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Muscular fitness and cardiorespiratory fitness are associated with health-related quality of life: Results from labmed physical activity study

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ABSTRACT

Background/Objective: Adolescents' physical fitness levels are an important indicator of their lifestyle and seem to have positive consequences in health-related quality of life (HRQoL).

The purpose of this study is to analyse the combined associations of cardiorespiratory fitness and muscular fitness with HRQoL and to assess the differences between HRQoL scores across groups of cardiorespiratory fitness and muscular fitness in Portuguese adolescents.

Methods: This is a cross-sectional analysis with 567 Portuguese adolescents aged 12–18 years-old. HRQoL was measured using the Kidscreen-10 questionnaire. Cardiorespiratory fitness was estimated with the 20-m shuttle-run test. Muscular fitness was evaluated using the handgrip and the standing long jump tests and a muscular fitness index was computed by means of standardized measures of both tests. Socioeconomic status was assessed using the Family Affluence Scale. Body composition (body mass and height) was measured according to standard protocols. Accelerometers were used to obtain objective physical activity time. Pubertal stage was assessed using Tanner stages. Adherence to the Mediterranean diet was assessed using the KIDMED index. Participants were divided into four groups based on low or high values of both cardiorespiratory and muscular fitness. Regression analysis, mediation analysis and ANCOVA were performed.

Results: HRQoL was positively associated with cardiorespiratory fitness ($B = 0.112$; $p < 0.05$) and muscular fitness score ($B = 0.328$ $p < 0.05$), after controlling for potential confounders. However, when both fitness variables were entered in the same model only cardiorespiratory fitness remained significantly associated with HRQoL ($B = 0.093$ $p < 0.05$). Cardiorespiratory fitness acted as a full mediator variable on the relationship between muscular fitness and HRQoL in adolescents ($p < 0.05$). ANCOVA showed that adolescents with high cardiorespiratory fitness/high muscular fitness exhibit better HRQoL scores when compared to those with low muscular fitness/low cardiorespiratory fitness and with those with low muscular fitness/high cardiorespiratory fitness ($p < 0.05$).

Conclusions: In adolescents, the combination of high cardiorespiratory fitness and high muscular fitness was positively associated with a better HRQoL.

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Introduction

Research on health-related quality of life (HRQoL) has increased in the last years.^{1–5} HRQoL can be defined as a multidimensional construct that relates to a person's self-perceived health and

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consists of ratings of well-being and functionality in important life areas, including physical well-being/functioning, emotional well-being, self-esteem, social functioning, and family relations.² Assessing HRQoL in youth can be useful to detect early impairments in well-being and functioning, as well as identify the subgroups of the population at higher risk for health problems.²

Physical fitness is widely recognized as a powerful marker of health-related outcomes, both in childhood and adulthood and an important determinant of current and future health status.^{6,7} Indeed, low levels of physical fitness during childhood and adolescence are associated with important health-related outcomes, such as increased risk of obesity and cardiovascular risk,^{6–8} novel cardiovascular disease risk factors⁹ and with arterial compliance,¹⁰ impaired skeletal health,^{11,12} reduced quality of life,^{13,14} and mental health.^{7,15} Although most research has focused on the relationship between cardiorespiratory fitness and health outcomes, there is a growing interest in the relationship between muscular fitness and its health-related benefits. Indeed, high levels of muscular fitness and have been associated with decreased cardiovascular risk in youth independent of body mass and cardiorespiratory fitness^{16,17} and it has also been favorably correlated with improved bone health, enhanced self-esteem, and decreased adiposity in children.^{16,18}

Recently, some studies have investigated the associations between cardiorespiratory fitness and muscular fitness with HRQoL in children^{13,14,19} and in adolescents, using self-reported measures of fitness.²⁰ However, to the best of our knowledge, no studies have explored the combined associations between cardiorespiratory fitness and muscular fitness (assessed by field measures) with HRQoL in adolescents, controlling the analyses for a series of potential confounders such for age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern or physical activity.

Therefore, the purpose of this study was to examine the combined associations between cardiorespiratory fitness and muscular fitness with HRQoL and to assess the differences between HRQoL score across groups of cardiorespiratory fitness and muscular fitness in adolescents.

