

1 **The influence of adherence to the Mediterranean diet on academic performance is**
2 **mediated by sleep quality in adolescents**

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30 **ABSTRACT**

31 **Aim:** This study examined the association of adherence to the Mediterranean diet with
32 academic performance and tested whether this association was mediated by sleep in
33 Spanish adolescents.

34 **Methods:** We recruited 269 adolescents (52% boys) aged 13.9 ± 0.3 years from the
35 *Deporte, ADOlescencia y Salud* study of 38 secondary schools and sport clubs in
36 Castellon, Spain, between February and May 2015. Adherence to the Mediterranean diet
37 was assessed by the KIDMED questionnaire, sleep quality was evaluated with the
38 Pittsburgh Sleep Quality Index test and sleep duration was objectively computed using a
39 wrist-worn accelerometer. Academic performance was assessed through final school
40 grades and a validated test.

41 **Results:** Greater adherence to the Mediterranean diet was associated with higher scores
42 in language, core subjects, grade point average and verbal ability ($p < 0.05$). Sleep quality
43 acted as a significant mediator of the association between adherence to the Mediterranean
44 diet and final grades in maths, language, core subjects and the grade point average.

45 **Conclusion:** Our data show that the influence of adherence to the Mediterranean diet on
46 academic performance was mediated by sleep quality in adolescents. Education and
47 public health professionals should work together to achieve both improved health status
48 and academic performance in adolescents.

49

50 **Key Notes**

- 51 • We recruited 269 adolescents (52% boys) aged 13.9 ± 0.3 years from a study
52 of 38 secondary schools and sport clubs in Castellon, Spain.,
- 53 • Our results showed that adherence to the Mediterranean diet was positively
54 associated with academic grades and verbal ability in our cohort.
- 55 • The study carried out between February and May 2015 also revealed the
56 potential mediating effect that sleep quality had on that association.

57

58 **Key words.** academic achievement, adolescence, Mediterranean diet, school
59 performance, sleep patterns.

60 INTRODUCTION

61 The Mediterranean diet is characterised by a high consumption of fruit,
62 vegetables, breads, legumes, nuts and seeds, a low intake of red meat, a low-to-moderate
63 consumption of wine, fish and poultry and the use of olive oil as the principal source of
64 fat (1). In terms of nutrients, the Mediterranean diet is rich in polyunsaturated fatty acids,
65 fibre, antioxidants and vegetable proteins (2). Greater adherence to the Mediterranean
66 diet has been associated with a lower risk of morbidity and mortality (3), as well as better
67 sleep patterns (4,5) and cognition (6,7).

68 Academic performance during adolescence has a significant influence on future
69 health (8) and work conditions (9). Individual behaviours, such as diet, may differently
70 influence cognition (10), and in turn, academic performance. For instance, consuming
71 fish, milk, fruits and vegetables, and a lower intake of soft drinks and salty snacks, have
72 been associated with better academic and cognitive performance in adolescents (11).
73 However, dietary patterns seem to be more strongly associated with cognition than
74 individual foods, due to the synergistic effects of each food component (11). Despite this
75 growing evidence of the influence of diet on cognition, the effect of adherence to the
76 Mediterranean diet on academic performance in adolescents has been poorly investigated
77 (7).

78 Greater adherence to the Mediterranean diet has also been associated with better
79 sleep patterns, such as duration and quality (4,5), as a result of the effect of different
80 nutrients (12,13). Interestingly, prior research has shown that sleep has also been related
81 to memory consolidation, brain plasticity and cognition (14), which, in turn, may improve
82 academic performance in adolescents (15).

83 Given the association between adherence to the Mediterranean diet and academic
84 performance in adolescents, and the independent associations of sleep patterns with
85 Mediterranean diet and cognition mentioned above, the aims of the present study were:
86 (i) to examine the association of adherence to Mediterranean diet with academic
87 performance and (ii) to test whether the association of adherence to the Mediterranean
88 diet with academic performance was mediated by sleep patterns in healthy adolescents.

89 **METHODS**

90 **Study design and sample selection**

91 A national three-year longitudinal research project, DADOS (Deporte,
92 ADOlescencia y Salud; from 2015 to 2017), was performed to assess the influence of
93 physical activity on health, cognition and psychological wellness through adolescence.
94 Participants meeting the general inclusion criteria were recruited from secondary schools
95 and sport clubs in Castellon; adolescents born in 2001, enrolled in the second grade of
96 secondary school and free from any chronic disease. The results presented in this study
97 come from baseline data obtained from February to May 2015. The sample analysed
98 comprised 269 adolescents (52% boys) aged 13.9 ± 0.3 years with valid baseline data on
99 sleep variables, Mediterranean dietary patterns and academic performance.

