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Independent and Joint Associations of Physical Fitness and Mental Health Symptoms in University Students: A Cross-sectional Analysis

Fitness and Mental Health in University Students

Maria E. A. Guimarães [1]*, Debora Tornquist[2], Eduarda Bitencourt dos Santos[2,] Julia Amaral Teixeira[2], Aline Josiane Waclawovsky[1,2], Juliana Dias [1], Gabriela Remor[5], Gabriel Peinado Costa[6], Átila Alexandre Trapé[6], Laura Santos Castro[10], Isadora Fernanda de Freitas Cunha[10] , Pedro Moraes Dutra Agricola[14], Thiago Sousa Matias[5], Ana Carolina Guidorizzi Zanetti[7,8,90], Danilo Rodrigues Pereira da Silva[10], Nicole Leite Galvão-Coelho[11,12], Daniel Alvarez Pires[13], Andrea Camaz Deslandes[1], Felipe Barreto Schuch[1,3,4]

[1] Federal University of Rio de Janeiro, Psychiatry Institute, Rio de Janeiro, RJ, Brazil.

[2] Postgraduate Program of Movement and Rehabilitation Sciences, Federal University of Santa Maria, Santa Maria, RS, Brazil.

[3] Department of Sports Methods and Techniques, Federal University of Santa Maria, Santa Maria, RS, Brazil.

[4] Faculty of Health Sciences, Universidad Autónoma de Chile, Providencia, Chile.

[5] Department of Physical Education, Federal University of Santa Catarina, Florianópolis, SC, Brazil.

[6] School of Physical Education and Sport of Ribeirão Preto, University of São Paulo, Ribeirão Preto, SP, Brazil.

[7] Department of Psychiatric Nursing and Human Sciences, University of São Paulo, São Paulo, SP, Brazil.

[8] WHO Collaborating Centre for Nursing Research Development, Ribeirão Preto, SP, Brazil.

[9] Collaborating Centre for Nursing Research Development, Ribeirão Preto, SP, Brazil.

[10] Departament of Physical Education, Federal University of Sergipe, SE, Brazil.

[11] Laboratory of Hormone Measurement and Postgraduate Program of Psychobiology, Brazil.

[12] Department of Physiology and Behavior, Federal University of Rio Grande do Norte, Natal, RN, Brazil.

[13] Graduate Program in Human Movement Sciences, Federal University of Pará, Castanhal, PA, Brazil.

[14] Post-Graduate Program on Mental Health and Behavioural Sciencies (FMRP/USP), SP, Brazil.

Corresponding Author:
Maria Eduarda Guimaraes
Universidade Federal de Santa Maria
Av. Roraima nº 1000 Cidade Universitária
Camobi, Santa Maria - RS, 97105-900.
mariaeadornes@gmail.com

ABSTRACT

The relationship between physical fitness and mental health is recognized, with evidence suggesting that physical fitness components may offer added protection against mental health issues. However, whether this applies to university students, who commonly experience anxiety and depression, is less clear. This cross-sectional study explores the association of physical fitness with anxiety and depression symptoms in ≥18-year-old students from seven Brazilian universities. Mental health was evaluated using the Diagnostic and statistical manual of mental disorders (DSM-5), the Patient Health Questionnaire-9 (PHQ-9), and the Generalized Anxiety Disorder-7 (GAD-7). Physical fitness was assessed via handgrip strength, vertical jump, and the 20m Shuttle-Run test, with students classified into low or high fitness based on genderspecific medians .. Poisson regression with robust variance was used to analyze the relationship between physical fitness, anxiety, and depression. The sample included 199 students (52.6% women; median age=21). Those scoring

above the median in 2 or 3 physical fitness tests had lower rates of depressive symptoms (PR= 0.53; 95%Confidence Interval (CI): 0.33 – 0.84) compared to those with 0 or 1 tests. Higher jump height also corresponded with reduced depression risk (PR=0.65; 95%CI: 0.44–0.97) and lower co-occurrence of depression and anxiety (Adjusted PR = 0.55; 95%CI = 0.31 - 0.99). 2 or 3 tests above the median corresponded to a decreased likelihood of co-ocurrence of anxiety and depressive symptoms (PR= 0.43; 95%CI: 0.26 – 0.71). No significant association was found between physical fitness and anxiety alone. Thus, higher physical fitness was associated with fewer depressive symptoms among university students.

Keywords: Physical fitness; Depression; Anxiety; University students.

INTRODUCTION

Emerging adulthood is the peak period for the onset of most mental health problems, such as anxiety and depression[1]. Concomitantly, it is in this period of life when some students enroll at the university, and mental health problems are prevalent among university students[2], with estimates suggesting that 31% of the students screened positive for at least one mental disorder[2].

