Association of aerobic capacity and muscular strength with health-related quality of life in adolescents: A school-based cross-sectional study

Asociación de la capacidad aeróbica y la fuerza muscular con la calidad de vida relacionada con la salud en adolescentes: Un estudio transversal basado en la escuela

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Abstract

Background: The independent associations of aerobic capacity and muscular strength on health-related quality of life (HRQoL), when mutually adjusted, remain understudied, particularly in adolescents.
Aim: To examine the association between aerobic capacity, muscle strength, and HRQoL in adolescents.
Methods: A cross-sectional design was employed, including 202 Brazilian adolescents. Aerobic capacity was assessed using the PACER test and categorized into "healthy zone", "needs improvement", and "at risk". Muscle strength was evaluated through field tests, including the 90º push-up, and categorized as "healthy zone" or "needs improvement". HRQoL was measured using the validated KIDSCREEN-27 questionnaire. A generalized gamma regression model was used to estimate coefficients (β) and 95% confidence intervals for HRQoL domains, adjusting mutually for aerobic capacity and muscle strength as predictors.
Results: In the physical domain, adolescents with aerobic capacity in the healthy zone (β=11.2; p<0.001) and needs improvement category (β=8.8; p=0.007) scored higher than those in the at-risk zone. Similarly, those with muscle strength in the healthy zone scored higher than in the needs improvement category (β=6.6; p=0.012). In the psychological domain, adolescents with aerobic capacity in the healthy zone (β=8.1; p=0.002) and needs improvement (β=5.9; p=0.027) also had higher scores than those at risk, as did those with healthy muscle strength compared to needs improvement (β=4.5; p=0.043). No significant associations were found in other domains (p>0.05).
Conclusion: Adequate levels of aerobic capacity and muscle strength are positively associated with HRQoL, particularly in the physical and psychological well-being domains among adolescents.

Keywords

Adolescent health; Cardiorespiratory fitness; HRQoL; Physical fitness; Psychological well-being.

Resumen

Introducción: Las asociaciones independientes de la capacidad aeróbica y la fuerza muscular sobre la calidad de vida relacionada con la salud (CVRS), cuando se ajustan mutuamente, siguen siendo poco estudiados, especialmente en adolescentes.
Objetivo: Examinar la asociación entre la capacidad aeróbica, la fuerza muscular y la CVRS en adolescentes. Metodología: Se empleó un diseño transversal que incluyó a 202 adolescentes brasileños. La capacidad aeróbica se evaluó mediante la prueba PACER y se clasificó en "zona saludable", "necesita mejorar" y "en riesgo". La fuerza muscular se evaluó mediante pruebas de campo, incluyendo la prueba de flexión de brazos a 90º, y se clasificó como "zona saludable" o "necesita mejorar". La CVRS se midió utilizando el cuestionario validado KIDSCREEN-27. Se utilizó un modelo de regresión gamma generalizada para estimar los coeficientes (β) e intervalos de confianza del 95% para los dominios de CVRS, ajustando mutuamente para la capacidad aeróbica y la fuerza muscular como predictores.
Resultados: En el dominio físico, los adolescentes con capacidad aeróbica en la zona saludable (β=11,2; p<0,001) y necesita mejorar (β=8,8; p=0,007) obtuvieron puntajes más altos que aquellos en la zona de riesgo. De manera similar, los adolescentes con fuerza muscular en la zona saludable obtuvieron puntajes más altos que en necesita mejorar (β=6,6; p=0,012). En el dominio psicológico, los adolescentes con capacidad aeróbica en la zona saludable (β=8,1; p=0,002) y necesita mejorar (β=5,9; p=0,027) también mostraron mejores puntajes que en la zona de riesgo, al igual que aquellos con fuerza muscular saludable frente a necesita mejorar (β=4,5; p=0,043). No hubo asociaciones significativas en otros dominios (p>0,05). Conclusiones: Niveles adecuados de capacidad aeróbica y fuerza muscular están positivamente asociados con la CVRS, especialmente en los dominios de bienestar físico y psicológico en adolescentes.

Palabras clave

Salud adolescente; Condición cardiorrespiratoria; CVRS; Aptitud física; Bienestar psicológico.

