



## ORIGINAL ARTICLE

# The effect of sleep quality on academic performance is mediated by Internet use time: DADOS study<sup>☆</sup>



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### KEYWORDS

School achievement;  
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### Abstract

**Objective:** The aims of the present study were to analyze the association of sleep patterns with academic and cognitive performance in adolescents, and to test the potential mediating effect of different activities of screen media usage on this association.

**Methods:** A sample of 269 adolescents (140 boys) aged 14 years from the baseline data of the Deporte, ADOlescencia y Salud study completed questionnaires about sleep quality, cognitive performance, and leisure-time sedentary behaviors. Sleep duration was objectively computed using a wrist-worn GENEActiv accelerometer and academic performance was analyzed through school records.

**Results:** Sleep quality (but not sleep duration) was associated with all the academic performance indicators (all  $p < 0.05$ ). Analysis of covariance revealed higher grades among adolescents with better sleep quality ( $PSQI \leq 5$ ; all  $p < 0.05$ ). These analyses showed no differences regarding cognitive performance. Internet use time was revealed as a mediator of the association between sleep quality and academic performance, being significant for all academic performance indicators ( $P_M$  ranging from 15.5% to 16.0%).

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**PALAVRAS-CHAVE**

Desempenho escolar;  
Cognição;  
Padrões de sono;  
Adolescência

**Conclusions:** The association between sleep quality and academic performance in adolescents is mediated by time of Internet use. Overall, reducing Internet use in adolescents could be an achievable intervention for improving sleep quality, with potentially positive effects on academic performance.

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### O efeito da qualidade do sono no desempenho acadêmico é mediado pelo tempo de uso da internet: estudo DADOS

#### Resumo

**Objetivo:** Analisar a associação dos padrões de sono com o desempenho acadêmico e cognitivo em adolescentes e testar o efeito mediador potencial de diferentes atividades com uso de dispositivos (mídias) com tela nessa associação.

**Métodos:** Uma amostra de 269 adolescentes (140 meninos) de 14 anos, da linha de base do estudo DADOS (*Deporte, ADOlescencia y Salud*) preencheu uma série de questionários sobre qualidade do sono, desempenho cognitivo e comportamentos sedentários no lazer. A duração do sono foi calculada objetivamente com um acelerômetro de pulso GENEActiv e o desempenho acadêmico foi analisado por meio de registros escolares.

**Resultados:** A qualidade do sono (mas não a duração do sono) foi associada a todos os indicadores de desempenho acadêmico (todos os valores de  $p < 0,05$ ). A análise de covariância revelou notas mais altas nos adolescentes com melhor qualidade de sono ( $PSQI \leq 5$ ; todos os valores de  $p < 0,05$ ). Essas análises não mostraram diferenças em relação ao desempenho cognitivo. O tempo de uso da Internet revelou-se como um mediador da associação entre qualidade do sono e desempenho acadêmico, foi significativo para todos os indicadores de desempenho acadêmico ( $P_M$  variou de 15,5% a 16,0%).

**Conclusões:** A associação entre qualidade do sono e desempenho acadêmico em adolescentes é mediada pelo tempo de uso da internet. No geral, reduzir o tempo de uso da internet pelos adolescentes pode ser uma intervenção viável para melhorar a qualidade do sono, com efeitos potencialmente positivos no desempenho acadêmico.

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## Introduction

Screen media usage (SMU), defined as screen-based activities such as mobile phone use, Internet surfing, computer use, videogames, and television, is the most popular leisure-time sedentary behavior among children and adolescents.<sup>1</sup> Recent studies have focused on the association between SMU and a wide range of adverse health consequences<sup>2</sup> such as obesity, cardiovascular disease risk,<sup>3</sup> unhealthy diet,<sup>4</sup> low academic and cognitive performance,<sup>5,6</sup> and poor sleep patterns.<sup>7</sup>