Methods

Study design and sample

The current report is part of the “Longitudinal Analysis of Biomarkers and Environmental Determinants of Physical Activity (LabMed Physical Activity Study)”, a school-based prospective cohort study carried out in five cities from the Northern Region of Portugal. This study aimed to evaluate the independent and combined associations of fitness levels and dietary intake on blood pressure over a 2-years period. A full description of the study protocol can be seen elsewhere.^{21,22}

Baseline data was collected in the fall of 2011, for all students that agreed to participate in the study ($n = 1229$; aged 12–18 years). From this initial total sample, 567 adolescents (287 girls and 280 boys) provided full data for the variables of interest for the current report and the present study was restricted to them.

The study was conducted in accordance with the World Medical Association’s Helsinki Declaration for Human Studies.²³ The Portuguese Data Protection Authority (#1112434/2011), the Portuguese Ministry of Science and Education (0246,200,001/2011) and the Faculty of Sports of University of Porto approved the study. All participants were informed of the study’s goals, and written informed consent was obtained from participating adolescents and their parents or guardians.

Measures

Health-related quality of life

Health-related quality of life (HRQoL) was assessed using the Portuguese self-report version of the KIDSCREEN-10 questionnaire²⁴ that has been transculturally developed in 13 European countries for the population of children and adolescents aged 8–18 years. KIDSCREEN-10 is a reduced version of the KIDSCREEN-52 questionnaire, which contains ten items assessed on a five-point Likert response scale ranging from 1 (never; not at all) to 5 (always; extremely). KIDSCREEN-10 scores provide an overall value for quality of life. This one-dimensional measure represents a global score adequate for use in large epidemiological surveys.^{25,26} A low value on this tool suggests a feeling of dissatisfaction and inadequacy in many areas of the lives of children and adolescents, in particular, family, peer group and school. A high value, conversely, suggests a perception of adequacy and satisfaction with the aforementioned contexts.²⁴

Physical fitness

Physical fitness was assessed following the protocols of the ALPHA health-related fitness battery.²⁷ Cardiorespiratory fitness was assessed with the 20-m shuttle run test. Adolescents were required to run, in a straight line, between two lines distanced 20-m apart, while keeping pace with a pre-recorded audio CD. The initial speed was 8.5 km h^{-1} , which was increased by 0.5 km h^{-1} each minute (1 min = one stage). The test was finished when the adolescent failed to reach the end lines before the audio signal on two occasions. The maximum oxygen consumption (VO_2max , mL/kg/min) was estimated using the equation of Leger, Mercier, Gadoury, Lambert.²⁸ Adolescents were then classified into two groups (low or high cardiorespiratory fitness) according to proposed cut-offs by Ruiz, Caverro-Redondo, Ortega, Welk, Andersen, Martinez-Vizcaino²⁹ (low cardiorespiratory fitness level: below 42 and 35 mL/kg/min, for boys and girls, respectively).

Muscular fitness was assessed using the handgrip strength and the long jump tests. The handgrip strength (upper body isometric strength) was assessed using a handgrip dynamometer, (T.K.K. 5001, Grip-A produced by Takei, Japan). The participants were instructed to stand with their arms by their side, fully extended, squeezing the handgrip continuously for at least 2 s, performing the test with the right and left hands in turn. A rest period of 90-sec was given between trials. The grip-span of the dynamometer was adjusted according to the hand size and sex to determine the maximum handgrip strength using the equations specifically developed for children³⁰ and adolescents.³¹ The test was performed twice and the highest score for each hand was used for the analysis. The handgrip score (kg) was calculated as the average of the best left and right scores and then was expressed as kilogram of body mass.^{17,32,33}

In the standing long jump test (lower body explosive strength) the adolescents were instructed to jump, from the starting line and to push off vigorously and jump as far forward as possible landing on both feet and staying upright. The test was performed twice and the best distance was recorded in centimeters. The distance between the first heel-mark and the take-off line determined the standing jump score.²⁷

The results of the handgrip strength and long jump tests were transformed into standardized values (Z-scores) according to age and sex. Then the sum of the Z-scores of the two tests was used to create the muscular fitness score. Since there is no universally agreed cut-off for muscular fitness, scores below the 20th percentile were classified as low and those above as high score.^{17,34,35}

