

# **Health-related behaviors, physical fitness, and health-related quality of life in children and adolescents**

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**July 2022**



**UNIVERSITAT  
JAUME·I**

# Tesis Doctoral Internacional



## Programa de Doctorado en Ciencias Biomédicas y Salud

### Escuela de Doctorado de la Universitat Jaume I

Hábitos saludables, condición física y calidad de vida  
relacionada con la salud en niños/as y adolescentes

Memoria presentada por Alba Solera Sánchez para optar al grado  
de doctor/a por la Universitat Jaume I

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Castellón de la Plana, julio de 2022



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### **Financiación recibida**

La doctoranda no recibió ningún tipo de financiación por parte de instituciones y/o empresas públicas o privadas.

Los proyectos de investigación que forman parte de esta tesis recibieron la siguiente financiación:

(i) El Proyecto DADOS (Deporte, ADOlescencia y Salud) fue financiado por:

- El Ministerio de Economía y Competitividad, MINECO (DEP2013–45515-R), Plan Estatal de Investigación Científica y Técnica y de Innovación 2013 Programa Estatal de Investigación, Desarrollo e Innovación Orientada a los Retos de la Sociedad.

- Universitat Jaume I, UJI (P1·1A2015-05), Plan de promoción de la investigación de la Universitat Jaume I 2015, Plan de fomento de proyectos de investigación.

- Universitat Jaume I, UJI (UJI-B2018-40), Plan de promoción de la investigación de la Universitat Jaume I 2018, Plan de fomento de proyectos de investigación.

- Universitat Jaume I, UJI (UJI-A2019-12), Plan de promoción de la investigación de la Universitat Jaume I 2019, Plan de fomento de proyectos de investigación.

(ii) El Proyecto The Active West Lancs programme fue financiado por:

El ayuntamiento de West Lancashire Borough y el órgano administrativo del condado de Lancashire.

## Doctoral thesis by compendium of publications

### List of scientific publications:

1. **Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Health-related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study). *Qual Life Res.* 2021;30(4):1093-1101. doi: 10.1007/s11136-020-02699-9. **Impact factor: 3.78.**
2. **Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study. *Eur J Sport Sci.* 2021;29:1-7. doi: 10.1080/17461391.2021.2012596. **Impact factor: 4.05.**
3. **Alba Solera-Sanchez**, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mhairi J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity. *Perspectives in Public Health* (under second revision). **Impact factor: 4.94.**
4. **Alba Solera Sánchez**, Mireia Adelantado Renau, Diego Moliner Urdiales, María Reyes Beltrán Valls. Adherence to the Mediterranean diet and health-related quality of life in adolescents: the mediating role of physical fitness. (Submitted for publication).

**“This thesis has been accepted by the co-authors of the publications listed above that have waved the right to present them as a part of another PhD thesis”**



Muchísimas gracias, mamá y papá, por vuestro apoyo

Thanks very much, mum and dad, for your support

Gracias a todas las personas que han estado en el camino ayudándome

Thanks to all who have been helping me along the way

“El mayor peligro que nos depara el futuro es la apatía”

Jane Goodall, 1934

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## ABSTRACT

**Background.** Health-related quality of life (HRQoL) is a multiple construct, affecting individual's physical, mental, and social well-being. Its maintenance during childhood and adolescence is one of the major public health challenges nowadays. Building a healthy lifestyle during those lifetime periods would help to keep a suitable physical, mental, and social well-being through life having a direct positive impact in children's and adolescents' HRQoL.

The adherence to health-related behaviors and the improvement of individual attributes contribute to achieve better physical and mental health status, which in turn, could improve overall HRQoL in children and adolescents. However, previous research in this field is limited, and the possible mechanisms explaining these relationships have not been investigated in children and adolescents.

**Purposes.** i) To investigate the relationship between health-related behaviors and HRQoL; ii) to analyse the association between physical fitness and HRQoL; iii) to examine the mechanisms that could explain those associations in children and adolescents.

**Methods.** This work employed two different population samples. On one hand, a total of 262 (study I) and 199 (study II) adolescents aged  $13.9 \pm 0.3$  years, and 181 (study IV) aged  $15.8 \pm 0.3$  from DADOS (Deporte, ADOlescencia y Salud) study. On the other hand, 383 children aged  $10 \pm 0.5$  years from "The Active West Lancs" programme. The variables used were HRQoL as a dependent variable for all the studies, several health-related behaviors (i.e., vigorous physical activity, adherence to the Mediterranean diet, sleep quality, sleep duration, and screen time), physical fitness (i.e., cardiorespiratory fitness, muscular strength, and motor competence) and psychological correlates of physical activity (i.e., self-efficacy and enjoyment) as dependent variables and possible mechanisms influencing associations with HRQoL, respectively.

**Main findings.** The main findings of this work were: study I) adherence to the Mediterranean diet, sleep quality, and sleep duration showed an individual positive association with HRQoL; besides, adolescents that presented good sleep quality and duration and lower screen time reported greater HRQoL; finally, adolescents achieving 3 or more health-related behaviors had higher HRQoL levels; study II) physical fitness at baseline showed a positive association with HRQoL at 24-month follow-up. Both, health-related behaviors and physical fitness components at baseline showed a cumulative positive impact on adolescent's HRQoL at baseline and at 24-month follow-up, respectively; study III) cardiorespiratory fitness at baseline was associated with HRQoL at baseline and at 12-week follow-up in children, and psychological correlates of physical activity (i.e., self-efficacy and enjoyment) acted as mediators in this association; study IV) cardiorespiratory fitness and muscular strength acted as mediators in the association between adherence to the Mediterranean diet and HRQoL in adolescents.

**Overall conclusion.** The adoption of health-related behaviors as well as achieving higher physical fitness may improve children's and adolescents' HRQoL. Besides, the study of possible mediators allows us to better understand possible mechanisms influencing the association between health-related behaviors and physical fitness with HRQoL. Childhood and adolescence are lifetime periods characterized by changes and behaviors' adoption which appear to track into adulthood. Therefore, the present Doctoral Thesis represents an important step forward from a public health perspective since its findings could help to develop successful strategies to improve overall children's and adolescents' HRQoL.

## RESUMEN

**Introducción.** La calidad de vida relacionada con la salud (CVRS) es un concepto interdisciplinar, que afecta al bienestar físico, psicológico y social del individuo. Su mantenimiento durante la infancia y la adolescencia representa uno de los retos más importantes para la salud pública actualmente. La adopción de un estilo de vida saludable durante estos periodos de la vida contribuirá al mantenimiento del bienestar físico, mental y social a través del ciclo vital, impactando positivamente en la CVRS de la población infantil y adolescente.

La adopción de hábitos saludables y la mejora de atributos individuales contribuye a la consecución de un aumento en el estado de salud tanto a nivel físico como mental, lo cual podría influir positivamente sobre la CVRS. Sin embargo, las investigaciones previas sobre esta temática o aquellas que analizan los posibles mecanismos psicológicos involucrados en la misma son limitadas e incluso inexistentes en niños/as y adolescentes.

**Objetivos.** Por ello, los objetivos de la presente Tesis Doctoral fueron: i) investigar la relación entre los hábitos saludables y la CVRS; ii) analizar la relación entre la condición física y la CVRS; y iii) examinar los mecanismos que podrían explicar esas asociaciones en población infantil y adolescente.

**Métodos.** El presente trabajo empleó dos muestras de estudio. Por un lado, un total de 262 (estudio I) y 199 (estudio II) adolescentes de  $13.9 \pm 0.3$  años, y 181 (estudio IV) de  $15.8 \pm 0.3$  años procedentes del Proyecto DADOS (Deporte, ADOlescencia y Salud). Por otro lado, 383 niños/as de  $10 \pm 0.5$  años procedentes del estudio “The Active West Lancs”. Las variables utilizadas fueron CVRS como variable dependiente para todos los estudios, varios hábitos saludables (i.e., actividad física vigorosa, adherencia a la dieta Mediterránea, calidad del sueño, duración del sueño y tiempo de pantalla), condición física (i.e., resistencia cardiorrespiratoria, fuerza muscular y competencia motriz) y factores psicológicos relacionados con la actividad física (i.e., autoeficacia y disfrute) como variables dependientes y posibles mecanismos influyendo las asociaciones con la CVRS, respectivamente.

**Resultados.** Los principales hallazgos de este trabajo fueron: estudio I) la adherencia a la dieta Mediterránea y la calidad y duración del sueño mostraron una asociación positiva con la CVRS; además, los/as adolescentes que presentaron una mayor calidad y duración de sueño así como menor tiempo de pantalla reportaron una mayor CVRS; finalmente, los/as adolescentes que adoptaron múltiples hábitos saludables (al menos 3) presentaron mayores niveles de CVRS; estudio II) la condición física al inicio del estudio mostró un impacto positivo en la CVRS de los/as adolescentes 24 meses después. Tanto los hábitos saludables como la condición física al inicio del estudio mostraron un efecto acumulativo positivo sobre la CVRS al inicio del estudio y

24 meses después en adolescentes; estudio III) la resistencia cardiorrespiratoria al inicio del estudio se asoció con la CVRS al inicio del estudio y 12 semanas después en niños/as, presentando las variables psicológicas relacionadas con la actividad física (i.e., eficacia y disfrute) un efecto mediador en esta relación; estudio IV) la resistencia cardiorrespiratoria y fuerza muscular actuaron como mediadores en la asociación entre la adherencia a la dieta Mediterránea y la CVRS en adolescentes.

**Conclusión.** La adopción de hábitos saludables, así como presentar niveles elevados de condición física podría mejorar la CVRS de la población infantil y adolescente. Además, el estudio de posibles mediadores nos permite entender mejor posibles mecanismos que pueden influir en la asociación entre los hábitos saludables y la condición física con la CVRS. La adolescencia es un periodo vital caracterizado por cambios y la adopción de hábitos los cuales parecen perdurar hasta la edad adulta. Por ello, la presente Tesis Doctoral representa un importante paso adelante desde una perspectiva de salud pública, ya que sus hallazgos muestran información relevante que puede ser utilizada en el desarrollo de estrategias para la mejora de la CVRS de los/as niños/as y adolescentes.

## FRAMEWORK

The present PhD thesis provides new insights on the associations between health-related behaviors, physical fitness, and HRQoL as well as the mechanisms behind those relationships. DADOS (Deporte, ADOlescencia y Salud) study is a 3-year longitudinal research project (from 2015 to 2018) aimed to assess the influence of physical activity and fitness on health, psychological well-being, and academic performance through adolescence. Active West Lancs is a 3-year longitudinal project which offered programmes of early intervention in physical activity promotion, weight management, and obesity prevention in different populations. DADOS study and Active West Lancs project contribute to the development of international strategies such as the Global Strategy on Diet,<sup>1</sup> the European framework to promote physical activity and health<sup>2</sup> or Global action plan on physical activity 2018–2030.<sup>3</sup> DADOS also makes a contribution to national strategies such as the NAOS (Nutrition, Physical Activity and the Prevention of Obesity)<sup>4</sup> strategy and the health promotion and prevention strategy in the national health care system.<sup>5</sup> Thus, the results obtained in this PhD Thesis will be relevant to establish new strategies and school-based programs aimed to improve children's and adolescents' general health and well-being.

This PhD Thesis is divided in six parts: introduction, aims, method, manuscripts, conclusions, and implications and future perspectives. The aims were approached through four scientific publications. The present PhD Thesis has been designed and developed in accordance with the Universitat Jaume I Doctorate Regulations (approved on January 26<sup>th</sup> of 2012) and with the PhD Programme in Biomedical Science and Public Health for the academic year 2019/2020, both based on the Royal Decree 99/2011, of January 28th, which regulates official doctoral studies (information retrieved from: [www.uji.es/estudis/centres/escola-doctorat/normativa/normestudi/](http://www.uji.es/estudis/centres/escola-doctorat/normativa/normestudi/)).



## INTRODUCTION

### **Health-related quality of life**

Health-related quality of life (HRQoL) is a multidimensional concept which reflects individual's own perception of physical, mental, and social health, and functionality.<sup>6</sup> HRQoL has been highlighted as an important health indicator since perceived well-being and functionality are considered important components of health surveillance.<sup>7</sup> Indeed, over the past twenty-five years, HRQoL has become an important outcome in children and adolescents,<sup>8</sup> being commonly used by professionals, such as clinicians, caregivers, educators, or public health authorities due to a collective interest towards the subjective perception and evaluation of individual's own life.<sup>9</sup> HRQoL measurement makes possible to demonstrate the impact of general health on perceived quality of life.

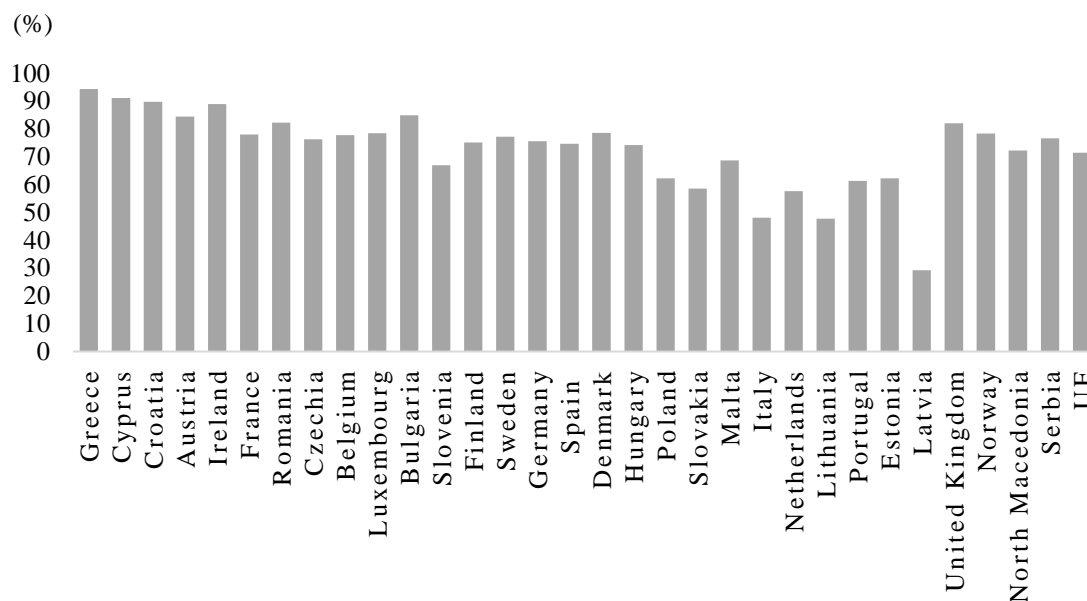
Measuring HRQoL can help to determine the burden of preventable disease, injuries, and disabilities, and can provide valuable new insights into the relationships between HRQoL and risk factors.<sup>10</sup> In fact, investigating HRQoL has been nowadays considered relevant due to its relationship with both self-reported chronic diseases (e.g., diabetes, breast cancer, arthritis, and hypertension) and their risk factors (e.g., body mass index, physical inactivity, sleep patterns, diet quality, and smoking status).<sup>11</sup> The assessment of HRQoL will help to monitor the progress in achieving the country's public health aims. In addition, analysis of HRQoL surveillance data can identify subgroups with poor perceived health and help to guide interventions to improve their situations as well as avert more serious consequences.<sup>12,13</sup> Interpretation and publication of these data can represent a significant support for health policies and legislation, help to allocate resources based on needs, guide the development of strategic plans, and monitor the effectiveness of community interventions.<sup>13</sup>

Given the importance of HRQoL, finding a standardized way to measure it has been fundamental for the research on this field. Over the past two decades, a valid and reliable instrument to measure children's and adolescents' HRQoL has been the KIDSCREEN questionnaire.<sup>7,14</sup> The KIDSCREEN measures were developed within the project "Screening and Promotion for Health-related Quality of Life in Children and Adolescents – A European Public Health Perspective." The project took place from 2001 to 2004 and was funded by the European Commission (grant number QLG-CT-2000-00751). The countries participants of the project were Austria, Czech Republic, France, Germany, Greece, Hungary, Ireland, Poland, Spain, Sweden, Switzerland, The Netherlands, and the United Kingdom. Its development was driven by the need of a generic instrument for the assessment of healthy and ill children and adolescents from 8 to 18 years old. In this sense, the instrument would become useful in the identification of youth at risk with regard to their subjective health and help public health authorities in the design and implementation of

early interventions to tackle the future society issues that might cause a poor health-related quality of life during early stages of life.

The KIDSCREEN project used a simultaneous approach to include the 13 participant countries in the development of the measure. The creation of the questionnaire was based on literature reviews, expert consultation, and children's focus groups of all the countries, turning into a cross-cultural harmonized measure. This process was done to measure all the dimensions of HRQoL construct, which are relevant to the responders (i.e., children, adolescents, parents, caregivers). There are three different KIDSCREEN questionnaires: KIDSCREEN-52, KIDSCREEN-27, and KIDSCREEN-10, all of them measuring the dimensions of HRQoL: physical, psychological, and social, but with different time required to perform them, due to their length (i.e., items to respond). This PhD Thesis used the KIDSCREEN-10 questionnaire, which provides a singular index of global HRQoL covering all three dimensions (10 items). The items are scored on a 5-point scale ranging from never/not at all to always. This sub-scale enables true cross-cultural measurement on interval scale level by fulfilling the assumption of the Rasch-model and displaying no DIF. This instrument has been adequately analysed, showing internal consistency (Cronbach's  $\alpha = 0.82$ ) for the self-reported version, test-retest reliability at a 2 week interval (reaching 0.55) and criterion validity ( $r = 0.91$ ).<sup>15,16</sup> Therefore, KIDSCREEN-10 questionnaire is an applicable measure to continuously monitor, evaluate, and improve the health and well-being of this population.<sup>7</sup>

Regarding the level of children's and adolescents' own optimal perception of HRQoL in Europe, Eurostat statistics reported that this population perceive themselves in high overall good or very good health status (figures 1 and 2).<sup>17,18</sup> In fact, more than a 50% of the children younger than 16 years shared that optimal perception of health. Nevertheless, even sharing a general positive belief about their overall health and well-being,<sup>17,18</sup> their HRQoL had a decreasing tendency over the years,<sup>19,20</sup> representing a public health concern. Thus, identifying factors that could contribute to improve youth overall HRQoL is of paramount importance for the future society.<sup>21,22</sup>



**Figure 1.** Children, under 16 years old, of the fifth quintile group who perceive themselves in very good health (2017).<sup>23</sup> Fifth quintile group: 20% of the population with the highest income.



**Figure 2.** Youths who perceive themselves in good health or very good health, by sex (2018).<sup>24</sup>

### Health-related behaviors and attributes

From a public health perspective, childhood and adolescence are unique periods of life which require special attention since multiple physiological and psychological changes take place at those ages.<sup>25-27</sup> Identifying factors that could make a difference in their health and well-being is

of importance. In fact, during the past two decades, research focused more attention in the study of children's and adolescents' health and development.<sup>28</sup> Several studies revealed that children's and adolescents' health behaviour choices and the subsequent practices are likely to influence their current and later life health status.<sup>29,30</sup> Indeed, the engagement in some health-related behaviors, such as physical activity, leads to the improvement of individual attributes<sup>31</sup> which have been associated with a greater health.<sup>32,33</sup> Thus, to prevent negative physical and mental health outcomes,<sup>34,35</sup> which may have lifelong implications, research is needed to help in the development of public health strategies and policies promoting health-related behaviors and attributes.

Health-related behaviours and attributes could be defined as activities and achieved qualities that positively affect health status and may prevent disease and disability at an early stage.<sup>33,36,37</sup> Common health-related behaviors are, for instance, physical activity practice, suitable dietary patterns, appropriate screen media usage, or adequate sleep quality and duration; and common attributes are physical fitness components (i.e., cardiorespiratory fitness, muscular strength, and motor competence).

Previous literature investigated the individual relationship between both: health-related behaviors and physical fitness with HRQoL reporting positive associations.<sup>38-43</sup> Prior evidence supported a cumulative influence of health-related behaviors on HRQoL,<sup>44</sup> and attributes on health.<sup>45</sup> This literature showed that adhering to several health-related behaviors and maintaining various attributes simultaneously might increase their individual effect on health by synergically interacting with each other.<sup>45,46</sup> However, only one previous cross-sectional study examined the combined impact of some health-related behaviors on HRQoL suggesting an increased positive effect.<sup>47</sup> Thus, expanding and adding new research approaches to the current knowledge about the combined influence of several health-related behaviors and attributes on adolescents' HRQoL is of interest of educators and public health authorities.