100 Adolescents and their parents or guardians were informed of the nature and
101 characteristics of the study and all provided written, informed consent. The study protocol
102 was designed in accordance with the ethical guidelines of the 2013 revision of the
103 Declaration of Helsinki 1961 and approved by the Research Ethics Committee of the
104 University Jaume I of Castellon.

105 **Adherence to the Mediterranean diet**

106 Adherence to the Mediterranean diet was assessed by using KIDMED (16), a
107 questionnaire that was based on the Mediterranean dietary guidelines for children and
108 adolescents and provides an overall indication of their diet. The KIDMED includes 16
109 questions about if subjects consume fast food, sweets and soft drinks, daily fruit and
110 vegetables and weekly fish and legumes, with yes or no answers required. The score for
111 the subjects' adherence to the Mediterranean diet was calculated as the sum of each
112 answer, ranging from zero to 12. Levels of adherence were classified into three groups:
113 poor (0-3), average (4-7) and good (8-12).

114 **Sleep patterns**

115 Sleep quality over the last month was assessed by using the Spanish version of the
116 Pittsburgh Sleep Quality Index (PSQI) test (17). The overall PSQI score ranges from zero
117 to 21, with scores ≤ 5 defined as good sleep quality. Because the overall PSQI score is
118 inversely related to sleep quality, it was multiplied by -1 in the first instance.

119 Daily sleep duration was objectively measured by a GENEActiv accelerometer
120 (Activinsights Ltd, Cambridgeshire, UK), which is a lightweight 16 grams, triaxial and
121 waterproof. It has been found to be reliable for examining sleep ($\kappa = 0.85 \pm 0.06$)
122 (18). Participants were instructed to wear 24-hours day the accelerometer on their left
123 wrist for at least four consecutive days, including two weekend days and two weekdays.
124 If the unit was removed, the data for that day were excluded from the analyses. Sleep
125 duration was calculated by the algorithm included in the macro provided by the
126 manufacturer. By combining all the registered days for each participant, sleep duration
127 was then expressed as the average number of hours per day. Short sleep duration was
128 defined as less than eight hours per night, as defined by the American National Sleep
129 Foundation for the adolescent population (19).

130 **Academic performance**

131 Academic performance was assessed by two components. First, we looked at the
132 final academic grades from the first year of secondary school, which were provided by
133 each school. The following subjects were included in the analyses: individual grades for
134 the core subjects of maths and the Catalan language, the official language taught at the
135 school, an average of these core subjects and the grade point average score. The grade
136 point average score was defined as the single average for geography and history, natural
137 sciences, maths, Spanish, Catalan and English languages and physical education grades.
138 All the subjects are measured on a ten-point scale, where one was the worst and 10 was
139 the best. Second, we used the Spanish version of the validated Science Research
140 Associates Test of Educational Abilities (20). This test measures the subject's ability to
141 learn by evaluating three basic skills: verbal ability, which is their command of language;
142 numerical ability, which refers to their speed and precision in performing operations with
143 numbers and quantitative concepts and reasoning ability, which refers to their aptitude to
144 find logical ordination criteria in sets of numbers, figures or letters. Scores for the three
145 areas were obtained by adding positive answers. Overall academic ability was calculated
146 by adding the scores for the three areas of ability. This battery test provides three
147 complexity levels based on the age range of the sample. The present study used level
148 three, which is designed for adolescents aged 14 to 18 years. The alpha scores for its
149 reliability have been reported to be 0.74 for verbal ability, 0.87 for numerical ability, 0.77
150 for reasoning ability and 0.89 for overall academic ability (20).

