Objectively measured physical activity has a negative but weak association with academic performance in children and adolescents

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ABSTRACT

Aim: There is an emerging body of evidence on the potential effects of regular physical activity on academic performance. The aim of this study was to add to the debate, by examining the association between objectively measured physical activity and academic performance in a relatively large sample of children and adolescents.

Methods: The Spanish UP & DOWN study is a 3-year longitudinal study designed to assess the impact, overtime, of physical activity and sedentary behaviours on health indicators. This present analysis was conducted with 1778 children and adolescents aged 6–18 years. Physical activity was objectively measured by accelerometry. Academic performance was assessed using school grades.

Results: Physical activity was inversely associated with all academic performance indicators after adjustment for potential confounders, including neonatal variables, fatness and fitness (all p < 0.05). This association became nonsignificant among quartiles of physical activity. There were only slight differences in academic performance between the lowest and the second quartile of physical activity, compared to the highest quartile, with very small effect size (d < 0.20).

Conclusion: Objectively measured physical activity may influence academic performance during both childhood and adolescence, but this association was negative and very weak. Longitudinal and intervention studies are necessary to further our understanding.

INTRODUCTION

Children and adolescents should participate in at least 60 min of moderate to vigorous physical activity (MVPA) a day to achieve substantial health benefits (1). Although the physical health benefits are known (2), there is an emerging body of evidence of the potential effects of regular physical activity on academic performance (3).

The majority of studies investigating associations between physical activity and academic performance in children and adolescents relied on self-reported measures of physical activity (4–11), which have demonstrated lower validity than objective measures, such as accelerometers (12). These studies mainly showed either a positive association (5–9) or no association between self-reported physical activity and academic performance (10,11). There are only four studies that objectively assessed physical activity in relation to academic performance (13–16). Two studies found no association between physical activity and academic performance in students aged 10–12 years (13,14). A study in a small sample of 15–16-year-old adolescents found that vigorous physical activity (VPA) was only positively associated with academic performance in girls (15) and another study showed both positive and negative associations between academic indicators and physical activity variables in adolescents (16).

Key notes

- This study examined the association between objectively measured physical activity and academic performance in 1778 children and adolescents aged 6–18 years.
- We found that the association between physical activity and academic performance was negative and very weak and independent of potential confounders, including neonatal variables, fatness and fitness.
- Longitudinal and intervention studies are necessary to further understand changes overtime.

Abbreviations

CI, Confident interval; CPM, Count per minutes; GPA, Grade point average; MPA, Moderate physical activity; MVPA, Moderate to vigorous physical activity; VPA, Vigorous physical activity.
As such, it is difficult to draw a conclusion from previous studies due to their contradictory results. In addition, such studies were solely focused on adolescence, which is a period involving important psychological and physiological changes. However, the transitions from early childhood to middle childhood and adolescence imply lifestyle changes that might affect physical activity and academic performance. To the best of our knowledge, there is no evidence that focuses on both children and adolescents.

The present study examined the association of objectively measured physical activity with academic performance in a relatively large sample of children and adolescents aged between 6–18 years.

**METHODS**

**Sample and study design**

UP & DOWN was a 3-year longitudinal study designed to assess the impact overtime of physical activity and sedentary behaviours on health indicators, such as physical fitness, metabolic and cardiovascular disease risk factors, inflammation-immunity biomarkers and mental health. It also aimed to identify the psycho-environmental and genetic determinants of physical activity in a Spanish sample of children and adolescents (17). A total of 2225 children and adolescents aged 6–18 years from schools in Cadiz and Madrid participated in the UP & DOWN study. The present analyses included 1778 children and adolescents (870 girls; 79% of the original sample) with complete data at baseline on maternal education level, objectively measured physical activity and academic performance. Data were collected from September 2011 to June 2012.

Before the children and adolescents took part in the UP & DOWN study, their parents and school supervisors received a letter about the study and written, informed consent was provided. The study protocol was approved by the Ethics Committee of the Hospital Puerta de Hierro (Madrid, Spain) and the Bioethics Committee of the National Research Council (Madrid, Spain).