The university years are characterized by life changes encompassing new demands and responsibilities[3]. This transition may be associated with adopting poor lifestyle behaviors, such as reduced physical activity levels and long periods spent in sedentary behavior[4]. Some evidence suggests that university students engage in low physical activity and spend long hours sitting, resulting in low physical fitness[5]. Physical fitness is defined as a set of attributes that enable daily tasks to be performed with vigor[6] and encompasses various components, including cardiorespiratory fitness (CRF) and muscular strength. CRF is commonly assessed using tests like the 20-meter shuttle run[7], while muscular strength is evaluated using handgrip strength[8] and lower limb power[9].

Some evidence suggests that physical fitness associates with mental health outcomes, such as depression and anxiety [5,10–13]. For instance, Higher levels of CRF and muscular strength are associated with a lower risk of presenting and developing mental health problems, such as anxiety and depression, among middle-aged and older adults[5,10,11]. Among students, cross-sectional evidence suggests that those with

lower levels of estimated CRF[14] and lower strength levels[15] are more likely to present higher depressive symptoms. However, most of the evidence only evaluates one physical fitness component in isolation.

CRF and muscular strength are independently associated with mental health outcomes. However, combined CRF and muscular strength offer a more comprehensive approach to physical health and cardiometabolic and mortality risks of an individual[16], it seems that this holds true for mental health outcomes[15]. The more comprehensive approach, consisting of the two physical fitness components (CRF and muscular strength), is more strongly associated with mental health outcomes than each one of them independently among adults from the general population[10]. For instance, lower CRF and lower handgrip strength show independent incidence risk for mental health problems[15,17], but when combined, a higher effect resulting in a greater incidence risk of anxiety and depression is found (Odds Ratio (OR)=1.814; 95%CI=1.46-2.25)[10]. There is a paucity of studies investigating if these findings are also observed among university students.

Depression and anxiety are highly comorbid and some symptoms overlap[18]. Precisely, it is estimated that 45.7% of people with depression also have anxiety, and 51.7% with anxiety have depression[18]. Despite this, most of the extant evidence evaluating the relationship between physical fitness and depression and anxiety focuses only on one of these outcomes. To the best of our knowledge, one study found that higher physical fitness is associated with a lower risk of co-occurring anxiety and depression (OR=1.48; 95%CI=1.30-1.69, OR=1.38; 95%CI=1.31-1.45 respectively)[10]. Further, there is a paucity of studies evaluating if fitness is associated with symptoms of anxiety, depression, and the co-occurrence of them in university students.

Given the aforementioned gaps, the present study aimed to assess the independent and joint associations of physical fitness (CRF, lower limb muscular strength, and handgrip strength) and anxiety, depressive symptoms, and the co-occurrence of symptoms in a sample of university students.

METHOD

Design and study population

This cross-sectional study was developed with data from the MENTAL-UNI study. The MENTAL-UNI was a pilot study for The UNIversity Student's LIFEstyle and Mental Health Study (UNILIFE-M) cohort, a multicenter and international initiative

aimed at investigating the associations of lifestyle behaviors with mental health symptoms in university students. This study received approval from the Ethics Committees via Plataforma Brasil (CAAE: 55481422.5.1001.5346), valid for all participating study sites. This study has followed the STROBE checklist for observational studies[19].

Data collection took place from June 2022 to December 2023. Study data were collected and managed using Research Electronic Data Capture (REDCap) hosted at the Federal University of Ceará. REDCap is a secure, web-based software platform that supports data capture for research studies[22-23].

Participants

Students enrolled in included universities Universidade Federal de Santa Maria (UFSM), Universidade Federal de Santa Catarina (UFSC), da Universidade Federal do Pará (UFPA), Universidade Federal do Rio Grande do Norte (UFRN), and Universidade Federal do Sergipe (UFS), were invited to participate in an online survey. Participants were recruited through flyers distributed across campuses, face-to-face lectures, social media, and email communication. After completing the online questionnaire in the first stage, students were invited by the research team to schedule the tests through their preferred contact method (Email, WhatsApp, or other social media) as indicated in the survey.

Inclusion and exclusion criteria

University students aged 18 to 35 years, enrolled in the participating universities, who consented to take part in the survey were included. Individuals with physical conditions that could affect performance in the physical tests, such as muscular disorders, or those who were pregnant, were excluded. All participants provided their consent to both the online survey and the physical fitness evaluations. Owing to the pilot nature of this study, the researchers established a suggested sample of 50 students for each center, and no sample size calculation was conducted.

