



Mediating role of physical fitness on the association between diet and health-related quality of life in adolescents

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ABSTRACT

Objective: The aim of this study was to analyse whether the association between adherence to the Mediterranean diet and health-related quality of life (HRQoL) is mediated by physical fitness components (i.e., cardiorespiratory fitness, lower-limb strength, upper-limb strength and motor competence) in adolescents.

Methods: This is a cross-sectional study including mediation analyses. This study involved 181 adolescents (86 girls) aged 15.8 ± 0.3 years recruited from secondary schools and sport clubs located in Castellon (Spain). Adherence to the Mediterranean diet was evaluated using the KIDMED questionnaire. HRQoL was assessed with the KIDSCREEN-10 questionnaire. Cardiorespiratory fitness was assessed using the 20-m shuttle run test. Lower-limb strength was assessed through the standing broad jump test. Upper-limb strength was evaluated using a handgrip dynamometer. Motor competence was assessed using the 4×10 m shuttle run test. Mediation analyses were performed for each physical fitness component in order to assess its mediating effect on the association between adherence to the Mediterranean diet and HRQoL. Indirect effects (IE) with confidence intervals (CI) not including zero were interpreted as statistically significant.

Results: Cardiorespiratory fitness and lower-limb strength had a mediating effect on the positive association between adherence to the Mediterranean diet and HRQoL (IE = 0.11, 95 % CI = 0.01; 0.27 and IE = 0.07, 95 % CI = 0.01; 0.19). Upper-limb strength and motor competence did not act as mediators in the association between adherence to the Mediterranean diet and HRQoL (IE = 0.00, 95 % CI = -0.04; 0.07 and IE = 0.01, 95 % CI = -0.03; 0.07, respectively).

Conclusion: Our findings showed that the positive association of adherence to the Mediterranean diet on adolescents' HRQoL was mediated by physical fitness. Educational and public health strategies aiming to improve Spanish adolescents' HRQoL should focus on diet and physical fitness.

1. Introduction

The understanding of individuals' self-perceived well-being and functionality in life including physical, mental, and social domains of health¹ is currently known as health-related quality of life (HRQoL). This construct has been suggested an important health indicator² due to its relationship with disease prevention and health promotion.³ Indeed, over the past twenty-five years, HRQoL has become an important health outcome in adolescents,³ due to a collective interest towards the subjective perception and evaluation of an individual's own life⁴ being commonly examined by professionals, such as clinicians, educators, or public health authorities.⁴ Previous evidence stated the importance of

adolescents' multidimensional health (i.e., physical, mental, and social domains) embraced by HRQoL due to the impact that the well-being in all dimensions of health would represent for their global development.⁵ Unfortunately, HRQoL during adolescence tend to decrease with age.⁶ In this regard, screening adolescents' HRQoL should be a public health priority,^{7,8} since it could help to determine disease or treatment related burdens in this age population.⁷ Thus, identifying factors that may contribute to improving adolescents' HRQoL is of interest.^{7,8}

Previous research has suggested that HRQoL may be influenced by health-related behaviors and individual's attributes, such as adolescent's physical fitness or adherence to good dietary patterns.^{9,10} On one hand, physical fitness, which is considered a set of attributes related to a

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person's ability to perform physical activities,¹¹ has been suggested a powerful health marker in adolescents.¹² Moreover, it has been also suggested to positively influence adolescents' HRQoL¹⁰ due to its impact in several body systems such as skeletomuscular, cardiorespiratory, psychological, and endocrine-metabolic.¹² On the other hand, the Mediterranean diet, which is based on the consumption of those good food groups such as fruits, vegetables, fish, whole grains, and dairy food sources,¹³ has been pointed as the dietary pattern with the greatest benefits and preventive traits for general well-being.¹⁴ Prior evidence in adolescents showed that this dietary pattern is positively associated with all three HRQoL domains (i.e., physical, mental, and social).¹⁵ A previous meta-analysis in children and young adolescents reported that adherence to the Mediterranean diet was positively associated with cardiorespiratory fitness and muscular strength, but negatively associated with motor competence.¹⁶ Similarly, cross-sectional research with normal weight, overweight, and obese adolescents revealed that the greater the adherence to the Mediterranean diet, the better physical fitness (i.e., cardiorespiratory fitness, muscular strength, and motor competence).¹⁷ Given that Mediterranean diet is related to both physical fitness and HRQoL, investigating the link between these variables in adolescents is of interest. Recent research in young adults highlighted the mediating role of cardiorespiratory fitness and muscular strength in the association between Mediterranean diet adherence and HRQoL, with an indirect effect (confidence interval 95 %) of 0.15 (0.03–0.32) and of 0.14 (0.01–0.28), respectively.¹⁸ Nevertheless, to the best of our knowledge no studies in adolescents analysed the role of physical fitness components in the association between adherence to the Mediterranean diet and HRQoL. In fact, little is known about the mechanisms behind this association, neither the influence that they could have in this population overall HRQoL and their future development,⁵ mainly during the later adolescence, when they go through major life transitions.¹⁹ This knowledge could be useful to health authorities seeking to improve the overall HRQoL in this age population. Therefore, the aim of this study was to analyse whether the association between adherence to the Mediterranean diet and HRQoL is mediated by physical fitness components in adolescents.