**Physical activity**

Objectively measured physical activity was obtained by the ActiGraph accelerometer models GT1M, GT3X and GT3X+ (Actigraph TM; LLC, Pensacola, FL, USA). The GT1M is a small and lightweight uniaxial accelerometer (3.8 × 3.7 × 1.8 cm, 27 g) designed to detect vertical accelerations ranging in magnitude from 0.05 to 2.00 g with a frequency response of 0.25–2.50 Hz. The epoch duration was set at 2-sec. The GT3X and GT3X+ are triaxial accelerometers (4.6 × 3.3 × 1.5 cm, 19 g) capable of measuring accelerations from –6 to 6 g with a frequency response of 0.25–2.50 Hz. The epoch duration was set at 30 Hz and the data were subsequently converted into 2-sec epochs. The ActiGraph accelerometers have been widely calibrated for children and adolescents in laboratory and free-living conditions (18).

Each participant wore the accelerometer at the lower back for seven consecutive days, removing it during sleep- and water-based activities. The inclusion criteria were an activity monitor recording of at least 10 h per day for 5 days (19). The data were downloaded and analysed using the ActiLife software (v.6.6.2 Actigraph TM, Pensacola, FL, USA). Before analyses, data were reintegrated into 10-sec epochs (19). Nonwear time was defined as a period of 60 min of zero counts and an allowance of up to two consecutive minutes <100 counts per minutes (cpm) with the up/downstream 30 min consecutive of zero counts for detection of artifactual movements (19,20). Physical activity was estimated using cut-points of 2000 and 4000 cpm for moderate physical activity (MPA) and VPA, respectively (18). These cut-points to define the intensity categories are similar to those used in previous studies with European children and adolescents (21). The physical activity variables included in this study were minutes per day at MPA, VPA and MVPA.

**Academic performance**

Academic performance was assessed through school records at the end of academic year. Four main indicators were used: mathematics, language, an average of these two core subjects and the grade point average (GPA) score, which was an average of the scores achieved by students in all subjects. For standardised purposes, individual letter grades were converted to numeric data as follows: A = 5, B = 4, C = 3, D = 2, F = 1.

**Covariates**

Age, sex, city and maternal education level as below university education and university education were recorded (22). Neonatal characteristics, such as gestational age at time of delivery in weeks and birthweight in kilograms (kg) were reported by parents.

Anthropometric measurements and fitness were assessed with the ALPHA health-related fitness test battery (23). Height was measured to the nearest 1 mm and weight to the nearest 0.05 kg using a standard beam balance with a stadiometer (SECA 701; SECA, Hamburg, Germany). Both measurements were performed twice and averages were recorded. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared (kg/m²). Cardiorespiratory fitness was assessed by the 20-m shuttle-run test (23). The score was the number of stages completed. Motor fitness was assessed with the 4 × 10-m shuttle-run test of speed-of-movement, agility and coordination. The test was performed twice and the fastest time was recorded in seconds (23). The individual score of each test (cardiorespiratory fitness and motor fitness) was standardised as follows: Z-standardised value = (value – mean)/SD. A single physical fitness score was calculated as the mean of the two Z-standardised scores. Before standardisation, the motor fitness score was multiplied by −1, because it is inversely related to physical fitness. Neonatal characteristics, anthropometric measurements and fitness were included because we found that these covariates were associated with academic performance in previous works with the present sample (24,25).
Statistical analysis
The characteristics of participants are presented as means (SD) or percentages. Differences between sexes were tested by one-way analysis of variance and chi-squared tests for continuous and nominal variables, respectively. Preliminary analyses showed no significant interactions of sex and age with physical activity variables (all p > 0.1), and therefore, all participants were analysed together. All variables were checked for normality of distribution graphically (Q-Q plots) and with standardised normality test, and appropriate transformations applied when necessary. Specifically, only VPA was square-root-transformed before analysis to achieve normality in the residuals.

The associations between physical activity variables (MPA, VPA and MVPA) and academic performance were analysed by linear regression using three separate models. Model one was controlled for sex, age, city and maternal education, model two was additionally controlled for birthweight, gestational age and BMI and model three was further adjusted for physical fitness score. Differences in academic performance were examined by sex-specific and age-specific quartiles of physical activity at different intensities using analysis of covariance for the three previous models. Cohen’s effect size statistics (d) as standardised mean differences between quartiles and 95% confidence interval (CI) were also calculated. Cohen’s d values of 0.2, 0.5 and 0.8 were considered small, medium and large effects, respectively (26).