Cognitive and academic performance have been directly related with work achievement and career success during adulthood.<sup>8</sup> Despite the fact that many studies have shown the negative effects of SMU on cognition during childhood and adolescence,<sup>5,6</sup> results remain inconclusive depending on the analyzed leisure-time sedentary behavior. Recent evidence has shown a negative effect of television time on school performance<sup>9</sup> and a positive impact of videogame time on cognitive abilities.<sup>10</sup> However, Internet use time has been less studied, possibly due to the new growth of this SMU activity among youth. Recently, Kim et al.<sup>11</sup> revealed that academic performance was positively associated with

Internet use for study, but negatively associated with Internet when used for other purposes. Interestingly, Syväoja et al.<sup>12</sup> found that SMU was only linked to academic performance when considering later bedtime, highlighting the importance of considering together sleep, SMU, and cognition in adolescents.

Sleep patterns, including sleep quality and duration, are considered particularly important for physiological and psychological development, having implications on cognition during adolescence.<sup>13,14</sup> Recently, several studies and systematic reviews have suggested an adverse association between sleep patterns and SMU.<sup>7,15–17</sup> For instance, in a longitudinal study, Lemola et al.<sup>18</sup> found that SMU at night was negatively associated with sleep duration and positively associated with sleep difficulties in a sample of 362 adolescents.

Adolescence is a crucial period of life often viewed as an important time frame in terms of development of cognitive abilities and establishment of many health-related behaviors such as sleep. There is compelling evidence that links sleep patterns to cognition during this period of life.<sup>13,14,19</sup> Although previous studies have mostly focused on sleep duration, sleep quality, defined as the satisfaction level of

the sleep experience, is currently considered a stand-alone component of sleep due to its specific influence on cognition. In fact, poor sleep quality has been associated with impairments in memory, concentration, and learning, leading to poor academic performance.<sup>14,19</sup>

Due to the important role of sleep on academic and cognitive performance in adolescents, and the previously demonstrated independent associations of SMU with cognition and with sleep patterns, elucidating the relationship between these behaviors and their impact on academic performance is of major interest. To the best of the authors' knowledge, no previous study has analyzed the mediating role of SMU on the sleep-cognition association. Therefore, statistical analyses of mediation are needed to examine the percentage of the total effect explained by SMU as potential mediator. Thus, the aims of the present study were to analyze the association of sleep patterns with academic and cognitive performance in adolescents, and to test the mediating effect of the different activities of SMU on this association.

## Methods

### Study design and participants

The DADOS (Deporte, ADolescencia y Salud) study is a three-year longitudinal research project (from 2015 to 2017) aimed to assess the influence of physical activity on health, cognition, and psychological wellness through adolescence. All the participants were recruited from secondary schools and sport clubs of Castellón (Spain), and met the general DADOS inclusion criteria: born in 2001, enrolled in second grade of secondary school, and free of any chronic disease. The results presented in this study belong to baseline data obtained between February and May of 2015. From the total DADOS study sample ( $n = 274$ ), five adolescents did not complete the assessment protocol. Thus, the final sample had 269 adolescents (140 boys) with valid baseline data for sleep patterns, SMU, as well as academic and cognitive performance.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided written informed consent. The DADOS study protocol was designed in accordance with the ethical guidelines of the 1961 Declaration of Helsinki (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of the Jaume I University of Castellón.

### Physical characteristics of the study sample

Measures were assessed in duplicate by trained members of the DADOS research group following standardized procedures. The average measure was used for data analysis. Briefly, body weight was measured to the nearest 0.1 kg using an electronic scale (SECA 861 – Hamburg, Germany); subjects were lightly dressed and shoeless. Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer (SECA 213 – Hamburg, Germany). Body mass index (BMI) was calculated as weight/height square ( $\text{kg}/\text{m}^2$ ).