Mental health outcomes

The online survey consisted of self-assessed questionnaires on demographic information, lifestyle, and the symptoms screening tools. The mental health issues were assessed at two levels: first, all participants completed the Level 1 Symptoms

Cross-Cutting Measure from the DSM-5. For students scoring mild or more severe symptoms (≥2) for any mental health issue on the Level 1 symptom scale, the questionnaire automatically directed them to the specific Level 2 symptom scale for the symptoms presented. In this sense, individuals who had mild or more severe symptoms of anxiety on the Level 1 scale were directed to the Generalized Anxiety Disorder scale (GAD-7), and those who presented symptoms of depression on the Level 1 scale were directed to the depressive symptoms scale, the Patient Health Questionnaire 9 (PHQ-9).

The PHQ-9 is a self-reported questionnaire that assesses depressive symptoms in the previous two weeks. Its scores range from 0 to 27[22]. The GAD-7, also a self-reported questionnaire, assesses the presence of anxiety symptoms in the past two weeks. Its scores range from 0 to 21[23].

Students with anxiety and depressive symptoms were those who scored >2 on the DSM-5 tool for anxiety/depression and scored ≥10 on the PHQ-9 and/or the GAD-7. The cut-off point of ≥10 provides a sensitivity of 95% and specificity of 67% for the PHQ-9 scale[24] and an 87% sensitivity and 78% specificity for the GAD-7 scale[24]. Following this rationale, each outcome was dichotomously categorized as “presence of no to light symptoms” and “presence of moderate to severe symptoms”. Also, a variable regarding the co-occurrence of mental health problems was created, describing students who present symptoms for both mental health outcomes. Those students who scored for suicide risk were forwarded to mental health programs at their universities or to the public health system, according to the availability in each of the different universities.

Physical Fitness

The tests were conducted at the facilities of each participating center that received previous training for the application of the assessments. All the researchers involved in the evaluation received prior training on the execution of the protocol. Participants were contacted in advance to assess their interest in participating in the physical evaluation and their availability to undergo it, only then was the assessment scheduled. The handgrip test assessed upper body strength, the vertical jump test assessed lower body strength, and the Shuttle run gauged CRF. Participants were instructed to wear suitable clothes for physical activity and avoid heavy meals before

the assessments. The tests were systematically administered in the following order: the handgrip, vertical Jump, and 20-meter shuttle run tests.

Handgrip

The participants were asked to stand with their arms alongside their bodies, elbows in extension, holding the handgrip with their hands in a neutral position, and then perform the maximum strength possible in a “closing hand” movement. Verbal incentive was given[25]. The highest recorded attempt was utilized for analysis[25–27].

Vertical jump

The Vertical Jump test was applied to assess lower limb strength. Initially, the participants were requested to mark a line on a wall with their shoulders fully extended above their heads and positioned side to a wall. Before the maximal height test, participants were required to execute six one-quarter squat jumps distributed across two sets of three submaximal jumps each. After the warm-up phase, participants were positioned laterally adjacent to a plain wall and directed to jump to their greatest height while marking a chalk line at the highest point achieved. Each attempt was separated with a 30-second rest. The measurement was carried out considering the distance from the line marked in the first stage and the highest point of the line marked during the execution of each jump. The analysis considered the highest point achieved among the three attempts[9].

20-meter Shuttle Run Test

The third test was the 20-meter Shuttle Run Test (20mSRT), which assessed the students' CRF[7]. Participants engaged in 20-meter sprints each time a beep sound signaled the start. The test involves running back and forth between two parallel lines spaced 20 meters apart. An audio recording guided the participants, starting at a speed of 8.5 km/h and increasing by 0.5 km/h every successive minute. The test was interrupted and ended when the participant could not reach the 20-meter mark for two consecutive times before the sound. This maximal oxygen uptake (VO_{2max}) estimation relied on the total distance covered by the participant and the corresponding velocity attained for each stage[7].

Each test was independently assessed, considering each physical fitness outcome, and categorized differently, considering the median for each sex. A variable

combining both tests that involve muscular strength (handgrip and vertical jump) was created. For this sample, we considered those that had results above the median in 0 or 1 test as “lower physical fitness” and those with 2 or 3 results above the median as “higher physical fitness”. In addition, a variable combining the three tests (CRF, handgrip, and vertical jump) was created and dichotomously assigned to those who scored 0 or 1 test above the median and 2 or 3 tests above the median.

Covariates

We gathered self-reported information on family history of mental disorder (yes; no), medication use (yes; no), and overall lifestyle. Lifestyle was assessed by The Short Multidimensional Inventory Lifestyle Evaluation (C-SMILE)[28]. For inclusion in the study, the lifestyle score was divided by the median, categorizing the subjects into two quantiles (unhealthy and healthy).