151 **Covariates**

152 Briefly, body weight was measured to the nearest 0.1 kilograms using a seca 861
153 electronic scale (seca, Hamburg, Germany) with the subjects lightly dressed and without
154 shoes. Height was measured to the nearest 0.1 centimetres using a wall-mounted seca 213

155 stadiometer (seca, Hamburg, Germany). Measures were assessed in duplicate by trained
156 members of the project's research group following standardised procedures and average
157 measures were used for the data analysis (21). Body mass index (BMI) was calculated as
158 weight/height square (kg/m^2). Pubertal status was self-reported according to the five
159 stages defined by Tanner and Whitehouse. Physical activity (PA) was objectively
160 measured using the GENEActiv accelerometer, as stated above, which has shown an
161 intra-assay and inter-assay precision coefficient of variation of 1.4% and 2.1%,
162 respectively. By combining all registered days for each participant and using the Excel
163 macro (Microsoft Corp, Washington, USA) to summarise the data, PA was expressed as
164 the average minutes per day spent in light, moderate, and vigorous PA. Moderate and
165 vigorous PA (MVPA) was calculated by adding moderate PA and vigorous PA.

166 **Statistical analyses**

167 The descriptive characteristics are presented as means and standard deviations
168 (SD) or percentages. Differences between sexes were examined using the t-test and chi-
169 square test for continuous and nominal variables, respectively. All variables were checked
170 for normality using both graphical normal probability plots and statistical Kolmogorov-
171 Smirnov test procedures. Due to its skewed distribution, the PSQI score was log-
172 transformed when required. As the preliminary analyses showed no significant
173 interactions between sex and adherence to the Mediterranean diet and sleep variables in
174 relation to academic performance (all $p > 0.10$), all the analyses were performed for the
175 whole sample.

176 Partial correlations coefficients were used to confirm the relationships between adherence
177 to the Mediterranean diet, sleep variables and academic performance indicators,
178 controlled for sex, pubertal stage, BMI and MVPA.

179 Multiple linear regression was used to study the association of adherence to the
180 Mediterranean diet and academic performance using three separate models: model 1
181 comprised sex, pubertal stage, BMI and MVPA; model 2 comprised model 1 plus sleep
182 duration and model 3 comprised model 1 plus sleep quality.

183 In order to elucidate whether the associations between adherence to the
184 Mediterranean diet and academic performance were mediated by sleep patterns,
185 mediation analyses were conducted using the PROCESS macro according to the
186 procedures proposed by Hayes (22) and controlling for sex, pubertal stage, BMI and
187 MVPA. The first equation regressed the mediator (sleep) on the independent variable
188 (adherence to the Mediterranean diet). The second equation regressed the dependent
189 variable (academic performance) on the independent variable. The third equation
190 regressed the dependent variable on both the independent and mediator variables. The
191 mediation analyses included continuous variables and was considered significant when
192 zero was not in the 95% confidence interval of the indirect effects, estimated by
193 bootstrapping, as recommended by Preacher and Hayes (23). The part of the total effect
194 that was explained by the mediation, namely the percentage of mediation (P_M) was
195 calculated as follows: (indirect effect/total effect) x 100. All the analyses were performed
196 using SPSS Statistics for Windows version 22.0 (IBM Corp, New York, USA) and the
197 level of significance was set to $p < 0.05$.

198 **RESULTS**

199 The descriptive characteristics of the study population are presented in Table 1.
200 Overall, boys were taller, more physically active ($p < 0.001$) and had greater adherence to
201 the Mediterranean diet than girls ($p < 0.01$). We found that 74% of boys and 54% of girls
202 showed good sleep quality ($p < 0.001$). The boys also had a better mean sleep quality score

203 (4.2 versus 5.5, $p<0.01$), shorter sleep duration (7.8 versus 8.1 hours; $p<0.01$) and higher
204 numerical ability (14.8 versus 11.9; $p<0.001$) than the girls.

205 Partial correlations controlling for sex, pubertal stage, BMI and MVPA are shown
206 in Table 2. Adherence to the Mediterranean diet was positively correlated with sleep
207 quality, language, core subjects, grade point average and verbal ability (all $p<0.05$). Sleep
208 quality was positively correlated with academic grades (all $p<0.01$), while sleep duration
209 was negatively correlated with verbal ability ($p<0.01$).

210 The results of the multiple linear regression models showing the association of
211 adherence to the Mediterranean diet with academic performance are presented in Table
212 3. According to the academic grades, adherence to the Mediterranean diet was positively
213 associated with language, core subjects and the grade point average (all $p<0.05$) after
214 controlling for sex, pubertal stage, BMI and MVPA (model 1). These associations
215 disappeared after further controlling for sleep duration (model 2) and sleep quality (model
216 3). Regarding academic abilities, adherence to the Mediterranean diet was positively
217 associated with verbal ability (model 1), even after controlling for potential confounders
218 (models 2 and 3).