Introduction

Adolescence represents a critical period in human development, characterized by profound transformations in physical, emotional, and social dimensions (Best & Ban, 2021). During this phase, individuals face numerous health challenges, including a notable increase in the prevalence of mental health issues such as anxiety disorders and depression (Brasil Costa et al., 2024; Paricahua-Peralta et al., 2024; Rosa et al., 2023). These conditions are intricately linked with health-related quality of life (HRQoL), exerting lasting effects on overall well-being across the lifespan (Rasalingam et al., 2021; Weitkamp et al., 2013).

HRQoL is influenced by various factors, including socio-cultural aspects of the individual's environment, psychosocial factors, economic indicators, emotional and environmental influences, as well as the intrinsic lifestyle of each individual (Soares et al., 2011; Vella et al., 2015; X. Y. Wu et al., 2017). Physically active adolescents demonstrate better physical and mental health conditions and improved psychosocial well-being than their physically inactive peers (Janssen & LeBlanc, 2010; X. Y. Wu et al., 2017). Moreover, regular physical activity plays a fundamental role in improving physical fitness, especially aerobic capacity and muscular strength, in adolescents (J. Wu et al., 2023). Consequently, elevated levels of physical fitness are associated with an improved quality of life, positively impacting physical, psychological, and social well-being (da Costa et al., 2023).

Previous studies have highlighted the positive association between aerobic capacity, muscular strength, and HRQoL in children and adolescents (Bermejo-Cantarero et al., 2021; da Costa et al., 2023; Evaristo et al., 2019; Marković et al., 2022). The meta-analysis conducted by Bermejero-Cantero et al. (2021), which included 12 cross-sectional studies with 10,712 children and adolescents aged 4 to 18 years, showed that both aerobic capacity and muscular strength are positively associated with HRQoL, especially in the domains of physical well-being, psychological well-being, and interpersonal relationships. However, most of these studies analyzed aerobic capacity and muscular strength independently, leaving the impact of a mutually adjusted approach to these fitness components on HRQoL unclear. Moreover, the studies included in this meta-analysis mostly consisted of research with children, and those involving adolescents were mixed with children, making it challenging to analyze age moderation.

Therefore, this study aims to examine the mutually adjusted association between aerobic capacity and muscular strength and HRQoL in school-aged adolescents. We hypothesize that both aerobic capacity and muscular strength are independently associated with HRQoL in this population.

Method

Study design

This was a school-based observational study with a cross-sectional design. Data collection was conducted between June and October 2023, at the Federal Institute of Education, Science and Technology of Paraíba (IFPB), in Sousa, Brazil. Sousa is a city located in the interior of the state of Paraíba, with approximately 70 thousand inhabitants, situated in the semi-arid region of the northeastern backlands. The study adhered to the STROBE statement (von Elm et al., 2014).

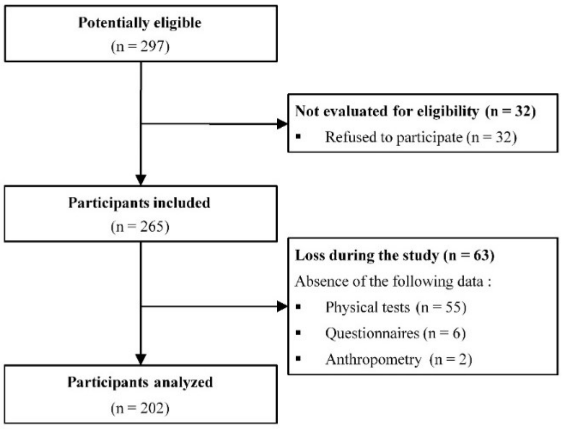
Ethical considerations

This study was approved by the Research Ethics Committee of the Institute of Higher Education of Paraíba - UNIESP (CAAE: 49857421.0.0000.5184) and conducted in accordance with the Declaration of Helsinki and the Brazilian National Health Council Resolution No. 466/2012. All participants provided signed informed consent. For participants under 18 years old, the Informed Consent Form was signed by their parents or legal guardians, in addition to the Assent Form signed by the adolescents themselves. For participants aged 18 or 19 years, only the signed Informed Consent Form was required.