Potential covariates were selected based on previous studies, including sex, lifestyle factors, family history, and previous treatment[29,30]. These factors were self-reported through a questionnaire on the online platform and applied together with mental health instruments in the first stage of data collection.

Statistical Analysis

Shapiro-Wilk tests were performed to assess the normality of scores for each physical fitness test and each mental health instrument. The results are presented as medians and quartile intervals for both the total sample and stratified by gender. Sample characteristics are described as absolute and relative frequencies. The chi-square tests for heterogeneity were applied to assess differences in the proportion of subjects with or without symptoms for each mental health outcome.

The associations between physical fitness and mental health were tested using Poisson regression models with robust variance. The results are presented as crude and adjusted prevalence ratios (PR) with their respective 95% confidence intervals (95%CI). The covariates that presented a p-value ≤0.20 in the bivariate analysis for each outcome (chi-square tests) were included as adjustment variables in the models adjusted for each outcome[31]. The following were included in the statistical analysis: sex, age, family history of mental disorder, medication use, and lifestyle[29,30].

The collinearity of the variables included was tested using a correlation matrix. The models that included depressive symptoms as an outcome were adjusted for

gender, family history of mental disorder, medication use, and general lifestyle. When anxiety symptoms were considered an outcome, models were adjusted for sex, family history of mental health disorders, general lifestyle, and medication use[29,30]. In the analysis in which the outcome was the co-occurrence of symptoms, we included in the model as covariables family history of mental disorder, medication use, sex, and general lifestyle[29,30]. All analyses were performed in Stata 15.1 and adopted an alpha of 5%.

RESULTS

Table 1 describes the characteristics of the study sample. A total of 199 participants were included. Among them, 51.3% were female, 37.9% were in the age range of 21 to 25 years, and 66.3% had an underweight/standard body mass index. Exploring the context of a family history of mental disorders, it was found that 44.1% of participants reported a family history of mental disorders. Considering that the eligibility criteria were that all the participants recruited had completed the online survey, all participants had demographic and contact information available. Whenever the participant presented any physical condition that could cause any harm, the participant would not do the specific tests. Of the 199 participants, 6 did not complete the vertical jump, 16 did not complete the handgrip strength, and 3 did not complete the shuttle run test.

Among the participants, 32.7% exhibited symptoms of anxiety, with a higher prevalence among women (64.6%; p=0.011), individuals with a family history of mental disorders (60.9%; p=0.002), those with an overall unhealthy lifestyle (45.3%, p=0.001), and those using medication (84.6%, p=0.025). Additionally, 39.7% of participants showed symptoms of depression, with a higher prevalence among women (58.2%, p=0.110), individuals with a family history of mental health issues (59%, p=0.001), those not using medication (84.4%, p=0.009), and those with an overall less healthy lifestyle (76.7%, p<0.001). Among participants experiencing a co-occurrence of anxiety and depression symptoms (25.6%), the prevalence was higher in women (64.7%, p=0.030), individuals with a family history of mental health issues (60%, p=0.001), those not using medication (80.4%, p=0.005), and those with unhealthy lifestyle (74.5%, p<0.001). Table 2 presents the median physical fitness scores and anxiety and depression symptoms for the general sample, and stratified by sex. Participants had a median vertical jump of 40.5 centimeters (cm), a median handgrip strength of 35

kilograms (kg), and a median VO2max of 32.6 milliliters per kilogram per minute (ml/kg/min). The median anxiety symptom score was 8, while the median depressive symptom score was 9.

Table 1. Characteristics of the participants of the MENTAL-UNI Study.

	Overall Sample (n=199)	**Anxious symptoms** (n=65)		**Depressive symptoms** (n=79)		**Depressive and anxiety symptoms** (n= 51)	
	n (%)	n (%)	p-value*	n (%)	p-value*	n (%)	p-value*
Sex			0.011		0.110		0.030
Female	102 (51.26)	42 (64.62)		46 (58.23)		33 (64.71)	
Male	97 (48.74)	23 (35.38)		33 (41.77)		18 (35.29)	
Family history of mental disorder			0.002		0.001		0.001
Yes	86 (44.10)	39 (60.94)		46 (58.97)		30 (60.00)	
No	109 (55.90)	25 (39.06)		32 (41.03)		20 (40.00)	
Medication use			0.025		0.009		0.005
Yes	17 (8.67)	10 (15.38)		12 (15.19)		10 (19.61)	
No	179 (91.33)	55 (84.62)		67 (84.81)		41 (80.39)	
General lifestyle			0.001		<0.001		<0.001
Unhealthy	96 (51.61)	43 (45.26)		56 (76.71)		35 (74.47)	
Healthy	90 (48.39)	18 (20.93)		17 (23.29)		12 (25.53)	

*Chi-square test (comparator group: no symptoms). #Number of observations varies due to missing values.