2. Material and methods

This study is part of the DADOS (*Deporte, ADolescencia y Salud*; in English: Sport, Adolescence, and Health) research project, a 3-year longitudinal study aimed to analyse the influence of health-related behaviors on health and academic performance during adolescence. The results presented in this study belong to data obtained between February and May of 2017. A convenience sampling technique was used to recruit participants. For that purpose, advertising leaflets about the research project were sent to secondary schools and sport clubs located in the province of Castellon (Spain), which included information about the aim and the study protocol. The inclusion criteria in 2015, at baseline, were to be enrolled in second grade of secondary school and not to be diagnosed of any physical (i.e., locomotor system injury) or mental (i.e., intellectual disability) impairment. Volunteers who met the inclusion criteria were included in the study. A total of 181 white Spanish adolescents (86 girls) aged 15.8 ± 0.3 years with valid data for adherence to the Mediterranean diet, physical fitness components, and HRQoL were included in the analyses.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, providing a written informed consent. The DADOS study protocol was designed in accordance with the ethical guidelines of the Declaration of Helsinki 1964 (last revision of Fortaleza, Brazil, 2013) and approved by the Research Ethics Committee of the University Jaume I of Castellon (Spain).

2.1. Adherence to the mediterranean diet

Adherence to the Mediterranean diet was assessed using the

KIDMED,²⁰ a questionnaire based on the Mediterranean dietary guidelines for children and adolescents. The KIDMED questionnaire includes 16 yes/no questions, 12 with a positive connotation and 4 with a negative one with respect to dietary patterns quality. Questions with a positive connotation with respect to a high-quality diet were assigned a value of +1 (e.g., daily fruit and vegetables consumption, weekly fish and legumes intake), while those with a negative connotation were assigned a value of -1 (e.g., subjects' consumption of fast food, sweets and soft drinks). Questions answered with "no" scored 0. The final score for the participants' adherence to the Mediterranean dietary pattern was calculated as the sum of each answer, which ranges from 0 to 12.

2.2. Health-related quality of life

HRQoL was assessed with the KIDSCREEN-10 questionnaire, a valid and reliable scale to analyse HRQoL among youth population.²¹ The reliability and validity of the questionnaire have been examined previously in adolescents showing good reliability (Cronbach's $\alpha = 0.82$) and criterion validity ($r = 0.91$).²¹ Optimal reliability results have also been obtained in the current study (Cronbach's $\alpha = 0.77$). This questionnaire consists of 10 items rated in a 5-point Likert scale (i.e., 1 = "nothing" and 5 = "very much"). Responses were coded so that higher values indicate better HRQoL. Then, the sum of the items was calculated, and it was transformed based on the RASCH-Person parameters estimates.² A higher score in the questionnaire indicates better HRQoL.

2.3. Physical fitness

Cardiorespiratory fitness was assessed using the 20-m shuttle run test.²² Each participant ran straight between 2 lines 20 m apart at a pace established by recorded audio signals. The initial speed was 8.5 km/h and it was increased 0.5 km/h each minute. The test was completed when participants could not reach the end lines at the pace of the audio signals for 2 consecutive times or when they stopped. The number of shuttles completed was used in the analyses.

Lower-limb strength was assessed through the standing broad jump test.²² From a starting position behind a line marked on the ground, standing with slightly feet apart, the adolescent jumped as far as possible landing on both feet at the same time without falling backwards. The measurement was taken from the line to the nearest point of contact (back of the heels). The participants were allowed to perform the test twice. The longest distance achieved (centimetres) was used in the analyses.