RESULTS
Table 1 shows the descriptive characteristics of the study sample. The levels of fitness were significantly greater in boys than girls (p < 0.001). Moreover, boys engaged in higher levels of MPA, VPA and MVPA than girls (all p < 0.001). Girls had higher scores than boys in language and GPA (p < 0.001).

Table 2 shows the differences in academic performance between quartiles of MPA, VPA and MVPA. In models one and two, there were only significant differences in mathematics between quartiles of MPA (p < 0.05). In model three, there were slight differences in three academic performance indicators between the lowest and the second quartile compared to the highest quartile of MPA with very small effect size (all d < 0.20). For language, there were only small differences between the lowest quartile and the highest quartile of MPA (d = 0.12; 95% CI, –0.01 to 0.33). Among quartiles of MVPA, there were slight differences in two academic indicators between the lowest and the highest quartile of MVPA with very small effect sizes: for mathematics d = 0.10 (95% CI, –0.03 to 0.23), and for the average of mathematics and Language d = 0.09 (95% CI, –0.04 to 0.22).

Table S1 shows the association of physical activity with academic performance. In model one, MPA and MVPA were inversely associated with all academic performance indicators (all p < 0.05). In model two, these associations remained significant, except for the association of MVPA with GPA score (p = 0.118). In model three, after further adjustment for fitness, MPA, VPA and MVPA were inversely associated with all academic performance indicators (all p < 0.05).

<table>
<thead>
<tr>
<th>Table 1 Descriptive characteristics of study sample</th>
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<tbody>
<tr>
<td>All</td>
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<tr>
<td>Physical characteristics</td>
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<td>Age (year)</td>
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<td>Weight (kg)</td>
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<td>Height (cm)</td>
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<td>Body mass index (kg/m²)</td>
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<td>Fitness (z-score)*</td>
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<td>Maternal education level university (%)</td>
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<td>Physical activity</td>
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<td>Moderate PA (min/day)</td>
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<td>Vigorous PA (min/day)*</td>
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<td>MVPA (min/day)</td>
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<td>Academic performance</td>
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<td>Math (1–5)</td>
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<td>Language (1–5)</td>
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<tr>
<td>Math and language (1–5)</td>
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<td>Grade point average (1–5)</td>
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</tbody>
</table>

Values are mean ± SD or percentages. Statistically significant values are showed in bold.

PA, Physical activity; MVPA, Moderate to vigorous PA.

* z-score computed from cardiorespiratory and motor fitness tests.

† Square-root-transformed values were used in the analysis, but nontransformed values are presented in the table.

DISCUSSION
We examined the associations between objectively measured physical activity and academic performance in
Table 2 Differences in academic performance according to quartiles of physical activity in children and adolescents (n = 1778)