Table 2. Description of physical fitness and anxiety, depression symptoms score of the participants of the MENTAL-UNI Study.

	Overall	Female	Male
	Median [II]	Median [II]	Median [II]
Vertical jump (cm)	40.5 [33.0 – 50.0]	34.0 [29.0 – 40.0]	49.0 [43.0 – 55.0]
Handgrip strength (kg)	35.0 [28.0 – 44.0]	28.0 [25.0 – 32.0]	45.0 [39.0 – 50.0]
VO_{2max} (ml/Kg/min)	32.6 [29.6 – 38.6]	29.6 [26.6 – 32.6]	38.6 [32.6 – 41.6]
Anxiety symptoms (score)	8 [5 – 13]	10 [6 – 14]	7 [4 – 12]
Depression symptoms (score)	9 [6 – 13]	11 [6 – 15]	9 [5 – 12]

Median [II]: Median [Interquartile Interval].

Physical fitness and mental health outcomes

Crude associations were found between vertical jump, higher physical fitness in 2 or 3 tests and anxiety symptoms showing a higher prevalence of symptoms (PR=0.64; 95%CI=0.42–0.96); muscular strength, where the higher physical fitness group in both tests (dynamometry and vertical jump) showed a lower prevalence (PR=0.52; 95%CI=0.29–0.93), and combined components of physical fitness, where individuals with higher physical fitness in 2 or 3 tests also showed a lower prevalence of anxious symptoms (PR=0.51; 95%CI=0.31-0.85) (Fig 1b). However, the associations lost statistical significance when the model was adjusted for covariates (table 3).

An association between higher physical fitness in 2 or 3 tests and depression symptoms was found within the crude and adjusted analysis (Adjusted PR=0.53; 95%CI=0.33–0.84). Higher vertical jump was also significantly associated with lower occurrence of depressive symptoms in the crude and adjusted analysis (Adjusted PR=0.65; 95%CI=0.44–0.97) (Fig 1a). There were no statistically significant associations between depressive symptoms and VO_{2max}, handgrip strength, or muscular strength (table 4).

Higher vertical jump was associated with lower co-occurrence of depression and anxiety symptoms (Crude PR=0.58; 95%CI=0.36-0.93, Adjusted PR=0.55; 95%CI=0.31-0.99) (Fig 1c). In the adjusted analysis, individuals with higher physical fitness in 2 or 3 tests showed lower co-occurrence of anxiety and depression (Adjusted

PR=0.39; 95%CI=0.18-0.81) (table 5). Both crude and adjusted models showed no statistically significant differences in muscular strength.

Table 3. Crude and adjusted associations of physical fitness and anxiety symptoms in participants of the MENTAL-UNI Study.

	Crude PR (95%CI)	p-value	Adjusted PR (95%CI)	p-value*
Vertical jump		0.033		0.351
Lower jump	1		1	
Higher jump	0.64 (0.42; 0.96)		0.77 (0.45; 1.33)	
Handgrip strength		0.051		0.716
Lower strength	1		1	
Higher strength	0.63 (0.40; 1.00)		0.87 (0.40; 1.89)	
Maximum VO2		0.318		0.525
Lower VO2	1		1	
Higher VO2	0.81 (0.53; 1.23)		1.20 (0.69; 2.08)	
Muscular Strength #		0.024		0.301
0 tests	1		1	
1 tests	1.05 (0.65; 1.70)		1.10 (0.66; 1.83)	
2 tests	0.52 (0.29; 0.93)		0.54 (0.23; 1.27)	
Combined physical fitness #		0.009		0.173
Lower physical fitness	1		1	
Higher physical fitness	0.51 (0.31; 0.85)		0.58 (0.27; 1.27)	

PR (95%CI): Prevalence Ratio (95% Confidence Interval) - Poisson regression with robust variance;

Number of tests in which the participant reached values above the median.

* Adjusted for sex, family history of mental disorder, medication use, and overall lifestyle.

Table 4. Crude and adjusted associations of physical fitness and depressive symptoms in participants of the MENTAL-UNI Study.