## **Health-related behaviors and HRQoL**

### **1. Physical activity and HRQoL**

Physical activity has been defined as any movement of the body performed by the skeletal muscles that requires energy expenditure above a basal level.<sup>48-50</sup> A wide range of tools for physical activity assessment currently exist. The instruments vary in their level of simplicity, precision, and the information provided, but this does not mean that they are not trustworthy.<sup>51</sup> Traditionally, physical activity has been measured through subjective tools (e.g., questionnaires, interviews)<sup>51</sup> which are a low burden for the participants, versatile, cost-effective, and generally accepted by research and medical communities.<sup>52</sup> Nevertheless, they sometimes can lead to an over-estimation of physical activity levels.<sup>53</sup> On the other hand, we have the objective tools (e.g., accelerometers,

pedometers) which can estimate parameters such as intensity, volume, and duration more accurately.<sup>53</sup> The use of direct instruments has helped in the reduction of the human error when reporting physical activity data.<sup>53</sup>

Within the quantitative data (i.e., frequency, duration, intensity) that can be assessed with regard to physical activity, the intensity has shown to be significant when referring to health outcomes.<sup>54</sup> Even the physical activity recommendations from the World Health Organization (WHO) refers to intensities, specifically to moderate to vigorous.<sup>55</sup> In children and adolescents aged 5 to 17 years the guidelines establish 60 minutes a day at least 3 days a week.<sup>55</sup> Nevertheless, vigorous physical activity trends in European adolescents and moderate-to-vigorous physical activity trends in European children and adolescents have shown a global declining tendency during the last decades.<sup>56-58</sup> In fact, between a 70% and 89.9% of the adolescents from Europe aged 13-15 years do not meet the recommendations per day.<sup>59</sup> Similarly, longitudinal evidence in children aged 8-11 reported that in the first, second and third year of the study a 83.1%, 81.4%, and 63.9% of children, respectively, did not meet the recommendations either.<sup>60</sup>

Despite of the trends in children and adolescents, previous evidence reported positive associations between higher intensities of physical activity and better cardiometabolic status,<sup>61</sup> sleep restoring, psychological functioning,<sup>62</sup> and lower risk of suffering depressive disorders.<sup>63</sup> Thus, since higher physical activities intensities have a positive impact one's physiological and psychological functioning, it might be possible that this could affect their general well-being and quality of life. In fact, previous cross-sectional, longitudinal, and interventional research reported positive associations between physical activity and HRQoL in children and adolescents,<sup>39</sup> showing that higher vigorous physical activity duration and frequency were linked to greater HRQoL. However, further research is needed in children and youth when referring to higher intensities of physical activity, as well as objectively measured physical activity.<sup>64</sup> Thus, it would be interesting to expand the current knowledge about (i) the effect that higher physical activity intensities might have on overall health dimensions and (ii) the use of objective tools to measure children's and adolescents' current vigorous physical activity and better understand its relationship and influence on overall children's and adolescents' HRQoL.

## 2. Adherence to the Mediterranean diet and HRQoL

Adherence to the Mediterranean diet has been defined as a high consumption of vegetables, fruit, legumes, nuts, beans, whole grains, fish, and unsaturated fats (e.g. olive oil) and low consumption of red meat and dairy products.<sup>65</sup> Dietary patterns data collection can be carried out through questionnaires, interviews, or food records.<sup>66</sup> Although previous literature stated that subjective tools have been commonly used in previous research,<sup>66</sup> authors reported that the variation and timing of a person consumption of specific food or the combination of them (i.e., meals) could only be assessed by objective instruments (i.e., cameras, microphones, or pattern recognition).

However, depending on the population assessed, not all the tools are suitable.<sup>67</sup> Instruments that require them to record or weighting all consumed food and drinks might be a burden for children and adolescents, who constantly form new eating habits, maybe need help (i.e., parents or caregivers) for completing the questionnaire, easily become irritated or simply forget to get record of the food.<sup>68</sup> Thus, questionnaires related to food frequency or food recalls to assess food patterns in children and adolescents can be suitable instruments.<sup>68</sup>

Previous evidence regarding nutritional recommendations for children reported that the intake of fruits and vegetables, fiber, seafood, and lean proteins would be suitable.<sup>69</sup> In addition, enough calcium remains a priority in children and a minimal consumption of sugary beverages, desserts, fast foods, and foods high in salt are recommended.<sup>69</sup> In adolescents, overall protein intake should increase, and a suitable intake of milk products, fish and omega-3-fatty acids, red meat, beans, and nuts is recommended.<sup>69</sup> In Europe, during the last two decades, children's and adolescents' dietary patterns have shown a steady increase in consumption of sugar intake,<sup>70</sup> fruits, and vegetables.<sup>71</sup> Nevertheless, a global change in nutrition patterns among Mediterranean countries is nowadays happening in the general population. It is called "Westernization" of the diet, and it is leading them to change their preferences to "junk" food<sup>72</sup> and lowering their adherence to the Mediterranean diet.<sup>73</sup> This phenomenon implies a greater intake of energy-dense and nutrient-poor foods, and beverages such as salted snacks, candies, and soft drinks. For instance, García Cabrera et al. carried out a systematic review including papers from several European countries and Chile, with a population between 2 and 25 years, and reported that a 10% of the population studied had a high adherence to the Mediterranean diet, while a 21% had a low adherence.<sup>74</sup> The low adherence to this Mediterranean diet pattern and the high consumption of nutrient-poor foods could lead to an increase in the incidence of non-communicable diseases.<sup>73</sup> Indeed, adherence to this dietary pattern has been associated to a reduced risk of suffering major chronic diseases (e.g. metabolic, cardiovascular, and neurodegenerative) and cancer<sup>75</sup>. In addition, prior cross-sectional evidence in children and adolescents revealed an individual positive association between adherence to the Mediterranean diet and all the components and the total score of HRQoL.<sup>76-78</sup> This is probably due to the role that specific nutrients from the Mediterranean diet might have on physical and mental health status<sup>79</sup>. However, there is no previous evidence analysing the mechanisms that could have an influence in the association between this dietary pattern and HRQoL in children and adolescents. Therefore, it would be helpful adding to the current knowledge new evidence regarding the mechanisms that could influence the relationship between Mediterranean diet adherence and HRQoL to design improved public health strategies.

### 3. Sleep patterns and HRQoL

Sleep has been defined as an individual state distinguished by an increased threshold for response to sensory input, a decrease in motor function, and a lack of consciousness.<sup>80</sup> Sleep patterns

embrace sleep duration (i.e., total sleep time per night) and sleep quality (i.e., satisfaction level of the sleep experience). They can be subjectively (e.g., sleep logs, questionnaires, interviews) or objectively measured (e.g., actigraphy, polysomnography).<sup>81</sup> Since there is a limited screening for sleep-related issues in children and adolescents, comprehensive questionnaires may be used to increase screening sleep alterations in these age populations.<sup>81</sup> Sleeping recommendations for youth according to Paruthi et al. have been established in 9 to 12 hours for children aged 6 to 12 years and 8 to 10 hours for adolescents aged 13 to 18 years, both per 24 hours on a regular basis.<sup>82</sup> However, current sleep patterns of European children and adolescents reported to be insufficient (i.e., less than 8-10 or 9-11 hours).<sup>83,84</sup> Specifically, the trends are in a 0.75 minutes per year decline over 100 years in 103 countries, being the European older boys (during school days), the ones with the greatest declining rates.<sup>83</sup>

The relationship between sleep patterns and HRQoL has been previously investigated. Several studies in children and adolescents showed that sleep patterns, both sleep quality and duration, were positively associated with HRQoL.<sup>41,85</sup> Inversely, adolescents suffering from sleep deprivation and complaining about their health status showed an overall lower HRQoL.<sup>86</sup> In this age population, poor sleep patterns have been related to multiple cognitive and affective impairments,<sup>87-89</sup> which in turn may negatively influence their HRQoL. However, there is a scarce literature investigating how having a greater HRQoL could be determined by engaging in poor or good sleep duration and quality in adolescents. Therefore, widening the knowledge regarding how this health-related behaviour could be useful for the effectiveness of the current or future public health strategies focused on children's and adolescents' HRQoL increasement might be of interest.

#### 4. Screen time and HRQoL

Sedentary behaviors, such as sitting and lying-down activities, involve an energy expenditure equivalent to basal metabolism.<sup>90</sup> Among them, screen time is defined as the amount of time spent watching TV and using or playing with computers or electronic devices,<sup>91</sup> and has become the most popular sedentary behavior in children and adolescents.<sup>92</sup> Screen time activities could be objectively measured (i.e., screen time tracking applications); however, asking participants to use a tracking app (or several) in all their devices could be a burden or even an invasion of the personal space.<sup>93</sup> Thus, screen time assessed using subjective (e.g., questionnaires, interviews) tools,<sup>94</sup> seem to be a fast, no-cost, and an anonymous way to collect that data.<sup>93</sup>

On average, during their free time, children and adolescents watch television between 1.8 and 2.8 hours, play video games for 40 minutes, and use the computer 34 minutes per day.<sup>95</sup> Overall, 28% of children and adolescents are engaged in these screen-based activities more than 4 hours per day,<sup>95</sup> despite of the recommendations being 2 hours or less per day.<sup>96</sup> Trends in European adolescents during the first decade of the 2000s have shown a significant increase in screen time

behaviors,<sup>97</sup> which kept its growing tendency all the way to the present days.<sup>98</sup> Time spent in front of a screen has been associated to poorer locomotive skills, physical strength, dietary habits, and mental health in children and adolescents,<sup>99</sup> which could reduce their quality of life.<sup>100</sup> Previous cross-sectional evidence in children and adolescents reported that longer exposure to screens was associated to poorer HRQoL.<sup>99,101</sup> The more time spent in those activities, the less time practicing other health-related behaviors, such as plenty sleeping or regular physical activity,<sup>102</sup> which in turn could affect their HRQoL. However, there is evidence supporting that the concerning messages about the harmful consequences of a high exposure to screen-based activities are inherited and not based in solid evidence.<sup>103</sup> Besides, additional previous literature reported that education promotes its use among these age populations.<sup>104</sup> Since the current evidence is controversial, adding new evidence to clarify how screen time could impact children's and adolescents' HRQoL is of interest.

### **Physical fitness and HRQoL**

Physical fitness has been defined as a set of attributes related to a person's ability to perform physical activities, which main components are cardiorespiratory fitness, muscular strength, and motor competence.<sup>33</sup> Cardiorespiratory fitness represents a measure of the body's ability to deliver and use oxygen to support muscular activity during physical activity;<sup>105</sup> muscular strength is the capacity to carry out work against a resistance;<sup>33</sup> and motor competence can be defined as a person's ability to execute different motor acts, including coordination of fine and gross motor skills that are necessary to perform everyday tasks.<sup>106</sup> All components of physical fitness can be assessed objectively, through laboratory tests, and subjectively, using field-based tests.<sup>107,108</sup> Importantly, field-based tests have been proposed as a good alternative to laboratory tests due to facilities in administration, time efficiency and low cost.<sup>109</sup>

Physical fitness is nowadays considered a powerful health marker, being a predictor for morbidity and mortality in children and adolescents.<sup>27</sup> Indeed, it has been previously associated with less risk of developing metabolic diseases and positively associated with skeletal and mental health in children and adolescents.<sup>27</sup> Nevertheless, trends in physical fitness of European children and adolescents have shown an overall declining tendency from 1995 until 2014.<sup>110</sup>

Over the past years, its components have been cross-sectionally related to HRQoL. Those studies revealed positive associations with cardiorespiratory fitness and muscular strength.<sup>42,43,111</sup> In addition, one prior longitudinal study examined the association between cardiorespiratory fitness and HRQoL reporting positive associations.<sup>112</sup> Nevertheless, no study examined the longitudinal relationship of muscular strength and motor competence with HRQoL. Therefore, it could be of importance for the public health authorities to investigate, for the first time, those associations in these age populations.



According to the above-mentioned evidence, taking in account the importance of health-related behaviors and attributes during childhood and adolescence for HRQoL, the scarce literature on mechanisms that could influence this association and the synergic effect that adhering to several health-related behaviors or attributes simultaneously might have on health,<sup>46</sup> we believe that widening the literature on this topic is warranted.

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## **AIMS**

The main aim of this PhD Thesis was to investigate the associations of health-related behaviors and attributes with HRQoL in children and adolescents, and the possible mechanisms that may explain these associations.

The aim mentioned above was approached by the following specific aims according to three sections:

### Section 1. Health-related behaviors and HRQoL (studies I and IV)

- To investigate the associations between health-related behaviors (i.e., vigorous physical activity, adherence to the Mediterranean diet, sleep patterns, and screen time) and HRQoL.

### Section 2. Physical fitness and HRQoL (studies II and III)

- To analyse the association between physical fitness components and HRQoL.

### Section 3. Possible mechanisms (studies III and IV)

- To examine possible mechanisms that explain the associations of health-related behaviors and physical fitness with HRQoL.

## **METHODS**

### **DADOS Study**

DADOS study (Deporte, ADOlescencia y Salud) was a 3-year longitudinal project aimed to study the effects of health-related behaviors and physical fitness on health and academic performance during adolescence. This project has been carried out by the Physical activity, fitness and health (LIFE) research group from Universitat Jaume I.

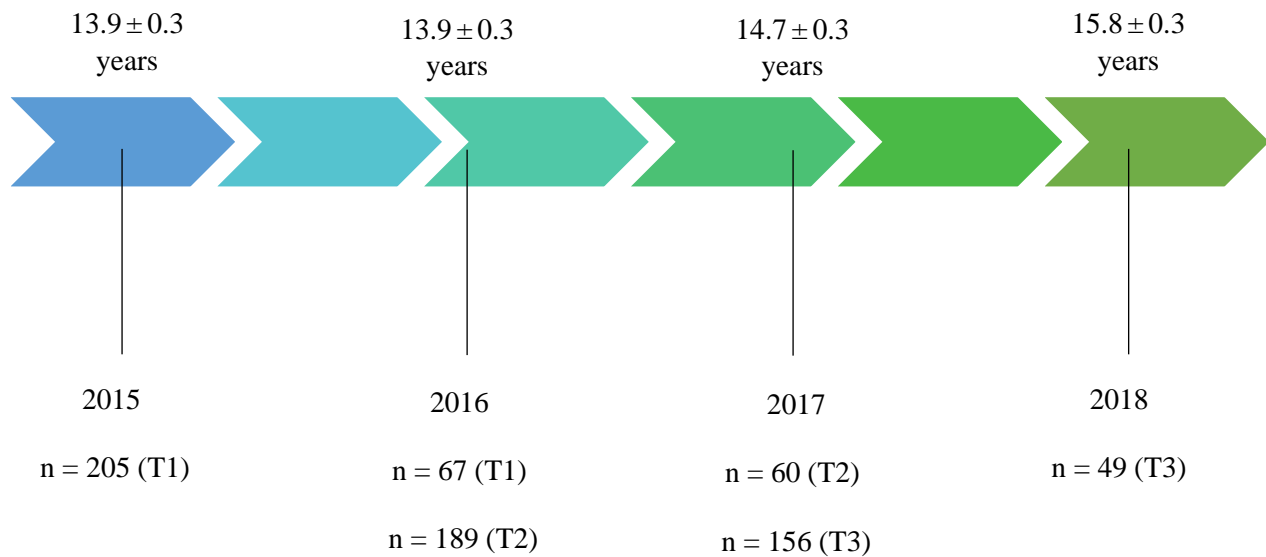
Based on the main aim of the project, DADOS study set several sub-aims to give an explanation to some of most usual concerns of educational institutions, health authorities, and families:

- To find out whether adolescents reach the minimum physical activity recommendations.
- To find out how physical activity influences the level of physical fitness.
- To know how physical activity influences body composition.
- To analyze the influence of physical activity on cardio-metabolic risk indicators.
- To analyze the influence of physical activity in cognition and academic performance.
- To analyze the influence of physical activity on psychological well-being.

During DADOS study we analyzed the evolution of physical activity levels, physical health, psychological well-being, and academic performance in a group of 274 adolescents in the province of Castellón. The participants belonged to secondary schools and sports clubs and engaged in different levels of physical activity and sporting activities in their daily lives. All of them were volunteers and had the approval and consent of their parents or legal guardians.

The DADOS study assessments were carried out at the Universitat Jaume I campus. Adolescents who participate in the project completed one assessment per academic year during 2015, 2016, and 2017. The evaluation protocol designed was approved by the Deontological Commission of the Universitat Jaume I of Castellón, and was applied in a single afternoon and presented the following structure:

- Overall health status assessment, blood analysis, and placement of an accelerometer to evaluate the level of physical activity.
- Questionnaires for the evaluation of cognition and psychological well-being.
- Physical fitness assessment tests.



**Figure 3.** DADOS Study design including number of participants (n) and phases of data collection (T) per year.

Food and beverages were provided to all participants during the assessment. In addition, to make sure that the participants wore a suitable sportive outfit, all participants received a gift voucher for clothing and sports equipment. The data obtained were treated anonymously and confidentially by the research team. In addition, at the end of each annual assessment, participants received a complete report of their health status, cognitive capacity, and psychological well-being. If the research team detected any health issue, the families were informed.

### Active West Lancs programme

The aim of this research project was to evaluate the impact of the West Lancashire Sport Partnership Dr Feelwell (DFW) and Born to Move (BTM) primary school programmes with respect to children’s physical activity behaviours, fitness, and well-being.

Fifteen schools participated in the research to date, totalling 469 pupils. Six schools participated in the BTM intervention (200 pupils), seven in the DFW intervention (225 pupils) and two schools participated in both interventions (44 pupils). Evidence of maintained or positive changes in physical activity, fitness, knowledge and understanding, wellbeing, and psychosocial correlates

was observed across both projects. Teachers and pupils offered positive qualitative feedback on the DFW and BTM programmes stating they were inclusive in nature and tended to engage those normally disinterested in Physical Education.

### **Background**

The Active West Lancs (AWL) school initiative centred on the Dr Feelwell (DFW) healthy lifestyle education programme, and the Born to Move (BTM) physical activity and fitness programme. Both programmes were delivered once a week for 12-weeks to primary school aged children across the West Lancashire area. Since September 2017, West Lancashire Borough Council have partnered with Edge Hill University with the aim of evaluating both these AWL programmes. Postgraduate researcher, Dr Danielle Christian, under the leadership of a small team of experienced and internationally recognised academics has led the evaluation.

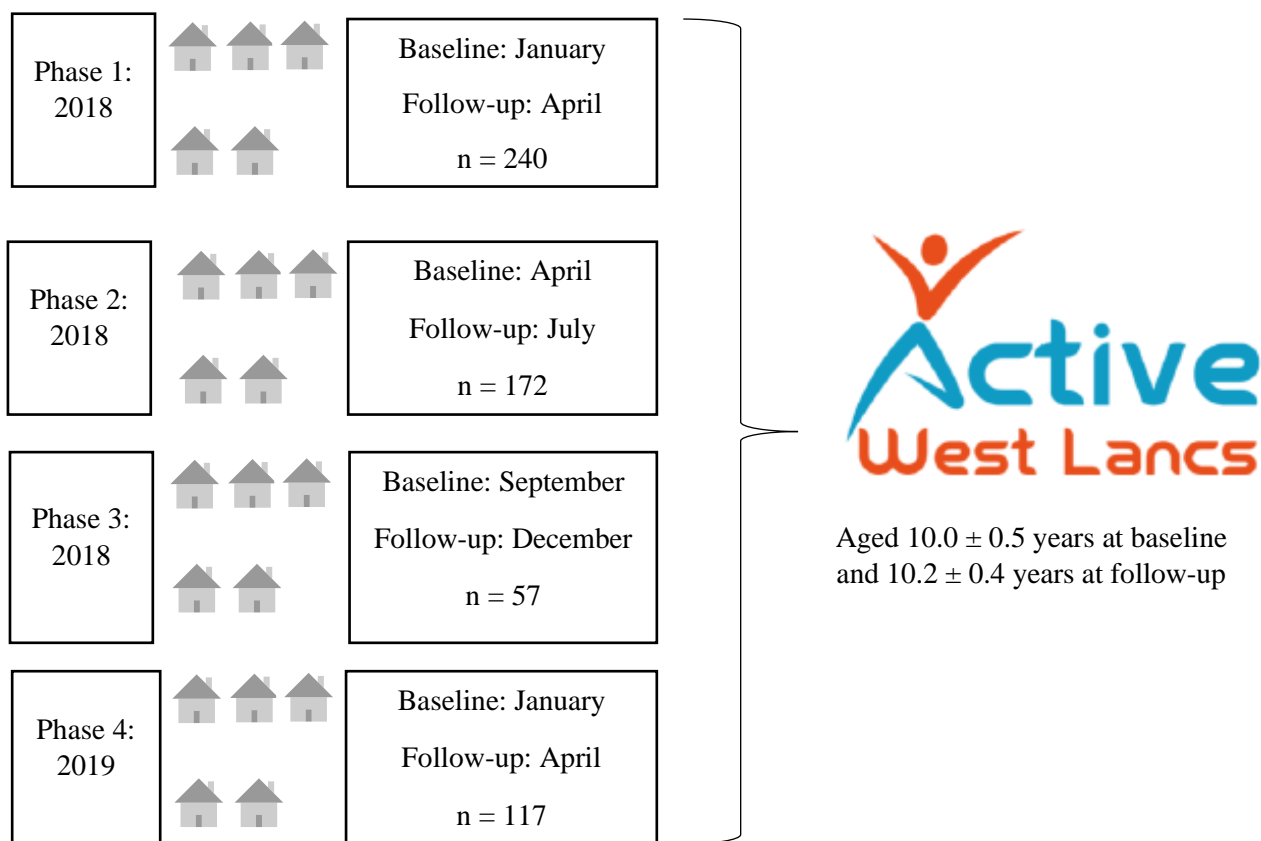
### **Proposed implementation and rationale**

The aim of this research project was to evaluate the impact of the AWL, DFW, and BTM school programmes with respect to children's physical activity behaviours, fitness, and well-being. The project also aimed to evaluate the fidelity of the programme delivery and the perceptions of the participants. The current Year 5 pupils from participating schools were the target population for the evaluation of the project in this instance.