Participants

The participants in the study were selected from high school students enrolled at the IFPB in Sousa. This institution is a federal public school that offers integrated high school with technical courses, including agriculture and livestock farming, agroindustry, environment, and informatics, all full-time (morning and afternoon). The research was strategically promoted in classrooms and through electronic and social media platforms widely used by students. The sample consisted of 202 adolescents from the mentioned educational institution (see Figure 1). The inclusion criteria were as follows: age between 14 and 19 years old; absence of any physical conditions that may hinder the execution of physical tests; medical fit for physical activity according to institutional medical evaluation; absence of previously diagnosed physical, psychiatric, or cognitive disorders. The exclusion criteria were as follows: voluntary withdrawal; absence of data included in the study. Written informed consent was provided by all volunteers, along with their respective legal guardians.

Figure 1. Flowchart of the study sample.



Source: Own authorship

Procedures

A team of properly trained researchers conducted data collection in the physical assessment laboratory of the Department of Physical Education at IFPB, as well as in the covered sports court. After disclosure and recruitment, volunteer participants underwent an initial screening to verify eligibility criteria. They then completed the questionnaires face-to-face, with one examiner assigned to each participant. Subsequently, anthropometric measurements were taken. Finally, participants performed the muscular strength tests (trunk lift, 90º push-up, and curl-up tests; in this sequence) and the progressive aerobic cardiovascular endurance run (PACER), both from the FitnessGram.

Aerobic capacity

Aerobic capacity was assessed using the PACER test (The Cooper Institute, 2013). Participants were encouraged to run continuously back and forth on an indoor gym floor, covering 20 meters at an increasing pace every minute. A prerecorded audio guided the cadence, and the course was marked with cones. Participants ran to the line at the sound signal and returned to the starting point. The test continued until they could not reach the line within the signal time on two non-consecutive attempts or chose to voluntarily stop. The recorded score was the total number of completed laps, with each lap equivalent to 20 meters. Maximum oxygen consumption (VO_2max) was estimated using a validated equation for adolescents based on the number of laps achieved in the test, age, and body mass index (Mahar et al., 2018). VO_2max values were categorized according to the FitnessGram table, considering sex and age, into “healthy zone”, “needs improvement”, and “health risk zone”.

Muscle strength

Muscular strength was assessed by three specific FitnessGram tests: the 90º push-up, curl-up, and trunk lift tests (The Cooper Institute, 2013). (a) The 90º push-up test assessed upper body strength and endurance, with participants aiming for as many 90° arm flexions as possible at a steady pace. Instructions were given via audio for a cadence of 20 flexions per minute. Participants began in a face-down position on a mat, hands below or slightly wider than the shoulders, fingers extended, and legs straight. They pressed the mat with their arms until fully extended, then lowered their body until the elbows reached a 90° angle. The test concluded after a second form correction, voluntary exhaustion, or extreme discomfort, with the score based on completed 90° flexions. (b) The curl-up test assessed abdominal strength and endurance. Participants aimed to complete as many curl-ups as possible, up to a maximum of 75, at a specified pace guided by an audio recording. Mats and a measuring strip were used for the test. Participants lay on their backs with knees bent, feet flat on the floor, and arms straight beside them with palms facing down. They slowly curled upwards until their head touched the mat and then returned to the starting position. The test was stopped if participants couldn't continue, completed 75 curl-ups, or had to correct their form twice. Scores were based on the number of completed curl-ups. (c) The trunk lift test assessed back muscle strength and flexibility. Participants lay face down on a mat and lifted their upper body off the floor, aiming for a maximum height of 12 inches. They held this position while a ruler was placed on the floor to measure the distance from the floor to their chin. Two attempts were allowed, with the highest score recorded in inches. The results of all muscle strength tests were categorized according to the FitnessGram table, considering sex and age, into “healthy zone” and “needs improvement”.

Health-related quality of life

The HRQoL was assessed using the KIDSCREEN-27 questionnaire (Ravens-Sieberer et al., 2007). This questionnaire is validated for Brazilian children and adolescents (Farias Júnior et al., 2017). The KIDSCREEN-27 consists of 27 questions distributed across five domains: physical well-being, psychological well-being, parent relations and autonomy, social support and peers, and school environment. In each question, the participant is asked to select the option that best reflects how they felt in the previous week. Each question is rated on a five-point Likert scale, considering intensity (“not at all” to “extremely”) or frequency (“never” to “always”). Scores range from 0 to 100 points, with higher scores indicating higher levels of quality of life. The results were expressed in scores for each domain and for the overall score.