<table>
<thead>
<tr>
<th>Q1 Mean ± SD</th>
<th>Q2 Mean ± SD</th>
<th>Q3 Mean ± SD</th>
<th>Q4 Mean ± SD</th>
<th>P Model 1</th>
<th>P Model 2</th>
<th>P Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moderate PA</td>
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</tr>
<tr>
<td>Math (1–5)</td>
<td>3.37 ± 1.26*</td>
<td>3.44 ± 1.33†</td>
<td>3.29 ± 1.35</td>
<td>3.20 ± 1.36</td>
<td>0.024</td>
<td>0.026</td>
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<tr>
<td>Language (1–5)</td>
<td>3.42 ± 1.25*</td>
<td>3.43 ± 1.29</td>
<td>3.34 ± 1.33</td>
<td>3.26 ± 1.35</td>
<td>0.240</td>
<td>0.0269</td>
</tr>
<tr>
<td>Math and language (1–5)</td>
<td>3.40 ± 1.17*</td>
<td>3.43 ± 1.23†</td>
<td>3.31 ± 1.25</td>
<td>3.23 ± 1.27</td>
<td>0.060</td>
<td>0.069</td>
</tr>
<tr>
<td>Grade point average (1–5)</td>
<td>3.61 ± 0.88*</td>
<td>3.65 ± 0.90†</td>
<td>3.53 ± 0.96</td>
<td>3.46 ± 0.99</td>
<td>0.068</td>
<td>0.075</td>
</tr>
<tr>
<td>Vigorous PA</td>
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<tr>
<td>Math (1–5)</td>
<td>3.31 ± 1.34*</td>
<td>3.32 ± 1.26</td>
<td>3.36 ± 1.35</td>
<td>3.32 ± 1.36</td>
<td>0.991</td>
<td>0.989</td>
</tr>
<tr>
<td>Language (1–5)</td>
<td>3.36 ± 1.31</td>
<td>3.37 ± 1.26</td>
<td>3.38 ± 1.30</td>
<td>3.32 ± 1.36</td>
<td>0.939</td>
<td>0.864</td>
</tr>
<tr>
<td>Math and language (1–5)</td>
<td>3.34 ± 1.25*</td>
<td>3.35 ± 1.18</td>
<td>3.37 ± 1.24</td>
<td>3.32 ± 1.28</td>
<td>0.993</td>
<td>0.956</td>
</tr>
<tr>
<td>Grade point average (1–5)</td>
<td>3.53 ± 0.93</td>
<td>3.56 ± 0.89</td>
<td>3.50 ± 0.93</td>
<td>3.58 ± 0.97</td>
<td>0.861</td>
<td>0.990</td>
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<td>Moderate to vigorous PA</td>
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</tr>
<tr>
<td>Math (1–5)</td>
<td>3.37 ± 1.28*</td>
<td>3.37 ± 1.31</td>
<td>3.33 ± 1.35</td>
<td>3.24 ± 1.36</td>
<td>0.421</td>
<td>0.318</td>
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<tr>
<td>Language (1–5)</td>
<td>3.40 ± 1.25</td>
<td>3.39 ± 1.30</td>
<td>3.33 ± 1.33</td>
<td>3.31 ± 1.34</td>
<td>0.605</td>
<td>0.508</td>
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<tr>
<td>Math and language (1–5)</td>
<td>3.39 ± 1.19*</td>
<td>3.38 ± 1.22</td>
<td>3.35 ± 1.26</td>
<td>3.28 ± 1.27</td>
<td>0.494</td>
<td>0.380</td>
</tr>
<tr>
<td>Grade point average (1–5)</td>
<td>3.58 ± 0.88</td>
<td>3.59 ± 0.94</td>
<td>3.56 ± 0.94</td>
<td>3.52 ± 0.97</td>
<td>0.860</td>
<td>0.741</td>
</tr>
</tbody>
</table>

Values are standardised regression coefficients (β). Statistically significant values are showed in bold.

PA, Physical activity.

Model 1: Analyses were adjusted by sex, age (years), city (Cadiz/Madrid) and maternal education (university level/below university level).

Model 2: Adjustments for model 1 plus birthweight (kg), gestational age (week) and body mass index (kg/m²). Model 3: Adjustments for model 2 including fitness (z-score values computed from cardiorespiratory and motor fitness tests).

*Significant differences between Q1 and Q4 for model 3.

†Significant differences between Q2 and Q3 for model 3.

children and adolescents. The main finding of the present study was that physical activity was negatively associated with academic performance, independent of potential confounders, including neonatal variables, fitness and fitness. However, this association was negative and very weak.

These results may indicate that more physically active children and adolescents spend less time on studying. To confirm this hypothesis, we carried out a post hoc analysis with a subsample (n = 1217; 49% girls) of the present study using information on time spent studying. This showed a weak relationship between time spent studying and physical activity (r = −0.178, −0.145 and −0.184 for MPF, VPA and MVPA, respectively). However, when including the time spent studying as a covariate in all analyses, the results were virtually the same and there was no evidence of a moderating effect of time spent studying (i.e., p for physical activity variables*time spent studying interactions >0.1) on the association between physical activity and academic performance. Although the present results concur with a previous study, which used self-reported measurements of physical activity (4), there is strong evidence using self-reported physical activity measurements that has mainly showed a positive association with academic performance (5–9). Few studies found no association between academic performance and self-reported physical activity in children and adolescents (10,11).