A pre-post research design was implemented to evaluate the short-term effects of the programme (i.e., 12 weeks). Process evaluation and participant perceptions data was collected on a rotational basis throughout each 12-week block. The January 2018 phase of the AWL programme coincided with the explicit requirement for children to engage in 30 minutes of physical activity during the school day, as recommended in the DH Childhood Obesity Strategy. Therefore, this unique context provided the basis to evaluate the AWL programme to estimate the effects on children's well-being, fitness, and health.

### **Project Design**

Four phases of data collection (January-April, April-July, September-December 2018 and January-April 2019) have been completed. Fifteen schools participated in the research to date, totalling 200 pupils receiving the BTM programme and 225 pupils participating in DFW. One school with 29 pupils, and another with 15 pupils, received both interventions.



**Figure 4.** Active West Lincs programme design including number of participants (n) and phases of data collection.

### Outcome measures

A multitude of measures were implemented to fully evaluate the BTM and DFW programmes. Physical activity was assessed via self-report, utilising a new internationally developed Youth Activity Profile survey, and objectively, via Actigraph accelerometers. The 20m multi-stage shuttle run test was employed to estimate cardiorespiratory fitness in addition to the push up test and grip strength for muscular fitness. Psychological correlates of physical activity including self-efficacy, attitudes and intentions, sports competence, and enjoyment were established through a range of questionnaires. General health and well-being were also measured using the KIDSCREEN-10 questionnaire. Teacher interviews, pupil focus groups, session observations, and a knowledge and understanding questionnaire completed the evaluation complement.



**Study I: Health Related Quality of Life in  
Adolescents: Independent and combined impact  
of health-related behaviors (DADOS Study)**

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Quality of Life Research. 2020; 30(4):1093-1101.

DOI: [10.1007/s11136-020-02699-9](https://doi.org/10.1007/s11136-020-02699-9)



## Health-related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study)

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Accepted: 6 November 2020  
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### Abstract

**Purpose** To investigate the individual and combined effect of physical activity, adherence to the Mediterranean diet, sleep quality, sleep duration, and screen time on health-related quality of life (HRQoL) in adolescents.

**Methods** This is a cross-sectional analysis with 262 adolescents ( $13.9 \pm 0.3$  years) from DADOS (Deporte, ADOlescencia y Salud) study. Physical activity was assessed with a wrist-worn GENEActiv triaxial accelerometer. Adherence to the Mediterranean diet was evaluated by the KIDMED questionnaire. Sleep patterns were self-reported through the Spanish version of Pittsburgh Sleep Quality Index questionnaire. Screen time was assessed through the HELENA sedentary behavior questionnaire. HRQoL was measured using the KIDSCREEN-10 questionnaire. Scores were categorized into low and high using a normative cut-off used to identify factors associated with being in a high HRQoL group. A healthy lifestyle index was created including positive scores for each individual behavior, and five categories of achievement were established (0, 1, 2, 3,  $\geq 4$ ).

**Results** Sleep patterns and screen time revealed a significant individual relationship with HRQoL ( $p < 0.05$ ). Adolescents achieving  $\geq 3$  positive health-related behaviors showed higher HRQoL levels compared to those fulfilling none ( $p < 0.05$ ). Logistic regression analysis revealed an increased likelihood of high HRQoL according to the number of positive health-related behaviors achieved ( $p < 0.05$ ).

**Conclusions** Our results reveal higher levels of HRQoL in those adolescents achieving  $\geq 3$  health-related behaviors compared to their peers achieving none. Moreover, our findings show a cumulative effect of health-related behaviors on HRQoL. These findings underline the key role of promoting a healthy lifestyle in order to improve adolescents' health and well-being.

**Keywords** Adolescence · Diet · Sleep · Physical activity · Screen time

### Introduction

Health-related quality of life (HRQoL) could be defined as individuals' functioning performance in life and their perceived well-being in physical, mental, and social domains of health [1]. Since perceived health and functionality are considered important components of health surveillance, HRQoL has been suggested as an important health indicator [2]. Thus, identifying the elements that could contribute to improve HRQoL should be a health priority nowadays.

Prior research has shown that HRQoL is closely linked to health-related behaviors in adolescents [3–7]. For instance, high levels of physical activity were associated with greater

HRQoL in children and adolescents [8]. Regarding healthy dietary patterns, adherence to the Mediterranean diet was positively associated with HRQoL [3]. In addition, prior scientific evidence has suggested that adolescents with poor sleep quality [4, 7] and short sleep duration [6] showed lower HRQoL. Screen time was also negatively associated with HRQoL in children and adolescents [5].

Although youth adherence to single health-related behaviors seems to significantly contribute to HRQoL [3–7], adolescents tend to adhere to a number of health-related behaviors simultaneously [9], which may increase each single health-related behavior effect. Indeed, previous research suggested that the adherence to multiple health-related behaviors simultaneously may improve their respective individual impact on health by synergistically interacting with each other [10]. Studies performed on different populations have reported an association between the number of health-related behaviors adhered

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and indicators such as weight status, physical functioning, or mortality [11–13]. However, to the best of our knowledge, only one study has investigated the combined effect of these behaviors on HRQoL in this age population [14] reporting a positive relationship between a healthy lifestyle composite score and HRQoL. Yet, as recognized by Marques et al. [14] reliability and validity of the lifestyle behaviors measured was not considered.

Therefore, it would be interesting to expand the scarce knowledge in adolescents about the effect of adhering to several modifiable lifestyle factors on HRQoL, including valid measuring instruments and quantifying the magnitude of the effect. This understanding would help to design effective public health policies and would be informative for allocating prevention resources. Thus, the aim of the present study was to investigate the individual and combined effect of several health-related behaviors (i.e., physical activity, adherence to the Mediterranean diet, sleep quality, sleep duration, and screen time) on HRQoL in adolescents.

## Methods

### Study design and sample selection

This study is part of the DADOS (Deporte, ADOlescencia y Salud) research project, a 3-year longitudinal study aimed to analyze the influence of lifestyle behaviors on health and academic performance in adolescents. The results presented in this study belong to baseline data obtained between February and May of 2015. 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 basic information and the general inclusion criteria of DADOS study. The inclusion criteria were to be enrolled in second grade of secondary school, and to be free of physical (i.e., locomotor system) and cognitive (i.e., intellectual ability) impairments. Volunteers who declared to meet these criteria were included in the study. A total of 262 adolescents aged  $13.9 \pm 0.3$  years (48% girls) completed the baseline assessment with valid data for vigorous physical activity, adherence to the Mediterranean diet, sleep quality, sleep duration, screen time, and HRQoL.

Adolescents and their parents or guardians were informed about the nature and characteristics of the study, and all provided 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).

## Health-related behaviors

### Physical activity

Levels of physical activity were objectively measured using the GENEActiv accelerometer (Activinsights Ltd, Kimbolton, Cambridgeshire, UK), a waterproof device which contains a triaxial microelectromechanical accelerometer that records both motion-related and gravitational acceleration, and has a linear and equal sensitivity along the three axes. Participants wore the accelerometer on their non-dominant wrist. GENEActiv accelerometer offers a body temperature sensor to detect wear and non-wear time. Accelerometer-derived data from all participants comprised at least four complete days, including weekend and weekdays, with 24-h valid data. This device provides a reliable (coefficient of variation intra- and inter-instrument of 1.4% and 2.1%, respectively) [15] and valid assessment of physical activity in young people ( $r=0.925$ ,  $p=0.001$ ) [16]. 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 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. [16], GENEActiv cut-off point for vigorous intensity in children/adolescents was established for values over 60 g. In the current study, vigorous physical activity was chosen to be included in the analyses due to its stronger relationship with health parameters than moderate or light intensities [17, 18]. Participants above the sex-specific 75th percentile were categorized as high vigorous physical activity.

### Adherence to the Mediterranean dietary patterns

Adherence to the Mediterranean diet was assessed using the KIDMED [19], a questionnaire based on the Mediterranean dietary guidelines for children and adolescents which provides an overall indication of the adequacy to its dietary patterns. The KIDMED 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 vegetable consumption, weekly fish and legume intake), while those with a negative connotation were assigned a value of -1 (e.g., subjects' consumption of fast food, sweets, and soft drinks). The final score for the participants' adherence



to the Mediterranean dietary pattern was calculated as the sum of each answer, which ranges from zero to 12. According to the KIDMED questionnaire instructions [19], levels of adherence are classified into (1)  $\geq 8$  points: optimal adequacy to the Mediterranean dietary patterns; (2) 4–7 points: improvement needed to adjust intake to Mediterranean patterns; (3)  $\leq 3$  points: very poor diet quality according to Mediterranean guidelines. For the purposes of the current study, the scores were organized into two groups: poor (0–7) vs. optimal (8–12).

### Sleep quality

Sleep quality was assessed through the Spanish version of the Pittsburgh Sleep Quality Index (PSQI) questionnaire [20]. Good psychometric properties have been established in adults in both clinical and non-clinical settings [19, 21, 22]. In addition, previous data from adolescents' population also showed that the PSQI has adequate reliability (Cronbach's  $\alpha = 0.72$ ), good test–retest stability over a 6-week period ( $r = 0.81$ ,  $p < 0.001$ ), and good divergent ( $r = -0.35$ ) and convergent ( $r = 0.42$ ) validity with positive mood and fatigue, respectively [23]. Similar reliability results have been obtained in the current sample (Cronbach's  $\alpha = 0.70$ ). It includes 19 questions that assess 7 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 3-point ascending scale, with 0 points indicating ideal sleep quality and 3 points indicating poor sleep quality. The global score of the PSQI was used in the analysis as the addition of all component scores, ranging from 0 to 21, with lower scores representing better sleep quality. According to Buysse et al., the PSQI questionnaire provides a sensitive measure to identify good sleep quality if total PSQI score is  $\leq 5$  [21].

### Sleep duration

Subjective information on sleep duration was estimated from the PSQI questionnaire [20] through the following questions: “during the past month, when have you usually gone to bed at night?” and “during the past month, when have you usually gotten up in the morning?” Sleep duration was calculated as the difference between bedtime and time for getting up. According to the definition of the National Sleep Foundation for adolescent populations, good sleep duration was defined as  $\geq 8$  h per day [24].

### Screen time

Screen time was assessed using the HELENA (Healthy Lifestyle in Europe by Nutrition in Adolescence) sedentary

questionnaire [25]. For both, weekend and weekdays, adolescents reported the number of hours spent on television, videogames, internet, and mobile phone. Seven possible answers were available for each item: no time,  $< 30$  min,  $\geq 30$  to  $< 60$  min,  $\geq 1$  to  $< 2$  h,  $\geq 2$  to  $< 3$  h,  $\geq 3$  to  $< 4$  h, and  $\geq 4$  h. Total screen time for weekend and weekdays was calculated adding the mean time of each screen-based activity. The overall time was established as follows:  $1/7 \times (2 \times \text{week-end days} + 5 \times \text{weekdays})$ , and participants under the sex-specific 25th percentile were categorized as low screen time.

### Healthy lifestyle index

A healthy lifestyle index ranging from a score of 0 to 5 was specifically defined for our sample according to the number of health-related behaviors accomplished by each adolescent: (1) high vigorous physical activity; (2) optimal adherence to the Mediterranean diet; (3) good sleep quality; (4) good sleep duration, and (5) low screen time. Thus, a higher score indicates a healthier lifestyle.

### Health-related quality of life

HRQoL was assessed with the KIDSCREEN-10 questionnaire, a valid and reliable scale to analyze HRQoL among youth population [26]. The reliability and validity of the questionnaire has been examined previously in adolescents showing good reliability (Cronbach's  $\alpha = 0.82$ ) and criterion validity ( $r = 0.91$ ) [26]. Optimal reliability results have also been obtained in the current study (Cronbach's  $\alpha = 0.77$ ). This questionnaire consists of a 10-item scale to assess vitality and energy, symptoms of depressed mood, youth's opportunities to structure his/her leisure time and enjoying social activities, and youth's perception of his/her cognitive capacity and satisfaction with school performance. Each item is 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. Participants above the sex-specific mean normative value from European adolescents [2], which establishes the threshold on 49.00 mean value for females and 51.12 mean value for males, were classified as having high HRQoL.

### Covariates

Sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level were included as covariates in the statistical analyses [27, 28].

### Pubertal stage

Pubertal stage was self-reported according to the five stages described by Tanner and Whitehouse [29]. It is based on external primary and secondary sexual characteristics, which are described by the participants using standard pictures according to Tanner instructions. Self-assessment can be validly used in epidemiologic studies for evaluation of sexual maturation [30].

### Socioeconomic status

The Family Affluence Scale (FAS) developed by Currie et al. was used as a proxy of socioeconomic status (ranging from 0 to 8), which is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access [31].

### Waist circumference

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. The average measure was used for the analyses.

### Parents' education level

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.

### Statistical analysis

Study sample characteristics are presented as mean  $\pm$  standard deviation and percentages for continuous and categorical variables, respectively. Sex differences were assessed using independent *t* test for continuous variables, and chi-square test for nominal variables. All variables were checked for normality using both graphical (normal probability plots) and statistical (Kolmogorov–Smirnov test) procedures. As preliminary analyses did not show a significant interaction of sex with the health-related behaviors variables in relation to HRQoL (all  $p > 0.10$ ), all analyses were performed with the total sample.

Differences in HRQoL between health-related behaviors categories individually were analyzed by one-way analysis of covariance (ANCOVA). Linear regression analyses were conducted to examine the associations between individual health-related behaviors and HRQoL. Moreover, ANCOVA analyses, with a Bonferroni post hoc test, were performed to investigate HRQoL differences based on the number of

health-related behaviors accomplished by adolescents (i.e., healthy lifestyle index). Partial eta-squared ( $\eta^2_p$ ) was calculated to evaluate the effect size with following interpretation:  $< 0.01$  = trivial;  $0.01$ – $0.06$  = small;  $0.06$ – $0.14$  = medium; and  $> 0.14$  = large [32]. Additionally, logistic regression was conducted to examine the likelihood of having high HRQoL based on the number of health-related behaviors achieved (i.e., healthy lifestyle index). For these analyses, the following categories of the healthy lifestyle index (independent variable) were used: 0, 1, 2, 3, and  $\geq 4$ . The analyses were adjusted for sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level and were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp). A *p* value of  $< 0.05$  was set as statistically significant.

## Results

Descriptive characteristics of the study sample are presented by sex in Table 1. Overall, compared to boys, girls showed lower levels of daily vigorous physical activity, poorer adherence to the Mediterranean diet, poorer sleep quality, and shorter sleep duration (all  $p < 0.05$ ). Regarding HRQoL, boys scored greater than girls ( $p < 0.05$ ).

Table 2 shows associations between health-related behaviors individually and HRQoL, adjusted for sex, pubertal stage, socioeconomic status, waist circumference, and parent's education level. Linear regression analyses indicated that adherence to the Mediterranean diet ( $p < 0.05$ ), sleep quality, and sleep duration ( $p < 0.001$ ) were individually associated with adolescents HRQoL. However, vigorous physical activity ( $p = 0.703$ ) and screen time ( $p = 0.072$ ) showed no individual associations.

Figure 1 shows HRQoL differences between categories of health-related behaviors individually, adjusted for sex, pubertal stage, socioeconomic status, waist circumference, and parent's education level. Adolescents with good sleep quality (PSQI scores  $\leq 5$ ) reported higher HRQoL than their peers with poor sleep quality ( $50.9 \pm 0.6$  vs.  $48.5 \pm 0.8$ ,  $p = 0.016$ ). Regarding sleep duration, participants with good sleep duration ( $\geq 8$  h per day) showed a higher HRQoL than those with poor sleep duration ( $51.2 \pm 0.6$  vs.  $47.4 \pm 0.9$ ,  $p < 0.001$ ). Moreover, participants with low screen time (sex-specific  $< 25$ th percentile) showed greater HRQoL than those with high screen time ( $52.1 \pm 0.9$  vs.  $49.3 \pm 0.6$ ,  $p = 0.010$ ).

The differences in HRQoL according to the healthy lifestyle index are presented in Fig. 2. The analyses showed significant differences in HRQoL between healthy lifestyle index categories ( $F_{(4,260)} = 5.17$ ,  $p = 0.001$ ;  $\eta^2_p = 0.08$ ), after adjusting for sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level. Specifically,

**Table 1** Descriptive characteristics of the study sample (n=262)

	Girls (n=125)	Boys (n=137)	All	p value *
Age (years)	13.9±0.3	13.9±0.3	13.9±0.3	0.956
Pubertal stage (II–V) (%)	6/35/54/5	10/32/44/14	8/34/49/9	–
Socioeconomic status (0–8)	4.4±1.4	4.0±1.3	4.2±1.4	<b>0.032</b>
Waist Circumference (cm)	66.5±6.0	68.1±5.5	67.3±5.8	<b>0.021</b>
Obese participants (%)	2.4	2.2	2.3	0.967
Parents with university-level education (%)	54.0	42.6	48.1	0.066
<b>Health-related behaviors</b>				
Vigorous physical activity (min/day)	8.9±7.6	15.6±7.8	12.4±8.3	< <b>0.001</b>
High vigorous physical activity (%)	24.8	24.8	24.8	0.997
Adherence to the Mediterranean Diet (0–12)	6.7±2.2	7.3±2.1	7.0±2.2	<b>0.033</b>
Optimal adherence (%)	38.4	47.4	43.1	0.140
Sleep quality (0–21)	5.5±2.7	4.2±2.7	4.8±2.8	< <b>0.001</b>
Good sleep quality (%)	53.6	73.7	64.1	<b>0.001</b>
Sleep duration (h/day)	8.1±0.9	8.3±0.7	8.2±0.8	<b>0.008</b>
Good sleep duration (%)	59.2	77.4	68.7	<b>0.002</b>
Screen time (h/day)	5.0±2.6	4.7±2.5	4.8±2.5	0.300
Low screen time (%)	28.8	24.8	26.7	0.467
Health-related quality of life (Minimum—maximum values)	47.5±7.4 (31.93—83.81)	52.3±7.8 (40.24—83.81)	50.0±8.0 (31.93—83.81)	< <b>0.001</b>
High health-related quality of life (%)	68.8	87.6	78.6	< <b>0.001</b>

Data are presented as mean±standard deviation or percentages. Differences between sexes were examined by *t* test or chi-square test. Statistically significant values are in bold. High vigorous physical activity was defined as the sex-specific ≥75th percentile. Good adherence to Mediterranean diet indicates a score ≥8. Good sleep quality indicates a Pittsburgh sleep quality index ≤5. Good sleep duration indicates ≥8 h per day. Low screen time was defined as the sex-specific ≤25th percentile. Health-related quality of life was assessed with the KIDSCREEN-10 questionnaire. High health-related quality of life indicates high level according to European normative values for adolescents

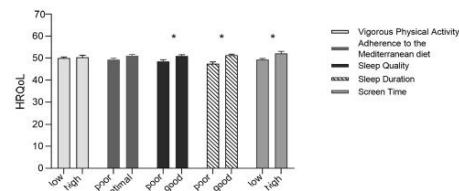
**Table 2** Associations between health-related behaviors and health-related quality of life (n=262)

	Health-related quality of life		
	β	95% CI	p
Vigorous physical activity	0.026	0.024; 0.064	0.703
Adherence to the Mediterranean diet	0.163	0.606; 0.222	<b>0.007</b>
Sleep quality	−0.232	−0.664; 0.173	< <b>0.001</b>
Sleep duration	0.236	2.334; 0.583	< <b>0.001</b>
Screen time	−0.111	−0.006; 0.003	0.072

Data are presented as standardized regression coefficient (β) and 95% confidence interval (CI). Analyses were adjusted by sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level. Health-related quality of life was measured using KidScreen-10. Statistically significant values are in bold

adolescents with a healthy lifestyle index of 3 or ≥4 had higher HRQoL than those with a healthy lifestyle index of 0 (52.2±0.9 and 52.5±1.1, respectively, vs. 45.7±1.7; all *p* = 0.01).