	Crude PR (95%CI)	p-value	Adjusted PR (95%CI)	p-value*
Vertical jump		0.029		0.034
Lower jump	1		1	
Higher jump	0.67 (0.47; 0.96)		0.65 (0.44; 0.97)	
Handgrip strength		0.270		0.866
Lower strength	1		1	
Higher strength	0.81 (0.56; 1.18)		1.06 (0.54; 2.10)	
Maximum VO2		0.064		0.073
Lower VO2	1		1	
Higher VO2	0.69 (0.47; 1.02)		0.69 (0.46; 1.04)	
Muscular Strength #		0.079		0.169
0 tests	1		1	
1 tests	0.89 (0.57; 1.38)		0.92 (0.56; 1.52)	
2 tests	0.67 (0.43; 1.05)		0.60 (0.32; 1.14)	
Combined physical fitness #		0.014		0.006
Lower fitness	1		1	
Higher fitness	0.60 (0.40; 0.90)		0.53 (0.33; 0.84)	

PR (95%CI): Prevalence Ratio (95% Confidence Interval) - Poisson regression with robust variance;

Number of tests in which the participant reached values above the median.

* Adjusted for sex, family history of mental disorder, medication use, lifestyle overall.

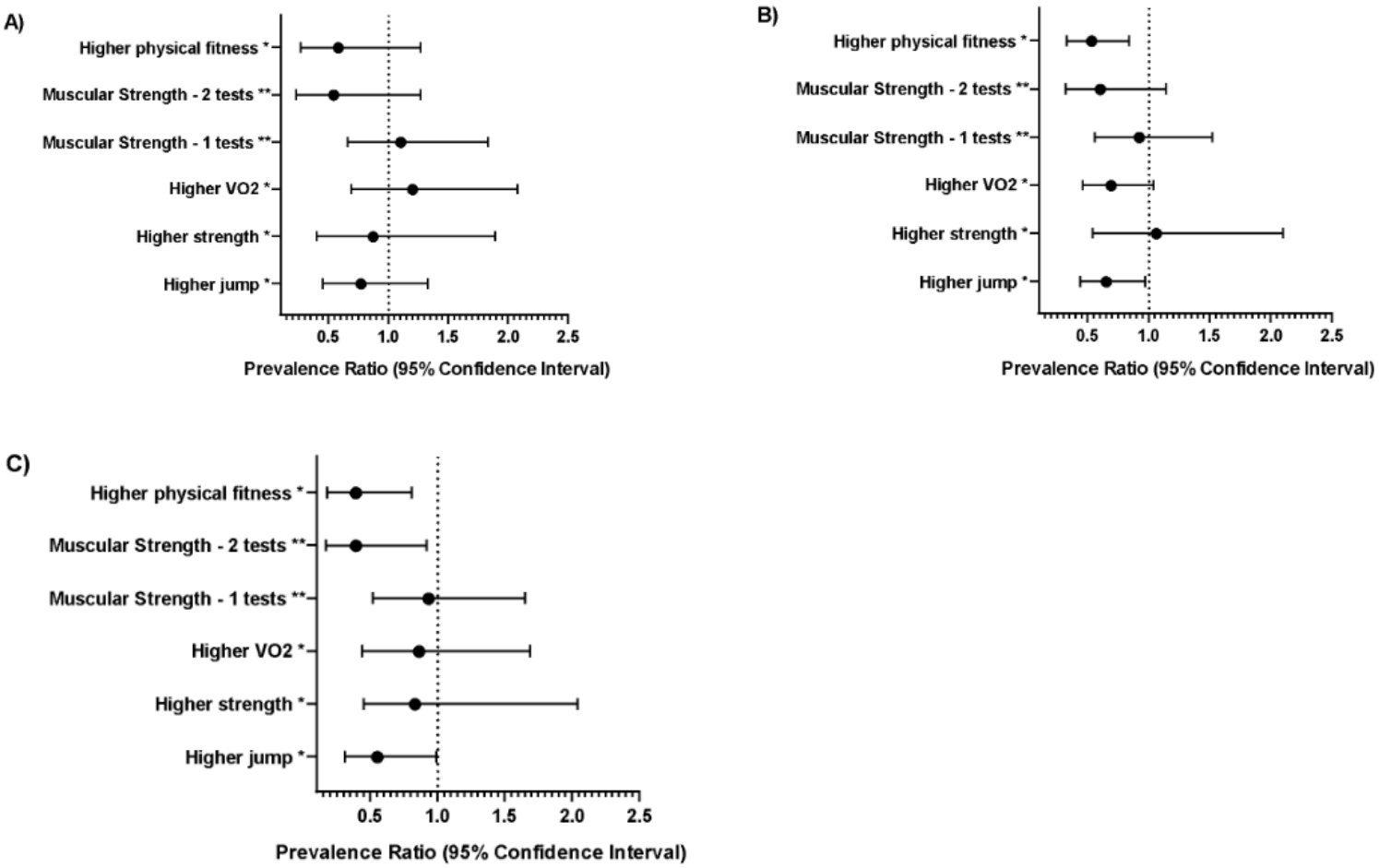

Figure 1. Associations of physical fitness and depressive and anxiety symptoms in participants of the MENTAL-UNI Study.

