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Physical activity in and out-of-school and academic performance in Spain

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Abstract

Background: Academic performance in school stems from an interaction of factors associated with students, families and schools. Among these factors, physical activity could play a very relevant role.

Objective: The goal of this study was to determine whether students' physical activities in and outside school were related to their academic performance.

Design, setting and method: We used the Programme for International Student Assessment (PISA) 2015 database for Spain using ordinary least squares (OLS) regression models to answer our research questions.

Results: Results suggest a positive association between the number of days per week doing moderate physical activities and academic performance in science, reading and mathematics. However, a higher number of days per week doing vigorous physical activities was associated with lower scores in reading and science. We also find a negative association between exercising or practising sports before going to school and the scores achieved in the three competences evaluated.

Conclusions: Our results show that physical activity can play an important role in academic performance and that the effects of physical activity on children and teenagers should be further investigated.

Keywords

Academic performance, PISA, Physical activity, Spain

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Introduction

Academic performance in school stems from an interaction of factors associated with students, families and schools. Among these factors, physical well-being may play a role in students' academic performance (Donnelly et al., 2016; Esteban-Cornejo et al., 2015).

The goal of this study was to determine whether students' physical activity in and outside of school was related to their academic performance. Our research had two main goals. The first is to examine whether students' physical activity was associated with their academic performance in mathematics, reading and science. The second was to analyse how various forms of physical activity relate to students' performance in these three academic domains. We addressed three research questions: (1) are physical education classes associated with students' academic performance, (2) is there a relationship between moderate and vigorous physical activity and students' academic performance, and (3) is there a relationship between exercising before and/or after school and students' academic performance?.

One of the novelties of this research was that we used a large empirical data set and econometric techniques to examine the relationship between students' physical activity in and outside of school and their academic achievement. Most previous studies in this area have used small samples and descriptive analysis or experimental designs. Furthermore, our analysis focuses on Spain, where the effects of physical activity on academic performance have barely been explored (Ardoy et al., 2014; Pellicer-Chenoll et al., 2015; Valdes and Yanci, 2016). In addition, over the past decade, three regional governments have introduced a reform to increase the number of hours of physical education classes in schools (Úbeda Palomares, 2017). However, the impact of these reforms on students' academic performance is not clear.

To test our research questions, we used Programme for International Student Assessment (PISA) 2015 cycle data for Spain. To study the association between physical activity and academic performance, we used students' academic test scores in mathematics, reading and science as dependent variables, and the following as independent variables: (1) number of days students attended physical education classes each week, (2) the number of days students practised moderate physical activities (such as walking and cycling) outside of school for at least 60 minutes per day, (3) vigorous physical activities that made them sweat and breathe hard for a total of at least 20 minutes per day, (4) information about whether students exercised or practised a sport before going to school, or (5) after leaving school.

Regarding actual trends in physical well-being habits, a report by Currie et al. (2009) states that young people enjoy better health than ever before, but many are involved in behaviours that compromise their physical well-being. A recent study (Aston, 2018) also shows that teenagers are engaging in behaviours that put their physical health at risk, and are influenced by changes in society, including the increasing use of technology.

Literature review

A number of studies have found a positive association between more time on physical education at school and higher academic grades. Nelson and Gordon-Larsen (2006) used data from a sample of US adolescents in grades 7 through 12 and found that students with a high level of participation in school-based physical activities were more likely to earn higher grades. In Kansas, Donnelly et al. (2009) also found that children in grades 4 and 5 who had an additional 90 minutes of physical education per week improved their grades. These results are in line with recent research by Simms et al. (2014) for fifth graders in the Early Childhood Longitudinal Study.

In Spain, Ardoy et al. (2014) analysed the effects of an intervention focused on increasing the time and intensity of physical education classes. They found that overall, four sessions/week of high intensity (activities involving a heart rate above 120 bpm) improved students' grades more than four sessions/week of normal intensity did, while no difference was found between the effect of four sessions/week and two sessions/week.