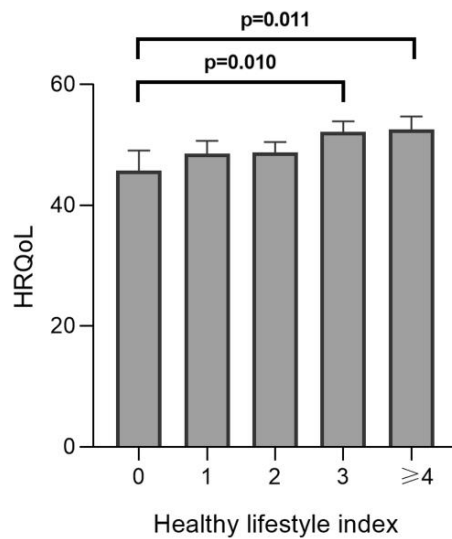
Table 3 shows the results of the healthy lifestyle index predicting high HRQoL in adolescents. Logistic regression analyses in the unadjusted model (model 1) indicated that



**Fig. 1** ANCOVA analysis examining individual effects of health-related behaviors on health-related quality of life in adolescents. Analyses were adjusted by sex, pubertal stage, socioeconomic status, waist circumference and parents' education level. Estimated marginal means with their 95% Confidence Intervals are depicted. HRQoL: Health-related quality of life. \* indicates significant differences between groups (*p* < 0.05)

adolescents with a healthy lifestyle index of 1 (OR 4.07 [95% CI 1.37–12.14]), 2 (OR 5.41 [95% CI 1.89–15.54]), 3 (OR 5.81 [95% CI 1.97–17.07]), or ≥4 (OR 6.64 [95% CI 2.01–21.90]) were more likely to achieve greater HRQoL than their peers with 0. When the analyses were adjusted for sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level (model 2), adolescents





**Fig. 2** Differences in health-related quality of life according to the healthy lifestyle index, after adjusting for sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level. Estimated marginal means with their 95% Confidence Intervals are presented. HRQoL: Health-related quality of life. Adolescents with a healthy lifestyle index = 0 ( $n=20$ ), 1 ( $n=51$ ), 2 ( $n=75$ ), 3 ( $n=69$ ), and  $\geq 4$  ( $n=45$ )

with a healthy lifestyle index of 2 (OR 4.17 [95% CI 1.37–12.73]), 3 (OR 3.96 [95% CI 1.28–12.28]), and  $\geq 4$  (OR 4.63 [95% CI 1.32–16.25]) showed greater odds of having high HRQoL, compared to their peers with a healthy lifestyle index of 0.

## Discussion

The main finding of the present cross-sectional research reveals that a combination of health-related behaviors, including high vigorous physical activity, optimal adherence to the Mediterranean diet, good sleep quality, good sleep duration, and low screen time, was associated with higher HRQoL in adolescents. Additionally, the more health-related behaviors accomplished, the more likelihood of having high HRQoL. Our results extend the scarce current scientific literature by suggesting that the combination of several health-related behaviors has a stronger impact on HRQoL than their respective individual effects.

We found a significant association between sleep quality and duration with HRQoL, indicating that better and longer

**Table 3** Logistic regression analysis predicting high health-related quality of life according to the healthy lifestyle index ( $n=262$ )

Healthy lifestyle index	High health-related quality of life				
	<i>n</i>	Model 1		Model 2	
		OR (95% CI)	<i>p</i>	OR (95% CI)	<i>p</i>
0	20	1 (ref.)	–	1 (ref.)	–
1	51	4.07 (1.37–12.14)	<b>0.012</b>	3.04 (0.97–9.54)	0.057
2	75	5.41 (1.89–15.54)	<b>0.002</b>	4.17 (1.37–12.73)	<b>0.012</b>
3	69	5.81 (1.97–17.07)	<b>0.001</b>	3.96 (1.28–12.28)	<b>0.017</b>
4	45	6.64 (2.01–21.90)	<b>0.002</b>	4.63 (1.32–16.25)	<b>0.017</b>

Model 1: Unadjusted odds ratio

Model 2: Adjusted odds ratio. Analyses were adjusted by sex, pubertal stage, socioeconomic status, waist circumference, and parents' education level. Health-related quality of life scores were grouped into low and high, according to normative cut-offs: 49.00 mean value for females and 51.12 mean value for males. Odds ratio (95% Confidence Intervals) represents increased odds of achieving high health-related quality of life. High vigorous physical activity, optimal adherence to the Mediterranean dietary patterns, good sleep quality, good sleep duration, and low screen time were included in the healthy lifestyle index

Statistically significant values are in bold. OR odds ratio, CI confidence intervals, *n* number of participants in the group

sleep were associated with higher HRQoL. In addition, good sleepers reported significantly higher HRQoL than poor sleepers. This study supports prior research by confirming the individual positive influence of sleep quality and sleep duration on HRQoL [4, 7, 33]. Our results might be partially explained by the direct consequence that both poor and insufficient sleep have on increased daytime sleepiness [34]. Increased daytime sleepiness may lead to reduced alertness and compromise daytime functioning, including fatigue, mood changes, performance decrements, memory difficulties, and difficulties in coping with daily life [35]. Thus, daytime impairments resulting from reduced sleep quality and duration influence cognitive, physical, and emotional performance throughout the day, which may in turn impact HRQoL in adolescents [36, 37].

In line with previous scientific literature, our results showed that adolescents with low screen time (i.e., use of media devices such as television, phone, and videogames) had higher HRQoL [5]. However, we did not find a significant association between total screen time and HRQoL in our sample. Our findings could be related to the passivity and solitary characteristics of screen activities, which may replace social activities and do not imply situations that require problem solving, cognitive or physical challenges

[38, 39]. These characteristics could influence life satisfaction, psychological well-being, or physical health status, which in turn may influence HRQoL [40].

Our study agrees with previous research which also showed that adherence to the Mediterranean diet was positively associated with HRQoL [3]. However, we did not find significant differences between adolescents with optimal and poor adherence to this dietary pattern. A possible explanation of this association is that Mediterranean dietary patterns includes food rich in nutrients such as antioxidants, fiber, minerals, vitamins, omega-3 fatty acids (from fish) and monounsaturated fatty acids that have shown a protective role for physical and mental health status [41], so we could hypothesize that it may translate in better HRQoL.

Vigorous physical activity was not independently related with HRQoL in our study. Nevertheless, previous research in adolescents has reported a positive association between physical activity and HRQoL [3, 8]. Vigorous physical activity has been related to less risk of suffering depressive symptoms [17], better cardiometabolic status [18], and sleep restoring and psychological functioning [42] in adolescents, which could influence HRQoL. Thus, although we did not find an individual association between vigorous physical activity levels and HRQoL, it is likely that combined with the other health-related behaviors investigated, it may also impact HRQoL [43]. Hence, based on prior evidence, these health-related behaviors were included in the healthy lifestyle index to examine the combined relationship with HRQoL.

The combined effect analysis revealed that adolescents with a healthy lifestyle index of 3 or  $\geq 4$  compared with those with an index of 0 showed greater mean score values for HRQoL with a moderate effect as denoted by the medium effect size obtained. Additionally, a cumulative effect of the health-related behaviors on HRQoL was found in our sample. Although our results indicated that not all the health-related behaviors included on the current research have the same impact on adolescents' HRQoL, from a practical point of view, the combined effect analyses revealed that the more health-related behaviors achieved, the better HRQoL. To date, only one study has analyzed the combined influence of several health-related behaviors on HRQoL in adolescents [14]. The mentioned study included 6 health-related behaviors (i.e., physical activity, screen time, sleep duration, daily fruit and vegetable consumption, drinking alcohol, and smoking), and found that adolescents engaged in all the healthy behaviors showed significantly higher HRQoL. Our results agree with this previous research by confirming that adhering to several health-related behaviors is associated with higher levels of HRQoL. For the first time we revealed an increased likelihood of high HRQoL as the number of health-related behaviors accomplished raised. These

findings could be explained by the combination of all the positive effects that some health-related behaviors have on the HRQoL, which may exert a cumulative effect on adolescents' HRQoL. Yet, it is necessary to highlight that the regression analysis results showed large confidence intervals, indicating a low level of precision of the odds ratio predicting high HRQoL.

Our research combined five health-related behaviors in a healthy lifestyle index to provide a better comprehension of the influence of those behaviors on HRQoL in adolescent population. Given the cumulative effect of adopting several health-related behaviors [43], it would be interesting that public health strategies focus on the promotion of multi-behavioral health policies. This is especially relevant during adolescence, an important period of life in terms of establishment of health-related behaviors, which appear to track into later age-spans [44], influencing health during adulthood [9].

Strengths of the study included homogeneous age-matched sample of adolescents, the use of validated and standardized tests to assess adherence to the Mediterranean diet, sleep quality, sleep duration, and HRQoL, and the objective measure of physical activity by accelerometry. In addition, our results were adjusted by waist circumference and socioeconomic status [27, 28], which have been previously shown to affect the HRQoL. Limitations of our study include the cross-sectional design, which not allow us to report causality. In addition, the sample size and the use of some subjective data could have influenced our results. It is also important to mention that health-related behaviors choices during adolescence are strongly determined by other factors such as family and school environments [45, 46], but these variables were not considered in our analyses, which could have influenced our findings. Additionally, dietary patterns of the participants could be influenced by family structure, traditions, and parents' diet habits. However, these variables were not evaluated in our sample. Finally, although participants self-reported being free of physical or mental impairments their mental health was not taken into consideration in our analyses, which could have influenced the results.

In conclusion, the results of the current research show that sleep quality, sleep duration, and screen time have an individual positive relationship with HRQoL in adolescents. Furthermore, the combined effect of several health-related behaviors has a stronger influence on HRQoL. Our findings are important because of the key role of holding a high HRQoL throughout life. Educational and public health interventions and prevention strategies directed towards adolescents should focus on developing multiple health-related throughout youth.



**Author contributions** All authors contributed to the study conception and design. Material preparation, data collection, and analysis were performed by ASS, MAR, DMU, and MRBV. The first draft of the manuscript was written by ASS and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

**Funding** The DADOS Study is funded by the Spanish Ministry of Economy and Competitiveness, MINECO (DEP2013-45515-R) and by the Jaume I University of Castellon, UJI (P1-1A2015-05 and UJI-A2019-12).

### Compliance with ethical standards

**Conflicts of interest** The authors declare that they have no conflict of interest.

**Ethical approval** This study was performed in line 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).

**Consent to participate** Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all provided a written informed consent.

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**Publisher's Note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Study II: Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study**

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European Journal of Sport Science. 2021 Dec; 1-7.  
DOI: 10.1080/17461391.2021.2012596



## Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study

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### ABSTRACT

The purpose of the present study was to investigate the individual and combined impact of physical fitness components at baseline on health-related quality of life (HRQoL) at 24-month follow-up in adolescents. This longitudinal research included 199 adolescents (13.9 ± 0.3 years at baseline) from the DADOS study. Cardiorespiratory fitness was assessed using the 20-m shuttle run test. Muscular strength was assessed using the standing broad jump test. Motor competence was assessed using the 4 × 10-m shuttle run test. A physical fitness z-score was calculated as the mean of the z-scores values of each fitness test. A fitness index ranging from 0 to 3 was created according to the number of physical fitness components in which participants achieved high levels according to normative values. HRQoL was evaluated by the KIDSCREEN-10 questionnaire. Linear regression analyses showed that cardiorespiratory fitness, muscular strength, and the physical fitness z-score at baseline were individually associated with HRQoL at follow-up ( $\beta$  ranging from 0.123 to 0.183; all  $p < 0.05$ ). Moreover, logistic regression analysis revealed that adolescents with a fitness index  $\geq 1$  at baseline were more likely to achieve high HRQoL at 24-month follow-up, compared with their peers with an index of 0 (OR ranging from 3.554 to 9.087; all  $p < 0.05$ ). Our results revealed an individual and cumulative positive impact of physical fitness at baseline on HRQoL at 24-month follow-up. These findings underline the key role of promoting the enhancement of overall physical fitness components in order to improve adolescents' health and well-being.

### KEYWORDS

Cardiorespiratory fitness;  
health; muscular strength;  
youth

### Highlights

- Adolescents with high levels of cardiorespiratory fitness, muscular strength and motor competence will benefit from a greater physical and mental well-being over the time.
- The more physical fitness components with optimal levels, the greater likelihood of reaching better HRQoL over the time.
- Public health authorities should focus on the promotion of multiple physical fitness components to increase adolescent's likelihood of achieving greater HRQoL over the time.

### Introduction

Physical fitness is a set of attributes related to a person's ability to perform physical activities, which main components are cardiorespiratory fitness, muscular strength, and motor competence (Ortega et al., 2018). It is considered an integrated measure of the body systems involved in movement (i.e. cardiorespiratory,

hematocirculatory, metabolic, and psychoneurological). High levels of physical fitness indicates an optimal physiological functioning of those systems, being considered a strong health-related marker (Ortega et al., 2008b). Indeed, previous evidence has shown that physical fitness in children and adolescents is inversely associated with the risk of developing diabetes and obesity, as well as positively associated with skeletal health (Ortega et al., 2008b). Additionally, recent evidence has revealed that physical fitness is also positively associated with mental health and well-being in adolescents (Bou-Sospedra, Adelantado-Renau, Beltran-Valls, & Moliner-Urdiales, 2020; Wheatley et al., 2020), suggesting a positive relationship with adolescents' health-related quality of life (HRQoL) (Yi, Fu, Burns, & Ding, 2019; Evaristo et al., 2019a).

HRQoL has been defined as individuals' functioning performance in life and their perceived well-being in physical, mental, and social domains of health (Hays & Reeve, 2010). It has been suggested as an important health indicator since perceived well-being and functionality are considered important components of health surveillance (Ravens-Sieberer et al., 2006).

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Previous evidence showed that adolescents' HRQoL decreases with age (Meade & Dowswell, 2015), probably due to the fact that it is a period in which coping with physical, physiological, and social changes become a difficult challenge (Hampel, 2007). Thus, identifying the elements that could contribute to improve adolescents' HRQoL over time should be a public health priority nowadays.

Due to the influence of physical fitness on several dimensions of health, previous cross-sectional evidence intended to investigate its association with HRQoL in youth. These studies reported positive associations with cardiorespiratory fitness and muscular strength in adolescents (Evaristo et al., 2018; Yi et al., 2019), while in children the evidence showed a positive association with motor competence (Redondo-Tébar et al., 2019). However, only one research examined the longitudinal relationship between cardiorespiratory fitness and HRQoL (Evaristo et al., 2019a), concluding that adolescents with persistent high cardiorespiratory fitness reported greater scores of HRQoL than those whose cardiorespiratory fitness decreased over a 2-year period. Nevertheless, to our knowledge, the longitudinal associations of muscular strength and motor competence with HRQoL during adolescence have not been investigated. Moreover, due to the fact that physical fitness components seem to benefit health synergically (Evaristo et al., 2019b; Esteban-Cornejo et al., 2014), it would be interesting to expand the knowledge about the combined impact of physical fitness components on HRQoL. Thus, the aim of the present study was to investigate the individual and combined impact of physical fitness components at baseline on HRQoL at 24-month follow-up in adolescents.

## Materials and methods

### Study design and sample selection

This study is part of the DADOS (Deporte, ADOlescencia y Salud) research project, a 3-year longitudinal study aimed to analyse the influence of physical activity and physical fitness on health and academic performance during adolescence. The results presented in this study belong to baseline (obtained between February and May of 2015) and follow-up 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 main information about the aim and the study protocol. The inclusion criteria 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 199 adolescents (92 girls) aged  $13.9 \pm 0.3$  years at baseline with valid data for physical fitness and HRQoL at baseline and at 24-month follow-up were included in the analyses.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all of them provided 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).

### Physical fitness

Cardiorespiratory fitness was assessed using the 20-m shuttle run test (Léger, Mercier, Gadoury, & Lambert, 1988). 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.

Muscular strength was assessed through the standing broad jump test (Ortega et al., 2008a). 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 is 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.

Motor competence was assessed using the 4 × 10 m shuttle run test of speed of movement, agility, and coordination (Ortega et al., 2008a). 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 better motor competence.

The individual score of each physical fitness component was transformed into sex-specific standardized values (z-scores). A physical fitness z-score was



calculated as the mean of the z-scores values for cardiorespiratory fitness, muscular strength, and motor competence. Higher z-scores values in physical fitness indicate better fitness performance.

### **Fitness index**

All physical fitness components were dichotomized based on normative data from Tomkinson et al. (2018) for cardiorespiratory fitness and muscular 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, and a fitness index ranging from 0 to 3 was created according to the number of physical fitness components classified as high. Hence, higher fitness index scores indicated better physical fitness levels.

### **Health-related quality of life**

HRQoL was assessed with the KIDSCREEN-10 questionnaire, a valid and reliable scale to analyze HRQoL among youth population (Ravens-Sieberer et al., 2010). The reliability and validity of the questionnaire have been examined previously in adolescents showing good reliability (Cronbach's  $\alpha = 0.82$ ) and criterion validity ( $r = 0.91$ ) (Ravens-Sieberer et al., 2010). 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 (Ravens-Sieberer et al., 2006). A higher score in the questionnaire indicates better HRQoL. Participants above the sex-specific mean normative value from European adolescents (Ravens-Sieberer et al., 2006), which establishes the threshold on 49.00 mean value for females and 51.12 mean value for males, were classified as having high HRQoL.

### **Covariates**

Sex, pubertal stage, waist circumference, and socioeconomic status were included as covariates in the statistical analyses due to their relationship with the study variables (Pogodina, Rychkova, Kravtsova, Klimkina, & Kosovtzeva, 2017; Svedberg, Nygren, Staland-Nyman, & Nyholm, 2016). Pubertal stage was self-reported according to the five stages described by Tanner and Whitehouse (1976). It is based on external primary and secondary sexual characteristics, which are described

by the participants using standard pictures according to Tanner instructions. 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. The average measure was used for the analyses. The Family Affluence Scale (FAS) developed by Currie et al. was used as a proxy of socioeconomic status (ranging from 0 to 8), which is based on material conditions in the family such as car ownership, bedroom occupancy, computer ownership, and home internet access (Currie et al., 2008).

### **Statistical analyses**

Descriptive sample characteristics were presented as mean  $\pm$  standard deviation or frequency (percentage). Differences between descriptive data at baseline and at 24-month follow-up were assessed by paired *t*-test for continuous variables and Chi-square test for nominal variables. All variables were checked for normality using both graphical (normal probability plots) and statistical (Kolmogorov-Smirnov test) procedures. As preliminary analyses did not show a significant interaction of sex with physical fitness components in relation to HRQoL (all  $p > 0.10$ ), analyses were performed with the total sample.

Linear regression analyses were performed to assess the individual associations of all physical fitness components and the physical fitness z-score at baseline with HRQoL at 24-month follow-up. Moreover, logistic regression analysis was conducted to examine the likelihood of having high HRQoL at 24-month follow-up based on the fitness index at baseline. All the analyses were adjusted for sex, pubertal stage, waist circumference, socioeconomic status, and HRQoL at baseline. The analyses were performed using the IBM SPSS Statistics for Windows version 22.0 (Armonk, NY: IBM Corp). A *p*-value of  $p < 0.05$  was set as statistically significant.

### **Results**

The mean (standard deviation) age of the adolescents was 13.9 (0.3) years at baseline and 15.8 (0.3) years at 24-month follow-up. Their pubertal stage was between 2 and 5 stages at baseline and between 3 and 5 at 24-month follow-up. The mean value for socioeconomic status was 4.2 (1.4). Mean values for waist circumference were 67.1 (5.7) centimetres at baseline and 71.6 (6.4) centimetres at 24-month follow-up. With respect to the participants' physical fitness and HRQoL characteristics,

**Table 1.** Participants' physical fitness and HRQoL at baseline and at 24-month follow-up ( $n = 199$ ).

	Baseline	Follow-up	$p$ -value
<i>Physical fitness</i>			
Cardiorespiratory fitness (shuttles)	66.6 ± 24.1	70.6 ± 26.8	<0.001
High cardiorespiratory fitness	155 (77.9)	150 (78.5)	<0.001
Muscular strength (cm)	172.8 ± 26.0	186.8 ± 32.9	<0.001
High muscular strength	100 (50.3)	106 (55.2)	<0.001
Motor competence (s)	12.5 ± 1.0	11.7 ± 1.0	<0.001
High motor competence	44 (22.1)	78 (39.2)	<0.001
Physical fitness z-score <sup>1</sup>	0.05 ± 0.88	-0.01 ± 0.42	0.163
HRQoL	50.5 ± 8.1	48.7 ± 6.2	<0.01
High HRQoL	160 (80.4)	77 (38.7)	<0.001

Data are presented as mean ± standard deviation, or frequency (percentage). Differences between baseline and follow-up were examined by paired  $t$ -test and Chi-square test. Statistically significant values are in bold. HRQoL: health-related quality of life.