Other variables

The information used to describe the sample or as covariates in the multiple models was collected through the Global School-based Student Health Survey (World Health Organization, 2021), covering data on education, demographics, social aspects, and moderate-to-vigorous physical activity (MVPA), as well as standardized anthropometric measurements. The level of MVPA was classified as physically inactive (<60 min/day) or physically active (60+ min/day) (World Health Organization, 2020). Body weight and height were measured using an electronic scale (W200, Welmy, Brazil) and a portable stadiometer (ES2060, Sanny, Brazil), respectively. Body mass index (BMI) was calculated by dividing body weight by height squared (kg/m^2). The BMI z-score classification for each volunteer was performed according to age and sex, using the World Health Organization reference table (WHO Multicentre Growth Reference Study Group, 2006).

Statistical analysis

Continuous sample characteristic variables were presented as mean, standard deviation, or 95% percentile bootstrap confidence interval (CI), while categorical variables were described as absolute and relative frequencies. In this study, analyses were performed using three models:
a) Bivariate models (unadjusted models): These models assessed the association between each physical fitness predictor (either aerobic capacity or muscular strength) and each HRQoL outcome using the generalized gamma model. In this analysis, only one physical fitness predictor was considered in each model.
b) Multiple models (non-mutually adjusted association): These models examined the relationship between each physical fitness predictor (aerobic capacity or muscular strength) and each HRQoL outcome, adjusting for confounding variables, including age, ethnicity, area of residence, BMI, and MVPA, using the generalized multiple gamma model. In this case, each fitness predictor was considered individually in the model.
c) Multiple models (mutually adjusted association): These models included both aerobic capacity and muscular strength in the same analysis and examined their independent associations with each HRQoL outcome, adjusting for the same confounding variables, using the generalized multiple gamma model. In these analyses, independent association refers to the separate contribution of each predictor to

HRQoL, with both predictors included in the model mutually, allowing us to evaluate their independent associations on HRQoL.
Model assumptions were evaluated, including multicollinearity. Sex variable was not included in adjusted models due to multicollinearity with physical fitness variables. Robust variance matrix was used in all analyses. Model results were expressed as estimated marginal means (EMM), estimated coefficients (β), and 95% Wald CI. The Omnibus test was utilized to evaluate the goodness of fit of the models. The gamma distribution model was determined by distribution of the residuals in the Q-Q plot and/or by the lowest value of the Akaike Information Criterion. Additionally, the generalized linear model and Fisher's exact test were used to compare the sample characteristics between physical fitness categories. A value of $p<0.05$ was considered statistically significant for all analyses. All analyses were conducted using SPSS software version 27 (IBM Corp., Armonk, NY).

Results

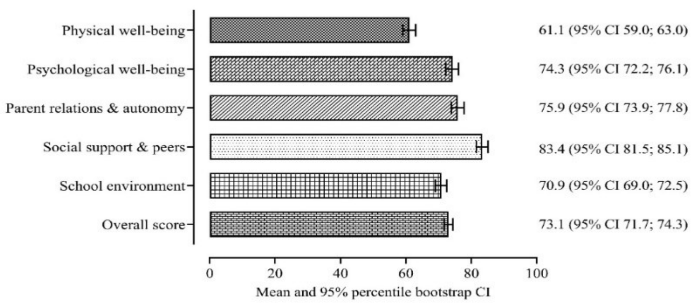
Table 1 presents the participant characteristics. The majority were female (64.4%), 47.5% were brown/black, and 52.5% were white/yellow, with most residing in urban areas (70.3%). Most adolescents had a weight within the ideal range (72.3%) and were physically inactive (69.3%). Additionally, 74.8% were in the health risk zone for aerobic capacity, 80.7% needed to improve upper body strength, 80.2% needed to improve abdominal strength, and 86.6% needed to improve trunk extensor strength.

Table 1. Characteristics of study participants (n = 202)

Variables	Mean ± SD or n (%)
Age, years	16.6 ± 1.2
Girls	130 (64.4)
Boys	72 (35.6)
Brown/Black	96 (47.5)
White/Yellow	106 (52.5)
Living in an urban area	142 (70.3)
Living in a rural area	60 (29.7)
Height, m	1.65 ± 0.09
Weight, kg	61.4 ± 12.4
Body mass index, kg/m2	22.5 ± 3.9
Normal weight	146 (72.3)
Overweight	46 (22.8)
Obesity	10 (5.0)
Physically active	62 (30.7)
Physically inactive	140 (69.3)
Aerobic capacity	
Healthy zone	31 (15.3)
Needs Improvement	20 (9.9)
Health risk zone	151 (74.8)
Upper Body Strength	
Healthy zone	39 (19.3)
Needs Improvement	163 (80.7)
Abdominal Strength	
Healthy zone	40 (19.8)
Needs improvement	162 (80.2)
Trunk Extensor Strength	
Healthy zone	25 (12.4)
Needs improvement	175 (86.6)

Continuous data are presented as mean ± standard deviation (SD), while categorical data are expressed as absolute (n) and relative frequencies (%).