Pubertal status was self-reported according to the five stages defined by Tanner and Whitehouse.<sup>20</sup>

### Sleep data

The Spanish version of the Pittsburgh Sleep Quality Index (PSQI) questionnaire was used to assess sleep quality over the last month.<sup>21</sup> It includes 19 questions referring to seven components of sleep quality: subjective sleep quality, sleep duration, sleep latency, habitual sleep efficiency, sleep disturbance, use of sleep medication, and daytime dysfunction. Each component score is rated on a three-point scale, with 0 points indicating ideal sleep quality and 3 points indicating poor sleep quality. The overall PSQI score is the sum of all component scores, ranging from 0 to 21, with lower scores representing better sleep quality. The PSQI provides a sensitive measure to identify poor sleep quality if total PSQI score is  $>5$  and good sleep quality if total PSQI score is  $\leq 5$ . Because the overall PSQI score is inversely related to sleep quality, it was multiplied by  $-1$  for an easier understanding of the results.

Daily sleep duration was objectively measured by a GENEActiv accelerometer (Activinsights Ltd – Kimbolton, United Kingdom). It has been found reliable to examine sleep ( $\text{kappa} = 0.85 \pm 0.06$ ).<sup>22</sup> Sleep duration was calculated by the algorithm included in the macro provided by the Activinsights company. In addition, to check possible inconsistencies in the accelerometer data, participants kept a sleep log of their sleep-wake schedule. A high level of agreement was observed between the accelerometer and the participants' sleep log data. Only in a few cases were the results discrepant, and then the data from the non-consistent day removed. All participants included data of at least four complete days (two weekend days and two weekdays). By combining all registered days for each participant, sleep duration was then expressed as average h/day. According to the definition of the National Sleep Foundation, for adolescent populations, good sleep duration is defined as  $\geq 8$  h per day.

### Academic performance

Based on the information provided by the secretary office of each school, academic performance was assessed through the final grades from the first course of secondary school on a ten-point scale. According to previous scientific literature, four indicators were used to define academic performance: individual grades for the core subjects (math and Spanish), an average of the core subjects, and grade point average (GPA) score. GPA score was defined as the single average for geography and history, natural science, math, Spanish, Catalan, English, and physical education grades.

### Cognitive performance

Cognitive performance was measured using the Spanish version of the "SRA Test of Educational Ability" (TEA).<sup>23</sup> This test provides general measures of three areas of intelligence and skills of learning: verbal (command of language), numeric (speed and precision in performing operations

with numbers and quantitative concepts), and reasoning (the ability to find logical order in sets of numbers, figures, or letters) abilities. Scores for the three areas were obtained by adding positive answers. Overall cognitive performance was calculated by adding the three area scores (verbal + numeric + reasoning). Based on the age range of our sample, level three of the TEA questionnaire was used (reliability: verbal  $\alpha = 0.74$ , numeric  $\alpha = 0.87$ , reasoning  $\alpha = 0.77$ , and overall cognitive performance  $\alpha = 0.89$ ).

### Screen media usage

Leisure-time sedentary behaviors were assessed using the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) sedentarism questionnaire, designed *ad hoc*.<sup>24</sup> For both weekdays and weekend days, adolescents reported the number of hours spent on television, videogames, Internet surfing, and mobile phone use. Seven possible answers were available for each item: no time, less than 1/2 h; 1/2–1 h; 1–2 h; 2–3 h; 3–4 h; and, more than 4 h. The mean time of each answer was used to calculate the daily overall time for each sedentary behavior as follows:  $1/7 \times (2 \times \text{weekend day hours} + 5 \times \text{weekday hours})$ .

### Statistical analysis

The descriptive characteristics of the study sample are presented as mean  $\pm$  standard deviation unless otherwise stated. The Kolmogorov–Smirnov test and histograms were used to check for normal distribution, and data for the PSQI score were log-transformed before statistical analysis. Sex differences were assessed by analysis of variance (ANOVA) for continuous variables and by the chi-squared test for categorical variables. For each ANOVA, the effect size, partial eta squared ( $\eta^2$ ), was calculated and interpreted following the Cohen's guidelines: small,  $0.01 < \eta^2 < 0.06$ ; medium,  $0.06 \leq \eta^2 < 0.14$ ; and large,  $\eta^2 \geq 0.14$ .<sup>25</sup> Preliminary analyses showed no significant interactions among sex and sleep variables (all  $p > 0.10$ ); therefore, all analyses were performed with the total sample.