With respect to the relationship between overall participation in physical activity and school grades, the studies that have examined this have mostly found a positive association. Coe et al. (2006) found that vigorous physical activity outside of school is associated with higher grades, but moderate physical activity outside of school did not affect grades for sixth grade students. Castelli et al. (2007) carried out fitness tests for students in third and fifth grades in the USA and found that physical activity was positively related to scores on the Illinois Standards Achievement Test. Stevens et al. (2008) collected data about physical activity of children and families in the USA and found that physical activity was significantly and positively related to both mathematics and reading grades of students in the fifth grade. Lorenz et al. (2017) analysed fourth grade students in the USA and found a positive association between physical activity and school grades. Recently, the report of Organisation for Economic Co-operation and Development (OECD, 2017), also found a positive relationship between students' physical activity and academic performance based on PISA data.

In Spain, Pellicer-Chenoll et al. (2015) examined a sample of students in the first year of secondary education from five schools in Barcelona and concluded that students with better physical fitness exhibited higher school grades. Valdes and Yanci (2016), also conducting a study in Spain, found that fourth grade students who practised non-competitive physical activity had better academic records than students who engaged in competitive physical activity.

On the other hand, several studies have found that devoting more time to physical education classes is not associated with school grades. Coe et al. (2006), using data from sixth-grade students from a public school in Michigan, found that students who attended more hours of physical education did not get better or worse school grades. This finding was substantiated by Ahamed et al. (2007) who used data from children in fourth and fifth grades in Canada and by the research by Stevens et al. (2008) who collected data from fifth graders in the USAs. Meanwhile, Carlson et al. (2008) conducted a study using data from the Early Childhood Longitudinal Study of students from kindergarten through fifth grade in the USA and found that increased physical education (70–300 minutes per week, being the referent 0–35 minutes per week) was not positively or negatively associated with school grades among boys, but had limited benefits for girls' grades.

Finally, some authors have also found no significant associations between participation in physical activity and school grades. Daley and Ryan (2000) asked children aged between 8 and 11 in the UK to list all the sports-based physical activities in which they participated, and no significant correlation was found between school grades and participation in physical activity. In Canada, a study conducted with data from the Elementary School Climate Study questionnaire reported a negative association between physical activity and mathematics and reading scores for 12-year-old students (Tremblay et al., 2000). Similarly, in Spain, Valdes and Yanci (2016) found that students who practised competitive physical activity had poor academic records.

Methodology

In this study, we used 2015 data from Spain from the OECD's PISA.[1] PISA was launched in 2000 and tests 15-year-old students attending educational institutions in grades 7 and higher in reading, mathematics and science every three years. In 2015, about 540,000 students from 72 countries took the tests.

Participants

The population of 15-year-olds in Spain in 2015 was 440,084, of which 414,276 were students enrolled in schools and therefore eligible for inclusion in the PISA study. The PISA 2015 student database for Spain contains 6,736 students from 201 schools which, when weighted, represent a total of 399,935 students. Some student observations and school data were missing. Omitting the missing values reduces the sample size to 5,327 students and 178 schools. We used this restricted sample to test our research questions

Sampling procedure

PISA uses a stratified two-stage sample design. The first-stage sampling units consist of individual schools that had 15-year-old students enrolled or had the possibility of having such students at the time of assessment. Schools are sampled systematically from a comprehensive national list of all PISA-eligible schools with probabilities that proportional to a measure of size. In the PISA 2015 study, 201 schools were selected in Spain. At a second stage, a complete list of each sampled school's 15-year-old students was prepared. From this list, 42 students were then selected with equal probability. In PISA 2015, 6,736 students were selected from Spain.

While the students included in the final PISA sample are chosen randomly, the selection probabilities of the students varied. The final student weight incorporates both the school weight (the inverse of the school's probability of selection) and the within-school student weight (the inverse of the student's probability of selection), and five adjustment factors that attempt to adjust for non-random non-response.