Figure 2. Means and 95% percentile bootstrap confidence intervals (CI) of the domains and overall score of health-related quality of life (HRQoL) in school adolescents (n = 202).



Source: Own authorship

Figure 2 presents the mean values of the domains and the overall score of HRQoL of the participants. The mean value for the physical well-being domain was 61.1 (95% CI 59.0; 63.0), for psychological well-being was 74.3 (95% CI 72.2; 76.1), for parent relations and autonomy was 75.9 (95% CI 73.9; 77.8), social support and peers was 83.4 (95% CI 81.5; 85.1), school environment was 70.9 (95% CI 69.0; 72.5), and the overall score was 73.1 (95% CI 71.7; 74.3).

Table 2 (and Table S1) present the results of the non-mutually adjusted models of physical fitness predictors and each HRQoL outcome. Regarding the adjusted analyses, only aerobic capacity and upper body muscular strength showed positive associations with physical well-being, psychological well-being, and overall score (p<0.05). Participants with aerobic capacity in the healthy zone and those needing improvement exhibited higher values of physical and psychological well-being (healthy zone only) compared to their peers in the health risk zone (p<0.05). Similarly, participants with upper body muscular strength in the healthy zone showed higher values of physical and psychological well-being compared to those needing improvement (p<0.05). Regarding the overall HRQoL score, only participants with aerobic capacity in the health zone had a higher score compared to those in the health risk zone (p<0.05). Abdominal strength and trunk extensor strength predictors were not associated with any HRQoL outcome (p>0.05).

Table 2. Non-mutually adjusted associations of aerobic capacity and muscular strength with health-related quality of life in school adolescents (n = 202).

	Physical well-being		Psychological well-being		Parent relation & autonomy		Social support & peers		School environment		Overall score	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Unadjusted models												
Aerobic capacity												
Healthy zone	12.7 (8.1, 17.4)	<0.001	7.8 (3.0, 12.6)	0.001	2.9 (-1.5, 7.3)	0.197	-2.3 (-7.6, 3.1)	0.405	1.9 (-3.4, 7.3)	0.483	5.1 (1.8, 8.3)	0.002
Needs improvement	10.3 (3.1, 17.5)	0.005	6.0 (0.9, 11.0)	0.021	0.3 (-6.3, 6.8)	0.937	0.0 (-5.2, 5.3)	0.988	-0.9 (-6.4, 4.5)	0.743	3.4 (-0.9, 7.7)	0.120
Health risk zone	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Upper body strength												
Healthy zone	9.1 (3.8, 14.4)	0.001	5.2 (1.1, 9.4)	0.014	3.7 (-0.4, 7.8)	0.075	-2.3 (-7.5, 2.9)	0.394	-0.6 (-4.9, 3.7)	0.786	3.6 (0.5, 6.7)	0.023
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Abdominal strength												
Healthy zone	-1.2 (-5.9, 3.5)	0.617	0.0 (-4.7, 4.8)	0.990	-0.9 (-5.2, 3.5)	0.695	0.2 (-4.2, 4.6)	0.941	-2.5 (-7.1, 2.1)	0.293	-0.8 (-4.0, 2.4)	0.631
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Trunk extensor strength												
Healthy zone	-2.4 (-8.3, 3.5)	0.416	-4.5 (-10.7, 1.7)	0.157	-0.1 (-4.6, 4.4)	0.969	1.1 (-3.4, 5.5)	0.633	-1.9 (-6.7, 2.9)	0.427	-1.8 (-5.2, 1.7)	0.310
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Adjusted models[a]												
Aerobic capacity												
Healthy zone	12.2 (7.0, 17.4)	<0.001	7.1 (2.1, 12.1)	0.005	1.5 (-3.3, 6.3)	0.540	-2.3 (-7.8, 3.1)	0.403	0.9 (-5.1, 6.9)	0.766	4.2 (0.7, 7.7)	0.018
Needs improvement	9.0 (2.0, 16.0)	0.012	4.9 (-0.4, 10.2)	0.069	-0.1 (-7.1, 6.9)	0.981	-1.3 (-6.3, 3.8)	0.627	-0,9 (-6.7, 4.9)	0.763	2.6 (-1.9, 7.1)	0.257
Health risk zone	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Upper body strength												
Healthy zone	7.4 (2.2, 12.6)	0.005	5.0 (0.9, 9.2)	0.018	3.1 (-1.3, 7.5)	0.164	-3.1 (-8.4, 2.2)	0.256	0.0 (-4.1, 4.1)	0.996	3.1 (-0.2, 6.3)	0.069
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Abdominal strength												
Healthy zone	-0.1 (-4.8, 4.6)	0.963	0.1 (-4.6, 4.8)	0.966	-0.2 (-4.1, 4.4)	0.946	-0.1 (-4.8, 4.7)	0.982	-2.4 (-6.9, 2.0)	0.285	-0.5 (-3.6, 2.7)	0.766
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Trunk extensor strength												
Healthy zone	-1.6 (-7.5, 4.3)	0.597	-4.1 (-10.0, 1.8)	0.178	-0.3 (-4.7, 4.2)	0.905	1.3 (-3.2, 5.7)	0.570	-1.3 (-6.3, 3.8)	0.622	-1.4 (-4.7, 2.0)	0.417
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	