Physical activity

Physical activity was assessed with accelerometry (GT1M Actigraph, Pensacola, Florida, USA). The accelerometer was tightly attached to the waist (on the right hip), and worn over five consecutive days (three weekdays and two weekend days), during waking hours and removed during sleep and water-based activities.^{36,37} To be included, adolescents had to wear the monitor for at least three valid days (two weekdays and one weekend valid day).³⁸ The epoch length was set to 2 s. We worked with an automated data reduction program (ActivLive 6.12, ActiGraph, Pensacola, Florida, USA) to treat accelerometer data. Each period of 60 min of consecutive zeros was detected as non-wear time^{39,40}; a minimum of 10 h/day of accelerometer wear time was considered as a valid day.^{39,40} The screening procedures were consistent with current accelerometry studies and also similar to the screening used in National Health and Nutrition Examination Survey (NHANES).^{39,40}

The time spent in the different physical activity intensities was determined by the raw activity “counts”, considering Evenson’s cut-points.⁴¹ MVPA was expressed as average minutes per day.

Adherence to the mediterranean diet

Dietary patterns were assessed with the KIDMED index (Mediterranean Diet Quality Index for children and adolescents).⁴² The index is a self-administered, 16-item questionnaire, which reflects the principles of the Mediterranean dietary patterns, as well as, those that undermine it. The final results of the index varied between 0 and 12 points, with higher scores indicating higher adherence to the Mediterranean diet. Responses to questions that had a negative connotation in relation to Mediterranean diet were given a score equal to (−1) and the questions that constituted positive aspects were scored (+1).

Body mass and height

Anthropometric measurements were performed according to standard procedures.⁴³ Body mass and height were measured using a portable electronic weight scale (Tanita Inner Scan BC 532, Tokyo, Japan), and a portable stadiometer (Seca 213, Hamburg, Germany), respectively, with the participant barefoot, wearing light clothing. Body mass index (BMI) was calculated as body mass divided by height squared (kg/m^2).

Pubertal stage

Adolescents self-reported their pubertal stage (from 1 to 5) relative to their secondary sex characteristics, according to the criteria of Tanner and Whitehouse.⁴⁴ Briefly, girls were assessed by the stage of breast development (Tanner A) and pubic hair distribution (Tanner B); boys were assessed by stage of genitalia development (penis size and testicular volume - Tanner A) and pubic hair distribution (Tanner B).

Socioeconomic status

Adolescents’ socioeconomic status was assessed using the Family Affluence Scale⁴⁵ developed specifically to measure children and adolescents socioeconomic status in the context of the Health Behavior in School-Aged Children Study. The Family Affluence Scale is a four-item questionnaire that helps students report their family income objectively. The final score ranges from 0 to 9 points, with higher scores indicating higher socioeconomic status.

Statistical analysis

Descriptive data are presented as mean and standard deviation for continuous variables and percentages for categorical variables. To assess differences between the sexes, the independent two-tailed Student’s *t*-test was used for the continuous variables and the chi-square test for the categorical variables.

According to the cardiorespiratory fitness levels (low and high) and muscular fitness score (low and high), four exclusive groups were created (low cardiorespiratory fitness/low muscular fitness, low cardiorespiratory fitness/high muscular fitness, high cardiorespiratory fitness/low muscular fitness and high cardiorespiratory fitness/high muscular fitness).

Linear regression models were used to determine the associations between HRQoL (as the dependent variable) and cardiorespiratory fitness and muscular fitness score (as predictor variables), adjusted for age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, accelerometer wear time and daily average of MVPA. Unstandardized regression coefficients were used to express the B in the linear regression analyses.

To examine whether the association between muscular fitness and HRQoL was mediated by cardiorespiratory fitness, linear regression models were fitted using bootstrapped mediation procedures included in the PROCESS SPSS macro.⁴⁶ The first equation regressed the mediator (cardiorespiratory fitness) on the independent variable (muscular fitness). The second equation regressed the dependent variable (HRQoL) on the independent variable (muscular fitness). The third equation regressed the dependent variable (HRQoL) on both the independent (muscular fitness) and the mediator variable (cardiorespiratory fitness). The following criteria were used to establish mediation: (1) the independent variable (muscular fitness) is significantly related to the mediator (cardiorespiratory fitness); (2) the independent variable (muscular fitness) is significantly related to the dependent variable (HRQoL); (3) the mediator (cardiorespiratory fitness) is significantly related to the dependent variable (HRQoL); and (4) the association between the independent and dependent variable is attenuated when the mediator is included in the regression model. The Sobel test was used to test the hypothesis that the indirect effect was equal to zero. This analysis was adjusted by age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, accelerometer wear time and daily average of MVPA.