Data analysis took three steps. Firstly, in order to confirm the relationships among the sleep patterns, SMU variables, and cognitive and academic performance indicators, a series of partial correlations were performed, controlling for sex and pubertal status. From these analyses, Internet use was identified for further analysis owing to its consistently strong associations with sleep quality and academic and cognitive performance. Internet use was categorized as low (first and second tertiles;  $5.8 \pm 6.2$  and  $37.8 \pm 9.6$  min/day, respectively) and high (third tertile;  $118.0 \pm 57.7$  min/day). Analysis of covariance (ANCOVA) models were used to assess differences in academic and cognitive performance across categories of sleep quality and Internet use, controlling for sex, and pubertal status (model 1), and with further adjustment for Internet use or sleep quality depending on the fixed factor (model 2). For each ANCOVA effect, a partial  $\eta^2$  is reported.<sup>25</sup> Finally, separate mediation analyses were performed using the PROCESS macro in order to elucidate whether the association between sleep quality and academic performance was mediated by the Internet use time. The following steps for mediation were used: the

first equation regressed the mediator (Internet use) on the independent variable (sleep quality). The second equation regressed the dependent variable (math, Spanish, core subjects, and GPA) on the independent variable. The third equation regressed the dependent variable on both the independent variable and the mediator variable. Mediation was considered significant when 0 was not in the 95% confidence interval of the indirect effects (estimated by bootstrapping), as recommended by Preacher and Hayes.<sup>26</sup>  $P_M$  (%), or how much of the total effect was explained by mediation, was calculated as follows: (indirect effect/total effect)  $\times$  100. All the analyses were performed using IBM SPSS Statistics for Windows version 22.0 (IBM Corp.; Armonk, NY, United States), and the level of significance was set to  $p < 0.05$ .

## Results

Table 1 presents descriptive characteristics of the study sample by sex. Boys were taller than girls ( $p < 0.001$ ). Good sleep quality (total PSQI score  $\leq 5$ ) was reported by 74% of boys and 54% of girls ( $p < 0.001$ ). The 47% of the boys and the 54% of the girls presented good sleep duration ( $\geq 8$  h/day;  $p < 0.01$ ). No differences between sexes were found in academic performance. Regarding cognitive performance indicators, boys showed higher values for numeric and overall ability than girls (14.8 vs. 11.9 and 50.0 vs. 47.0; both  $p < 0.05$ ). Boys showed higher daily videogame time than girls ( $p < 0.001$ ) whereas girls showed higher daily mobile phone use time ( $p < 0.01$ ).

Table 2 shows the partial correlations among the study variables after controlling for sex and pubertal status. Sleep quality was negatively associated with videogame time, Internet time, and mobile phone use time, and positively associated with all the academic performance indicators included in the study (all  $p < 0.05$ ). Sleep duration was only associated with verbal ability ( $p \leq 0.001$ ). Internet use was negatively associated with all academic performance indicators, reasoning ability, and overall cognitive performance (all  $p < 0.05$ ). Mobile phone use was negatively associated with GPA ( $p < 0.05$ ). No associations of videogame and TV time with academic and cognitive performance indicators were found.

Mean differences in academic and cognitive performance by sleep quality and Internet use categories, controlling for sex and pubertal status (model 1), are shown in Table 3. Analysis of covariance (ANCOVA) showed that adolescents with good sleep quality (total PSQI score  $\leq 5$ ) presented better academic performance for math, core subjects and GPA, and lower Internet use time (all  $p < 0.05$ ). Regarding Internet use categories, adolescents spending lower Internet use time had higher GPA, better reasoning ability and overall cognitive performance, and better sleep quality (model 1;  $p < 0.05$ ). The effect sizes were small in all the reported significant associations. Results were similar when sleep quality was included as a confounder (model 2). As the results changed when Internet use was included as a confounder with sleep quality categories as the fixed factor and academic performance as dependent variable (model 2), Internet use time was revealed as a possible mediator variable on the association of sleep quality with academic performance.