Upper-limb strength was assessed using a hand dynamometer with adjustable grip (TKK 5401 Grip D; Takey Scientific Instruments, Tokyo, Japan). The test was performed while standing, with the arm straight and down by the side, with forearm and wrist in a neutral position. Neither the hand nor the dynamometer should touch the body or any other object. The optimal grip-span of the dynamometer was adjusted for the hand size of each participant by ensuring that the middle and proximal phalanges were bent to 90° and the middle phalanges rested flat above the handle. Each participant squeezed the grip with maximal effort for at least 2 s. The test was performed twice for each hand alternatively and the handgrip score (kg) was calculated as the average of the best score for each hand.

Motor competence was assessed using the 4 × 10 m shuttle run test.²² Adolescents sprint back and forth between two parallel lines 10 m apart. Every time the adolescent crossed any of the lines, he or she picked up (the first time) or exchanged (second and third time) a sponge, which was previously placed behind the lines. The participants performed two trials. The shortest time (seconds) was used in the analyses. For analytic purposes, values were multiplied by -1, so higher scores indicate greater motor competence.

All physical fitness components were dichotomized based on normative data from Tomkinson et al. (2018) for cardiorespiratory fitness, upper-limb and lower-limb strength, and based on Ortega et al.

(2011) for motor competence. Each physical fitness component above sex and age specific 60th percentile was categorized as high.^{23,24}

2.4. Covariates

Sex, pubertal stage, parent's education level, waist circumference, and vigorous physical activity were included as covariates in the statistical analyses due to their relationship with the study variables. Specifically, Mediterranean diet adherence has been positively associated with parent's education level and physical activity levels, and negatively associated with waist circumference.²⁵ Higher fitness levels have been related to pubertal stage,²⁶ lower waist circumference,²⁷ and higher levels of vigorous physical activity.²⁸ Moreover, greater HRQoL in adolescents has been linked to higher parent's education level²⁹ and physical activity levels,³⁰ and to lower waist circumference.³¹

Pubertal stage was self-reported according to the five stages described by Tanner and Whitehouse.³² It is based on external primary and secondary sexual characteristics, which were described by the participants using standard pictures according to Tanner instructions. Parents or legal guardians reported their education level which was categorized into two groups using the highest education level obtained by the mother or the father: (i) below university education, and (ii) university education. Waist circumference was measured twice to the nearest 1 mm with a non-elastic tape applied horizontally midway between the lowest rib margin and the iliac crest, at the end of gentle expiration with the adolescent in a standing position. Physical activity was objectively measured using the GENEActiv accelerometer (Activinsights Ltd, Kimbolton, Cambridgeshire, UK). This device provides a reliable (coefficient of variation intra- and inter-instrument of 1.4 % and 2.1 %, respectively)³³ and valid assessment of physical activity in young people ($r = 0.93$, $p = 0.001$).³⁴ Accelerometers were programmed to collect data at a sampling frequency of 100 Hz and stored in gravity (g) units. The raw acceleration output was added in 1-s epochs using the GENEActiv postprocessing PC software (version 2.2; GENEActiv). By combining all registered days (at least four complete days, including weekend and weekdays, with 24-h valid data) for each participant and using the Excel macro provided by the commercial brand to summarize the data, physical activity was expressed as average minutes per day of vigorous physical activity. According to Phillips et al.,³⁵ GENEActiv cut-off point for vigorous intensity in children/adolescents was established for values over 60 g.

2.5. Statistical analyses

Study sample characteristics are presented as mean (standard deviation) for continuous variables and as percentages for categorical variables. As exploratory analyses did not show a significant interaction of sex with adherence to the Mediterranean diet and physical fitness components in relation to HRQoL ($p > 0.05$), the main analyses were performed with the total sample.

Bootstrapped simple mediation procedures were performed to examine whether adherence to the Mediterranean diet and HRQoL were associated through the effect of each physical fitness component, controlling for sex, pubertal status, parent's education level, waist circumference, and vigorous physical activity. The PROCESS SPSS Macro version 2.16.3, model four, with 5.000 bias-corrected bootstrap samples and 95 % confidence intervals was used for the analyses. Mediation analyses were performed to examine the potential mediating effect of each physical fitness component on the association between adherence to the Mediterranean diet (independent variable) and HRQoL (dependent variable). The total (c path), direct (c' path), and indirect effect (a*b paths) are presented. Indirect effects with confidence intervals not including zero were interpreted as statistically significant, which can be so regardless of the significance of the total effect (the effect of adherence to the Mediterranean diet on HRQoL) and the direct effect (the effect on HRQoL when both adherence to the Mediterranean diet and

physical fitness components are included as predictors).³⁶ Percentage of mediation (P_M) was calculated as (indirect effect/total effect) $\times 100$ to know how much of the total effect was explained by the mediation. All the analyses were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp), and the level of significance was set at $p < 0.05$.