Analysis of covariance (ANCOVA) with Bonferroni post-hoc multiple comparison tests were used to assess the differences between mean values of HRQoL score across the four groups of cardiorespiratory fitness and muscular fitness. Covariates included were age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, daily average of MVPA and accelerometer wear time.

Data analysis was performed using the statistical software Statistical Package for Social Sciences (SPSS, Version 24.0). A *p*-value <0.05 denoted statistical significance.

Results

Table 1 shows the descriptive characteristics of the participants. Boys performed significantly better in the long jump and handgrip tests and had higher VO_2max and muscular fitness scores than girls; boys were also more active and reported better quality of life than girls ($p < 0.05$ for all).

Linear regression analysis (Table 2), showed that cardiorespiratory fitness ($B = 0.112$; $p = 0.007$) and a muscular fitness scores ($B = 0.328$; $p = 0.043$), were positively associated with HRQoL, after adjustments for age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, daily average of

Table 1
Descriptive characteristics of the participants by sex.

	Total (n = 567) ^a	Girls (n = 287) ^a	Boys (n = 280) ^a	p ^b
Age (year)	14.0 (1.7)	14.1 (1.6)	13.9 (1.7)	0.581
Body mass (Kg)	54.0 (12.4)	52.8 (11.1)	55.2 (13.6)	0.021
Stature (cm)	159 (0.09)	158 (0.06)	161 (0.11)	< 0.001
BMI (kg/m ²)	21.1 (3.8)	21.1 (3.7)	21.1 (3.9)	0.882
Pubertal stage A (I/II, III, IV, V) (%)	8.3/34.7/45/12	4.5/31/51.9/12.5	12.1/38.6/37.9/11.4	< 0.001
Pubertal stage B (I/II, III, IV, V) (%)	7.1/22.9/51.5/18.5	2.8/22.6/50.2/24.4	11.4/23.2/52.9/12.5	< 0.001
Long jump (cm)	158.2 (30.1)	145.4 (23.8)	171.3 (30.2)	< 0.001
Handgrip (kg)	26.1 (7.2)	23.2 (4.8)	29.1 (8.0)	< 0.001
Handgrip/body mass (kg)	0.49 (0.11)	0.44 (0.09)	0.53 (0.12)	< 0.001
Cardiorespiratory fitness – VO ₂ max (mL/kg/min)	42.3 (6.8)	38.8 (4.8)	45.9 (6.7)	< 0.001
Daily average MVPA (minutes/day)	56.9 (20.7)	51.1 (19)	62.9 (20.6)	< 0.001
Muscular fitness score	–0.30 (1.6)	–0.29 (1.5)	0.24 (1.7)	< 0.001
KIMED index	7.1 (2.1)	7.3 (1.8)	7.0 (2.3)	0.086
Socioeconomic status	6.4 (1.7)	6.6 (1.7)	6.2 (1.7)	0.011
Health-related quality of life (Kidscreen-10)	39.6 (5.4)	39.1 (5.5)	40.2 (5.3)	0.018

Abbreviations: BMI, body mass index; MVPA, moderate-to-vigorous physical activity.

^a The data shown in percentage for categorical variables and mean (SD) for continuous variables.

^b p value was calculated based on Qui-squared test for categorical variables and t-test for continuous variables.

Table 2
Regression analysis predicting Health Related Quality of Life.

	B (95% CI)	β	p-value
Model 1 - Cardiorespiratory Fitness	0.144 (0.094; 0.194)	0.206	< 0.001
Model 2 - Cardiorespiratory Fitness	0.112 (0.030; 0.194)	0.141	0.007
Model 3 - Muscular Fitness score	0.412 (0.202; 0.622)	0.135	< 0.001
Model 4 - Muscular Fitness score	0.328 (0.011; 0.646)	0.098	0.043
Model 5 - Cardiorespiratory Fitness and Muscular Fitness score	0.093 (0.004; 0.183)	0.117	0.041
	0.183 (–0.164; 0.529)	0.055	0.301

B: Unstandardized coefficients; **β:** Standardized coefficients CI– confidence interval.