**Table 1** Characteristics of the study population by sex.

	All (n = 269)	Boys (n = 140)	Girls (n = 129)	p	$\eta^2$
<i>Demographics</i>					
Age (years) <sup>a</sup>	13.9 ± 0.3	13.9 ± 0.3	13.9 ± 0.3	0.903	0.000
Tanner stage (I–V) (%)	0/8/34/48/10	0/10/32/44/14	0/5/36/54/5		
<i>Anthropometry<sup>a</sup></i>					
Height (cm)	163.0 ± 7.9	164.6 ± 8.6	161.2 ± 6.8	<b>0.000</b>	0.049
Weight (kg)	54.1 ± 9.2	54.5 ± 9.6	53.7 ± 8.8	0.486	0.002
BMI (kg/m <sup>2</sup> )	20.3 ± 2.7	20.0 ± 2.5	20.6 ± 2.9	0.059	0.014
<i>Sleep</i>					
Sleep quality (0–21) <sup>a</sup>	4.8 ± 2.8	4.2 ± 2.7	5.5 ± 2.7	<b>0.000</b>	0.071
Good sleep quality <sup>b</sup>	65 (174)	74 (104)	54 (70)	<b>0.001</b>	
Sleep duration (h) <sup>a</sup>	8.0 ± 0.9	7.8 ± 1.0	8.1 ± 0.8	<b>0.006</b>	0.028
Good sleep duration <sup>b</sup>	50 (135)	47 (66)	54 (69)	0.326	
<i>Academic performance (0–10)<sup>a</sup></i>					
Math	6.8 ± 1.6	7.0 ± 1.6	6.7 ± 1.6	0.196	0.006
Spanish	6.9 ± 1.5	6.7 ± 1.5	7.1 ± 1.5	0.075	0.013
Core subjects	6.9 ± 1.5	6.8 ± 1.5	6.9 ± 1.5	0.838	0.000
GPA	7.1 ± 1.3	7.1 ± 1.3	7.2 ± 1.3	0.420	0.003
<i>Cognitive performance<sup>a</sup></i>					
Verbal ability (0–50)	18.7 ± 5.3	19.1 ± 5.9	18.2 ± 4.6	0.131	0.009
Numeric ability (0–30)	13.4 ± 4.8	14.8 ± 4.6	11.9 ± 4.5	<b>0.000</b>	0.094
Reasoning ability (0–30)	16.5 ± 5.8	16.1 ± 5.6	16.9 ± 6.0	0.239	0.005
Overall (0–110)	48.6 ± 12.6	50.0 ± 12.8	47.0 ± 12.2	<b>0.049</b>	0.015
<i>SMU (min/day)<sup>a</sup></i>					
Videogames	34.5 ± 44.0	45.4 ± 45.9	22.7 ± 38.7	<b>0.000</b>	0.066
Internet	53.3 ± 58.5	47.4 ± 57.6	59.7 ± 59.1	0.086	0.013
Mobile phone	111.0 ± 84.3	97.0 ± 79.6	126.1 ± 86.8	<b>0.004</b>	0.031
Television	90.9 ± 52.9	92.4 ± 53.0	89.4 ± 53.0	0.647	0.001

Data are presented as <sup>a</sup> mean ± standard deviation or <sup>b</sup> frequency % (n). Differences between sexes were examined by <sup>a</sup> analysis of the variance test or <sup>b</sup> the chi-squared test. Values in bold font indicate significant results.

BMI, body mass index; Good sleep quality, PSQI score ≤5; Good sleep duration, total sleep time ≥8 h per night. Core subjects indicates the mean of math and Spanish; GPA, grade point average; Overall indicates the sum of the three ability scores; SMU, screen media usage.