A) Depressive symptoms; B) Anxiety symptoms; C) Depressive and anxiety symptoms; * Reference category: lower; ** Reference category: 0 tests

Table 5. Crude and adjusted associations of physical fitness and depressive and anxiety symptoms in participants of the MENTAL-UNI Study.

	Symptoms for anxiety and depression			
	Crude PR (95%CI)	**p-value**	**Adjusted PR (95%CI)**	**p-value***
Vertical jump		0.023		0.047
Lower jump	1		1	
Higher jump	0.58 (0.36; 0.93)		0.55 (0.31; 0.99)	
Handgrip strength		0.082		0.688
Lower strength	1		1	
Higher strength	0.63 (0.37; 1.06)		0.83 (0.45; 2.04)	
Maximum VO2		0.114		0.658
Lower VO2	1		1	
Higher VO2	0.66 (0.40; 1.10)		0.86 (0.44; 1.69)	
Muscular Strength #		0.030		0.089
0 tests	1		1	
1 tests	1.00 (0.58; 1.73)		0.93 (0.52;1.65)	
2 tests	0.49 (0.26; 0.95)		0.39 (0.17; 0.92)	
Combined physical fitness #		0.008		0.011
Lower fitness	1		1	
Higher fitness	0.46 (0.26; 0.81)		0.39 (0.18; 0.81)	

PR (95%CI): Prevalence Ratio (95% Confidence Interval) - Poisson regression with robust variance (Reference category: individuals without symptoms)

Number of tests in which the participant reached values above the median.

* Adjusted for sex, family history of mental disorder, medication use, and lifestyle overall.

Discussion

The present study investigated the association between physical fitness and depression and anxiety symptoms in university students. Our results demonstrate that students with higher vertical jump or combined fitness scores (vertical jump, handgrip strength, and Shuttle run) have a lower probability of depression and co-occurring anxiety and depression than their less fit peers. However, cardiorespiratory fitness and handgrip strength, individually, were not associated with a lower prevalence of anxiety and depression symptoms or the co-occurrence of both.

Higher values in vertical jump were associated with a lower likelihood of depression symptoms in university students, corroborating previous studies[26].

Contrary to the findings of Yin et al.[32], our study failed to find significant associations between anxiety, co-occurrence of anxiety and depression, and vertical jump. Although the crude analysis demonstrated a positive association when adjusting with covariables such as sex, medication use, and family history of mental disorders, the significance was not sustained. Additionally, the higher vertical jump was associated with a lower co-occurrence of anxiety and depression symptoms. We hypothesize that lower limb strength may be more associated with daily tasks and more susceptible to changes in sedentary behavior[33], especially in this young population.

The lack of association between handgrip strength and anxiety and/or depression may relate to strength decline over time. We speculate that, in this age group, the losses in handgrip strength associated with depression may not be substantial enough to be detected. Younger individuals experience less decline than older adults, so the small loss in those with depression may be not enough. However, this hypothesis should be tested in future studies. We hypothesize that students may be more sensitive to losses on explosive strength than handgrip, concerning anxiety and depression symptoms. Handgrip strength may be less used in students' daily routine activities when compared to explosive strength (measured by the vertical jump), especially considering that students are, for the most part, an inactive population[34]. Additionally, handgrip strength may be less influenced by depressive symptoms and sedentary behavior, considering that the natural force peak occurs in early adulthood (18-24 years)[35]. Since age-related declines in strength, which can make maintaining physical fitness a more prominent health factor, are not yet observed in this age group, this may explain why handgrip strength is not as relevant to mental health in this young population. Therefore, maximum handgrip strength may not be as relevant to mental health in a young population.

The current study also did not find associations between CRF and mental health, despite prior evidence suggesting otherwise. Prior evidence indicates that lower levels of cardiorespiratory fitness are associated with an increased risk of depressive symptoms[10,12]; however, it is important to consider that the samples included in these meta-analyses differ from those in the current study. The studies within these meta-analyses predominantly focus on adults and older adults and utilize a variety of methods to assess physical fitness, such as estimating CRF based on physical activity levels, maximal cycle ergometer tests, and maximal push-up tests. Thus, while there is literature demonstrating associations between combined physical

fitness and anxiety[5,10,13], our study did not replicate these findings. In our sample, this association was present in the unadjusted analyses but lost significance after adjusting for confounding factors such as sex, family history of mental disorders, medication use, and lifestyle. Another possible explanation for the non-significance of the adjusted results may lie in confounders such as genetic heritage, where those students, even with low levels of physical activity, and possibly higher anxiety and depressive symptoms, present higher levels of CRF due to heritability ability of CRF[34]. These findings suggest that confounding variables play a key role in the association between anxiety and combined physical fitness in this population of university students.