Model 1 and model 3 – unadjusted models; Model 2, model 4 and model 5 - adjusted for age, sex, pubertal stage, socioeconomic status, BMI, adherence to a Mediterranean dietary pattern, accelerometer wear time and daily average of MVPA.

MVPA and accelerometer wear time (models 2 and 4). However, when both cardiorespiratory fitness and muscular fitness score were included in the same model (model 5), after adjustments for aforementioned covariates, only cardiorespiratory fitness retained significance ($B = 0.093$; $p = 0.04$).

Next, we evaluated the mediating role of cardiorespiratory fitness on the association between muscular fitness and HRQoL (Fig. 1). In the first regression equation (a), muscular fitness was positively associated with cardiorespiratory fitness ($p < 0.001$). In the second equation (b), cardiorespiratory fitness was also positively associated with HRQoL ($p < 0.05$). Finally, in the third equation (c'), when muscular fitness and cardiorespiratory fitness were simultaneously included in the model, muscular fitness no longer significantly predicted HRQoL. These results suggest that the effect of muscular fitness on HRQoL was fully mediated by cardiorespiratory fitness. The Sobel test (2.30, $p \leq 0.05$) indicated a percentage of effect mediated by cardiorespiratory fitness of 74%.

As depicted in Fig. 2, adolescents, simultaneously, with high cardiorespiratory fitness and high muscular fitness showed significant higher HRQoL score when compared to those with low muscular fitness/low cardiorespiratory fitness and with those with low muscular fitness/high cardiorespiratory ($p < 0.05$ for both), after adjustments for age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, MVPA and accelerometer wear time.

Discussion

The main findings of this study suggest that both cardiorespiratory fitness and muscular fitness are positively associated with HRQoL. However, when both cardiorespiratory fitness and

muscular fitness score are included in the same model only cardiorespiratory fitness retains significance. Nevertheless, the interpretation should take into account the fact that the cut points of cardiorespiratory fitness were determined based on the cardiovascular disease risk, whereas the cut points for muscular fitness were based on percentile values. Using non parametric mediation analysis, our study demonstrates that cardiorespiratory fitness qualified as a full mediator on the association between muscular fitness and HRQoL. To our knowledge, this is the first study that examined this association. Despite this, a systematic review and meta-analysis⁴⁷ has demonstrated the superiority of combined resistance plus aerobic exercise vs aerobic exercise alone to improve cardiometabolic health outcomes in paediatric studies support the recommendations for paediatric populations to include both strength and aerobic activities for health maintenance and improvements which is in line with the American College of Sports Medicine recommendations for an appropriate public health approach.

Similar to our study, others studies have shown that cardiorespiratory fitness and muscular fitness are significantly related to physical and mental functioning of HRQoL. For example, Gu, Chang, Solmon,¹⁴ examined the association between physical activity, physical fitness and HRQoL in 201 schoolchildren aged 9–11 years and found that all components of physical fitness including cardiorespiratory fitness, muscular fitness, and BMI were significantly related to physical and mental functioning of HRQoL, except flexibility. Andersen, Natvig, Aadland, Moe, Kolotkin, Anderssen, Resaland,¹⁹ in a cross-sectional analysis that included 1129 school children, aged 10 years, from 57 schools in Norway found that cardiorespiratory fitness is positively associated with higher scores on all five KIDSCREEN-27 domains and that explosive strength in