**Table 2** Partial correlations of the study variables, controlling for sex and pubertal status.

	Sleep patterns		Academic performance				Cognitive performance			
	Sleep quality	Sleep duration	Math	Spanish	Core subjects	GPA	Verbal	Numeric	Reasoning	Overall
<i>Sleep patterns</i>										
Sleep quality	–	–0.085	0.225 <sup>b</sup>	0.143 <sup>a</sup>	0.194 <sup>a</sup>	0.205 <sup>b</sup>	0.034	0.111	0.071	0.088
Sleep duration	–0.085	–	–0.038	–0.064	–0.053	–0.073	–0.198 <sup>b</sup>	–0.018	0.006	–0.087
<i>SMU</i>										
Videogames	–0.150 <sup>a</sup>	0.048	–0.051	–0.050	–0.054	–0.076	–0.014	–0.005	0.009	–0.004
Internet	–0.179 <sup>a</sup>	0.001	–0.193 <sup>a</sup>	–0.165 <sup>a</sup>	–0.206 <sup>b</sup>	–0.221 <sup>b</sup>	–0.068	–0.100	–0.178 <sup>a</sup>	–0.148 <sup>a</sup>
Mobile phone	–0.131 <sup>a</sup>	0.004	–0.092	–0.110	–0.113	–0.143 <sup>a</sup>	–0.034	–0.089	–0.112	–0.099
Television	–0.001	0.091	–0.003	–0.028	–0.026	–0.057	0.116	–0.049	–0.079	–0.006

Core subjects indicates the mean of math and Spanish; GPA, grade point average; Overall indicates the sum of the three ability scores; SMU, screen media usage.

p-value = <sup>a</sup> p < 0.05 and <sup>b</sup> p ≤ 0.001.

## Mediation analysis

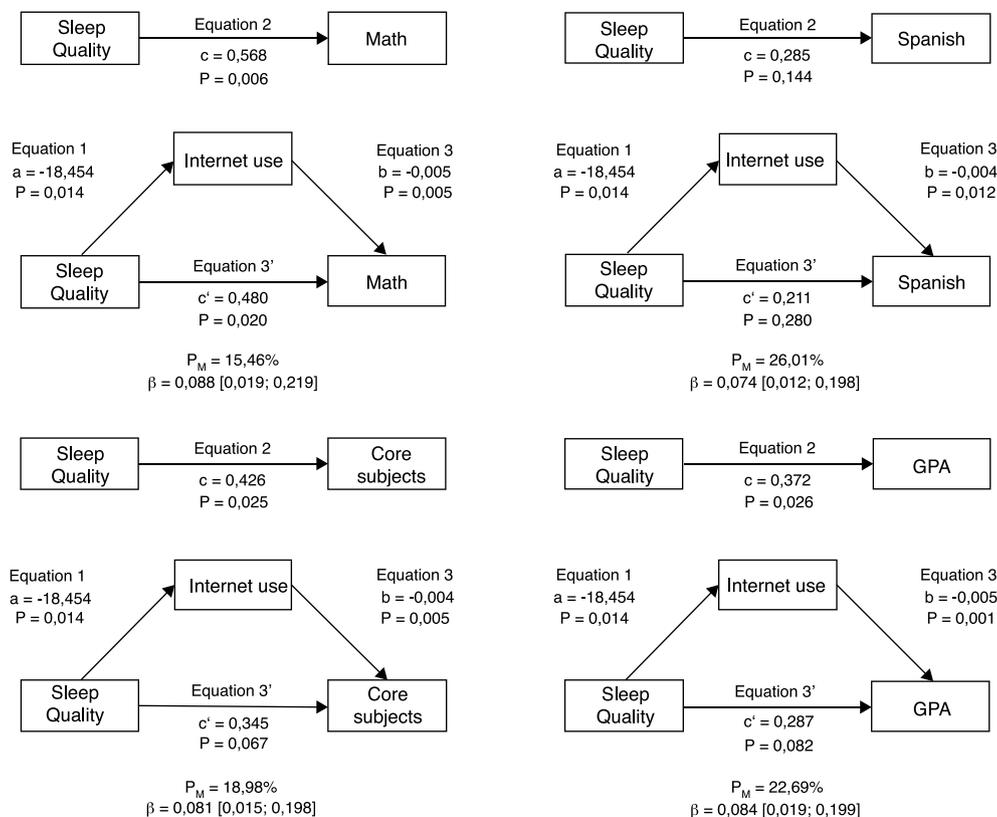
Based on previous statistical analyses, we tested Internet use time as a potential mediator of the association between sleep quality and academic performance, controlling for sex and pubertal status (Fig. 1). Sleep quality was associated with academic performance, and the change from poor to