<sup>1</sup>The physical fitness z-score was calculated as the mean of the z-scores values of cardiorespiratory fitness, muscular strength, and motor competence.

these are presented in Table 1. All physical fitness components improved from baseline to 24-month follow-up (all  $p < 0.001$ ). Conversely, participants showed higher HRQoL at baseline than at 24-month follow-up ( $p < 0.01$ ).

The results of the linear regression analyses showing the associations between physical fitness at baseline and HRQoL at 24-month follow-up are presented in Table 2. Cardiorespiratory fitness, muscular strength, and the physical fitness z-score at baseline were positively associated with HRQoL at 24-month follow-up, after adjusting for sex, pubertal stage, waist circumference, socioeconomic status, and HRQoL at baseline (all  $p < 0.05$ ). No significant association was found between motor competence at baseline and HRQoL at 24-month follow-up ( $p > 0.05$ ).

The combined effect of physical fitness at baseline on HRQoL at 24-month follow-up is shown in Figure 1. Logistic regression analysis revealed that adolescents with a fitness index  $\geq 1$  at baseline were more likely to achieve greater HRQoL at 24-month follow-up. Indeed,

**Table 2.** Linear regression analyses examining the association between physical fitness at baseline and health-related quality of life at 24-month follow-up ( $n = 199$ ).

	$\beta$	95% CI	$p$ -value
Cardiorespiratory fitness	0.183	0.008; 0.086	<b>0.019</b>
Muscular strength	0.175	0.008; 0.075	<b>0.014</b>
Motor competence	0.123	-0.198; 1.778	0.116
Physical fitness z-score <sup>1</sup>	0.162	0.215; 2.070	<b>0.016</b>

Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Analyses were adjusted for sex, pubertal status, waist circumference, socioeconomic status, and health related quality of life at baseline. Statistically significant values are in bold.

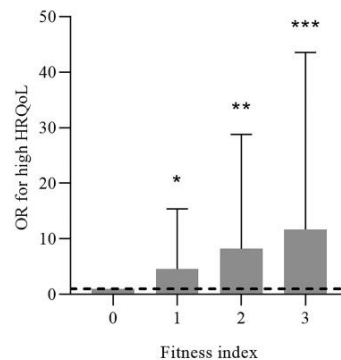
<sup>1</sup>The physical fitness z-score was calculated as the mean of the z-scores values of cardiorespiratory fitness, muscular strength, and motor competence.

the odds of having greater HRQoL at follow-up were 4.59 (95% CI: 1.37-15.40), 8.24 (95% CI: 2.36-28.82), and 11.68 (CI: 3.13-43.55) times higher for adolescents with a fitness index of 1, 2, or 3 at baseline, respectively, compared to their peers with a fitness index of 0 (OR: 1.00; reference), after adjusting for sex, pubertal stage, waist circumference, socioeconomic status, and HRQoL at baseline.

## Discussion

The main findings of the present longitudinal research indicated that cardiorespiratory fitness, muscular strength, and the physical fitness z-score at baseline were associated with HRQoL at 24-month follow-up in adolescents. Moreover, our results revealed that adolescents with a higher fitness index, which includes cardiorespiratory fitness, muscular strength, and motor competence at baseline, had more likelihood of having greater HRQoL at follow-up. These results extend the scarce current literature analyzing the relationship between physical fitness and HRQoL during adolescence.

Our results showed a positive association between cardiorespiratory fitness at baseline and HRQoL at follow-up. This outcome supports prior longitudinal research by confirming the individual positive influence of cardiorespiratory fitness at baseline on HRQoL at 24-month follow-up in adolescents (Evaristo



**Figure 1.** Logistic regression analysis predicting high HRQoL at 24-month follow-up according to the fitness index at baseline. The analysis was adjusted for sex, pubertal stage, waist circumference, socioeconomic status, and HRQoL at baseline. Reference Odds Ratio (OR = 1.00): adolescents with a fitness index = 0. \* ( $p < 0.05$ ), \*\* ( $p < 0.01$ ), \*\*\* ( $p < 0.001$ ). Fitness index: 0 ( $n = 35$ ), 1 ( $n = 67$ ), 2 ( $n = 59$ ), and 3 ( $n = 38$ ). HRQoL: health-related quality of life.

et al., 2019a). These findings might be partially explained by the influence that cardiorespiratory fitness has on several dimensions of health over time (Mintjens et al., 2018; Ruggero, Petrie, Sheinbein, Greenleaf, & Martin, 2015). For instance, increased cardiorespiratory fitness may lead to improved levels of adiposity, blood pressure, and glucose regulation, as well as mental health in adolescents (Janssen et al., 2020; Raghuvver et al., 2020; Ruiz et al., 2007). This fact may reduce the occurrence of cardiometabolic and mental diseases during adolescence, which may positively impact adolescents' HRQoL (Bermejo-Cantarero et al., 2021; Oberhuber et al., 2020; Pogodina et al., 2017).

The present study revealed for the first time a longitudinal positive association between muscular strength and HRQoL. Likewise, a previous cross-sectional study showed that muscular strength was positively associated with HRQoL in Portuguese adolescents (Evaristo et al., 2019b). A possible explanation of this result could be linked to the fact that optimal levels of muscular strength in adolescents have been related to reduced cardiometabolic disease risk factors, lower levels of adiposity, improved bone health, or increased self-esteem (García-Hermoso, Ramírez-Campillo, & Izquierdo, 2019; Smith et al., 2014). In this sense, these benefits may have a positive effect on adolescents' psychological well-being, mental health or physical health status, which in turn, may improve their HRQoL over time (Janssen et al., 2020; Ortega, Silventoinen, Tynelius, & Rasmussen, 2012; Smith et al., 2014).

Motor competence at baseline was not related with HRQoL at follow-up in our study. We speculate that this lack of association could be explained by the specific health benefits of motor competence. This physical fitness component has been associated with increased bone mineral density during youth (Ortega et al., 2008b), which appears to prevent osteoporosis, a disease manifested in later life (Johnston & Dagar, 2020), but not during adolescence. Hence, it is plausible that the health benefits of this fitness component are not directly related to HRQoL during adolescence.

We found a significant association between physical fitness z-score at baseline and HRQoL at follow-up after adjustment for cofounders. This finding agrees with a previous cross-sectional study, which involved 956 adolescents, suggesting that a composite z-score including cardiorespiratory fitness, muscular strength, and motor competence was positively associated with HRQoL (Evaristo et al., 2018). Prior research has suggested that the development of physical fitness may be of paramount importance to enhance health status (Ortega et al., 2008b; Evaristo et al., 2019b), which might positively influence HRQoL over time.

The combined effect analysis revealed that adolescents with a fitness index of  $\geq 1$  at baseline compared with those with an index of 0 showed an increased likelihood of high HRQoL at 24-month follow-up. Although our results indicated that not all the physical fitness components included in the current research have the same longitudinal association with adolescents' HRQoL, the combined analysis revealed that the greater the number of physical fitness components with high levels at baseline, the better HRQoL 24 months later. Previous interventional research in different populations showed that the combination of strength and cardiorespiratory exercise had a greater influence on intermediate health markers (Kim et al., 2018), as well as on HRQoL (Goldfield et al., 2017). These findings could be explained by the combination of benefits that physical fitness components have on HRQoL, which may exert a cumulative effect on adolescents' HRQoL at 24-month follow-up.

Our results support that physical fitness is an important indicator of health that influences adolescents' functionality and perceived well-being. However, research about temporal trends in adolescents' physical fitness reported a global declining tendency over the last years (Fühner, Kliegl, Arntz, Kriemler, & Granacher, 2021; Tomkinson et al., 2021), which may negatively impact their future health. Given this negative tendency and the fact that physical fitness seems to be a determinant factor of HRQoL, it is relevant to develop promotion strategies focusing on the improvement of overall physical fitness components during adolescence.

The current study has some strengths and limitations that must be mentioned. The strengths of the study comprise the homogeneous age-matched sample of adolescents and the use of validated and standardized tests to assess physical fitness and HRQoL. Limitations of this study include the fact that although the participants reported that they were not diagnosed of any physical or mental illness, their current mental health was not taken into consideration in our analyses, which could have influenced the results. Additionally, we acknowledge that more accurate data could be obtained for physical fitness in laboratory settings.

## Conclusion

The results of the current research showed that cardiorespiratory fitness, muscular strength, and the physical fitness z-score at baseline had an individual positive association with HRQoL at 24-month follow-up during adolescence. Furthermore, the more physical fitness components with high levels at baseline, the more likelihood of reaching a greater HRQoL in the future.



Education and public health professionals could benefit from collaborating on the design of interventions focused on enhancing overall physical fitness components levels to improve adolescents' HRQoL.

### Acknowledgements

The corresponding author affirm that she has listed everyone who contributed significantly to the work.

### Disclosure statement

No potential conflict of interest was reported by the author(s).

### Funding

This work was supported by the Spanish Ministry of Economy and Competitiveness under grant number DEP2013-45515-R; and by the University Jaume I of Castellon under grant numbers UJI P1-1A2015-05 and UJI-A2019-12.

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**Study III: Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity**

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Perspectives in Public Health  
(under second revision)

## **Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity**

### **Abstract**

**Purpose.** The aims were (i) to analyse the cross-sectional and longitudinal associations between children's cardiorespiratory fitness (CRF) and health-related quality of life (HRQoL), and (ii) to examine whether these associations were mediated by physical activity self-efficacy and physical activity enjoyment.

**Methods.** This study involved 383 children (10.0±0.5 years) recruited from 20 primary schools in northwest England. Data were collected on two occasions 12 weeks apart. The number of laps completed in the 20m Shuttle Run Test was used as the CRF indicator. HRQoL was assessed using the KIDSCREEN-10 questionnaire. Physical activity self-efficacy and enjoyment were assessed with the social-cognitive and Physical Activity Enjoyment Scale questionnaires, respectively. Linear mixed models with random intercepts (schools) assessed associations between CRF and HRQoL cross-sectionally, and longitudinally. Boot-strapped mediation procedures were performed, and indirect effects (IE) with 95% confidence intervals (CI) not including zero considered as statistically significant. Analyses were adjusted for sex, time of the year, socioeconomic status, waist-to-height ratio, maturation and physical activity.

**Results.** CRF was cross-sectionally associated with HRQoL ( $\beta=0.09$ ; 95%CI=0.02, 0.16,  $p=0.015$ ). In the longitudinal analysis, CRF at baseline was associated with HRQoL at 12 weeks after additionally controlling for baseline HRQoL ( $\beta=0.08$ ; 95%CI=0.002,  $p=0.15$ ,  $p=0.045$ ). Cross-sectionally, physical activity self-efficacy and enjoyment acted individually as mediators in the relationship between CRF and HRQoL (IE=0.069; 95%CI:0.038;  $p=0.105$  and IE=0.045; 95%CI:0.016;  $p=0.080$ , respectively). In the longitudinal analysis physical activity self-efficacy showed a significant mediating effect (IE=0.025; 95%CI=0.004;  $p=0.054$ ).

**Conclusions.** Our findings highlight the influence of CRF on children's psychological correlates of physical activity and their overall HRQoL.

**Key words:** Health, physical fitness, quality of life, youth.

## 1. Introduction

Health-related quality of life (HRQoL) is a multidimensional concept which reflects an individual's own perception of their physical, mental, social health, and functionality.<sup>6</sup> HRQoL has been highlighted as an important health indicator<sup>27</sup> since perceived well-being and functionality are considered important components of health surveillance.<sup>7</sup> Indeed, investigating HRQoL has been nowadays considered relevant due to its relationship with both self-reported chronic diseases (e.g., diabetes, breast cancer, arthritis, and hypertension) and their risk factors (e.g., body mass index, physical inactivity, sleep patterns, diet quality, and smoking status).<sup>11</sup> Measuring HRQoL can help to determine the burden of preventable disease, injuries, and disabilities, and can provide valuable new insights into the relationships between HRQoL and risk factors.<sup>10</sup> Thus, over the past twenty-five years, HRQoL has become an important outcome in healthy children, being commonly examined by professionals, such as clinicians, caregivers, educators, or public health authorities due to a collective interest towards the subjective perception and evaluation of an individual's own life.<sup>9,113,114</sup> Given the importance of HRQoL, identifying factors that may contribute to improving children's HRQoL is a public health priority.

Among possible factors influencing children's HRQoL, previous cross-sectional studies have revealed significant positive associations with cardiorespiratory fitness (CRF). CRF represents a measure of the body's ability to deliver and use oxygen to support muscular activity during physical activity<sup>105</sup> and is considered an important health marker.<sup>115</sup> Previous research suggests that CRF may be a potentially useful strategy to enhance children's HRQoL, however evidence of this relationship is limited to cross-sectional studies.<sup>43,116,117</sup> For example, Andersen et al.'s study of 1129 schoolchildren aged 10 years, showed that CRF was positively associated with overall HRQoL.<sup>116</sup> Another study including 415 children aged between 8 and 9 years reported a positive weak correlation between CRF and HRQoL in boys, but not in girls.<sup>43</sup> Moreover, the study of Redondo-Tébar et al., which involved 1413 younger children, aged 4 to 7 years, concluded that children with higher CRF levels had greater HRQoL.<sup>117</sup> While informative, these studies cannot explain the dynamic processes that could occur over time, neither provide a long-term perspective of the influence that CRF might have on HRQoL, which could contribute to understanding the determinants of children's health outcomes.<sup>118</sup> Thus, to strengthen the current evidence base, investigation into the longitudinal associations between CRF and HRQoL is warranted.<sup>119</sup>

CRF has been considered a physiological component that has been reported to influence psychological correlates of physical activity.<sup>120,121</sup> This is possibly due to the impact that sufficient levels of CRF have on brain functioning (e.g., serotonin), self-worth, life satisfaction<sup>120</sup> and the reward system.<sup>121</sup> Indeed, previous literature reported that children with higher levels of CRF had stronger psychological correlates of physical activity, such as physical activity self-efficacy<sup>122</sup>

and physical activity enjoyment<sup>16</sup> compared to low CRF peers. Thus, CRF seems to be an important attribute positively influencing psychological correlates. On the other hand, two previous studies which implemented new school playground activities, reported positive associations between children's physical activity enjoyment and HRQoL.<sup>124,125</sup> Taken together, it is plausible that the positive association between CRF and HRQL in children is explained through the influence that CRF exerts on the psychological correlates.

Based on this previous research, there is a need for future studies to investigate variables influencing HRQoL, specifically focusing on CRF as a variable that could impact HRQoL as well as other physical activity correlates,<sup>126</sup> which could act as possible underlying mechanisms in that association. This will be of interest for health authorities seeking to improve children's overall HRQoL through the implementation of educational interventions at schools and the design of public health strategies. Therefore, the aims of this research were (i) to analyse the cross-sectional and longitudinal association between children's CRF and HRQoL, and (ii) to examine whether these associations were mediated by physical activity self-efficacy and physical activity enjoyment separately, as key psychological correlates of physical activity.

## **2. Material and methods**

### **2.1 Study design**

This observational study used baseline and follow-up data from the *Active West Lancs* primary school physical activity and wellbeing programme. The aim of this programme was to evaluate the impact of a combined educational and exercise programme designed to promote and enhance children's physical activity behaviours and knowledge, fitness, and wellbeing. The programme aligned to the UK government's Childhood Obesity Strategy recommendation for children to engage in 30 minutes of physical activity during the school day.<sup>127</sup> The programme was delivered in four clusters of five schools over four consecutive 12-week phases between 2018 and 2019. As no significant pre-post changes were observed in CRF and HRQoL outcomes over the 12-weeks, for this study the baseline data were treated as cross-sectional, and the combined 12-week follow-up longitudinal data were treated as longitudinal.

### **2.2 Participants**

The 20 schools were situated in West Lancashire, northwest England. All year 5 children (age 9-10 years) in the schools were informed about the project and received an information pack to share with their parents/carers. Written informed consent and assent were required from parents/carers and children respectively, before children could participate in the project in accordance with the project approvals granted by the University Research Ethics Committee

(#SPA-REC-2015-182). Children were included if they provided the required informed parental consent, assent, and medical screening forms, which indicated an absence of any medical conditions or disabilities preventing participation in the data collection and/or regular physical education lessons. The analytical sample consisted of 383 children (44.4% girls) at baseline and 272 children (43.4% girls) at 12-week follow-up. The participants' drop-out at follow-up was primarily due to absence from school on data collection days. This study used participants' valid data for CRF at baseline and HRQoL at baseline and at 12-weeks follow-up.

### **2.3 Active West Lancs Programme**

The Active West Lancs programme consisted of classroom-based healthy lifestyle education lessons based on the 'Dr Feelwell' concept developed by MerseyCare National Health Service Foundation Trust (<https://www.merseycare.nhs.uk/>), and structured 'Born to Move' physical activity lessons (<https://www.lesmills.com/borntomove/>). Both were taught once per week for 45-60 minutes by physical activity specialists from an organisation which delivers physical education, physical activity, health, and wellbeing sessions in West Lancashire primary schools. The lessons complemented the regular curriculum and did not replace mandatory subjects that cover physical activity, health, and wellbeing concepts (e.g., physical education). The data reported in the present study are from the 20 schools involved in the four phases of the programme (January-April, April-July, September-December 2018, and January-April 2019) (supplementary figure 1).

### **2.4 Measures**

#### *2.2.4.1 Cardiorespiratory fitness*

The 20-m multistage shuttle run test (20mSRT)<sup>128</sup> was conducted to provide an estimate of CRF. This test has been used extensively with participants of a similar age to those in the current study.<sup>129</sup> Prior research showed its validity (corrected mean  $r$  at the population level [95% CI]:  $r_p = 0.78 [0.72-0.85]$ ) and reliability (intra-class correlation coefficients ranging from 0.78 to 0.93) in children.<sup>130</sup> Participants were encouraged to run for as long as possible until exhaustion or until they had reached their maximal effort. Otherwise, the test ended if the participant failed to reach within 2m of the marked line on two consecutive occasions. The 20mSRT was administered by the research team on a flat, clean surface indoors (e.g., sports/assembly hall) or outdoors (e.g., school playground) depending on available facilities and was completed in groups of up to 10 children. The total number of completed laps (shuttles) was used as a proxy indicator of CRF.

#### *2.2.4.2 Health-related quality of life*

The KIDSCREEN-10 Index questionnaire was used as a measure of global HRQoL<sup>7</sup>. KIDSCREEN-10 is a 10-item questionnaire, which asks participants how they felt in the last



week. Items reflect the factors of physical well-being, psychological well-being, autonomy, parent relations, peers and social support, and school environment, which are derived from the 27-item version of KIDSCREEN and are presented using a 1-5 Likert scale (i.e., 1 = “nothing” and 5 = “very much”).<sup>6</sup> Cronbach’s alphas are 0.82 and test–retest reliability was also generally satisfactory with internal consistent coefficients (ICCs) ranging from 0.61 to 0.70.<sup>14</sup> The Cronbach’s alpha for internal consistency of this questionnaire was 0.73 and 0.71 for the cross-sectional and longitudinal samples, respectively. Raw scores were converted to T-scores using the methodology described in the KIDSCREEN administration manual.<sup>7</sup> The questionnaire was completed in classrooms following instructions from the research team and in the presence of the class teachers.

#### *2.2.4.3 Socioeconomic status*

Neighbourhood-level socioeconomic status (SES) was calculated for each child using the 2019 Indices of Multiple Deprivation (IMD).<sup>131</sup> The IMD is a UK government-produced deprivation measure for England comprising income, employment, health, education, housing, environment, and crime.<sup>131</sup> IMD rank scores were generated from parent-reported home postcodes using the National Statistics Postcode Directory database. Every neighbourhood in England is ranked from one (most deprived area) to 32,844 (least deprived area).<sup>131</sup>

#### *2.2.4.4 Anthropometric variables*

Height was measured using a portable stadiometer (Leicester Height Measure, Seca, Birmingham, UK), and body mass was measured using calibrated scales (813 model, Seca). Body mass index (BMI) was calculated for each participant, BMI z-scores were assigned,<sup>132</sup> and International Obesity Task Force BMI cut-points applied to classify the participants as underweight, normal weight or overweight/obese.<sup>133</sup> Waist circumference was measured, using an anthropometric tape measure from the minimal waist site to the nearest millimetre, with participants in the standing position and at the end of expiration. Waist-to-height ratio (WHtR) was calculated as a measure of central obesity.<sup>134</sup> Age at peak height velocity (APHV) was used as a proxy somatic measure of biological maturation. This method is based on anthropometric variables to predict APHV, which is a commonly used indicator of biological maturity.<sup>135</sup> The method employs validated sex-specific regression equations which include participants’ chronological age and height.<sup>135</sup> All the measurements were undertaken by trained researchers. To ensure accurate and standardised measurements all researchers firstly completed a six-hour training and supervised practice session using the assessment protocols. In addition, in order to avoid interindividual variability each researcher was responsible for administering the same measures during baseline and follow up assessment periods.