219 Mediation analyses were carried out to test whether the associations between
220 adherence to the Mediterranean diet (independent variable) and academic performance
221 (dependent variables) were mediated by sleep patterns (mediator variables). Mediation
222 analyses were not significant for the association of adherence to the Mediterranean diet
223 with academic performance when sleep duration was included as a mediator variable
224 (data not shown). According to our mediation analyses (Figure 1), sleep quality acted as
225 a mediator for the relationship of adherence to the Mediterranean diet with academic
226 grades, but not with academic abilities (data not shown). In the first equation, adherence
227 to the Mediterranean diet was positively associated with sleep quality ($p<0.05$). In the

228 second equation, adherence to the Mediterranean diet was also positively associated with
229 final grades ($p < 0.05$). Finally, in the third equation, sleep quality was positively
230 associated with final grades ($p < 0.01$) and adherence to the Mediterranean diet was
231 positively related with final grades, although the associations were not statistically
232 significant. These results suggest that adherence to the Mediterranean diet could
233 indirectly influence some academic performance variables through its effects on sleep
234 quality: maths $P_M = 20.24\%$; language $P_M = 15.44\%$; core subjects $P_M = 15.52\%$ and
235 grade point average $P_M = 16.83\%$.

236 **DISCUSSION**

237 To our knowledge this is the first study investigating the potential mediator role
238 of sleep quality in the association between adherence to Mediterranean diet and academic
239 performance in adolescents. The main finding of the present study indicates a positive
240 association between adherence to the Mediterranean diet and academic performance in
241 adolescents, revealing a mediating effect of sleep quality on this association.

242 No previous studies have investigated the association between adherence to the
243 Mediterranean diet and academic abilities. However, we found three studies examining
244 the association between adherence to the Mediterranean diet and school grades. In
245 consonance with our results, Vassiloudis et al found a positive association between
246 adherence to the Mediterranean diet and self-reported academic performance in Greek
247 children (6) and adolescents (24). Similarly, Esteban-Cornejo et al (7) showed that greater
248 adherence to the Mediterranean diet was related with higher academic performance scores
249 in Spanish children and adolescents aged 10-15 years.

250 Our data show that adherence to the Mediterranean diet may have positively
251 influenced the adolescents' academic grades, but not their academic abilities. The

252 divergent results obtained for academic performance variables could have been due to
253 methodological differences. In fact, academic abilities were assessed through a
254 standardised test that evaluates individually specific content abilities in a single time-
255 point trial, whilst the multifactorial character of academic grades involve other social,
256 cultural and biological variables that have an impact on a final grade.

257 The association between the Mediterranean diet and academic performance could
258 be related to the key role that dietary patterns and nutrients exert on brain. The
259 consumption of polyunsaturated fatty acids, abundant in olives, nuts and fish, increases
260 the levels of brain-derived neurotrophic factors, which stimulates cognitive functioning.
261 This, in turn, may improve academic performance (25). Conversely, overconsumption of
262 saturated fat and simple sugars decreases the levels of brain-derived neurotrophic factors
263 and increases oxidative stress, which may impair cognitive processes (26,27). In addition,
264 the intake of flavonoid and non-flavonoid polyphenols, which are mainly found in fruits
265 and vegetables, has antioxidant and anti-inflammatory properties and promotes neuronal
266 signalling with positive effects on learning and memory (25). Therefore, the foods rich in
267 micronutrients and macronutrients that are found in the Mediterranean diet could act as
268 key factors leading to better academic performance.

269 When we examined whether sleep duration and quality could be underlying
270 mechanisms of the association between adherence to the Mediterranean diet and
271 academic performance, only sleep quality was revealed as a mediator. Few studies have
272 investigated the association between the Mediterranean diet and academic performance,
273 and none of them has evaluated the mediating role of sleep quality. Our results add
274 important information in relation to the relevance of sleep on academic performance and
275 highlight that sleep quality could play a more important role than sleep duration in
276 academic performance, which has also been previously suggested (15,28).