good sleep quality was associated with an increase in academic performance, ranging from 0.28 points for Spanish to 0.57 points for math. In addition, the change from poor to good sleep quality was associated with 18.5 less minutes spent using Internet per day (a path; p < 0.05), and Internet use time was negatively associated with academic performance (b path; all p < 0.05). The mediation effect of Internet

**Table 3** Mean differences in academic and cognitive performance by sleep quality and Internet use categories.

	Sleep quality						Internet use					
	Good sleep quality (n = 174)	Bad sleep quality (n = 95)	Model 1 <i>p</i>	$\eta^2$	Model 2 <i>p</i>	$\eta^2$	Low Internet use (n = 179)	High Internet use (n = 90)	Model 1 <i>p</i>	$\eta^2$	Model 2 <i>p</i>	$\eta^2$
<i>Academic performance</i>												
Math	7.0 ± 1.6	6.4 ± 1.6	<b>0.006</b>	0.027	<b>0.020</b>	0.019	7.0 ± 1.6	6.6 ± 1.6	0.068	0.008	0.208	0.004
Spanish	7.0 ± 1.6	6.8 ± 1.4	0.144	0.008	0.280	0.004	7.0 ± 1.5	6.7 ± 1.5	0.103	0.010	0.190	0.008
Core subjects	7.0 ± 1.5	6.6 ± 1.4	<b>0.024</b>	0.018	0.067	0.011	7.0 ± 1.4	6.6 ± 1.5	0.066	0.010	0.172	0.006
GPA	7.2 ± 1.3	6.9 ± 1.3	<b>0.026</b>	0.018	0.082	0.010	7.2 ± 1.2	6.9 ± 1.3	<b>0.017</b>	0.022	0.053	0.018
<i>Cognitive performance</i>												
Verbal ability	18.7 ± 5.4	18.7 ± 5.2	0.777	0.000	0.636	0.001	19.0 ± 5.1	18.1 ± 5.7	0.118	0.007	0.128	0.007
Numeric ability	13.7 ± 4.8	12.8 ± 4.7	0.573	0.001	0.762	0.000	13.8 ± 4.6	12.6 ± 4.9	0.137	0.005	0.222	0.003
Reasoning ability	16.4 ± 5.8	16.7 ± 5.9	0.920	0.000	0.583	0.001	17.0 ± 5.5	15.5 ± 6.4	<b>0.015</b>	0.018	<b>0.024</b>	0.017
Overall	48.8 ± 12.8	48.1 ± 12.3	0.969	0.000	0.729	0.000	49.8 ± 12.0	46.2 ± 13.4	<b>0.019</b>	0.015	<b>0.033</b>	0.013
Sleep quality	3.2 ± 1.3	7.8 ± 2.2	–	–	–	–	4.4 ± 2.4	5.8 ± 3.2	<b>0.006</b>	0.025	–	–
Internet use	46.1 ± 55.9	66.5 ± 61.2	<b>0.014</b>	0.025	–	–	20.8 ± 17.9	118.0 ± 57.7	–	–	–	–

Data are presented as mean ± standard deviation. Differences between categories were examined by analysis of covariance. Values in bold font indicate significant results. Categories of sleep quality are good (PSQI score ≤5) and poor (PSQI score >5). Categories of Internet use time are low (first and second tertiles) and high (third tertile). Core subjects indicates the mean of math and Spanish; GPA, grade point average; Overall indicates the sum of the three ability scores; Model 1, adjusted for sex and pubertal status; Model 2, further adjustment for Internet use time to sleep quality categories and for sleep quality score to Internet use time categories.