As evidenced, PISA has a complex survey design that violates the assumption of independence, since schools are selected as the primary sampling unit, and students are 'clustered' within schools. To handle this complex survey design and accurately estimate standard errors, we used the replicate weights in PISA along with the final student weight. Replicate weight methods use multiple subsamples to calculate the parameter of interest in each one and estimate the sampling variance from the variability of the parameter between the different samples and the calculation obtained from the whole sample.

Measures and descriptive statistics

Dependent variables. PISA 2015 measured students' academic performance in mathematics, science and reading. We used variables based on students' literacy test scores in these three respective academic domains as dependent variables to answer our research questions.

Mathematical competence assesses the student's capacity to formulate, employ and interpret mathematics in a variety of contexts. Competence in reading comprehension assesses the student's capacity to understand, use, reflect on and engage with written texts in order to achieve one's goals, develop one's knowledge and potential and to participate in society. Finally, competence in science reflects the ability to engage with science-related issues and with the ideas of science as a reflective citizen. Scores are scaled so that the OECD average in each domain is 500 and the standard deviation is 100.

Test items comprise a mixture of multiple-choice questions and questions requiring students to construct their own responses, with different students taking different combinations of test items. This characteristic makes it necessary to use scaling techniques to establish a common scale for all students. For PISA 2015, scores were estimated as plausible values using item response theory. Plausible values are generated through multiple imputations based upon pupils' answers to the subset of test questions they were randomly assigned and their responses to the background questionnaires, and represent the distribution of potential scores for all students in the population with similar characteristics and identical patterns of item response (OECD, 2015).

Independent variables. Regarding the explanatory physical activity questions, students had to report the number of days per week they attended physical education classes at school (ST031Q01NA),

Table 1. Descriptive statistics for dependent and the independent variables.

	Observations	Minimum maximum		Mean / frequency	Standard error (mean)	Standard deviation	Standard error (standard deviation)
Mean mathematics	5,327	188.11	780.79	491.74	2.09	82.03	1.34
Mean reading	5,327	196.89	760.87	502.94	2.22	82.72	1.24
Mean science	5,327	204.42	761.20	499.69	1.98	84.76	1.06
Physical education at school	5,327	0 = 0 days		1.41%	0.22	0.50	0.03
		1 = 1 day		8.14%	1.95		
		2 = 2 days		88.07%	2.03		
		3 = 3 days		1.02%	0.29		
		4 = 5 days		0.39%	0.11		
		5 = 5 days		0.97%	0.16		
Moderate physical activity outside of school	5,327	0 = 0 days		16.75%	0.52	2.42	0.02
		1 = 1 day		11.39%	0.53		
		2 = 2 days		16.83%	0.54		
		3 = 3 days		13.67%	0.55		
		4 = 5 days		8.76%	0.45		
		5 = 5 days		10.38%	0.45		
		6 = 6 days		3.81%	0.34		
		7 = 7 days		18.39%	0.55		
Vigorous physical activity outside of school	5,327	0 = 0 days		21.73%	0.69	2.06	0.02
		1 = 1 day		12.95%	0.50		
		2 = 2 days		20.06%	0.50		
		3 = 3 days		15.04%	0.45		
		4 = 5 days		12.45%	0.52		
		5 = 5 days		7.56%	0.36		
		6 = 6 days		3.88%	0.32		
		7 = 7 days		6.33%	0.39		
Exercise/sports before school	5,327	0 = no		56.76%	0.72	0.50	0.00
		1 = yes		43.24%	0.72		
Exercise/sports after school	5,327	0 = no		29.72%	0.65	0.46	0.00
		1 = yes		70.28%	0.66		

the number of days per week they engaged in moderate physical activity (e.g. walking and cycling) outside of school for at least 60 minutes per day (ST032Q01NA), or in vigorous activity (activities that make you sweat and breathe hard, such as jogging, or playing tennis or football) outside of school for at least 20 minutes per day (ST032Q02NA), and whether or not they exercised or practised sport before (ST076Q11NA) or after school (ST078Q11NA).[2]

Table 2. Descriptive statistics for control variables.