3. Results

Participants' characteristics are presented in Table 1. On average, participants showed an adherence to the Mediterranean diet score of 7.2 and a HRQoL score of 48.8. Regarding physical fitness, on average, in the CRF test adolescents performed 70.2 shuttles, in lower-limb strength assessment achieved 186.4 cm, in upper-limb strength, 33.2 kg, and 11.7 s in their motor competence evaluation.

Fig. 1 shows the mediating effect of each physical fitness component on the association between adherence to the Mediterranean diet and HRQoL in adolescents. Adherence to the Mediterranean diet was positively associated with HRQoL (total effect, path c; $p < 0.05$). Additionally, it was positively associated with cardiorespiratory fitness (path a; $p < 0.01$) and lower-limb strength (path a; $p < 0.05$), but not with upper-limb strength and motor competence ($p > 0.05$). Only cardiorespiratory fitness was positively associated with HRQoL (path b; $p < 0.05$). The analyses showed a significant indirect effect of cardiorespiratory fitness and lower-limb strength in the association between adherence to the Mediterranean diet and HRQoL (path a*b). The total effect of adherence to the Mediterranean diet on HRQoL explained by cardiorespiratory fitness was 22.0 % and by lower-limb strength was 15.1 %.

4. Discussion

The results of the present study showed that the association between adherence to the Mediterranean diet and HRQoL in a sample of 181 Spanish adolescents was mediated by cardiorespiratory fitness and lower-limb strength, but not by upper-limb strength and motor competence. Despite the reduced representativeness of our findings, these results expanded prior knowledge about the association between adherence to the Mediterranean diet and HRQoL in adolescents and

Table 1
Characteristics of the participants.

	Girls (n = 87)	Boys (n = 94)	All (n = 181)
Age (years)	15.9 (0.3)	15.8 (0.3)	15.8 (0.3)
Pubertal stage (III–V) (%)	14.0/70.0/ 16.0	4.0/38.0/ 57.0	9.0/53.0/ 38.0
Parents' education level (%)			
Below university/University	44.0/56.0	60.0/40.0	52.0/48.0
Waist circumference (cm)	69.9 (7.1)	73.4 (5.3)	71.7 (6.5)
Weight (kg)	58.4 (9.4)	64.3 (8.6)	61.4 (9.4)
Height (cm)	162.7 (6.4)	172.7 (6.5)	167.9 (8.2)
Body mass index (kg/m ²)	22 (3.3)	21.5 (2.6)	21.8 (2.9)
Vigorous physical activity (min/day)	4.2 (6.6)	9.4 (7.6)	7.0 (7.6)
Mediterranean diet adherence score (0–12)	6.7 (2.3)	7.6 (2.2)	7.2 (2.2)
Health-related quality of life	48.1 (6.1)	49.5 (6.4)	48.8 (6.2)
Physical fitness			
Cardiorespiratory fitness (shuttles)	51.2 (20.4)	87.8 (19.6)	70.2 (27.2)
Unfit/Fit (%)	21.8/78.2	8.5/91.5	14.9/85.1
Lower-limb strength (cm)	164.3 (25.5)	206.9 (26.1)	186.4 (33.4)
Unfit/Fit (%)	39.1/60.9	50.0/50.0	44.8/55.2
Upper-limb strength (kg)	27.6 (3.9)	38.3 (6.2)	33.2 (7.5)
Unfit/Fit (%)	67.4/32.6	87.2/12.8	77.8/22.2
Motor competence (s)	12.4 (0.8)	11.0 (0.7)	11.7 (1.0)
Unfit/Fit (%)	0.0/100.0	0.0/100.0	0.0/100.0

Data are presented as mean (SD) or percentages.