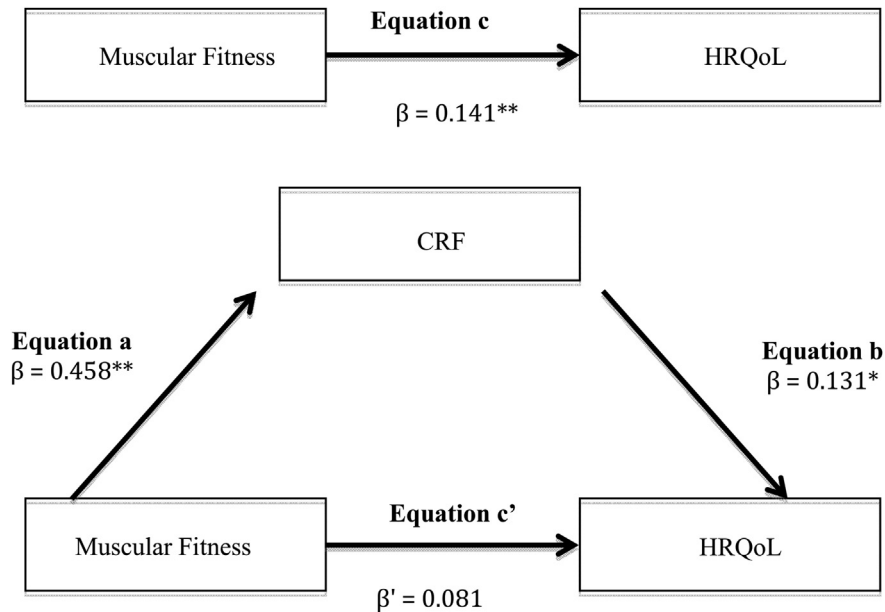


Fig. 1. Cardiorespiratory fitness (CRF) mediation models of the relationship between muscular fitness and Health related quality of life (HRQoL), after adjusting for age, sex, pubertal stage, socioeconomic status, adherence to a Mediterranean dietary pattern, daily average of MVPA and accelerometer wear time. * $P < 0.05$; ** $P < 0.001$.

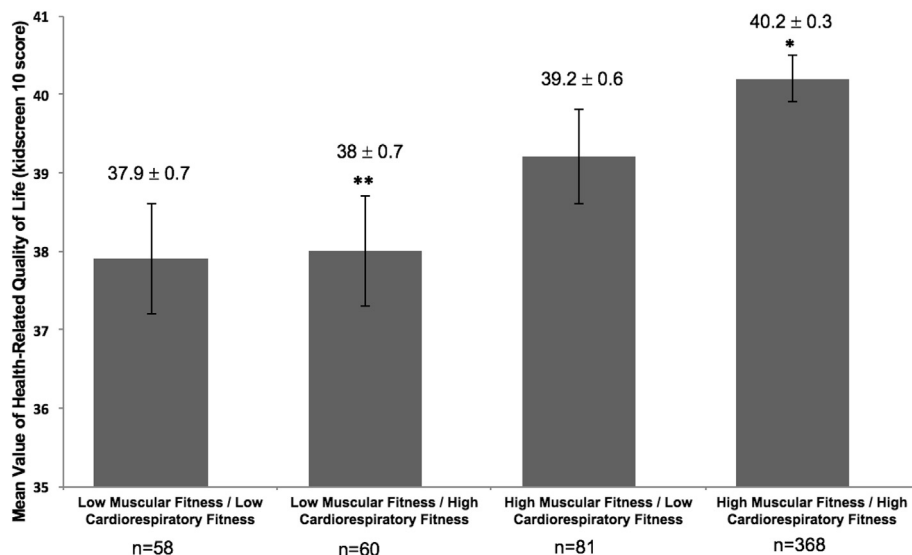


Fig. 2. Mean value of health-related quality of life (KIDSCREEN-10) stratified in groups of cardiorespiratory fitness (low or high) and muscular fitness score (low or high). * Significantly different from group High Muscular Fitness/High Cardiorespiratory Fitness, $p < 0.05$. ** Significantly different from group High Muscular Fitness/High Cardiorespiratory Fitness, $p < 0.05$. $\eta^2 = 0$.

the lower body was positively associated with higher autonomy and parent scores. Conversely, the Health Behavior in School-Aged Children study of Portuguese adolescents showed that self-reported cardiorespiratory fitness levels, but not muscular fitness, were positively and significantly associated with HRQoL.²⁰ Morales, Sánchez-López, Moya-Martínez, García-Prieto, Martínez-Andrés, García, Martínez-Vizcaíno¹³ provided the primary evidence of the relationship between fitness and HRQoL in 1158 Spanish schoolchildren aged 8–11 years and found that the association between being overweight and HRQoL almost disappeared when the analysis was controlled for cardiorespiratory fitness and muscular fitness. In that study, cardiorespiratory fitness and muscular fitness