	Observations	Minimum maximum	Mean / frequency	Standard error (mean)	Standard deviation	Standard error (standard deviation)
Student-level control variables						
Gender	5,327	1 = female	50.70%	0.68	0.50	0.00
		2 = male	49.30%	0.68		
Immigration index	5,327	1 = native	89.43%	0.74	0.57	0.02
		2 = 2nd generation	1.99%	0.18		
		3 = 1st generation	8.57%	0.68		
Index of economic. social and cultural status	5,327	−4.35, 3.09	−0.51	0.04	1.18	0.01
School-level control variables						
Student-teacher ratio	5,327	1.00, 40.80	12.58	0.22	4.03	0.50
Index of principals' perceptions of teacher-related factors affecting school climate	5,327	−2.12, 2.52	−0.13	0.08	1.11	0.05
Index of principals' perceptions of student-related factors affecting school climate	5,327	−2.39, 2.36	−0.11	0.06	1.01	0.05
Index of shortage of educational material	5,327	−1.32, 3.61	0.22	0.09	1.20	0.08
Index of shortage of education staff	5,327	−1.68, 2.84	0.30	0.07	0.98	0.05
School ownership	5,327	1 = private independent	5.49%		0.58	0.03
		2 = private government dependent	24.11%	1.53		
		3 = public	70.38%	1.90		
				1.74		

Student-level control variables. We used different control variables asked in PISA 2015 that previous literature has shown to be relevant to explain academic performance and physical activity engagement among young people. The non-inclusion of these variables could lead to an overestimation of the association between our independent and dependent variables.

At the student level, we included the variable gender since studies to date have reported a clear gender gap in academic achievement between boys and girls, with boys falling behind girls (Parker et al., 2018). In addition, research up to date has showed that boys are more active than girls (Santos et al., 2003). The ‘immigration status index’ was also included since in Spain several studies have confirmed that immigrant students underperform natives in terms of academic achievement (Santos et al., 2016; Vaquera and Kao, 2012). Likewise, research by Arjona Garrido et al. (2012) shows than in Spain the level of participation in physical activity and sport among young immigrants is lower than among others.

At the family level, we took into account an ‘index of economic, social and cultural status’ (ESCS). In Spain, several studies evidence a strong relation between the socioeconomic status and academic achievement (Suárez-Álvarez et al., 2014). Roman et al. (2008) show that socio-economic status also acts positively on the level of physical activity of children and adolescents. In Pisa 2015, ESCS is a composite score built up by the indicators: parental education, highest parental occupation, and home possessions including books in the home. The scale of all indexes in PISA has been transformed with zero being the score of an average OECD student and one being the standard deviation across equally weighted OECD countries.

School-level control variables. From the school questionnaire, we used as control variables school ownership (public, private government dependent,[3] or private independent) since according to Choi and Calero (2012) in Spain on average students benefit more of attending government dependent private schools than public schools. Moreover, research by Arriscado et al. (2014) shows that students attending public schools in Spain report significantly lower adherence to healthy behaviours. We also controlled for the number of students per teacher because previous research shows a moderate negative correlation between the student teacher ratio and achievement (Koc and Celik, 2015). In addition, when teaching loads are too high, physical education practices are not optimal and this could reduce students’ interest in physical activity (Turner et al., 2017).

We also included as control variables an ‘index of principals’ perceptions of student-related factors affecting school climate’. This index was derived from school principals’ reports on the extent to which learning in their school was hindered by such factors as: student absenteeism, students lacking respect for teachers, the use of alcohol or illegal drugs, and students bullying other students. Previous research has shown that factors such as students lacking respect for teachers (Miller et al., 2017), students using illegal drugs or alcohol (Rasberry et al., 2017), and students bullying other students (Lacey et al., 2017), negatively affect academic outcomes. Research in Spain has also associated the lower consumption of alcohol and other drugs with higher physical activity practice (Moreno et al., 2012).