#### *2.2.4.5 Moderate-to-vigorous physical activity*



Self-reported moderate-to-vigorous physical activity (MVPA) data were collected using the Youth Activity Profile (YAP) English version.<sup>136</sup> The YAP is a 15-item questionnaire comprised of three sections (school-day MVPA, out-of-school MVPA, and sedentary behaviour), with five questions per section. Participants are asked to recall their MVPA and sedentary behaviour over the past 7 days during context-specific time segments (e.g., active travel to and from school, break time, etc.). The out-of-school segment refers to activity levels before school, immediately after school, evening, and at weekends. All questions were structured using a 5-point Likert scale (e.g., for active travel to school, a score of 1 indicated 0 days per week of active travel, whereas a score of 5 indicated 4–5 days per week). For this study, only data from the school-day and out-of-school MVPA questions were used. For each child, mean values for school-day and out-of-school MVPA were calculated and averaged resulting in a score for overall MVPA (1=low, 5=high). The YAP was completed in classrooms following instructions from the research team and in the presence of the class teachers.

#### *2.2.4.6. Psychological correlates of physical activity: self-efficacy and enjoyment*

Self-efficacy was measured using a valid and reliable questionnaire which contained 8 items related to the child's ability to be physically active.<sup>137</sup> The items were rated on a 5-point Likert scale ranging from 1 (very easy / disagree a lot) to 5 (very difficult / agree a lot). The Cronbach's alpha for the internal consistency of the cross-sectional sample was 0.77 and 0.78 for the longitudinal sample. Enjoyment was assessed through the Physical Activity Enjoyment Scale (PACES) for children.<sup>138</sup> A 5-point Likert-type scale (1 = "disagree a lot" to 5 = "agree a lot") is used to answer 16 statements. The average of the answers assigned to the 16 items is the final score. The Cronbach's alpha for the internal consistency of the sample was 0.87 and 0.88 for the cross-sectional and longitudinal samples, respectively.

## **2.5 Statistical analyses**

Preliminary analyses involved checking all variables for normality using normal probability plots and Kolmogorov–Smirnov tests. The data assumed a normal distribution and descriptive statistics were calculated for all continuous measures using means (SD) and percentages for categorical variables. As exploratory analyses did not show a significant interaction of sex and CRF in relation to HRQoL ( $p > 0.05$ ), the main analyses were performed with the total mixed-sex sample.

For study aim (i), mixed linear models examined the cross-sectional association between CRF and HRQoL with adjustment for sex, time of year, SES, WHtR, APHV, and MVPA; and the longitudinal association between CRF at baseline and HRQoL 12-weeks later adjusted for sex, time of year, SES, WHtR, APHV, MVPA, and HRQoL at baseline. Schools were included as random intercepts for aim (i) analysis. For study aim (ii), mediation analyses were conducted to assess the mediating role of each psychological correlate of physical activity (i.e., physical

activity self-efficacy and physical activity enjoyment) on the association between CRF and HRQoL with adjustment for sex, time of year, SES, WHtR, APHV, MVPA and schools. Cross-sectional mediation analyses were performed with CRF as the independent variable, HRQoL as the dependent variable and physical activity self-efficacy, and physical activity enjoyment individually introduced as mediator variables, with adjustment for the covariates. Further, longitudinal mediation analyses were performed with CRF at baseline as the independent variable, HRQoL at 12-week follow-up as the dependent variable and each psychological correlate individually introduced as mediator variables, with adjustment for the same covariates, with the addition of HRQoL at baseline. Effect sizes (Cohen's  $d$ ) were calculated for both cross-sectional and longitudinal linear mixed models as suggested by Brysbaert and Stevens<sup>139</sup> and defined as: small ( $<0.2$ ), medium ( $0.2-0.5$ ), and large ( $0.5-0.8$ ). For the mediation analyses effect sizes,  $R^2$  was used to calculate  $f^2$  ranges, carried out as proposed by Cohen<sup>140</sup> and defined as small ( $<0.02$ ), medium ( $0.02-0.15$ ), and large ( $0.15-0.35$ ). The PROCESS SPSS Macro version 2.16.3, model 4, with 5000 bias-corrected boot-strap samples and 95% confidence intervals (CIs) was used for these analyses<sup>141</sup>. Mediation was assessed by the indirect effect of CRF (independent variable) on HRQoL (dependent variable) through (i) self-efficacy, and (ii) enjoyment (mediators). Indirect effects ( $a*b$  paths) with confidence intervals not including zero were considered significant. Mediation percentage ( $P_M$ ) indicates how much of the association between CRF and HRQoL was explained by the mediator variables.<sup>141</sup> We performed post-hoc power statistical analyses to examine the impact of the changes from 383 to 272 on the results presented. Statistical significance was set at  $p<.05$  for all analyses which were performed using IBM SPSS Statistics version 23 (IBM, Armonk, NY).

### 3. Results

Participants' baseline characteristics are presented in Table 1. The percentage of children at baseline and 12-week follow-up in the normal weight group was 78.1% and 82.7%, respectively. The drop-out from overweight and obese participants from baseline to follow up was 21.9% and 17.3%, respectively. On average, for the 20mSRT test, children performed 32.5 shuttles at baseline and 36.3 at 12-week follow-up. Mean HRQoL scores were 50.4 at baseline and 50.3 at 12-week follow-up. The psychological correlates of physical activity showed the same values at baseline and at 12-week follow-up.

**Table 1.** Characteristics of the participants at baseline and at 12-weeks follow-up.

	Baseline (n = 383)	Follow-up (n = 272)
<b>Variable</b>	<b>Mean (SD) or frequency (%)</b>	
Sex		
Boys	213 (55.6%)	154 (56.6%)
Girls	170 (44.4%)	118 (43.4%)
Age (y)	10.0 (0.5)	10.2 (0.4)
SES (IMD rank)	15902.2 (10201.5)	16513.47 (9911.7)
WHtR	0.5 (0.1)	0.5 (0.1)
APHV (years)	-2.5 (0.7)	-2.3 (0.7)
Height (cm)	139.8 (6.4)	140.8 (6.4)
Mass (kg)	35.4 (7.8)	35.9 (7.6)
BMI (kg·m <sup>-2</sup> )	18.0 (3.0)	18.0 (2.9)
Weight status		
Under Weight	24 (6.2%)	17 (6.3%)
Normal Weight	275 (71.8%)	203 (74.6%)
Overweight/Obese	84 (21.9%)	52 (19.1%)
Waist circumference (cm)	65.3 (8.0)	65.7 (8.8)
YAP MVPA score	3.4 (0.8)	3.7 (0.8)
CRF (shuttles)	32.5 (16.0)	36.3 (17.1)
HRQoL	50.4 (9.7)	50.3 (10.0)
Physical activity self-efficacy	3.6 (0.7)	3.6 (0.8)
Physical activity enjoyment	4.3 (0.6)	4.3 (0.7)

Data are presented as mean ( $\pm$  SD) or frequencies (percentages). Differences between baseline and follow-up were examined by paired *t*-test ( $p < 0.05$ ). SD: standard deviation; %: percentage; SES: socioeconomic status; IMD: indices of multiple deprivation; WHtR: waist to height ratio; APHV: peak height velocity; BMI: body mass index; YAP: youth activity profile; MVPA: moderate to vigorous physical activity; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

The results of the linear mixed model showing the cross-sectional associations between CRF and HRQoL are presented in Table 2. A positive association was observed between CRF and HRQoL ( $p = 0.015$ ) after adjusting for sex, time of year, SES, WHtR, APHV, and MVPA. A medium effect size ( $d = 0.26$ ) was found for this model. The unadjusted cross-sectional linear mixed model showing the association between CRF and HRQoL is presented in supplementary table 1. Table 3 presents the linear mixed model outcome analysing the longitudinal associations between CRF and HRQoL. The analysis revealed a positive association between CRF at baseline and HRQoL at 12-week follow-up ( $p = 0.045$ ) after adjusting for covariates including HRQoL at baseline. A

medium effect size ( $d = 0.35$ ) was found for this model. The unadjusted longitudinal linear mixed model showing the association between CRF at baseline and HRQoL at 12-week follow-up is presented in supplementary table 2.

**Table 2.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	57.67	44.43 – 70.90	<b>&lt;0.001</b>
Sex	2.80	-0.54 – 6.14	0.100
Project phase	-0.71	-1.75 – 0.32	0.158
SES	5.31	-5.41 – 0.00	0.324
WHtR	-18.24	-39.04 – 2.56	0.086
APHV	-0.09	-2.45 – 2.27	0.941
YAP MVPA	0.16	-1.09 – 1.40	0.806
Cardiorespiratory fitness	0.09	0.02 – 0.16	<b>0.015</b>

Model 1: adjusted for the fixed effects of sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity and moderate to vigorous physical activity. Clustering for analysis was schools. Health related quality of life was measured using KIDSCREEN-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold. HRQoL: health-related quality of life; SES: socioeconomic status; WHtR: waist to height ratio; APHV: peak height velocity; YAP: youth activity profile; MVPA: moderate to vigorous physical activity.

**Table 3.** Longitudinal associations between cardiorespiratory fitness at baseline and HRQoL at 12-weeks follow-up (n= 272).

	Model 2		
	$\beta$	95% CI	<i>p</i> -value
Intercept	21.46	6.7 – 36.22	<b>0.005</b>
Baseline HRQoL	0.52	0.42 – 0.63	<b>&lt;0.001</b>
Sex	3.41	0.04 – 6.78	0.47
SES	1.53	-8.52 – 0.00	0.764
Project phase	-0.63	-1.91 – 0.65	0.337
WHtR	0.50	-21.83 – 22.82	0.965
APHV	-0.58	-2.82 – 1.67	0.615
YAP MVPA	-0.05	-1.28 – 1.18	0.940
Cardiorespiratory fitness	0.08	0.02 – 0.15	<b>0.045</b>

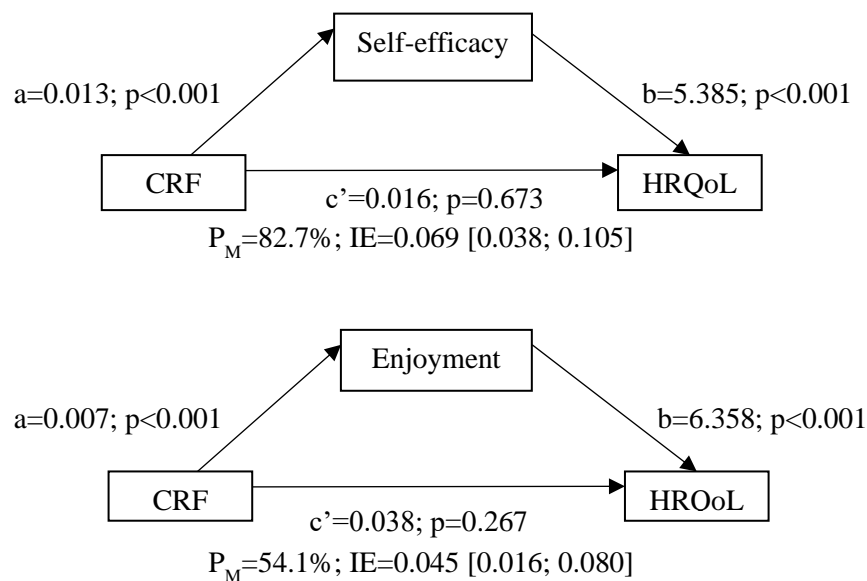
Model 2: adjusted for the fixed effects of sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity and baseline HRQoL. Clustering for analysis was schools. Health related quality of life was measured using KIDSCREEN-10.

Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold. HRQoL: health-related quality of life; SES: socioeconomic status; WHtR: waist to height ratio; APHV: peak height velocity; YAP: youth activity profile; MVPA: moderate to vigorous physical activity.

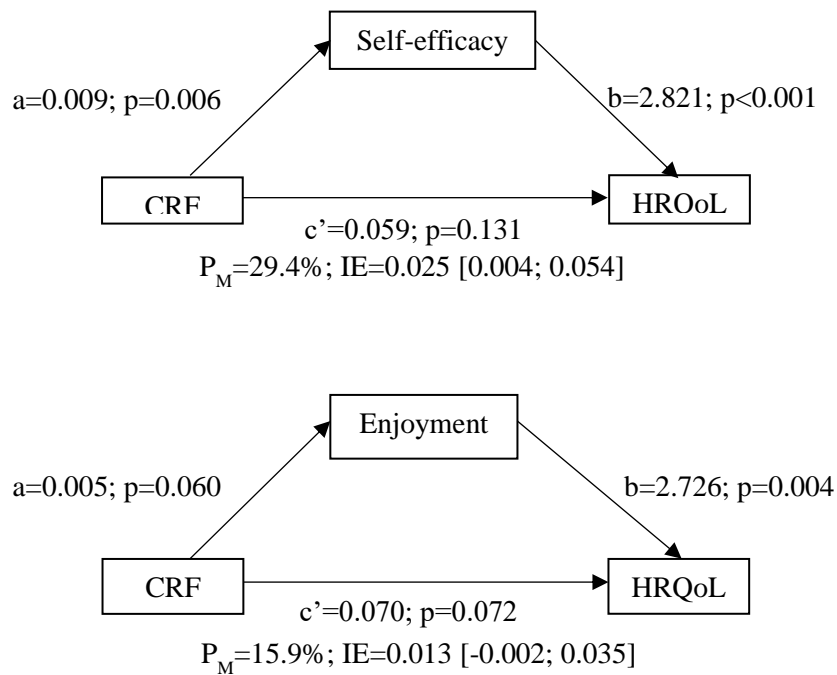
Figure 1 shows the adjusted cross-sectional mediating effect of self-efficacy and enjoyment in the association between CRF and HRQoL. There was a significant indirect effect (path  $a*b$ ) between CRF and HRQoL when each psychological correlate of physical activity was individually included in the analyses. CRF was positively associated with both single psychological correlates ( $a$  path; all  $p < 0.001$ ), which were also positively associated with HRQoL ( $b$  path; all  $p < 0.001$ ). However, in each model the direct effect between CRF and HRQoL was not significant ( $c'$  path; all  $p > 0.05$ ). The outcome of these cross-sectional mediation analyses suggested that CRF could indirectly influence HRQoL through its effects on children's physical activity self-efficacy ( $P_M = 82.7\%$ ) and enjoyment ( $P_M = 54.1\%$ ). Mediation analyses effect sizes were medium to large, with  $R^2$  ranging from 0.07 to 0.19 for enjoyment and from 0.09 to 0.22 for self-efficacy. For the cross-sectional mediation models the post-hoc power of the regressions included ranged from 99.7% to 100%.

The results of the adjusted longitudinal mediating effects of both physical activity self-efficacy and enjoyment on the association between CRF at baseline and HRQoL at 12-week follow-up are

shown in Figure 2. There was a significant indirect effect of baseline self-efficacy in the longitudinal association between baseline CRF and HRQoL at 12-week follow-up (path  $a*b$ ), but not for enjoyment. Moreover, baseline CRF was significantly associated with baseline self-efficacy ( $a$  path;  $p<0.01$ ), whereas a non-significant association was found with baseline enjoyment ( $a$  path;  $p>0.05$ ). Baseline self-efficacy and enjoyment were positively associated with HRQoL at 12-week follow-up ( $b$  path; all  $p<0.01$ ). Finally, the direct effect between baseline CRF and HRQoL at 12-week follow-up was non-significant ( $c'$  path; all  $p>0.05$ ). The results of the longitudinal mediation analyses suggested that baseline CRF could indirectly influence HRQoL 12 weeks later through its effects on children's baseline physical activity self-efficacy ( $P_M=29.4\%$ ) and enjoyment ( $P_M=15.8\%$ ), separately.  $R^2$  ranged from 0.10 to 0.20 for enjoyment, and from 0.09 to 0.25 for self-efficacy (i.e., medium to large effects). For the longitudinal mediation models the post-hoc power of the regressions included was 100%.



**Figure 1.** Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) mediation models of the cross-sectional relationship between CRF and HRQoL, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity and schools ( $n = 383$ ). Results are showed as unstandardized regression coefficients;  $p$ -value. IE = indirect effect [lower and upper levels for 95% confidence interval of the indirect effect between CRF and HRQoL].  $P_M$ : percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.



**Figure 2.** Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) of the longitudinal relationship between CRF at baseline and HRQoL at 12-week follow-up, adjusted for sex, time of the year, socioeconomic status, waist to height ratio, peak height velocity, moderate to vigorous physical activity, schools, and HRQoL at baseline (n = 272). 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 CRF at baseline and HRQoL at 12-week follow-up]. P<sub>M</sub>: percentage of mediation; CRF: cardiorespiratory fitness; HRQoL: health-related quality of life.

#### 4. Discussion

The results of our cross-sectional and longitudinal analyses showed that among northwest England primary school children (i) CRF was positively associated with HRQoL and (ii) this association was mediated by self-efficacy and enjoyment as psychological correlates of physical activity. Our findings expand prior knowledge about the association between CRF and HRQoL in children and reveal for the first time potential underlying mechanisms involved in the association between CRF and HRQoL, highlighting the significant roles of single physical activity correlates such as self-efficacy and enjoyment.

Our cross-sectional results showed a positive association between CRF and HRQoL. Similar findings were found in previous studies,<sup>43,116,117,142</sup> which reported that children with higher levels of CRF had better HRQoL. For instance, a study in Norwegian 10-year-olds revealed that CRF had a small to medium effect size ( $R^2$  ranging from 0.17 to 0.5) in its positive association with all HRQoL domains (i.e., physical and psychological well-being, autonomy and parents, social support and school environment).<sup>116</sup> Also, Redondo et al. reported a small (all  $R^2 < 0.5$ ) positive

association between CRF and HRQoL among children aged 4 to 7 years.<sup>43</sup> Regarding longitudinal associations between CRF and HRQoL, our novel findings revealed a positive association between CRF at baseline and children's HRQoL at 12-week follow-up after adjusting for confounders. This outcome is partially supported by previous longitudinal research in different age groups by confirming the individual positive small association of CRF at baseline on HRQoL over a 2-year period follow-up ( $R^2 < 0.5$ ).<sup>112</sup> These findings might be somewhat explained by the positive influence that CRF has on both physical and mental dimensions of health in children<sup>27</sup> over time,<sup>143,144</sup> which may positively impact children's HRQoL. We hypothesise that the similarity between our study's effect sizes and the ones of previous evidence might be due to the several dimensions of HRQoL which could not be fully influenced by CRF.

Since mediation analysis assumes that the independent variable influences the mediator, our cross-sectional and longitudinal results suggest that CRF at baseline influenced the psychological variables, which, in turn, may affect HRQoL at baseline and 12-weeks later. With respect to path *a*, our findings could be partially supported by a previous cross-sectional study which reported that children with higher CRF levels had higher physical self-efficacy and physical activity enjoyment than their peers with low CRF.<sup>122</sup> Regarding our longitudinal results, we were not able to make comparisons since no evidence relating CRF and physical activity self-efficacy over time was found. We hypothesise that it is plausible that CRF influenced physical activity self-efficacy and enjoyment through motor skill development/proficiency and sport experiences. Children's CRF levels are associated with increased motor competence,<sup>145</sup> positive sport and physical activity experiences,<sup>146,147</sup> which in turn may affect several domains of their HRQoL. However, there is paucity of evidence in this area and further research is warranted. With respect to path *b*, our findings are in line with previous cross-sectional<sup>125</sup> and interventional<sup>124</sup> studies which reported a positive association of children's physical activity enjoyment and their HRQoL. However, no previous studies have examined the cross-sectional and longitudinal associations between children's physical activity self-efficacy and their HRQoL. The association found in our study between both psychological correlates and HRQoL may be related to the mental domain of the construct, predisposing children to higher scores of psychological well-being.<sup>125,148</sup>

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,<sup>141</sup> add support for the psychological correlates of physical activity being an intermediate step on the causal pathway between CRF and children's HRQoL. Thus, our findings are consistent with the idea that the promotion of children's physical activity self-efficacy and physical activity enjoyment may be of importance to improve their HRQoL.

Our mediation results are partially supported by only one previous cross-sectional study. This involved overweight adolescents, and showed the mediating role that motivational variables (i.e.,



self-determined motivation) have in the association between CRF and HRQoL.<sup>149</sup> However, the mediating roles of physical activity self-efficacy and enjoyment in children have not been previously investigated. Yet, based on prior cross-sectional research in other populations framed by self-determined motivation, being more physically fit leads to the need for more autonomy and competence during physical activity practice and, therefore, the development of more autonomous forms of self-regulations, which might benefit persistence and mental well-being<sup>149,150</sup> with a positive impact on their HRQoL.

Given the need of further research on correlates of physical activity due to its influence on behavioural change<sup>121</sup> and the temporal trends in physical fitness reporting a global declining tendency over the years,<sup>151</sup> our data may have significant implications for HRQoL improvement. Indeed, maintaining children's HRQoL is important for current health, as well as, has transferable value for future societal health. Our findings are of interest to educators and policy makers, to raise the importance of CRF for improving children's psychological correlates of physical activity and their HRQoL.