The data are presented with coefficient estimates (β) and 95% confidence intervals (CI). Values in bold indicate models with p < 0.05. (a) Models were adjusted for age, ethnicity, area of residence, body mass index, and moderate-to-vigorous physical activity. All statistically significant models showed satisfactory goodness-of-fit (p < 0.05 on the Omnibus test).

Table 3. Mutually adjusted associations of aerobic capacity and muscular strength with health-related quality of life in school adolescents (n = 202).

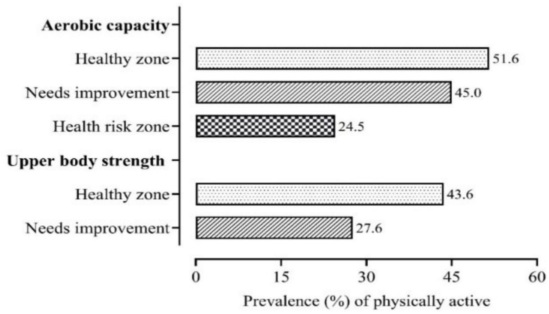
	Physical well-being		Psychological well-being		Parent relation & autonomy		Social support & peers		School environment		Overall score	
	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p	β (95% CI)	p
Models without covariates[a]												
Aerobic capacity												
Healthy zone	12.1 (7.4, 16.8)	<0.001	7.7 (2.8, 12.5)	0.002	2.5 (-2.0, 7.0)	0.276	-2.2 (-7.3, 3.0)	0.408	2.0 (-3.4, 7.3)	0.471	4.9 (1.5, 8.2)	0.004
Needs improvement	9.6 (2.7, 16.5)	0.006	5.6 (0.7, 10.5)	0.024	-0.1 (-6.5, 6.3)	0.970	0.2 (-5.1, 5.5)	0.939	-0.9 (-6.3, 4.6)	0.759	3.1 (-1.1, 7.3)	0.144
Health risk zone	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Upper body strength												
Healthy zone	8.0 (2.7, 13.3)	0.003	4.8 (0.7, 9.0)	0.023	3.5 (-0.6, 7.6)	0.097	-2.2 (-7.3, 2.9)	0.391	-0.7 (-5.0, 3.7)	0.764	3.2 (0.0, 6.4)	0.047
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Models with covariates[b]												
Aerobic capacity												
Healthy zone	11.9 (6.5, 17.2)	<0.001	7.0 (1.9, 12.0)	0.007	1.2 (-3.7, 6.1)	0.634	-2.2 (-7.6, 3.1)	0.413	0.9 (-5.1, 6.9)	0.767	4.0 (0.5, 7.6)	0.026
Needs improvement	8.6 (2.1, 15.1)	0.010	4.7 (-0.4, 9.8)	0.073	-0.3 (-7.1, 6.5)	0.925	-1.1 (-6.3, 4.0)	0.669	-0.9 (-6.7, 4.9)	0.763	2.4 (-1.9, 6.8)	0.272
Health risk zone	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	
Upper body strength												
Healthy zone	6.7 (1.5, 11.9)	0.012	4.7 (0.6, 8.9)	0.025	3.1 (-1.4, 7.5)	0.175	-3.0 (-8.2, 2.2)	0.258	0.0 (-4.2, 4.1)	0.993	2.8 (-0.5, 6.1)	0.095
Needs improvement	0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)		0.0 (Ref.)	