277 Several aspects of the Mediterranean diet, including specific nutrients, have been
278 shown to modulate sleep quality. In fact, adequate amounts of proteins, fibre,
279 carbohydrates, polyphenols, and monosaturated and polyunsaturated fatty acids intake
280 have been associated with better sleep quality (12,13). Moreover, the Mediterranean diet
281 includes foods, such as seeds, nuts, fish and chicken that are rich in tryptophan, an amino
282 acid that is related to the regulation of the circadian rhythms and which has been proposed
283 as the most helpful promotor of sleep (29). On the other hand, better sleep quality has
284 been positively related to synaptic plasticity and learning (30), with improvements in
285 attention and working memory, which might contribute to better academic performance
286 in adolescents (15). Therefore, despite the fact that we did not analyse the physiological
287 mechanisms involved in the processes of diet, sleep and cognition, we speculate that high
288 levels of specific compounds provided by the Mediterranean diet could contribute to
289 better sleep (12), with benefits in cognitive functioning (15,30), leading to higher
290 academic performances in adolescents.

291 **Limitations and strengths**

292 The limitations of our study include its cross-sectional design, which prevents us
293 from inferring causal relationships, and the use of a questionnaire to assess adherence to
294 the Mediterranean diet. Nonetheless, our mediation analysis strategy allowed us to
295 provide data supporting the importance of improving adherence to the Mediterranean diet
296 in order to enhance sleep and academic performance in adolescents. Moreover, the study
297 included the use of objective and standardised measures of sleep duration and quality,
298 respectively, and a relatively large and age-matched sample of adolescents aged 13.9 ± 0.3
299 years with no academic performance differences. In addition, the statistical analyses were
300 controlled for sex, pubertal status, BMI and MVPA, which are relevant given their
301 associations with diet, sleep and academic performance.

302 CONCLUSION

303 The current study showed that sleep quality plays a key mediating role in the relationship
304 between adherence to the Mediterranean diet and academic performance in adolescents.
305 If our findings are confirmed in prospective studies, they would indicate that following
306 Mediterranean dietary patterns may improve sleep quality, which could have potentially
307 positive effects on academic performance in adolescents. Due to the benefits of healthy
308 dietary patterns and good sleep behaviours, further longitudinal and intervention studies
309 should examine the effects of diet and sleep patterns on academic performances in
310 adolescents. Families, educators and policy makers should take into account our results
311 in order to promote school-based public health and educational support programmes that
312 consider nutrition and sleep patterns as key behaviours that can improve academic
313 performance.

314 FINANCE

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320 CONFLICT OF INTEREST

321 The authors have no conflicts of interest to declare.

322 **Abbreviations:** BMI, body mass index; PA, physical activity; MVPA, moderate and
323 vigorous physical activity; PSQI, Pittsburg Sleep Quality Index.

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Table 1. Descriptive characteristics of the Spanish adolescents from the DADOS study by sex.

	All	Boys	Girls	p
n (%)	269 (100)	140 (52)	129 (48)	
Demographics				
Age (years)	13.9 ± 0.3	13.9 ± 0.3	13.9 ± 0.3	0.903
Tanner stage (I-V) (%)	0/8/34/48/10	0/10/32/44/14	0/5/36/54/5	
Anthropometry				
Height (cm)	163.0 ± 7.9	164.6 ± 8.6	161.2 ± 6.8	< 0.001
Weight (kg)	54.1 ± 9.2	54.5 ± 9.6	53.7 ± 8.8	0.486
BMI (kg/m ²)	20.3 ± 2.7	20.0 ± 2.5	20.6 ± 2.9	0.059
Physical activity (min/day)				
Light	174.8 ± 55.8	173.7 ± 58.8	175.9 ± 52.6	0.748
Moderate	76.7 ± 25.4	81.7 ± 24.7	71.4 ± 25.2	< 0.001
Vigorous	12.5 ± 8.4	15.5 ± 7.7	9.2 ± 7.8	< 0.001
Moderate and vigorous	89.2 ± 30.3	97.2 ± 28.8	80.5 ± 29.6	< 0.001
Adherence to the Mediterranean diet				
Overall score (0-12)	7.0 ± 2.2	7.3 ± 2.1	6.6 ± 2.2	0.010
Categories (%)				0.115
Poor (0-3)	14 (5.2)	5 (3.6)	9 (7.0)	
Average (4-7)	139 (51.7)	67 (47.9)	72 (55.8)	
Good (8-12)	116 (43.1)	68 (48.6)	48 (37.2)	
Sleep patterns				
Sleep quality score (0-21)	4.8 ± 2.8	4.2 ± 2.7	5.5 ± 2.7	< 0.001
Good sleep quality (%)	174 (64.7)	104 (74.3)	70 (54.3)	< 0.001
Sleep duration (hours)	8.0 ± 0.9	7.8 ± 1.0	8.1 ± 0.8	0.005
Sleep duration ≥ 8 hours (%)	135 (50.2)	66 (47.1)	69 (53.5)	0.326
Academic grades (0-10)				
Maths	6.8 ± 1.6	7.0 ± 1.6	6.7 ± 1.6	0.196
Language	6.8 ± 1.5	6.6 ± 1.5	6.9 ± 1.5	0.168
Core subjects	6.8 ± 1.4	6.8 ± 1.5	6.8 ± 1.4	0.991
GPA	7.1 ± 1.3	7.1 ± 1.3	7.2 ± 1.3	0.420
Academic abilities				
Verbal ability (0-50)	18.7 ± 5.3	19.1 ± 5.9	18.2 ± 4.6	0.127
Numerical ability (0-30)	13.4 ± 4.8	14.8 ± 4.6	11.9 ± 4.5	< 0.001
Reasoning ability (0-30)	16.5 ± 5.8	16.1 ± 5.6	16.9 ± 6.0	0.239
Overall score (0-110)	48.6 ± 12.6	50.0 ± 12.8	47.0 ± 12.2	0.049