were associated with better scores in the dimensions of physical well-being. In boys, higher levels of cardiorespiratory fitness were associated with better scores for physical well-being and social support of peers; in girls, cardiorespiratory fitness was associated with physical well-being, self-perception, social acceptance, and overall KIDSCREEN-10 index.¹³ Furthermore, in boys, muscular fitness was also associated with social acceptance and social support of peers. In girls, muscular fitness was also associated with KIDSCREEN-10 index.¹³ According to Riiser, Ommundsen, Småstuen, Løndal, Misvær, Helseth,⁴⁸ KIDSCREEN 10 does not allow for analyses of dimensions of HRQoL. Even so, the contribution of cardiorespiratory fitness on overall HRQoL may emphasize the

importance of physical performance for well-being. Evidence suggests that improvements in cardiorespiratory fitness have a positive effect on the psychological well-being of children and adolescents.^{49,50}

As cardiorespiratory fitness is strongly and positively associated with physical activity, intervention programs aimed at enhancing physical activity and fitness levels of the youth population may benefit their cardiorespiratory fitness and consequently, improve their health perception and well-being.^{51,52} Thus, this is of great value to public health and an important subject of research.

One factor known to influence perceived health and well-being among adolescents is body image.⁵³ There is some research showing associations between lower levels of cardiorespiratory fitness and body dissatisfaction.⁵⁴ According to Neumark-Sztainer, Paxton, Hannan, Haines, Story,⁵⁵ body dissatisfaction is shown to be positively related to lower exercise rates in both boys and girls.

Another variable that may explain the potential relationship between cardiorespiratory fitness and HRQoL is exercise motivation. Self-determined motivation for physical activity and exercise has been positively associated with both HRQoL and exercise behavior in adolescents.^{48,56,57} According to self-determination theory, people can be intrinsically and extrinsically motivated, as well as motivated in their regulations towards physical activity and exercise.⁴⁸

Our ANCOVA results suggest that both cardiorespiratory fitness and muscular fitness may play a role on the HRQoL of adolescents after adjustment for several confounders. Indeed, adolescents with high cardiorespiratory fitness and high muscular fitness showed better HRQoL with significant differences between groups. Previous research investigating the relationship between physical fitness and health outcomes has mainly focused on cardiorespiratory fitness; however, recent studies have shown that muscular fitness is also favorably associated with health benefits in adolescents.^{32,33} Furthermore, children with high levels of cardiorespiratory fitness usually show higher physical activity levels later in life,^{58,59} improved academic performance, as well as improved inhibitory control (which allows children to better regulate their behavior), attention, emotions and academic performance,^{60–65} and leads to favorable structural and functional neuronal adaptations.⁶⁶

Recently, the findings of Ortega, Silventoinen, Tynelius, Rasmussen⁶⁷ in a study involving 1,142,599 Swedish male adolescents, aged 16–19 years, suggested that high muscular fitness had a 20–30% lower risk of early death from suicide and was 15–65% less likely to have any psychiatric diagnosis, such as schizophrenia or mood disorders, showing that muscular strength is inversely and independently associated with death from suicide.

Some limitations of the present study should be recognized. First, this is a cross-sectional study, which does not allow us to establish causality. Second, we used a sum score from the Kidscreen-10 questionnaire, which does not permit for analyses of the dimensions of HRQoL, which is verified in extended versions of this scale (27- and 52-items). Strengths of this study include the novelty of the analyses of combined associations of cardiorespiratory fitness and muscular fitness with HRQoL in adolescents. Furthermore, is the use of a valid health-related fitness battery²⁷ for physical fitness assessment, which can be administered in school settings where a large number of participants can be tested simultaneously, thus enhancing participant motivation and making it a valuable tool for routinely measuring physical fitness in youth.

Conclusions

The present study suggests that the combination of both high cardiorespiratory fitness and muscular fitness is synergistically associated with better HRQoL in a sample of Portuguese

adolescents.

From a public health perspective, our results underline the importance of promoting cardiorespiratory fitness and muscular fitness in programs aiming at improving adolescent's health and well-being. Further data are needed to replicate these findings using longitudinal designs.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jesf.2019.01.002>.

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Conflicts of interest

None declared.

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