School principals were also asked to report the extent to which they believed that learning in their schools was hindered by such factors as: poor teacher–student relations, teacher absenteeism, and teachers not being well-prepared for classes. Responses were combined to create an ‘index of principals’ perceptions of teacher-related factors affecting school climate’. The index was considered since there are several factors included in it that previous research has evidenced to have negative effects on academic outcomes (Nilsen and Gustafsson, 2016). Moreover, as suggested by Alderman et al. (2006) teachers’ preparation and involvement in the teaching process – especially for physical educators – plays a significant role in promoting the interest of children and adolescents in healthy behaviours such as physical activity.

Finally, we also included an ‘Index of shortage of education staff’ and an ‘Index of shortage of educational material’. PISA 2015 asked school principals to report the extent to which their school’s capacity to provide instruction was hindered by a shortage or inadequacy of physical infrastructure and educational material. Likewise, principals were asked if the lack or quality of teaching and assisting staff hinders the capacity to provide instruction in the school. Both indices include factors relevant to explaining academic performance as detailed in previous research (Chiu and Khoo, 2005). As shown by McKenzie and Lounsbery (2009), there are numerous barriers (including the shortage of resources and staff) that hinder physical education from playing a major role in providing and promoting physical activity in children and adolescents.

Analytic strategy

To analyse the relation between physical activity and academic performance, we used ordinary least squares regression (OLS). As explained in the sampling procedure section, to account for the complex PISA survey design, final student weights and balanced-repeated-replication (BRR) weights were applied throughout our analysis using the Stata routine 'repest' (Avvisati and Keslair, 2014). Our models were estimated following equation

$$Y_{ij} = \alpha + \beta P\mathrm{w}_i + \delta Xi + \gamma Ci + \lambda Zi + \mu j + \varepsilon ij$$

Where Y_{ij} refers to the score obtained by student '*i*' at school '*j*', Pw_i is a set of characteristics of physical activity factors of student '*i*', X_i is a set of control variables related to socio-demographic characteristics of student '*i*' (gender, socio-economic status, migration status), C_i is a vector of additional control variables related to school characteristics (school ownership and number of students per teachers), and Z_i includes control variables about behaviours hindering learning and shortage of educational material and staff. μj are school fixed-effects, and εij represents the individual error term.

Three different models were developed which included different control variables. Model 1 included only controls variables for socio-demographic characteristics (gender, immigration index, and index of economic, social and cultural status). Model 2 added control variables regarding important characteristics of the school (school ownership and student-teacher ratio). Finally, model 3 included additional control variables about the school's characteristics (index of principals' perceptions of teacher-related factors affecting school climate, index of principals' perceptions of student-related factors affecting school climate, index of shortage of educational material, and index of shortage of education staff). Although our models had missing observations, we opted for the non-imputation of missing values since we considered the sample large enough and imputing data could affect the validity of our conclusions (see Hughes et al., 2019).

The Stata routine we used allowed us to compute estimate statistics using replicate weights. Replicate weights are used to refine the calculation of standard errors in complex sampling designs since there are many possible samples of schools and they do not necessarily yield the same estimates. In addition, the package also allows for analyses with multiply imputed variables; where plausible values are used, the average estimator across plausible values is reported and the imputation error is added to the variance estimator. As evidenced by Jerrim et al. (2017), the use of this statistical package is advisable when working with PISA data since it i in line with the design of PISA database.

Results

Tables 3 to 5 show the main results of the models estimated for the three competences evaluated.[4] The results for the three estimated models are presented, although for the final interpretation we focus mainly on those obtained in model 3, as the is the one with the highest R^2 value. The results presented in this paper only allow establishing associations, but not causality, given the methodology used.

Table 3. Association between physical activity and academic performance in mathematics.