Data are presented as means \pm SDs or frequencies (percentages). Sex differences were examined by the t-test or chi-square test.

Statistically significant values are in bold.

BMI: body mass index; GPA: grade point average; Good sleep quality was measured by a Pittsburg sleep quality index of ≤ 5 . Core subjects indicates the mean of maths and language.

Overall score indicates the sum of the three abilities scores: verbal, numerical and reasoning.

Table 2. Partial correlation coefficients between adherence to the Mediterranean diet score, sleep patterns and academic performance indicators controlling for sex, pubertal stage, body mass index and moderate and vigorous physical activity (n=269).

	Adherence to the Mediterranean diet	Academic grades				Academic abilities			
		Maths	Language	Core subjects	GPA	Verbal	Numerical	Reasoning	Overall score
Adherence to the Mediterranean diet	-	0.115	0.122*	0.121*	0.121*	0.130*	0.063	-0.024	0.067
Sleep quality	0.120*	0.205***	0.169**	0.168**	0.182**	0.023	0.096	0.063	0.074
Sleep duration	-0.059	-0.038	-0.058	-0.072	-0.074	-0.194**	-0.022	-0.008	-0.094

Core subjects indicates the mean of maths and language; GPA: grade point average; Overall score indicates the sum of the three abilities scores:

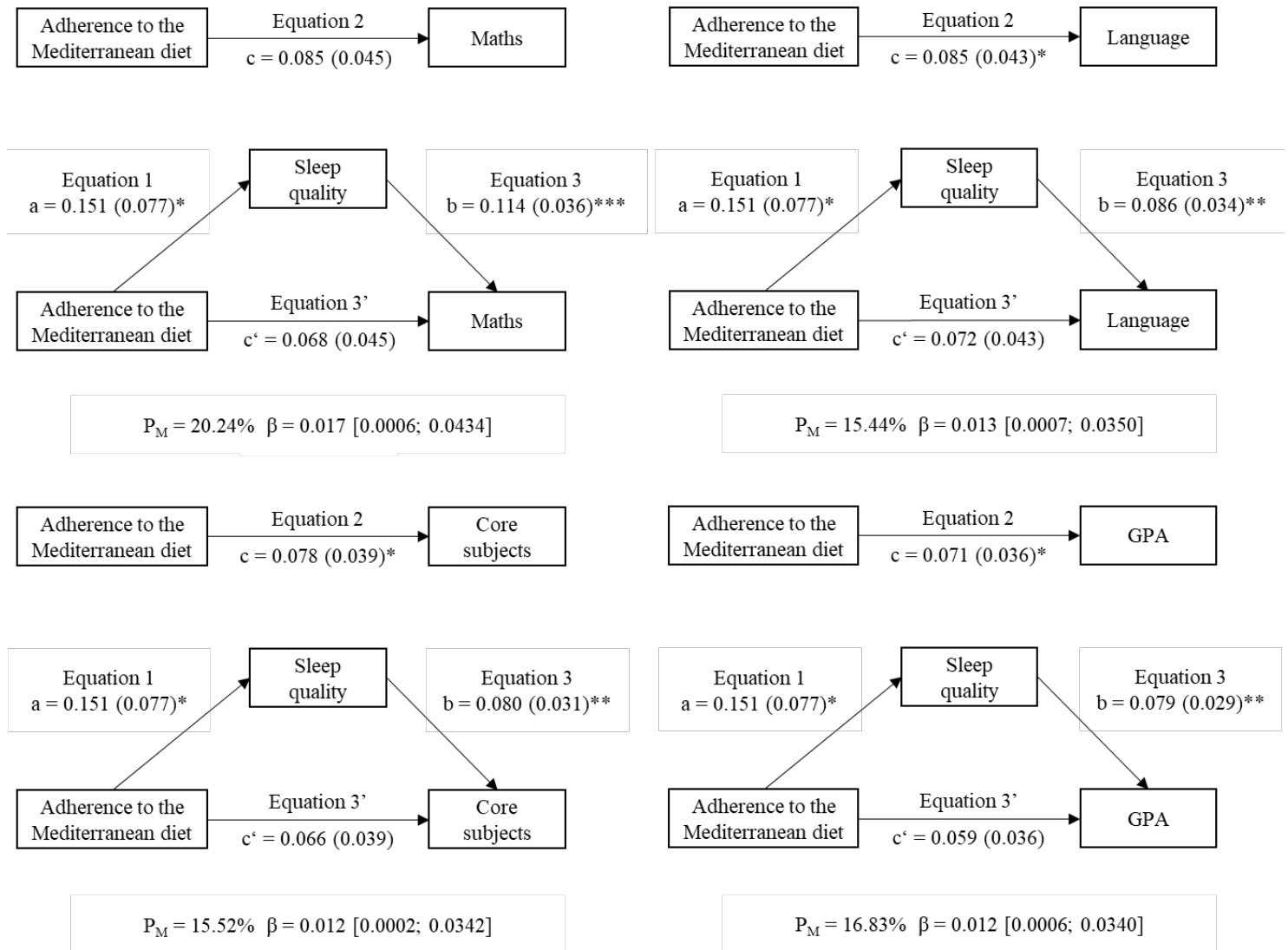
verbal, numerical and reasoning. p-value = *** $p \leq 0.001$, ** $p < 0.01$ and * $p < 0.05$.

Table 3. Multiple regression models showing the association between adherence to the Mediterranean diet and academic performance in adolescents (n = 269).

	Model 1			Model 2			Model 3		
	B	β	p	B	β	p	B	β	p
Academic grades									