Strengths of this study include the homogeneous age-matched and relatively large sample of children. The multilevel analyses accounted for school-level variance and adjusted for important fixed effects confounders. Furthermore, the mediation models added significant novelty to provide improved insights into the CRF-HRQoL relationships. There are also limitations which warrant consideration. The findings obtained from the cross-sectional elements of the study preclude claims of causal inferences and directionality between CRF and HRQoL, whereas there is more confidence about causality in those from the longitudinal aspects which controlled for baseline HRQoL and confounders. The 12-weeks duration of the follow-up is short which limits the significance of the longitudinal results. Moreover, the sample was drawn from one geographical region of northwest England, therefore the results may not be generalizable to populations elsewhere. MVPA was assessed using a self-report instrument which is open to recall and social desirability biases; however, the YAP is a validated method that was administered in the same way at both time points, thus limiting variation in responses between baseline and follow-up. Lastly, we acknowledge that more accurate estimates of CRF could have been obtained using a laboratory-based physiological direct measure. However, such measures were not feasible within our study, and the 20mSRT is the most widely used field-based test of CRF in children, which demonstrates criterion validity against gas-analyzed peakVO<sub>2</sub>, and has strong ecological validity and feasibility in school settings.

## 5. Conclusion

The results of the current study showed that CRF was cross-sectionally and longitudinally associated with HRQoL in primary school children in England. Furthermore, self-efficacy and enjoyment as psychological correlates of physical activity act separately as mediators in the positive association between CRF and HRQoL. Therefore, we contribute to the comprehension of the relationship between these key factors, suggesting that both optimal CRF levels and better psychological correlates of physical activity are important for children's HRQoL. Our findings should be considered when designing education and public health interventions and strategies aiming to improve HRQoL during childhood.

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## Supplementary material

**Supplementary table 1.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

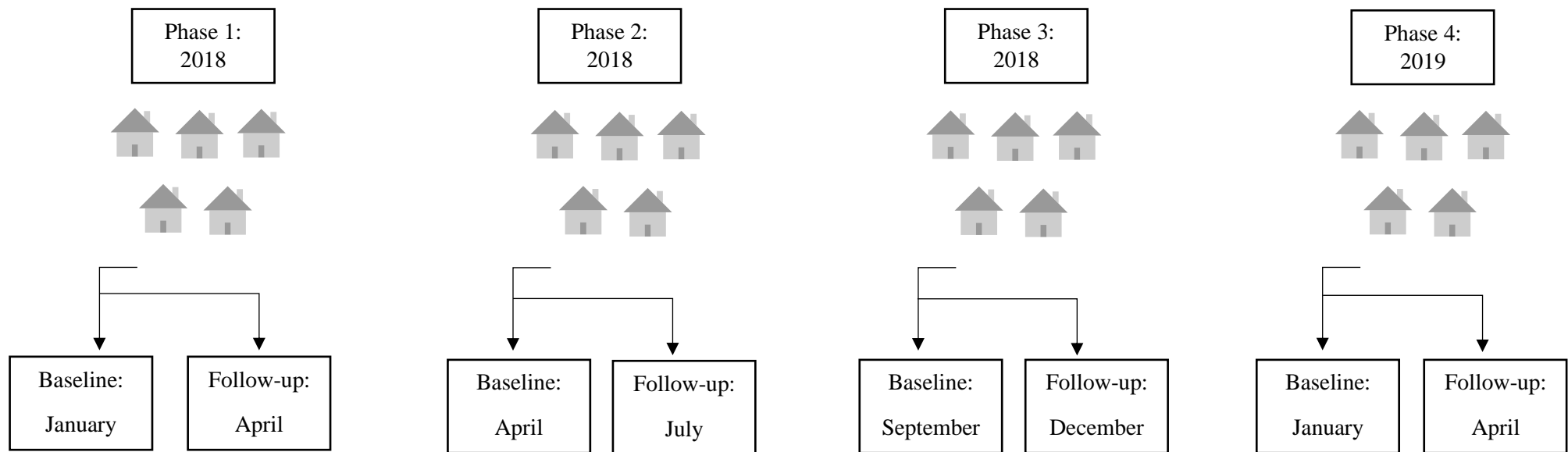
	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	57.30	44.94 – 49.66	< <b>0.001</b>
Cardiorespiratory fitness	0.09	0.04 – 0.16	<b>0.002</b>

Model 1: Unadjusted. Health related quality of life was measured using Kidscreen-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold.

**Supplementary table 2.** Cross-sectional associations between cardiorespiratory fitness and HRQoL (n= 383).

	Model 1		
	$\beta$	95% CI	<i>p</i>
Intercept	47.75	44.06 – 49.43	< <b>0.001</b>
Cardiorespiratory fitness	0.11	0.03 – 0.18	<b>0.004</b>

Model 1: Unadjusted. Health related quality of life was measured using Kidscreen-10. Data are presented as standardized regression coefficient ( $\beta$ ) and 95% confidence interval (CI). Statistically significant values are in bold.



**Supplementary figure 1.** Active West Lancs Programme phases of data collection.

**Study IV: Adherence to the Mediterranean diet  
and health-related quality of life in adolescents:  
the mediating role of physical fitness**

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(Submitted for publication)



## **Adherence to the Mediterranean diet and health-related quality of life in adolescents: the mediating role of physical fitness**

### **Abstract**

**Purpose.** The aim of this research was to analyse whether the association between adherence to the Mediterranean diet and health-related quality of life (HRQoL) is mediated by physical fitness (i.e., cardiorespiratory fitness, muscular strength, and motor competence) in adolescents.

**Methods.** This study involved 181 adolescents (86 girls) aged  $15.8 \pm 0.3$  years recruited from secondary schools and sport clubs located in the province of 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. Muscular strength was assessed through the standing broad jump test. Motor competence was assessed using the  $4 \times 10$  m shuttle run test of speed of movement, agility, and coordination. Mediation analyses were performed to examine whether each physical fitness component individually had a mediating effect on the association between adherence to the Mediterranean diet and HRQoL. Analyses were adjusted for sex, pubertal stage, parents' education level, waist circumference, and vigorous physical activity.

**Results.** Cardiorespiratory fitness and muscular strength had a mediating effect in the positive association between adherence to the Mediterranean diet and HRQoL (IE=0.106, 95% CI=0.002;0.273 and IE=0.073, 95% CI=0.001;0.192). However, motor competence did not act as a mediator on the association between adherence to the Mediterranean diet and HRQoL (IE=0.008, 95% CI=-0.028;0.066).

**Conclusions.** Our findings showed that the influence of adherence to the Mediterranean diet on adolescents' HRQoL was mediated by physical fitness. Education and public health authorities should design strategies focused on adherence to the Mediterranean diet and physical fitness to improve adolescents' HRQoL.

**Keywords:** Well-being, dietary patterns, fitness, quality of life, youth.

## Introduction

The understanding of individuals' self-perceived well-being and functionality in life including physical, mental, and social domains of health<sup>1</sup> is currently known as health-related quality of life (HRQoL). This construct has been suggested an important health indicator<sup>2</sup> due to its relationship with disease prevention and health promotion.<sup>3</sup> Indeed, over the past twenty-five years, HRQoL has become an important health outcome in adolescents,<sup>3</sup> due to a collective interest towards the subjective perception and evaluation of an individual's own life<sup>4</sup> being commonly examined by professionals, such as clinicians, educators, or public health authorities.<sup>4</sup> Previous evidence stated the importance of adolescents' multidimensional health (i.e., physical, mental, and social domains) embraced by this construct due to the impact that the well-being in all dimensions of health would represent for their global development.<sup>5</sup> Unfortunately, HRQoL during adolescence tend to decrease with age.<sup>6</sup> In this regard, screening adolescents' HRQoL should be a public health priority,<sup>1,2</sup> since it could help to determine disease or treatment related burdens in this age population.<sup>7</sup> Thus, identifying factors that may contribute to improving adolescents' HRQoL is of interest.<sup>7,8</sup>

Previous research has suggested that HRQoL may be influenced by health-related habits and individual's attributes, such as adolescent's adherence to good dietary patterns or physical fitness.<sup>9-11</sup> On one hand, physical fitness, which is considered a set of attributes related to a person's ability to perform physical activities,<sup>12</sup> has been suggested a powerful health marker in adolescents.<sup>13</sup> Moreover, it has been also suggested to positively influence adolescents' HRQoL<sup>14</sup> due to its impact in several body systems such as skeletomuscular, cardiorespiratory, psychological, and endocrine-metabolic.<sup>13</sup> 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 diary food sources,<sup>15</sup> has been pointed as the dietary pattern with the greatest benefits and preventive traits for general well-being.<sup>16</sup> Prior evidence in adolescents showed that this dietary pattern is positively associated with all three HRQoL domains.<sup>17</sup> 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.<sup>18</sup> 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).<sup>19</sup> 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 some physical fitness components (i.e., cardiorespiratory fitness and upper-limb muscle strength) in the association between Mediterranean diet adherence and

HRQoL.<sup>20</sup> Nevertheless, no studies in adolescents analysed the role of physical fitness 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 age population overall HRQoL and their future development,<sup>21</sup> mainly during the later adolescence, when they go through major life transitions.<sup>22</sup> This knowledge could be useful to health authorities seeking to improve the overall HRQoL in this age population. Therefore, the aim of this research was to analyse whether the association between adherence to the Mediterranean diet and HRQoL is mediated by physical fitness in adolescents.

## **Material and methods**

### **Study design and sample selection**

This study is part of the DADOS (Deporte, ADOlescencia y Salud) 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 main information about the aim and the study protocol. The inclusion criteria 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 adolescents (86 girls) aged  $15.8 \pm 0.3$  years with valid data for adherence to the Mediterranean diet, physical fitness, and HRQoL were included in the analyses.

Adolescents and their parents or guardians were informed of the nature and characteristics of the study, and all of them provided 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).

### **Adherence to the Mediterranean diet**

Adherence to the Mediterranean diet was evaluated using the KIDMED questionnaire, which includes 16 yes/no questions related to participants consumption of fast food, sweets and soft drinks, daily fruit and vegetables, and weekly fish and legumes.<sup>24</sup> Regarding the affirmative answers, a value of +1 was assigned to the questions with positive connotation in relation to Mediterranean diet (e.g., regular fruit consumption), while a value of -1 was assigned to the questions that constitute negative aspects (e.g., fast food consumption). Questions answered with

“no” scored 0. The score for the students’ level of adherence to the Mediterranean diet was calculated as the sum of each answer, ranging from 0 to 12.

### **Health-related quality of life**

HRQoL was assessed with the KIDSCREEN-10 questionnaire, a valid and reliable scale to analyze HRQoL among youth population.<sup>25</sup> The reliability and validity of the questionnaire have been examined previously in adolescents showing good reliability (Cronbach’s  $\alpha = 0.82$ ) and criterion validity ( $r = 0.91$ ).<sup>25</sup> 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.<sup>2</sup> A higher score in the questionnaire indicates better HRQoL.

### **Physical fitness**

Cardiorespiratory fitness was assessed using the 20-m shuttle run test.<sup>26</sup> 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.

Muscular strength was assessed through the standing broad jump test.<sup>27</sup> 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 is 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.

Motor competence was assessed using the 4 × 10 m shuttle run test of speed of movement, agility, and coordination.<sup>27</sup> 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.

### **Covariates**

Sex, pubertal stage, parents’ education level, waist circumference, and vigorous physical activity were included as covariates in the statistical analyses due to their relationship with the study variables.<sup>6,28–30</sup> Pubertal stage was self-reported according to the five stages described by Tanner

and Whitehouse.<sup>31</sup> It is based on external primary and secondary sexual characteristics, which are 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). Accelerometer-derived data from all participants comprised at least four complete days, including weekend and weekdays, with 24-h valid data. This device provides a reliable (coefficient of variation intra- and inter-instrument of 1.4% and 2.1%, respectively)<sup>32</sup> and valid assessment of physical activity in young people ( $r = 0.925$ ,  $p = 0.001$ ).<sup>33</sup> Physical activity was expressed as average minutes per day of vigorous physical activity. According to Phillips et al.,<sup>33</sup> GENEActiv cut-off point for vigorous intensity in children/adolescents was established for values over 60 g. In the current study, vigorous physical activity was chosen to be included in the analyses due to its stronger relationship with health parameters than moderate or light intensities.<sup>34,35</sup>

### **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 in relation to HRQoL ( $p > 0.05$ ), the main analyses were performed with the total sample.

Boot-strapped 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, parents' 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 (CIs) was used for the analyses. Mediation analyses were performed to examine the potential mediating effect of physical fitness 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 CIs 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 are included as predictors).<sup>36</sup> 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.<sup>36</sup> 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  $p < 0.05$ .

## 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 the muscular strength assessment achieved 186.4 centimetres, and 11.7 seconds in their motor competence evaluation.

Figure 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 muscular strength (path a;  $p < 0.05$ ), but not with 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 muscular 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 muscular strength was 15.1%.

## Discussion

The results of the present study showed that the association between adherence to the Mediterranean diet and HRQoL was mediated by cardiorespiratory fitness and muscular strength (but not by motor competence) in adolescents. Our findings expanded prior knowledge about the association between adherence to the Mediterranean diet and HRQoL in adolescents and revealed for the first time potential underlying mechanisms involved in this association in adolescents, highlighting the significant roles of cardiorespiratory fitness and muscular strength.

In concordance to previous research, our results showed a positive association between adherence to the Mediterranean diet and HRQoL in adolescents.<sup>17,37-39</sup> For instance, Evaristo et al. carried out a study involving 956 adolescents aged  $14.5 \pm 1.8$  years old, which revealed that the group with high adherence to the Mediterranean diet had greater HRQoL.<sup>39</sup> In addition, Costarelli et al. and Solera-Sanchez et al. performed cross-sectional studies, involving 359 and 262 adolescents, and found significant positive associations between this dietary pattern and overall HRQoL dimensions. This is probably due to the role those specific nutrients from the Mediterranean diet (i.e., antioxidants, minerals, vitamins and monosaturated fatty acids) might have on individuals' physical and mental health status,<sup>17,40,41</sup> 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 muscular strength, which in turn, may affect HRQoL. Our results agree with prior cross-sectional evidence in adolescents reporting a positive association of adherence to the Mediterranean diet with cardiorespiratory fitness and muscular strength.<sup>19,42</sup> In addition, a recent systematic review concluded that engaging in Mediterranean dietary patterns might be associated with higher cardiorespiratory fitness and muscular strength levels.<sup>18</sup> On one hand, it is plausible that specific nutrients provided by adhering to the Mediterranean diet benefit physical performance,<sup>43</sup> influencing cardiorespiratory fitness and muscular strength. On the other hand, adolescents engaged in this dietary pattern present better body composition<sup>19</sup> and greater levels of physical activity<sup>44</sup> which could directly influence cardiorespiratory fitness and muscular strength. Collectively, it is possible that those factors have an influence on adolescents' HRQoL. On the other hand, our findings are in line with a previous systematic review<sup>10</sup> reporting a positive association of adolescents' cardiorespiratory fitness and muscular strength with their HRQoL. The association found between both physical fitness components 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 risk<sup>45</sup> and positively associated with mental health,<sup>46</sup> which would influence adolescents' physical and mental domains of health. Additionally, both physical fitness components were associated with social competence<sup>47</sup> and an improved social health.<sup>48</sup> All these facts could predispose adolescents with higher levels of cardiorespiratory fitness and muscular strength to higher scores of overall HRQoL.<sup>10</sup>

Motor competence did not act as a mediator in the association between adherence to the Mediterranean diet and HRQoL in our study. Since no previous evidence was found for motor competence as a mechanism influencing the relationship between adherence to Mediterranean diet and HRQoL, we were not able to make comparisons. It is plausible, though, that the consumption of some nutrients provided by the Mediterranean diet pattern (i.e., omega-3 fatty acids and B-group vitamins) could benefit central nervous system functioning (i.e., neurotransmission)<sup>49</sup> improving motor competence during physical activity.<sup>50</sup> However, adolescents' brain would not be mature enough to leverage this nutrients' benefits during neurotransmission. This could affect their motor competence efficacy to perform physical activity, influencing some dimensions of their HRQoL.<sup>52</sup>

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,<sup>53</sup> add support for cardiorespiratory fitness and muscular 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 muscular 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.<sup>20</sup> 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  $20.9 \pm 2.5$  years.<sup>20</sup> Yet, based on prior mediation research in other populations, keeping a suitable daily nutrition could help in the achievement of a better performance,<sup>43</sup> leading to higher levels of cardiorespiratory fitness and muscular strength, which might benefit physical and mental well-being<sup>10</sup> with a positive impact on adolescents' overall HRQoL. Given the need for further research regarding factors that could influence overall adolescents' HRQoL<sup>2</sup> and the current decline in their adherence to the Mediterranean diet<sup>44</sup> and physical fitness,<sup>54,55</sup> 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 and limitations**

Strengths of the study included an age-matched sample, the use of validated and standardized tests to assess the adherence to the Mediterranean diet, physical fitness components, and HRQoL 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, we acknowledge that more accurate estimates of physical fitness components could have been obtained using laboratory-based physiological direct measures.

### **Conclusion**

In conclusion, the results of the present study show that cardiorespiratory fitness and muscular 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 good dietary patterns and physical fitness on adolescents' overall HRQoL. Health and education professionals in partnership with policymakers should take into account 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 adolescents' HRQoL.



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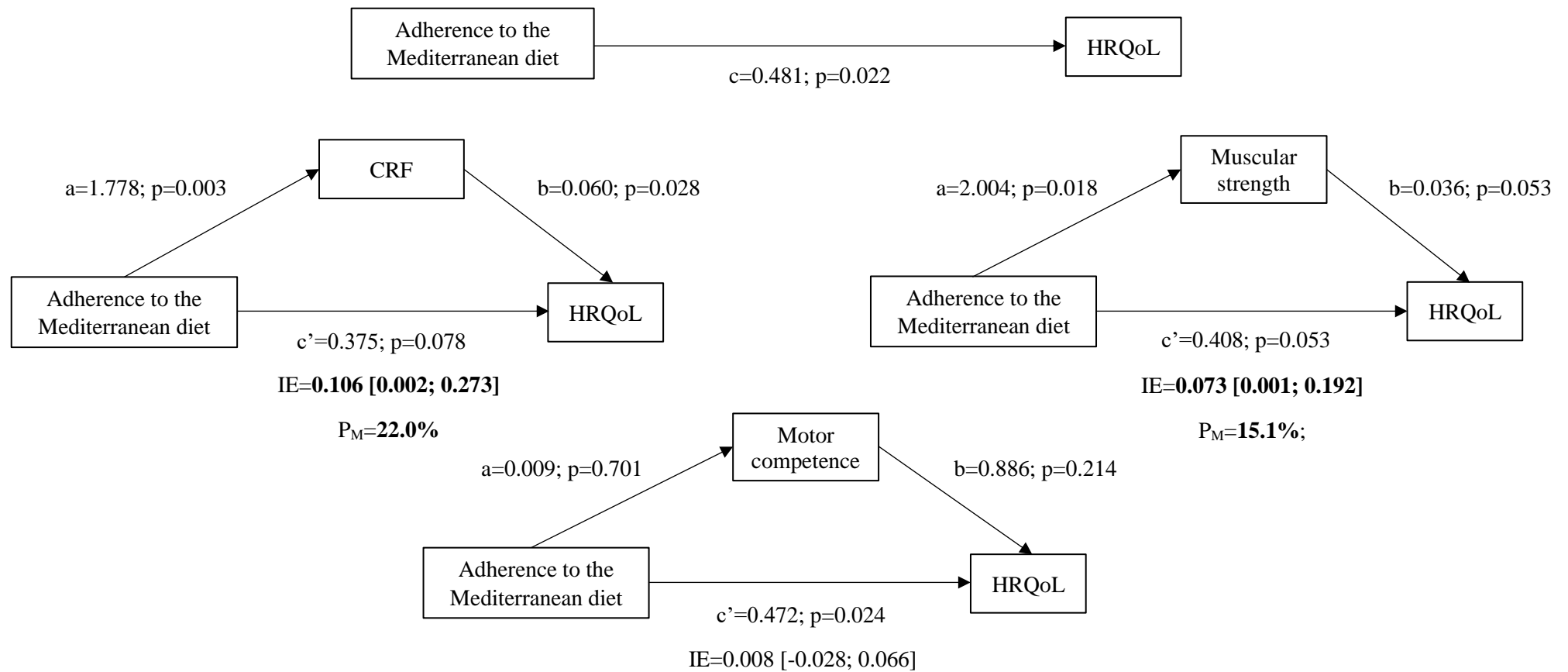
**Table 1.** Characteristics of the participants (N=181)

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Age (years)	15.8 (0.3)
Pubertal stage (III-V) (%)	9/53/38
Parents with university level (%)	48
Waist circumference (cm)	71.7 (6.5)
Vigorous physical activity (min/day)	7.0 (7.6)
Adherence to the Mediterranean diet (0-12)	7.2 (2.2)
Health-related quality of life	48.8 (6.2)
Physical fitness	
Cardiorespiratory fitness (shuttles)	70.2 (27.2)
Muscular strength (cm)	186.4 (33.4)
Motor competence (s)	11.7 (1.0)

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Data are presented as mean (SD) or percentages.