Variables	Model 1	Model 2	Model3
	Mathematics	Mathematics	Mathematics
Physical education at school	−2.84	−2.04	−1.53
	(3.13)	(2.80)	(2.65)
Moderate physical activity outside of school	1.78***	1.55***	1.58***
	(0.62)	(0.57)	(0.58)
Vigorous physical activity outside of school	0.57	0.27	0.20
	(0.69)	(0.63)	(0.63)
Exercise/sports before school	−39.09***	−30.07***	−30.03***
	(3.06)	(2.95)	(2.95)
Exercise/sports after school	7.08*	5.47	5.44
	(3.73)	(3.34)	(3.33)
R^2	.21	.35	.35
Constant	490.4***	484.0***	477.4***
	(9.26)	(18.33)	(23.47)
Observations	5,327	5,327	5,327

***$p<0.01$, **$p<0.05$, *$p<0.1$.

Table 4. Association between physical activity factors and academic performance in reading.

Variables	Model 1	Model 2	Model 3
	Reading	Reading	Reading
Physical education at school	−3.15	−2.85	−2.65
	(3.32)	(3.19)	(3.07)
Moderate physical activity outside of school	2.43***	2.21***	2.23***
	(0.55)	(0.50)	(0.50)
Vigorous physical activity outside of school	−1.08	−1.29*	−1.31**
	(0.69)	(0.67)	(0.66)
Exercise/sports before school	−40.45***	−32.11***	−32.13***
	(2.98)	(2.89)	(2.90)
Exercise/sports after school	4.90	3.44	3.42
	(3.47)	(3.12)	(3.15)
R^2	.18	.31	.31
Constant	554.4***	533.8***	526.1***
	(8.60)	(16.00)	(25.63)
Observations	5,327	5,327	5,327

***$p<0.01$, **$p<0.05$, *$p<0.1$.

Regarding our first research question (are physical education classes associated with students' academic performance?), our results show the coefficient for the variable 'number of days of physical education at school' was not statistically significant in any of the evaluated competences and models. Therefore, according to this result we can answer our first research question and conclude that, based on our results, we cannot determine whether there is a link between the number of days spent attending physical education classes and academic performance.

Table 5. Association between physical activity factors and academic performance in science.

Variables	Model 1	Model 2	Model 3
	Science	Science	Science
Physical education at school	−3.40	−2.93	−2.66
	(3.17)	(2.86)	(2.67)
Moderate physical activity outside of school	2.53***	2.30***	2.32***
	(0.54)	(0.47)	(0.47)
Vigorous physical activity outside of school	−0.81	−1.08*	−1.13*
	(0.68)	(0.64)	(0.64)
Exercise/sports before school	−41.96***	−32.73***	−32.68***
	(2.47)	(2.51)	(2.52)
Exercise/sports after school	5.92*	4.22	4.14
	(3.42)	(2.95)	(2.95)
R^2	.19	.33	.33
Constant	511.3***	495.0***	496.5***
	(8.80)	(14.69)	(21.89)
Observations	5,327	5,327	5,327

***$p<0.01$, **$p<0.05$, *$p<0.1$.

With respect to our second research question (is there a relationship between moderate and vigorous physical activity and students' academic performance?), in relation to physical activity outside of school our results for model 3 show that doing one more day of moderate activity per week is associated with an increase in the test scores of 1.58 points in mathematics, 2.22 points in reading and 2.32 points in science. These coefficients are similar to those obtained in models 1 and 2, both in terms of statistical significance (with a significance level of 1%) and in terms of magnitude. On the other hand, in the case of vigorous activity, according to models 2 and 3, performing one more day of activity per week was associated with a decrease of around 1.3 points in the reading test and 1.1 points in the science test. In mathematics, the coefficient obtained for the days of vigorous activity was not statistically significant in any of the models. However, it is important to note that, in model 1, the coefficients for the variable vigorous activity were not statistically significant for any of the competences, and that, in models 2 and 3, the level of significance for the coefficients was 10% (model 2 for reading, and models 2 and 3 for science) or 5% (model 3 for reading). Therefore, the answer to our research question regarding the link between physical activity outside of school and academic performance suggests that moderate activity is linked to better academic outcomes in mathematics, science and reading, while vigorous activity is linked to worse academic performance in reading and science. Likewise, it is important to emphasise that the association between moderate activity and academic performance seems clear and unequivocal, while, in the case of vigorous activity, lower levels of statistical significance were obtained, and even non-significant coefficients were seen in model 1.