Maths	0.085	0.116	0.062	0.084	0.114	0.067	0.068	0.092	0.132
Language	0.085	0.121	0.048	0.082	0.118	0.055	0.072	0.102	0.094
Core subjects	0.078	0.121	0.049	0.075	0.117	0.058	0.066	0.102	0.096
GPA	0.071	0.121	0.049	0.069	0.117	0.058	0.059	0.101	0.100
Academic abilities									
Verbal	0.319	0.131	0.035	0.293	0.120	0.049	0.317	0.130	0.038
Numerical	0.131	0.060	0.311	0.129	0.059	0.321	0.109	0.050	0.404
Reasoning	-0.065	-0.024	0.699	-0.066	-0.025	0.693	-0.086	-0.032	0.608
Overall score	0.386	0.067	0.280	0.355	0.061	0.319	0.340	0.059	0.345

Model 1: controlled for sex, pubertal stage, body mass index, and moderate and vigorous physical activity. Model 2: controlled for model 1 plus sleep duration. Model 3: controlled for model 1 plus sleep quality. Core subjects indicates the mean of maths and language; GPA: Grade Point Average. Overall score indicates the sum of the three abilities scores: verbal, numerical and reasoning. Statistically significant values are highlighted in bold. β , standardised coefficient.

Fig. 1. Sleep quality mediation models of the relationship between adherence to the Mediterranean diet and academic grades, controlling for sex, pubertal stage body mass index, and moderate and vigorous physical activity.



Results showed as regression coefficients (standard error). β = indirect effect; LLCI and ULCI = lower and upper levels for 95% confidence interval of the indirect effect between adherence to the Mediterranean diet and academic grades. Core subjects indicates the mean of maths and language. GPA: grade point average. p-value = $***p \leq 0.001$, $**p < 0.01$ and $*p < 0.05$.