**Figure 1.** Physical fitness (i.e., cardiorespiratory fitness, muscular 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 showed 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<sub>M</sub>: percentage of mediation.

## CONCLUSIONS

The main conclusions of this PhD Thesis are:

### Section 1: Health-related behaviors and HRQoL (studies I and IV)

- Adherence to Mediterranean diet is positively associated with HRQoL in adolescents.
- Sleep quality and duration are positively associated with HRQoL in adolescents.
- Screen time is negatively related to HRQoL.
- Adolescents with a higher the healthy lifestyle index, including high vigorous physical activity, optimal adherence to the Mediterranean diet, good sleep patterns (i.e., sleep quality and duration) and low screen time, have a greater HRQoL.

### Section 2. Physical fitness and HRQoL (studies II and III)

- Cardiorespiratory fitness, muscular strength, and the physical fitness z-score at baseline were individually and positively associated with HRQoL at 24-month follow-up in adolescents.
- Adolescents with a higher fitness index, combining cardiorespiratory fitness, muscular strength, and motor competence at baseline were more likely to achieve high HRQoL at 24-month follow-up.
- Cardiorespiratory fitness at baseline was positively associated with HRQoL at baseline and at 12-weeks follow-up in children.

### Section 3. Possible mechanisms (studies III and IV)

- Psychological correlates of physical activity (i.e., self-efficacy and enjoyment) act as mediators in the association between cardiorespiratory fitness at baseline and HRQoL at baseline and at 12-week follow-up in children.
- Cardiorespiratory fitness and muscular strength (but not motor competence) mediate the association between adherence to the Mediterranean diet and HRQoL in adolescents.



## IMPLICATIONS AND FUTURE PERSPECTIVES

### Section 1: Health-related behaviors and HRQoL

- We have demonstrated for the first time, regarding single health-related behaviors, that there is a significant difference in HRQoL of adolescents with good sleep quality and duration and low screen time compared to their peers with poor sleep and higher levels of screen-based activities. Future studies should investigate this difference in additional health-related behaviors and different approaches.
- We also showed that adopting several health-related behaviours has a cumulative positive influence in adolescents' HRQoL. There was only one previous study who reported similar conclusions and used the same approach. Further studies should focus in investigating the cumulative effect of health-related behaviors using longitudinal and interventional designs, as well as in different populations, not just to address the question of causality, but to investigate whether health-related behaviors or attributes could have a long-term influence on HRQoL.

### Section 2. Physical fitness and HRQoL

- We reported, for the first time, the longitudinal positive association between muscular strength at baseline and HRQoL at 12-month follow-up in adolescents. Further research might focus on the longitudinal study of other physical fitness components (i.e., speed, balance, flexibility and coordination) and HRQoL to provide additional information for the increasement of future public health interventions aiming to enhance HRQoL in this age population.
- In addition, we showed for the first time the cumulative effect that several physical fitness components at baseline have in HRQoL at 12-month follow-up in adolescents. Future evidence should focus in longer longitudinal designs and in other populations, to find out if public health strategies focused on the physical fitness increasement could be applicable to other age populations.
- We cross-sectionally and longitudinally analysed the association between cardiorespiratory fitness at baseline and HRQoL at baseline and at 12-weeks follow-up in children. Further studies could investigate a longer longitudinal approach and in children from several ages.

### Section 3. Possible mechanisms

- We showed the cross-sectional and longitudinal mediating effect of physical activity correlates (i.e., self-efficacy and enjoyment) in the association between cardiorespiratory

fitness at baseline and HRQoL at baseline and at 12-week follow-up in children. Further studies should focus on the study of additional psychological correlates of physical activity and their mediating effect between physical fitness components, sports or physical activities and HRQoL. It would be interesting to investigate until which point, they would be able to influence factors affecting children's HRQoL.

- We showed that cardiorespiratory fitness and muscular strength mediated the association between adherence to the Mediterranean diet and HRQoL in adolescents. Further studies should investigate this mediating influence in longitudinal and interventional approaches, not just to clarify the effect of an optimal adherence to Mediterranean diet on children's HRQoL, but also to show the long-term effects that it could have.

Childhood and adolescence are key periods to develop health-related behaviors and attributes since they are likely to influence their current and later life health status improving society's overall HRQoL.<sup>152</sup> The present PhD Thesis identifies the main limitations of the current scientific knowledge and provides additional and helpful information to the public health authorities to succeed on their strategies.



## APENDIX



Diego Moliner Urdiales, como coautor/ coautora doy mi **autorización** a Alba Solera Sánchez para la presentación de las siguientes publicaciones como parte de su tesis doctoral.

Relación de publicaciones:

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Health-related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study). Qual Life Res. 2021 Apr;30(4):1093-1101. doi: 10.1007/s11136-020-02699-9. Epub 2020 Nov 16.

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study. Eur J Sport Sci. 2021 Dec 29:1-7. doi: 10.1080/17461391.2021.2012596. Epub ahead of print.

**Alba Solera Sánchez**, Mireia Adelantado Renau, Diego Moliner Urdiales, María Reyes Beltrán Valls. Mediterranean diet pattern and health-related quality of life: the mediating role of physical fitness in adolescents. (In process).

Asimismo, **renuncio** a poder utilizar estas publicaciones como parte de otra tesis doctoral.

Y para que conste firmo el presente documento,

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Todo ello, atendiendo al artículo 28 del Reglamento de los estudios de doctorado de la Universitat Jaume I de Castelló, regulados por el RD 99/2011, en la Universitat Jaume I (Aprobado en la sesión nº 8/2020 del Consejo de Gobierno de 02 /10/2020):

*“(…)*

*4. En el caso de publicaciones conjuntas, todas las personas coautoras deberán manifestar explícitamente su autorización para que la doctoranda o doctorando presente el trabajo como parte de su tesis y la renuncia expresa a presentar este mismo trabajo como parte de otra tesis doctoral. Esta autorización se adjuntará como documentación en el momento del inicio de evaluación de la tesis.*

Mireia Adelantado Renau, como coautor/ coautora doy mi **autorización** a Alba Solera Sánchez para la presentación de las siguientes publicaciones como parte de su tesis doctoral.

Relación de publicaciones:

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Health-related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study). Qual Life Res. 2021 Apr;30(4):1093-1101. doi: 10.1007/s11136-020-02699-9. Epub 2020 Nov 16.

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study. Eur J Sport Sci. 2021 Dec 29:1-7. doi: 10.1080/17461391.2021.2012596. Epub ahead of print.

**Alba Solera-Sanchez**, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity. Perspectives in Public Health (under second revision).

**Alba Solera Sánchez**, Mireia Adelantado Renau, Diego Moliner Urdiales, María Reyes Beltrán Valls. Mediterranean diet pattern and health-related quality of life: the mediating role of physical fitness in adolescents. (In process).

Asimismo, **renuncio** a poder utilizar estas publicaciones como parte de otra tesis doctoral.

Y para que conste firmo el presente documento,

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ADELANTADO|  
RENAU

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Castellón de la Plana, 29 de abril de 2022

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Todo ello, atendiendo al artículo 28 del Reglamento de los estudios de doctorado de la Universitat Jaume I de Castelló, regulados por el RD 99/2011, en la Universitat Jaume I (Aprobado en la sesión nº 8/2020 del Consejo de Gobierno de 02 /10/2020):

*(...)*

*4. En el caso de publicaciones conjuntas, todas las personas coautoras deberán manifestar explícitamente su autorización para que la doctoranda o doctorando presente el trabajo como parte de su tesis y la renuncia expresa a presentar este mismo trabajo como parte de otra tesis doctoral. Esta autorización se adjuntará como documentación en el momento del inicio de evaluación de la tesis.*

María Reyes Beltrán Valls, como coautor/ coautora doy mi **autorización** a Alba Solera Sánchez para la presentación de las siguientes publicaciones como parte de su tesis doctoral.

Relación de publicaciones:

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Health-related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study). Qual Life Res. 2021 Apr;30(4):1093-1101. doi: 10.1007/s11136-020-02699-9. Epub 2020 Nov 16.

**Solera-Sanchez A**, Adelantado-Renau M, Moliner-Urdiales D, Beltran-Valls MR. Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study. Eur J Sport Sci. 2021 Dec 29:1-7. doi: 10.1080/17461391.2021.2012596. Epub ahead of print.

**Alba Solera-Sanchez**, Danielle L. Christian, María Reyes Beltrán-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity. Perspectives in Public Health (under second revision).

**Alba Solera Sánchez**, Mireia Adelantado Renau, Diego Moliner Urdiales, María Reyes Beltrán Valls. Mediterranean diet pattern and health-related quality of life: the mediating role of physical fitness in adolescents. (In process).

Asimismo, **renuncio** a poder utilizar estas publicaciones como parte de otra tesis doctoral.

Y para que conste firmo el presente documento,

MARIA REYES| Firmado digitalmente  
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Castellón de la Plana, 29 de abril de 2022



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Bicester, May 7<sup>th</sup>  
of 2022

I, Stuart Fairclough, hereby authorise Alba Solera Sanchez to include the publications listed below in his/her doctoral thesis. In addition, I waive the right to use those articles as part of any other doctoral thesis.

List of articles:

Alba Solera-Sanchez, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity (Submitted in Perspectives in Public Health and under second revision).

Signed,



*In accordance with article 28 of the Regulations on doctoral studies of the Universitat Jaume I in Castelló, regulated by RD 99/2011, at the Universitat Jaume I (Approved by the Governing Council at its meeting no. 8/2020 held on 2 October 2020):*

*"(...)*

*4. In the case of joint publications, all the co-authors must explicitly state their approval that the doctoral student presented the work as part of her/his thesis and the express waiver of presenting this same work as part of another doctoral thesis. This authorisation must be attached as documentation when the evaluation of the thesis begins."*

Bicester, May 7<sup>th</sup>  
of 2022

I, Richard Tyler, hereby authorise Alba Solera Sanchez to include the publications listed below in his/her doctoral thesis. In addition, I waive the right to use those articles as part of any other doctoral thesis.

List of articles:

Alba Solera-Sanchez, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity (Submitted in Perspectives in Public Health and under second revision).

Signed,



Dr. Richard Tyler

*In accordance with article 28 of the Regulations on doctoral studies of the Universitat Jaume I in Castelló, regulated by RD 99/2011, at the Universitat Jaume I (Approved by the Governing Council at its meeting no. 8/2020 held on 2 October 2020):*

*"(...)*

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Bicester, May 7<sup>th</sup>  
of 2022

I, Rhona Martin-Smith, hereby authorise Alba Solera Sanchez to include the publications listed below in his/her doctoral thesis. In addition, I waive the right to use those articles as part of any other doctoral thesis.

List of articles:

Alba Solera-Sanchez, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity (Submitted in Perspectives in Public Health and under second revision).

Signed,



*In accordance with article 28 of the Regulations on doctoral studies of the Universitat Jaume I in Castelló, regulated by RD 99/2011, at the Universitat Jaume I (Approved by the Governing Council at its meeting no. 8/2020 held on 2 October 2020):*

*"(...)*

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Bicester, May 7<sup>th</sup>  
of 2022

I, Mhairi J. MacDonald, hereby authorise Alba Solera Sanchez to include the publications listed below in his/her doctoral thesis. In addition, I waive the right to use those articles as part of any other doctoral thesis.

List of articles:

Alba Solera-Sanchez, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mhairi J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity (Submitted in Perspectives in Public Health and under second revision).

Signed, *M MacDonald*

*In accordance with article 28 of the Regulations on doctoral studies of the Universitat Jaume I in Castelló, regulated by RD 99/2011, at the Universitat Jaume I (Approved by the Governing Council at its meeting no. 8/2020 held on 2 October 2020):*

*"(...)*

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Bicester, May 7<sup>th</sup>  
of 2022

I, Danielle Christian, hereby authorise Alba Solera Sanchez to include the publications listed below in his/her doctoral thesis. In addition, I waive the right to use those articles as part of any other doctoral thesis.

List of articles:

Alba Solera-Sanchez, Danielle L. Christian, Maria Reyes Beltran-Valls, Mireia Adelantado-Renau, Rhona Martin-Smith, Mahiri J. MacDonald, Richard Tyler, Stuart J. Fairclough. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity (Submitted in Perspectives in Public Health and under second revision).

Signed,



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*"(...)*

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## **ANNEX**

### **Short curriculum vitae**

#### **Personal information**

Alba Solera Sánchez

April 21<sup>st</sup> 1989

Mollet del Vallés (Barcelona)

+44 07902597720

[alba.solera.sanchez@gmail.com](mailto:alba.solera.sanchez@gmail.com)

#### **Education**

2022. PhD in Biomedical Sciences and Health, University Jaume I

2022. Master's in research methodology in public health, University of Salamanca

2018. Master's in nutrition and public health, Open university of Catalonia

2017. Degree in Sport sciences, University of Vic

#### **Research projects**

2015. Effects of a trail race in the neuromuscular performance of trained athletes. Sport Performance Analysis Research Group (SPARG). University of Vic.

2020. DADOS Study. Physical activity, fitness and health (LIFE). Universitat Jaume I.

2022. Effects of Zumba in physical fitness and psychological well-being. Trauma Rehabilitation and Musculoskeletal Health (TRaMH), Oxford Brookes University.

#### **Research stays**

2020-2021. Edge Hill university (United Kingdom).

#### **Attended courses**

Title of course/seminar: Research communication and divulgation

Organising entity: Universitat Jaume I

Duration in hours: 25 hours

Start-End date: 08/04/2020 - 15/05/2020

Title of course/seminar: Multivariate data analysis

Organising entity: Universitat Jaume I

Faculty, institute or centre: Faculty of technology and experimental sciences

Duration in hours: 40 hours

Start-End date: 14/02/2020 - 13/03/2020

Title of course/seminar: Basic data analysis

Organising entity: Universitat Jaume I

Faculty, institute or centre: Faculty of technology and experimental sciences

Duration in hours: 40 hours

Start-End date: 30/01/2020 - 27/02/2020

Title of course/seminar: XVII Spanish Nutrition society congress

Organising entity: SPANISH NUTRITION SOCIETY

Faculty, institute or centre: University of Barcelona

Duration in hours: 27 hours

Start-End date: 27/06/2018 - 29/06/2018

Title of course/seminar: Biomechanical and sport podology conference

Organising entity: SEBIOR/SEPOD

Faculty, institute, or centre: University of Barcelona

Duration in hours: 8 hours

Start-End date: 15/06/2018

Title of course/seminar: Clinical Exercise Congress 2018

Organising entity: Resistance Institute

Faculty, institute, or centre: Resistance Institute, Barcelona

Duration in hours: 14 hours

Start-End date: 02/06/2018 - 03/06/2018

### **Teaching activities**

Type of event: Seminar

Name of the event: Health-related behaviors and health-related quality of life in adolescents

Organising entity: FUNDACION UNIVERSITAT JAUME I-EMPRESA

Hours of teaching: 3

Teaching date: 28/09/2021

### **Work submitted to congresses**

Title of the work: Association between motor competence and academic performance in adolescents: DADOS Study

Name of the conference: 1st International Congress: Promoting Brain Health Through Exercise Across the Lifespan

Organizing Entity: Universidad de Granada

Date of the event: 09-10/12/2021

Title of the work: Is muscular strength associated with academic performance in adolescents? DADOS Study

Name of the conference: 1st International Congress: Promoting Brain Health Through Exercise Across the Lifespan

Organizing Entity: Universidad de Granada



Date of the event: 09-10/12/2021

Title of the work: Weight status influences the Association between Physical Fitness Components and Self-esteem in Adolescents: DADOS Study

Name of the conference: 1st International Congress: Promoting Brain Health Through Exercise Across the Lifespan

Organizing Entity: Universidad de Granada

Date of the event: 09-10/12/2021

Title of the work: Health-related quality of life in English primary schoolchildren: cross-sectional and longitudinal associations with cardiorespiratory fitness

Name of the conference: ISBNPA XChange initiative 2021

Organizing Entity: ISBNPA

Date of the event: 08-10/06/2021

Title of the work: Longitudinal associations between physical fitness components and health-related quality of life in adolescents: DADOS Study

Name of the conference: ISBNPA XChange initiative 2021

Organizing Entity: ISBNPA

Date of the event: 08-10/06/2021

Title of the work: El tiempo de pantalla se asocia con el riesgo de depresión durante la adolescencia: Proyecto DADOS

Name of the conference: XXVI Jornadas para el fomento de la investigación en ciencias sociales

Organizing Entity: Universitat Jaume I

Date of the event: 14/05/2021

Title of the work: Relación entre la calidad de vida relacionada con la salud y la competencia motriz en alumnado de educación secundaria: Proyecto DADOS

Name of the conference: XXVI Jornadas para el fomento de la investigación en ciencias sociales

Organizing Entity: Universitat Jaume I

Date of the event: 14/05/2021

Title of the work: Changes in physical activity practice are associated to health-related quality of life changes during adolescence: DADOS Study

Name of the conference: Primer congreso internacional DOTS a l'Àgora

Organizing Entity: University of Lleida

Date of the event: 30/04/2021

Title of the work: La condición física y su relación con la salud psicológica en adolescentes: Proyecto DADOS

Name of the conference: VI Jornadas de Investigación en Ciencias de la Salud

Organizing Entity: Universitat Jaume I

Date of the event: 21/04-05/05/2021

Title of the work: Relación entre el nivel de condición física y la calidad de vida relacionada con la salud durante la adolescencia: Proyecto DADOS

Name of the conference: VI Jornadas de Investigación en Ciencias de la Salud

Organizing Entity: Universitat Jaume I

Date of the event: 21/04-05/05/2021

Title of the work: Relationship between adherence to the Mediterranean Diet and health related quality of life in adolescents

Name of the conference: VII Reunión de Jóvenes investigadores

Organizing Entity: Sociedad Española de Nutrición

Date of the event: 13-14/11/2020

Title of the work: Combined influence of health-related behaviors on health-related quality of life in adolescents: DADOS study

Name of the conference: 25th European College of Sport Sciences congress

Organizing Entity: European College of Sport Sciences

Date of the event: 28-30/10/2020

Title of the work: Is there a relationship between the levels of self-esteem and social stress with the risk of suffering from eating disorders in adolescents?

Name of the conference: XXV Jornadas de fomento de las ciencias sociales

Organizing Entity: Universitat Jaume I

Date of the event: 8/05/2020

Title of the work: Bullying and cyberbullying in a group of Castellón adolescents

Name of the conference: XXV Jornadas de fomento de las ciencias sociales

Organizing Entity: Universitat Jaume I

Date of the event: 8/05/2020

Title of the work: Relationship between screen time and health related quality of life in adolescents

Name of the conference: XXV Jornadas de fomento de las ciencias sociales

Organizing Entity: Universitat Jaume I

Date of the event: 8/05/2020

### **Scientific publications**

Solera-Sanchez A, Gamero-Lluna A. Hábitos saludables en universitarios de ciencias de la salud y de otras ramas de conocimiento: un estudio comparativo. Revista Española de Nutrición Humana y Dietética. 23 - 4, pp. 1 - 35. 2019.

Solera-Sanchez A, Adelantado Renau M, Moliner Urdiales D, Beltran Valls MR. Health related quality of life in adolescents: individual and combined impact of health-related behaviors (DADOS study). *Quality of Life Research*, 2021 Apr;30(4):1093-1101.

Solera-Sanchez A, Adelantado Renau M, Moliner Urdiales D, Beltran Valls MR. Individual and combined impact of physical fitness on health-related quality of life during adolescence: DADOS Study. *European Journal of Sport Science*, 2021 Dec 29:1-7.

Solera-Sanchez A, Adelantado Renau M, Moliner Urdiales D, Beltran Valls MR. Relación entre la condición física y la calidad de vida relacionada con la salud durante la adolescencia: Proyecto DADOS. *Fòrum de Recerca*, ISSN-e 1139-5486, N.º. 26, 2021 (Ejemplar dedicado a: XXVI Jornades de Foment de la Investigació en Ciències Humanes i Socials), págs. 89-89.

Solera-Sanchez A, Adelantado Renau M, Moliner Urdiales D, Beltran Valls MR. Cross-sectional and longitudinal relationships between cardiorespiratory fitness and health-related quality of life in primary school children in England: the mediating role of psychological correlates of physical activity. Under second revision. *Perspectives in Public Health*.

Solera-Sanchez A, Adelantado Renau M, Moliner Urdiales D, Beltran Valls MR. Mediterranean diet and health-related quality of life in adolescents. The mediating role of physical fitness: DADOS study. In progress.