Finally, regarding our third research question (is there a relationship between exercising before and/or after school and students' academic achievement?), according to our estimates, the fact that students claim to exercise or practise sports before going to school was associated with a worsening of the PISA test scores of about 30 points in mathematics, 32.13 in reading and 32.68 in science, according to model 3. These coefficients are similar to the ones obtained in model 1 and 2, both in terms of statistical significance (significance level of 1%) and in terms of magnitude. The variable 'exercising or practising sport after school' was not statistically significant for any of the competences in model 3. It only showed statistical significance and indicated a positive association with academic performance in model 1 for science and mathematics, but with a significance level of 10%. Thus, the answer to our third research question is that exercising before school is linked to worse academic achievement in mathematics, reading and science, while we cannot conclude whether or not there is an association between exercising after school and academic performance.

In addition to allowing us to answer our research questions, the results obtained shed light on the existence of differential effects by competences with regards to the association between physical activity and academic performance. Based on the results for model 3, it is evident that moderate activities are positively related to performance in all competences but affect reading and science more than mathematics. Similarly, in the case of vigorous activities, it is observed that these are associated with poorer performance in science and reading but are not associated with performance in mathematics. Based on these results, it can be concluded that physical activity outside of school especially affects reading and science performance, but has only a minor association with academic performance in mathematics. Besides these two variables, we did not find other differential effects by competences if we base the data on model 3.

Conclusion

Our research questions that addressed the association between various forms of physical activity and students' academic achievement were answered by estimating OLS models with PISA 2015 data for Spain and using final student weights and BRR. By so doing, this study identified several relations between physical activity and academic performance in mathematics, science and reading. The results of this research contribute to the previous literature because a robust and appropriate methodology that considers the design of the PISA survey was used, and very few previous studies have investigated the relations between physical activity and academic performance in Spain (Ardoy et al., 2014; Pellicer-Chenoll et al., 2015; Valdes and Yanci, 2016).

This study has three main findings. First, we found that the number of days per week spent doing moderate physical activity was positively associated with academic performance in science, reading and mathematics. This result allows us to answer our second research question and determine that there is a positive association between moderate physical activity and academic performance.

Second, we found a strong negative association between exercising or practising sport before going to school and the scores achieved in mathematics, reading and science. This result answers our third research question, evidencing a relation between exercising before school and academic performance. However, a recent study found a positive association between running/walking before school and students' on-task behaviour (Stylianou et al., 2016) and therefore suggests that our result should be analysed in greater detail.

Third, in addition to these main results, the research also shows that the number of days per week doing vigorous physical activity is associated with lower scores in reading and science. This result allows us to answer our second research question and determine that there is a positive association between moderate physical activity and academic performance, but a negative association between vigorous activities and academic performance in reading and science. The negative association should be more thoroughly investigated. One explanation may be that very vigorous exercise can lead to cognitive fatigue and even cognitive decline (Tomporowski, 2003).

Limitations

Several limitations to our study need to be acknowledged. First, and as already mentioned above, our econometric analysis does not allow for causal inferences. Second, variables obtained from the student questionnaire could present a problem of bias since they are self-reported. To overcome the limitations of this study and further investigate the relationships identified here, it would be appropriate to use experimental or longitudinal data, or apply multilevel structural equation modelling. In our opinion, the best option would be to carry out an experiment in which numerous participants are observed over time (longitudinal data) while measuring academic performance in all areas and not only in those defined in PISA. In the absence of resources to be able to carry out such an ideal study, the results obtained here allow us only to conclude that physical activity is a relevant factor when it comes to examining academic performance among secondary school students.

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Notes

1. Detailed information on PISA data can be obtained from OECD (2016).
2. Codebook for all the categorical variables used in this research can be found in Tables 1 and 2.
3. Private schools that receive subsidies by the Spanish Government.
4. Full results are available upon request.

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