design. Three of the 4 intervention studies,[16,21,25] including one of high methodological quality,[21] observed a significant beneficial effect of physical activity on academic performance. Sallis et al[25] reported positive effects on language skills (cohorts 1 and 2), reading skills (cohorts 1 and 2), and a basic test battery (cohort 2). There were no significant differences between the intervention and control groups with regard to mathematics (cohorts 1 and 2) and a basic test battery (cohort 1). Ahamed et al[15] reported no significant difference in cognitive performance test results between the intervention and control groups after a 16-month intervention (ie, 15 minutes of daily additional classroom-based physical activity).

### Evidence Synthesis

For the evidence synthesis, we combined the observational (n=10) and intervention (n=4) studies. According to the best-evidence synthesis,[14] we found strong evidence of a significant positive relationship between physical activity and academic performance. The findings of 1 high-quality intervention study[21] and 1 high-quality observational study[17] suggest that being more physically active is positively related to improved academic performance in children.

## COMMENT

Evidence from the studies included in the present systematic review and its methodological quality assessment suggests that there is a significant positive relationship between physical activity and academic performance. Nevertheless, we must stress that only 2 of 14 studies were rated as being of high methodological quality, which is the minimum number of studies needed for "strong evidence." However, both high-quality studies supported our hypothesis of physical activity being positively related to academic performance in children.

The main strengths of this review are (1) its extensive literature search and (2) its inclusion of longitudinal and intervention studies only. Because of the latter strength, it is difficult to compare our review with previous reviews. Our findings support the cautious conclusion of a positive relationship between physical activity and academic performance suggested by the 2 previous reviews.[9,10]

## LITERATURE SEARCH AND SELECTION PROCEDURE

Some of the following potential limitations we share with other systematic reviews, that is, limitations introduced by the literature search and selection procedure. We tried to minimize selection bias by checking reference lists of previously published reviews[9,10] and articles retrieved in the search for longitudinal or intervention studies that we might have missed. Owing to publication bias, posi-

tive findings are more likely to be published,[29,30] leading to an overestimation of a potential positive relationship between physical activity and academic performance. Screening references of identified studies and systematic reviews may have resulted in an overrepresentation of studies with positive results that are more likely to be referred to, leading to reference bias.

## SYNTHETIC APPROACH

Combining the results from all 14 studies is complicated by the heterogeneity between studies with regard to (1) outcome measures used to assess participation in physical activity; (2) outcome measures used to assess academic performance; (3) the study sample (size, sex, age, socioeconomic status, and ethnicity); and (4) study design (observational vs intervention studies).

In general, there were 2 types of physical activity measures. Studies defined children as being active based on their participation in organized sports, or they administered a physical activity questionnaire to the child or to significant others (eg, teachers, school administrators, or parents). Recording of the child's participation in certain physical (organized) activities alone does not provide a complete overview of the child's overall physical activity level and may therefore underestimate the relationship between physical activity and academic performance. This assumption is supported by the results of a recent study of Leek et al,[31] who argue that participation in organized sports does not ensure that youth meet physical activity recommendations.

Both studies[17,22] that used reliable and valid self-report measures of physical activity reported significant positive relationships between moderate to vigorous physical activity and academic performance.

None of the studies included in the present systematic review used objective measures of physical activity, indicating the necessity for future studies to assess physical activity by using accelerometers.

The heterogeneity of the studies is well illustrated by the variation of the intervention content between the intervention studies. The intervention study by Ahamed et al[15] describes a whole-school approach including a large range of physical activities integrated into the school environment with a duration of 16 months, whereas the study by Fredericks et al[16] reports on the effects of a developmental movement program focusing on perceptual-motor and sensory-motor skills, with a duration of 8 weeks.

We are well aware that one limitation of a synthetic approach is that it can give a false impression of homogeneity across studies. In particular, differences with regard to measurement instruments used and contents of the intervention studies complicate the accumulation of the results and comparability of the studies. Provision of the details on the studies included in the present review will enable the reader to gain insight into these differences (Table and eTable 2).

## METHODOLOGICAL CRITERIA LIST

In the absence of a standard list to adequately assess the methodological quality of studies examining the relationship between physical activity and academic performance in children, we used an adapted criteria list (eTable 1). Therefore, the choice of the items we selected for our quality assessment and the cutoff of 70% are, to some extent, arbitrary.

## EXTERNAL VALIDITY

Only half the studies met criterion 1 rating the participation rate (ie, ≥70% or a nonselective nonresponse). Because of the studies that did not meet this criterion,[15,18,19,22,26,27] the results have limited external validity. Another serious threat to the external validity of the studies is the comparison of those who dropped out with those who stayed in the study. Most of the studies did not report this comparison[23-25] or it was unclear from the article whether this was adequately assessed.[17-19,21,26-28]

The generalizability of our findings is limited by the fact that 12 of 14 of the studies included in our review were conducted in the United States. Outcomes for other parts of the world may be quite different.

## PHYSICAL ACTIVITY VS SCHOOL SPORTS/PHYSICAL EDUCATION

Most of the studies in the present review have focused on participation in school sports or physical education. Although these activities can provide a general basis for the physical activity habits of children, they do not cover the complete range of physical activities in which children can participate.[31] To gain insight into the dose-response relationship between physical activity and academic performance, we need more high-quality studies using objective measures of physical activity.

In conclusion, relatively few studies of high methodological quality have explored the relationship between physical activity and academic performance. However, we found evidence that participation in physical activity is positively related to academic performance in young people. More high-quality studies are needed on the dose-response relationship between physical activity and academic performance and on the explanatory mechanisms, using reliable and valid measurement instruments to assess this relationship accurately.

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**Correspondence:** Amika Singh, PhD, Department of Public and Occupational Health, VU University Medical Center, EMGO Institute for Health and Care Research, van der Boechorststraat 7, 1081 BT Amsterdam, the Netherlands (a.singh@vumc.nl).
**Author Contributions:** *Study concept and design:* Singh and Chinapaw. *Acquisition of data:* Singh and Uijtdewilligen. *Analysis and interpretation of data:* Singh, Uijtdewilligen, Twisk, van Mechelen, and Chinapaw. *Drafting of the manuscript:* Singh and Uijtdewilligen. *Critical revision of the manuscript for important intellectual content:* Uijtdewilligen, Twisk, van Mechelen, and Chinapaw. *Statistical analysis:* Singh, Twisk, and Chinapaw. *Administrative, technical, and material support:* van Mechelen. *Study supervision:* Singh, van Mechelen, and Chinapaw.
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