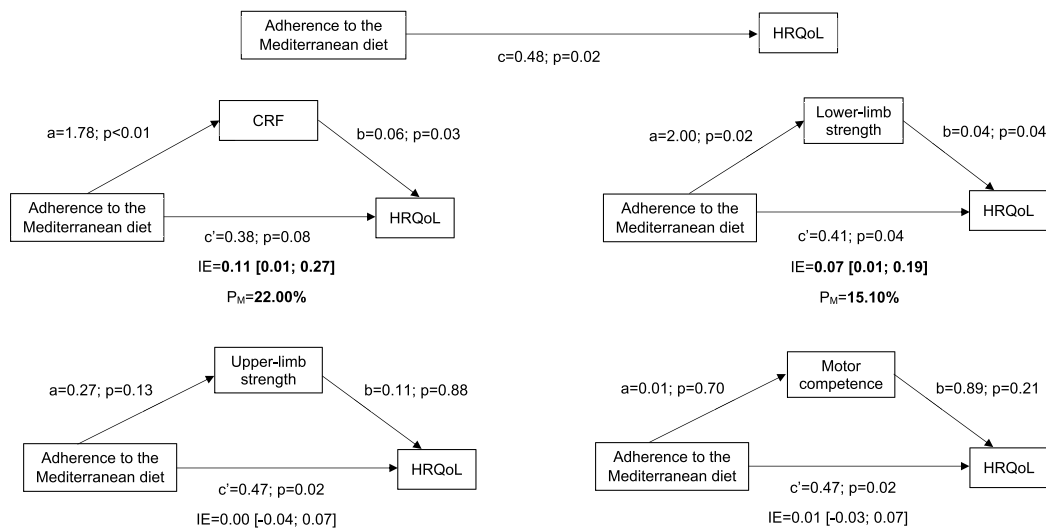


Fig. 1. Physical fitness (i.e., cardiorespiratory fitness, lower-body strength, upper-body strength and motor competence) mediation models of the relationship between adherence to the Mediterranean diet and HRQoL, adjusted for sex, pubertal stage, parents' education level, waist circumference, and vigorous physical activity (N = 181). Results are shown as unstandardized regression coefficients; p-value. IE = indirect effect [lower and upper levels for 95 % confidence interval of the indirect effect between adherence to the Mediterranean diet and HRQoL]. Statistically significant values are in bold. HRQoL: health-related quality of life; CRF: cardiorespiratory fitness; P_M: percentage of mediation.

revealed for the first time potential underlying mechanisms involved in this association in adolescents, highlighting the significant roles of cardiorespiratory fitness and lower-limb strength.

In concordance to previous research, our results showed a positive association between adherence to the Mediterranean diet and HRQoL in adolescents.^{15,36} For instance, Evaristo et al. carried out a study involving 956 adolescents aged 14.5 ± 1.8 years old, which revealed that the group with high adherence to the Mediterranean diet had greater HRQoL.³⁶ In addition, Costarelli et al.¹⁵ performed a study involving 359 adolescents, and found significant positive associations between this dietary pattern and overall HRQoL domains. This is probably due to the role those specific nutrients from the Mediterranean diet (e.g. antioxidants, minerals, vitamins and monosaturated fatty acids) might have on individuals' physical and mental health status,^{15,37,38} which in turn may positively influence HRQoL.

Since mediation analysis assumes that the independent variable influences the mediator, our results suggest that adherence to the Mediterranean diet influences cardiorespiratory fitness and lower-limb strength, which in turn, may affect HRQoL. Our results agree with prior evidence in adolescents reporting a positive association of adherence to the Mediterranean diet with cardiorespiratory fitness and lower-limb strength.^{39,40} On one hand, it is plausible that specific nutrients provided by adhering to the Mediterranean diet benefit physical performance,⁴¹ influencing cardiorespiratory fitness and lower-limb strength. On the other hand, adolescents engaged in this dietary pattern present better body composition¹⁹ and greater levels of physical activity⁴² which could directly influence cardiorespiratory fitness and lower-limb strength. Collectively, it is possible that those factors have an influence on adolescents' HRQoL. Our findings are in line with previous evidence¹⁰ reporting a positive association of children's and adolescents' cardiorespiratory fitness¹⁰ and lower-limb strength⁴³ with their HRQoL. Nevertheless, the evidence for lower-limb strength is controversial, since no association with HRQoL has also been reported.⁴⁴ Moreover, previous literature combined upper-limb and lower-limb strength,¹⁰ making difficult to clarify its individual relationship with HRQoL. The association found between both cardiorespiratory fitness and lower-limb strength and HRQoL may be related to the physical, psychological, and social domains included in the HRQoL construct. Indeed, previous research showed that cardiorespiratory fitness and muscular strength are inversely associated with cardiometabolic risk⁴⁵ and positively

associated with mental health.⁴⁶ Additionally, both physical fitness components were associated with social competence⁴⁷ and improved social health.⁴⁸ All these facts could predispose adolescents with higher levels of cardiorespiratory fitness and lower-limb strength to higher scores of overall HRQoL.¹⁰

