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

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Abstract

Purpose. The purpose of the present study is 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.

Methods. This longitudinal research included 199 adolescents (13.9 ± 0.3 years at baseline) from DADOS study. Cardiorespiratory fitness was assessed using the 20m shuttle run test. Muscular strength was assessed using the standing broad jump test. Motor competence was assessed using the 4×10m 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.

Results. 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 (β ranging from 0.123 to 0.183; all $p<0.05$). Moreover, logistic regression analysis revealed that adolescents with a fitness index ≥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 $p<0.05$).

Conclusions. 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.

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[1]. 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 body physiological functioning of those systems, being considered a strong health-related marker[2]. 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 [2]. Additionally, recent evidence has revealed that physical fitness is also positively associated with mental health and well-being in adolescents[3,4], suggesting a positive relationship with adolescents' health-related quality of life (HRQoL) [5,6].

HRQoL has been defined as individuals' functioning performance in life and their perceived well-being in physical, mental, and social domains of health[5]. It has been suggested as an important health indicator since perceived well-being and functionality are considered important components of health surveillance[6]. Previous evidence showed that adolescents' HRQoL decreases with age[7], probably due to the fact that it is a period in which coping with physical, physiological, and social changes become a difficult challenge[8]. 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[9,10], while in children the evidence showed a positive association with motor competence[11]. However, only one research examined the longitudinal relationship between cardiorespiratory fitness and HRQoL[13], 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[14,15], 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 ± 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[16]. 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[17]. From a starting position behind a line marked on the ground, standing with slightly apart, the adolescent jumped as far as possible landing on both feet together 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[17]. 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.[18] for cardiorespiratory fitness and muscular strength, and based on Ortega et al.[19] 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 reliably scale to analyze HRQoL among Spanish youth population[20]. The reliability and validity of the questionnaire have been examined previously in adolescents showing good reliability (Cronbach's $\alpha = 0.82$) and criterion validity ($r = 0.91$)[20]. 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[6]. A higher score in the questionnaire indicates better HRQoL. Participants above the sex- specific mean normative value from European adolescents[6], which stablishes 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[21,22]. Pubertal stage was self-reported according to the five stages described by Tanner and Whitehouse[23]. 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[24].

Statistical analyses

Descriptive sample characteristics were presented as mean ± 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, 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 ≥1 at baseline were more likely to achieve greater HRQoL at 24-month follow-up. Indeed, 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 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[13]. These findings might be partially explained by the influence that cardiorespiratory fitness has on several dimensions of health over time[25,26]. For instance, increased cardiorespiratory fitness may lead to improved levels of adiposity, blood pressure, and glucose regulation, as well as mental health in adolescents[27–29]. This fact may reduce the occurrence of cardiometabolic and mental diseases during adolescence, which may positively impact adolescents' HRQoL[21,30,31].

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[14]. 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-steem[32,33]. 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[32,34,35].

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[2], which appears to prevent osteoporosis, a disease manifested in later life[36], 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[10]. Prior research has suggested that the development of physical fitness may be of paramount importance to enhance health status[2,14], which might positively influence HRQoL over time.

The combined effect analysis revealed that adolescents with a fitness index of ≥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 analyses 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[37], as well as on HRQoL[38]. 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[39,40], 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.

Declaration of interest. The authors declare that they have no competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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

	Baseline	Follow-up	p-value
Physical fitness			
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 [1]	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.

[1] The physical fitness z-score was calculated as the mean of the z-scores values of cardiorespiratory fitness, muscular strength, and motor competence.

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).

	β	95% CI	p-value
Cardiorespiratory fitness	0.183	0.008; 0.086	**0.019**
Muscular strength	0.175	0.008; 0.075	**0.014**
Motor competence	0.123	-0.198; 1.778	0.116
Physical fitness z-score [1]	0.162	0.215; 2.070	**0.016**

Data are presented as standardized regression coefficient (β) 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.

[1] The physical fitness z-score was calculated as the mean of the z-scores values of cardiorespiratory fitness, muscular strength, and motor competence.

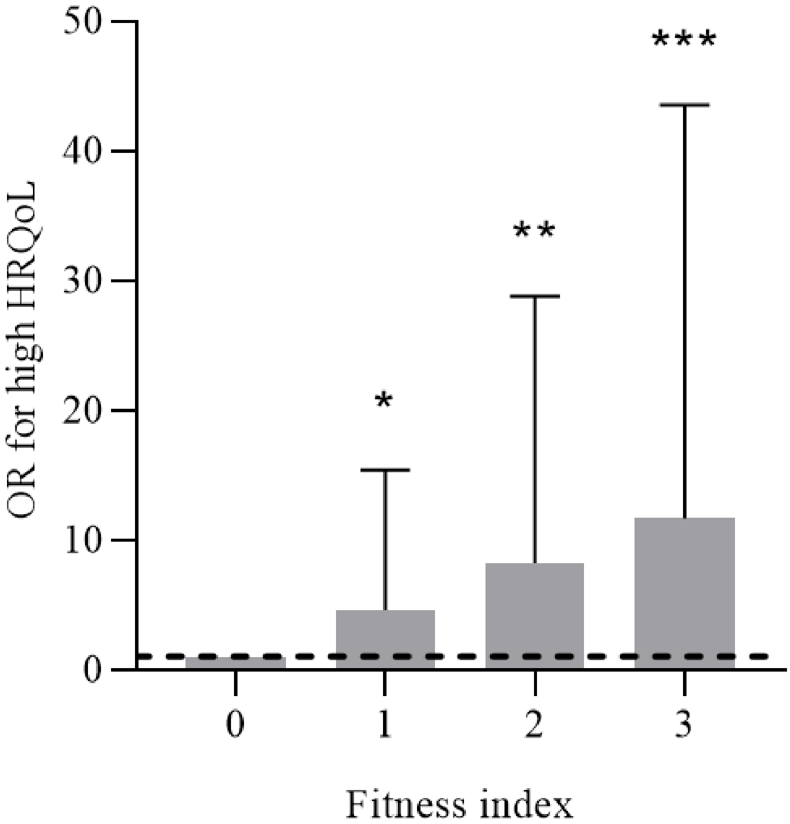

Figure 1. Logistic regression analysis predicting high HRQoL at 24-month follow-up according to the fitness index at baseline. The analysis was adjusted for sex, pubertal stage, waist circumference, socioeconomic status, and HRQoL at baseline. Reference Odd Ratio (OR = 1.00): adolescents with a fitness 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.