The data are presented with coefficient estimates (β) and 95% confidence intervals (CI). Values in bold indicate models with p < 0.05. All statistically significant models showed satisfactory goodness-of-fit (p < 0.05 on the Omnibus test). (a) Variables included in the model: aerobic capacity and upper body strength. (b) Variables included in the model: aerobic capacity, upper body strength, age, ethnicity, area of residence, body mass index, and moderate-to-vigorous physical activity.

In the mutually adjusted association models, the results were similar to those of the non-mutually adjusted models, with only minor differences (see Table 3 and Table S2). Specifically, aerobic capacity and upper body muscular strength were positively associated with physical well-being, psychological well-being, and the overall score (p<0.05).

Figure 3 (and Tables S3 and S4) presents the prevalence of physically active individuals classified by aerobic capacity and muscle fitness. A significant association was found between aerobic capacity and meeting MVPA recommendations (p=0.004). Participants with aerobic capacity categorized as in the healthy fitness zone (51.6%) and needing improvement (45.0%) exhibited a higher prevalence of meeting MVPA recommendations compared to those in the healthy risk zone (24.5%). Regarding upper body strength, there was a trend towards significance for association with meeting MVPA recommendations (p=0.081). Participants classified with upper body strength in the healthy zone (43.6%) demonstrated a higher prevalence of meeting MVPA recommendations compared to those needing improvement (27.6%).

Figure 3. Prevalence (%) of physically active individuals classified by aerobic capacity and muscle fitness among school adolescents (n = 202).



Source: Own authorship

Discussion

This study investigated the mutually adjusted associations of aerobic capacity and muscular strength with HRQoL in school adolescents. The main findings highlight the following points: (i) Higher levels of aerobic capacity and muscular strength (assessed through upper body strength) were independently and positively associated with greater physical and psychological well-being among adolescents. (ii) Adolescents with aerobic capacity in the healthy zone exhibited higher overall HRQoL scores compared to their peers in the health risk zone. (iii) Interestingly, abdominal and trunk extensor muscle strength showed no association with HRQoL outcomes within this cross-sectional cohort.

This study acknowledges the intricate relationship between physical fitness attributes and HRQoL by providing innovative evidence of independent association of aerobic capacity and muscle strength with HRQoL. It's important to note that aerobic capacity and muscular strength frequently correlate with each other; adolescents with high aerobic capacity often demonstrate greater muscular strength, and vice versa. Therefore, disentangling the independent effects of each variable on HRQoL becomes essential for a more nuanced understanding of their respective contributions and potential interplay. This enables a deeper understanding of how these physical fitness attributes influence HRQoL, thereby informing the development of more targeted and effective intervention strategies aimed at enhancing the overall health and well-being of this demographic. Furthermore, our study introduced novel insights by examining the associations of muscle strength from various body regions, highlighting that upper body strength emerges as a superior indicator of clinical prognosis compared to abdominal and trunk strength.

The positive association observed between high levels of aerobic capacity and better HRQoL among adolescents highlights the prognostic importance of aerobic capacity in promoting overall well-being in this age group. Echoing our findings, the study by Markovic et al. (2022) also identified a significant association between aerobic capacity and various domains of HRQoL, especially in the physical and psychological aspects, as well as the total score. It is plausible to suggest that increased MVPA or regular engagement in physical exercise may have contributed to this association, promoting improvements in aerobic capacity (J. Wu et al., 2023) and, consequently, in adolescents' HRQoL. Supplementary data suggests that adolescents with higher levels of aerobic capacity tended to engage in more MVPA and physical exercise. These findings corroborate international recommendations that emphasize the benefits of physical activity on adolescents' physical and mental health (World Health Organization, 2020). Additionally, self-determined motivation for exercise, whether intrinsic or extrinsic, may be a relevant factor in this association, as suggested by previous studies (Riiser et al., 2014). Taking together, our results and evidence from the literature suggest that improving aerobic capacity can provide significant benefits to adolescents, contributing to the promotion of better physical and mental health in this population.