Upper-limb strength and motor competence did not act as mediators in the association between adherence to the Mediterranean diet and HRQoL in our study. Our results agree with previous evidence which did not show significant associations between adherence to the Mediterranean diet, upper-limb strength^{17,49} and motor competence.⁴⁹ Moreover, our findings concur with prior research showing that upper-limb strength^{44,49} and motor competence⁵⁰ were not linked to HRQoL. We hypothesise that the lack of mediation effect of upper-limb strength and motor competence on the association between adherence to the Mediterranean diet and HRQoL could be explained by our participant's low levels of upper-limb strength and motor competence. It is likely that adolescents with lower levels of upper-limb strength and motor competence miss out the physical and psychosocial benefits derived from these physical fitness components. Such as positive physical self-perception and social interaction, which could have enhanced their HRQoL. In addition, previous evidence suggested that an optimal adherence to the Mediterranean diet and low levels of muscle strength may not benefit health status, which could partially explain the lack of mediation effect on HRQoL.⁵¹

The results obtained in the present study through mediation analyses, a powerful statistical technique that can be used to clarify the process underlying the relationship between two variables,⁵² add support for cardiorespiratory fitness and lower-limb strength being intermediate steps on the causal pathway between adherence to the Mediterranean diet and HRQoL in adolescents. Thus, our findings are consistent with the idea that the promotion of both, healthy diet and cardiorespiratory capacity and lower-limb strength, may be of paramount importance to improve adolescents' HRQoL. Our mediation results partially agree with the only one previous cross-sectional study carried out in university students.¹⁸ This research also showed a mediating role of cardiorespiratory fitness and muscular strength in the association between adherence to the Mediterranean diet and HRQoL in young adults aged 20.9 ± 2.5 years.¹⁸ Yet, based on prior mediation research in other populations, keeping a suitable daily nutrition could help in the achievement of a better performance,⁴¹ leading to higher

levels of cardiorespiratory fitness and muscular strength, which might benefit physical and mental well-being¹⁰ with a positive impact on adolescents' overall HRQoL. Given the need for further research regarding factors that could influence overall adolescents' HRQoL² and the current decline in their adherence to the Mediterranean diet⁴² and physical fitness,^{53,54} our results have significant importance for HRQoL improvement. Our findings are of interest to educators, health professionals and policy makers for the design of public health strategies or educational interventions aimed to improve HRQoL during high school. Strengths of the study included an age-matched sample and the adjustment for relevant cofounders. The limitations of our results include the cross-sectional design of the study, which might not allow us to report causality. In addition, the reduced representativeness of our sample compared to a wider Spanish, European or worldwide population might limit the applicability of our findings. Finally, we acknowledge that more accurate estimates of physical fitness components could have been obtained using laboratory-based physiological direct measures.

In conclusion, the results of the present study show that cardiorespiratory fitness and lower-limb strength act as mediators in the positive association between adolescents' adherence to the Mediterranean diet and HRQoL. Therefore, we contribute to the comprehension of the relationship between these key factors suggesting that both, optimal adherence to the Mediterranean diet and higher physical fitness levels, are important for adolescents' HRQoL. Furthermore, longitudinal and interventional research could examine the effects of dietary patterns and physical fitness on adolescents' overall HRQoL. Health and education professionals in partnership with policymakers should consider our results in order to promote high school-educational and public health programmes that consider healthy dietary patterns and physical fitness as key factors to enhance Spanish adolescents' HRQoL.

Author statement

Alba Solera-Sanchez: Conceptualization, Methodology, Software, Writing- Original draft preparation, Visualization, Investigation, editing. **Mireia Adelantado-Renau:** Data curation, validation, review, supervision. **Maria Reyes Beltran-Valls:** Reviewing and supervision. **Diego Moliner-Urdiales:** Reviewing.

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Declaration of competing interest

No potential competing interest was reported by the authors.

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