The lack of agreement between studies using self-reported and objective measures of physical activity in relation to academic performance might be due to the inherent characteristics of physical activity measures. Self-reported physical activity assesses specific domains of physical activity, such as extracurricular physical activity, physical education, active commuting and athletic participation, whereas accelerometry covers the complete range of physical activity in which children and adolescents are involved. Thus, the association between physical activity and academic performance might depend on which specific component of total physical activity is measured. For example, studies using self-reported physical activity measures providing a portion of adolescent’s daily physical activity, such as physical education or athletic participation, showed a positive association with academic performance (7,8). Additionally, studies using self-reported physical activity questionnaires to estimate weekly physical activity also found a positive association with academic performance (5,6). This reason could partially explain why studies using self-reported physical activity showed mainly positive associations with academic performance, while findings with objective measures of physical activity are controversial. However, further longitudinal research taking into account repeated measures of both outcomes (academic performance indicators) and exposures (objectively measured physical activity) is necessary to clarify the aforementioned association.

Few studies have investigated the associations between objectively measured physical activity and academic performance (13–16). It is important to investigate this association, because physical activity provided plasticity and flexibility to the brain, which in turn may have a positive influence on academic performance (27). Two recent studies in students aged 10–12 years found no association between objectively measured MVPA and academic performance (13,14). However, in a sample of 233 adolescents...
aged 15–16 years, Kwak et al. (15) showed that VPA was the only intensity level positively associated with academic performance, but solely in girls, which remained after controlling for fitness and maternal education. A longitudinal study found positive and negative associations between MVPA and academic performance depending on whether total physical activity as cpm was taken into account or not as a confounder, respectively (16). In the present study, we also found a negative relationship between the time spent at different physical activity intensities and academic performance when total physical activity was not taken into account. However, when we included total physical activity, it yielded no significant associations. The role that total physical activity plays in this association is difficult to interpret because includes all physical activity intensities. In this sense, adding in the same analyses both total physical activity and the time spent at any physical activity may be over adjusting the association.

The inconsistent findings in studies using accelerometers may be explained not only through the variations in samples and methods such as the age range or accelerometer procedures, but also through multiple other factors. First, academic performance was differently assessed through grades (13,15) and standardised tests (14,16). Our academic indicators were also grades, but those grades did not just relate to academic skills, they also related to teacher perception, the quality and quantity of academic teaching, family background and environment and even cultural factors. Therefore, the academic indicator used such as grades, standardised tests or cognitive skills tests, may be important to avoid bias (28).

Second, several confounding factors included in our study were not always taken into account in the previous studies, making comparisons difficult. For example, birth-weight and gestational age, variables broadly related to academic and cognitive performance (29), were only included in one study (16). Fitness was only incorporated as a covariate in one other study (15). According to Etnier et al. (30), fitness may mediate the relationship between physical activity and academic performance. We found that fitness was related to physical activity and to academic performance, and, therefore, fitness might indeed be mediated such association in our results. However, our findings, and those of Kwak et al. (15), showed there was no mediated effect between physical activity and academic performance through fitness. Lastly, it is possible that the volume of daily physical activity at different intensities is not a good indicator of the quality of physical activity related to academic performance. Future studies should investigate the association between objectively measured physical activity in specific periods as recess, physical education and active breaks, in relation to academic performance.

The present study has some limitations. The cross-sectional design limits the possibility to draw conclusions with regard to the causality of the observed associations. The fact that we assessed a convenience sample limits its generalisability across the population. Grades are socially valid measures of academic performance, but they have potential limitations of bias, so studies are recommended using standardised tests and measures of brain function. Strengths of the present study include its relatively large sample of children and adolescents, the use of accelerometers to assess physical activity and the objectively assessment of fitness.

In conclusion, we observed that objectively measured physical activity may influence academic performance in both children and adolescents, but this association was negative and very weak. Longitudinal and intervention studies are necessary to further understand changes over-time in physical activity and academic performance during both childhood and adolescence.

ACKNOWLEDGEMENTS

The authors thank children and adolescents, parents and teachers who participated in this study. The UP & DOWN study was supported by the DEP 2010-21662-C04-00 grant from the National Plan for Research, Development and Innovation (R+D+i) MICINN.

References


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APPENDIX

THE UP & DOWN STUDY GROUP

SUPPORTING INFORMATION
Additional Supporting Information may be found in the online version of this article:

Table S1 Associations of physical activity with academic performance in children and adolescents (n = 1778).