**Figure 1** Internet use mediation models of the relationship between sleep quality and academic performance indicators, controlling for sex and pubertal status. Core subjects indicates the mean of math and Spanish; GPA, grade point average;  $\beta$  = indirect effect; [LLCI; ULCI], lower and upper levels for 95% confidence interval of the indirect effect between sleep quality and academic performance.

use time on the relationship between sleep quality and academic performance was significant for all academic performance indicators (math  $P_M = 15.46\%$ ; Spanish  $P_M = 26.01\%$ ; core subjects  $P_M = 18.98\%$ , and GPA  $P_M = 22.69\%$ ).

## Discussion

The results of the present study concur with previous research, evidencing a positive association between sleep quality and academic performance in adolescents.<sup>14</sup> The data fit in line with previous studies showing a negative influence of Internet use on both sleep quality<sup>16,17</sup> and academic performance.<sup>5,6</sup> The main finding of this study reveals a mediating effect of Internet use time on the association between sleep quality and academic performance. These results contribute to the current scientific knowledge by suggesting that Internet use time could partially explain the association between sleep quality and academic performance in adolescents.

These results partially concur with the authors' hypothesis, showing that better self-reported sleep quality (but not objectively-measured sleep duration) was statistically associated with higher report-card academic performance (but not with cognitive performance). Additional analyses revealed that adolescents with good sleep quality ( $PSQJ \leq 5$ ) had higher school grades than those with poor sleep

quality ( $PSQJ > 5$ ). Consistent with these findings, several studies have analyzed this association using both subjective and objective sleep measures.<sup>8,14</sup> For instance, Gruber et al.<sup>8</sup> analyzed a sample of 75 children, showing that better academic performance was associated with higher objectively-measured sleep efficiency but not with objective sleep duration. Interestingly, a large review that examined the associations of sleep quality and duration with school performance showed that sleep quality was more strongly associated with school performance than sleep duration.<sup>14</sup> In fact, it has been recommended to treat sleep quality and duration as two separate sleep domains, since they seem to contribute differently to academic performance and because of the low correlation between them.<sup>14</sup> The large individual differences in the sleep experience, which can be captured by subjective tools but not by accelerometry due its methodological limitations, could explain the divergences between the present results and those found in the scientific literature. Several potential mechanisms by which sleep quality may positively influence academic performance have been postulated. First, poor sleep quality has been closely linked to adverse effects on prefrontal cortex cognitive processes, which may negatively influence working memory and executive function.<sup>19</sup> Second, poor sleep quality reduces daytime alertness<sup>27</sup> which in turn might affect attention, leading to academic performance impairment.

Previous literature is showing a growing interest about the association of SMU with sleep and cognition. Many of the studies show an inverse association of Internet use time with both sleep quality<sup>15,28</sup> and academic performance.<sup>11</sup> No previous studies have analyzed the mediating effect of SMU on the association between sleep quality and academic performance. Among all the SMU variables analyzed, the present results revealed a mediating effect of Internet use time on the association between sleep quality and academic performance. Diverse mechanisms could explain the role of Internet use found in this study. First, social networking and time spent online have been suggested to increase physical and emotional arousal, which could interfere with sleep quality.<sup>29</sup> Second, the bright light from screens before sleeping may have an acute alerting effect.<sup>30</sup> Finally, Internet use time might replace time for study, which together with poorer sleep quality, may result in lower academic performance.

Limitations of the present study include its cross-sectional design, which precludes establishing the causal direction of the observed associations, and the use of self-reported questionnaires to assess leisure-time sedentary behaviors and sleep quality. However, this study has several strengths, including the objective assessment of sleep duration by accelerometry, the inclusion of a wide range of leisure-time sedentary behaviors, the homogeneous characteristics of the adolescent sample, and the inclusion of pubertal status as a confounder.

These findings could have important implications from an educational and public health perspective, revealing that sleep quality in adolescents is more strongly related with academic performance than sleep duration. Moreover, the association between sleep quality and academic performance is mediated by Internet use time. Thus, if confirmed prospectively, reducing Internet use time in adolescents might be an achievable intervention for improving sleep quality with potentially positive effects on academic performance.

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## Conflicts of interest

The authors declare no conflicts of interest.

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