Furthermore, the explosive strength of lower limbs, CRF, and handgrip strength, as components of physical fitness are associated with a lower prevalence of co-occurring anxiety and depression symptoms in the present study, which supports the findings of Kandola et al.[10] in the general population regarding strength and its relationship with anxiety and depression symptoms. Although the study did not assess physical activity habits in the sample, we hypothesize that having higher indicators of strength and cardiorespiratory fitness may be associated with an active lifestyle. Therefore, higher healthy lifestyle habits may be associated with a decreased occurrence of co-occurrence anxiety and depression symptoms among the fittest students. Additionally, examining combined physical fitness components may provide a more comprehensive representation of muscular strength. It is possible that, for this population, considering only CRF or handgrip is not enough to estimate the risk for anxiety and depression symptoms. However, the combination of both components offers a more holistic assessment of physical fitness, and this comprehensive outcome is associated with anxiety and depression in our sample. Furthermore, the examination of a physical fitness variable derived from a combination of objective markers of physical fitness suggests a novel approach to objectively analyze the risk that university students may present symptoms of anxiety and depression simultaneously.

Some hypothesized mechanisms may explain the association of combined physical fitness with anxiety and depression. Physiologically, physical fitness is associated with a lower risk of neuroinflammation[35], an increase in the production and secretion of neurotrophins, such as brain-derived neurotrophic factor[36]. It is also linked to increases in gray matter volume in the brain[37] which are, in turn, associated with neurogenesis and neuronal survival, synaptic development, learning, and neural plasticity[36]. Additionally, from a psychosocial perspective, physical exercise, a key

contributor to physical fitness, can promote social interaction, independence, physical self-perception, enhanced mood, and emotions[38]. Overall, an increase in physical fitness levels is related to an improved quality of life[39].

This study has some limitations, including its cross-sectional design, which prevents the inference of causality or directionality. As a result, it remains unclear whether higher physical fitness is linked to a lower prevalence of anxiety and depression symptoms or if the presence of these conditions leads to reduced physical fitness. Additionally, the use of a convenience sample and data from a pilot study restricts the generalizability of the findings. Further, although the scales used have high validity and specificity, their isolated application is not sufficient to confirm diagnoses, but rather instruments for detecting symptomatology. It is also important to note that the reported symptoms refer to the two weeks preceding the questionnaire, which may be influenced by acute stressors related to academic life, such as exams and semester workload, as well as external factors like financial situation and personal matters affecting students and their lifestyle. This temporality could introduce bias in the responses, as it may not accurately reflect a long-term impact on quality of life or the chronic nature of the condition, both essential for establishing a diagnosis. Furthermore, the vo2max and vertical jump tests are indirect measures of CRF and lower limb strength, respectively. Additionally, the physical fitness tests are also influenced by the student's willingness to perform at their best.

Nonetheless, the study also presents some strengths. To the best of our knowledge, this is the first study aimed at evaluating the combined association of physical fitness components in the co-occurrence of anxiety and depression symptoms in Brazilian university students. This study evaluated different components of physical fitness and assessed combined physical fitness, diverging from most current evidence in the literature and focusing on the assessment of specific components. Also, assessing lower limb strength through jumps may be an important component to explore in this particular population, particularly given that the test is inexpensive and easily applicable. The present study utilized validated questionnaires for symptom assessment.

Further prospective studies are necessary to investigate the directionality of the association and whether this association remains true despite the different cultural contexts in the multicentric and international sample. Studies investigating the effects of interventions in different components of physical fitness on mental health are needed

to reinforce our results. Confirmation of this evidence can be useful to guide intervention programs and projects that promote students' physical fitness and can contribute to the prevention, management, and treatment of mental health disorders.

Conclusion

Students with higher levels of physical fitness in 2 or 3 components and with a greater height in the vertical jump are less likely to present symptoms of depression and the co-occurrence of anxiety and depression. However, handgrip strength or CRF are not, in isolation, associated with anxiety and depression in university students.

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Writing - review & editing-SupportingAndrea Camaz DeslandesInvestigation-Supporting, Methodology-Supporting, Project administration-Supporting, Writing - review & editing-SupportingFelipe Barreto SchuchConceptualization-Supporting, Investigation-Supporting, Methodology-Lead, Project administration-Lead, Writing - original draft-Supporting, Writing - review & editing-Supporting

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