In the present study, it was observed that adolescents with adequate levels of muscular strength, as assessed by the 90º push-up test (upper body strength), exhibit better HRQoL, especially in the domains of physical and psychological well-being. Divergent results were found in the study by Evaristo et al. (2019), which also investigated this relationship with Portuguese adolescents aged 12-18. Muscular strength lost its association with HRQoL when CRF was included in the model. Additionally, results from the meta-analysis by Bermejo-Cantarero et al. (2021) also revealed that muscular strength alone is positively associated with HRQoL in children and adolescents. However, these studies mainly assessed muscular strength through handgrip equipment. Unlike previous studies, our research employed a more practical field approach, such as the 90º push-up test as established by FitnessGram (The Cooper Institute, 2013), which does not require specialized equipment. This methodological choice allows for a closer assessment of real-world contexts, particularly within scholarly environments, and offers a more accessible application.

Studies suggest that adolescents with higher muscular strength have healthier bone health and body composition, as well as a lower risk of cardiometabolic diseases (Lang et al., 2018; Smith et al., 2014). These physical benefits contribute to an enhanced perception of physical well-being and, consequently, overall quality of life (Bermejo-Cantarero et al., 2021). Physical exercise, especially strength training, is effective in improving muscular strength and other health indicators, while also providing psychological benefits to adolescents (Barahona-Fuentes et al., 2021; World Health Organization, 2020). Furthermore, exercise promotes the release of neuropeptides, such as serotonin and endorphins, which contribute to psychological health by reducing symptoms of anxiety and depression (Biddle et al., 2019; Ortega et al., 2008). Thus, muscular strength emerges as an essential factor in promoting the physical and psychological well-being of adolescents, reinforcing the prognostic importance of this physical attribute in the adolescent population.

Our study revealed a lack of significant association between aerobic capacity, muscular strength, and three specific domains of HRQoL: autonomy and relationship with parents, social support, and school environment. Our findings are consistent with previous studies conducted with adolescents, which also did not identify significant associations between aerobic capacity, muscular strength, and the domains of autonomy and relationship with parents, social support, and school environment (Bermejo-Cantarero et al., 2021; Marković et al., 2022). This absence of association may be partially explained by the diversity of the adolescents, which included students from various residential areas (cities and states), genders, and socioeconomic classes. This diversity may have led to divergent interpretations of the questionnaire items. Additionally, the emotional state of the adolescents may have influenced these results, highlighting the complexity of the relationship between physical fitness and quality of life in such a diverse context.

The results of this study underscore the importance of promoting programs and public interventions aimed at improving the physical fitness of adolescents. Physical exercise plays a crucial role in developing both aerobic capacity and muscular strength (J. Wu et al., 2023). Additionally, promoting playful, planned, and structured physical activities using resources such as mats, bars, ropes, and exercises involving body weight and running can significantly contribute to physical fitness development.

The study presents weaknesses and strengths that should be considered. Firstly, due to its cross-sectional nature, we cannot infer causality. Data were obtained from a sample of Brazilian high school students from a federal public school, which may limit the generalization of the results. It was not possible to investigate sex differences due to the low sample power of males. However, the study innovates by mutually analyzing the associations between aerobic capacity and muscular strength as predictors of HRQoL in school adolescents, using widely used and validated instruments. Additionally, the study's strengths include the use of a well-defined and homogenous sample, the application of validated tools for physical fitness and quality of life assessment, and the contribution to understanding the interplay between physical fitness and quality of life in adolescents. To draw more robust conclusions, longitudinal studies with larger and more diversified samples in terms of age, sex, and physical fitness, as well as the inclusion of other variables that may influence quality of life, are needed.

Conclusions

In conclusion, the findings of this study have revealed a positive independent association between aerobic capacity and muscular strength with HRQoL among adolescents. Adolescents with higher levels of aerobic capacity demonstrate higher HRQoL, particularly in physical and psychological well-being domains. Likewise, adolescents demonstrating greater muscular strength, specifically in upper body strength, exhibited higher HRQoL, especially in physical and psychological well-being domains.

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Conflict of interest

The authors declare that there are no conflicts of interest.

Supplementary data

The supplementary data is available through this link:
https://osf.io/bj8y2/?view_only=ab53ebad4f6c4b06b69fbb99fcf62add

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