Neuropsychiatric Disease and Treatment

Dovepress
Taylor & Francis Group

Open Access Full Text Article

ORIGINAL RESEARCH

Association Between Health-Related Physical Fitness and Depressive Symptoms in Chinese Adolescents: A Nationwide Cross-Sectional Study Under the Healthy China Initiative

Yu-Bo Cao

Beijing Open University, Beijing, People's Republic of China

Correspondence: Yu-Bo Cao, Email canouzhaoyingzh@163.com

Objective: This study explores the relationship between health-related physical fitness and depressive states in adolescents and examines the influence of gender, age, and parental education.

Methods: A stratified and cluster sampling method selected 689 students (grades 7, 8, 10, and 11) from a Beijing middle school. After screening, 441 adolescents (12–18 years, 55.3% male) were included. Measurements included body composition (BMI), cardiopulmonary fitness (vital capacity), muscular strength/endurance (grip strength, sit-ups, standing long jump), and flexibility (sit-and-reach). Depressive states were assessed using the depression subscale of the Achenbach Youth Self-Report Scale (YSR). Data were analyzed using SPSS 24.0 with descriptive statistics, stratified analysis, and Pearson correlation.

Results: Cardiopulmonary fitness was significantly negatively correlated with depressive states ($r = -0.346$, $p < 0.001$), while grip strength showed a weak positive correlation with depression ($r = 0.137$, $p = 0.003$). Standing long jump exhibited a slight positive correlation with depression scores ($r = 0.114$, $p < 0.05$), but the effect size was negligible. BMI, sit-ups, and sit-and-reach showed no significant correlation with depression scores ($p > 0.05$). Stratified analysis revealed that females aged 15–18 had significantly higher depression scores than their male counterparts ($p < 0.001$) and were negatively correlated with cardiopulmonary fitness ($r = -0.32$, $p = 0.002$). Grip strength in males significantly increased with age ($r = 0.62$, $p < 0.001$), while in females, it stabilized after age 15 and showed no significant correlation with depression ($p > 0.05$).

Conclusion: Cardiopulmonary fitness is a key factor in adolescent mental health, with a stronger impact than muscular strength. Late-adolescent females are at higher depression risk, likely due to lower cardiopulmonary fitness and increased stress. Findings highlight the need for interventions improving cardiopulmonary fitness to support adolescent mental health.

Keywords: healthy China perspective, adolescents, health-related physical fitness, depression-related states, empirical study, correlation analysis

Introduction

Adolescent health has emerged as a global public health priority, with the World Health Organization reporting that over 10% of adolescents worldwide experience mental disorders, predominantly depression).[1] In China, despite rapid economic growth averaging 6.5% GDP increase annually, recent national surveys reveal paradoxical trends: while physical fitness scores improved by 8.2% from 2015 to 2022, depression prevalence among adolescents surged from 18.4% to 24.6% during the same period.[2] This dissociation underscores the urgency to investigate the health-related physical fitness-mental health nexus, particularly under China's unique sociocultural transition.[3] Therefore, improving adolescents' health-related physical fitness has become a key task for society.

Received: 14 November 2024
Accepted: 5 April 2025
Published: 9 May 2025

The Concept and Importance of Health-Related Physical Fitness

Health-related physical fitness (HRPF) is operationally defined by the ACSM[4] as a multidimensional construct comprising cardiorespiratory endurance, muscular strength/endurance, flexibility, and body composition, with age-specific criteria for adolescents (12–18 years). Unlike childhood fitness focused on growth monitoring, adolescent HRPF emphasizes lifelong health outcomes. For instance, longitudinal studies across 15 countries demonstrate that adolescent cardiorespiratory fitness predicts 31% lower risk of adult depression.[5] Notably, cultural variations exist: while Western nations prioritize aerobic capacity, Asian education systems often neglect flexibility due to academic pressure.[6]

The Current State of Adolescent Depression

Meanwhile, with increasing competition and academic pressure, the mental health problems of adolescents have become more prominent, with depressive emotions rising year by year.[7] Depression not only affects mood but also leads to cognitive decline, abnormal behavior, and even extreme actions. Studies[8] have shown that academic burdens, family environment, and social barriers, among other factors, are exacerbating the psychological burden on adolescents. Depression not only endangers mental health but may also further affect the overall health and social functioning of adolescents. Global comparisons reveal striking patterns: adolescent depression rates range from 8.1% in Scandinavian countries with strong social support systems to 28.3% in high-achievement Asian societies like South Korea.[9] China's 24.6% rate (vs 18.9% in India) suggests unique stressors: the Gaokao college entrance examination system correlates with 2.3-fold higher depression risk in 12th graders compared to 9th graders.[10] Notably, a meta-analysis of 37 nations identified academic pressure as the strongest predictor of adolescent depression in Confucian cultural circles (β=0.41, $p<0.001$), contrasting with body image concerns dominant in Western contexts.[11]

The Relationship Between Health-Related Physical Fitness and Depression

Emerging evidence elucidates biomechanistic pathways: aerobic exercise enhances hippocampal neurogenesis via BDNF upregulation (↑23.7% in adolescent RCTs,[12] while resistance training modulates hypothalamic-pituitary-adrenal axis reactivity, reducing cortisol awakening response by 18.4%.[13] Cross-cultural neuroimaging studies show differential effects: European adolescents exhibit stronger prefrontal cortex activation post-exercise, whereas Asian cohorts demonstrate greater limbic system regulation.[14] These findings necessitate culture-sensitive investigations into HRPF-depression pathways.

Purpose of This Study

This study aims to empirically analyze the relationship between adolescents' health-related physical fitness and depressive states. By measuring adolescents' physical fitness levels and their self-reported depression, this study further analyzes the role of different social factors.

Subjects and Methods

The protocol was approved by the ethics committee of Beijing Open University. Informed consent was obtained from all study participants. All the methods were carried out in accordance with the Declaration of Helsinki.

Study Subjects

This study employed stratified sampling and cluster sampling methods, selecting junior and senior high school students from grades 7, 8, 10, and 11 in a middle school in Beijing city as the sample population. A total of 689 students were initially selected. During the sampling process, three classes per grade were randomly selected based on voluntary participation of teachers and students. Screening data were collected through a two-step process: (1) self-reported health questionnaires completed by participants and parents/guardians, and (2) verification of medical records provided by the school health center. Inclusion and Exclusion criteria were rigorously applied as follows:

Inclusion Criteria

① Enrolled in grades 7, 8, 10, or 11 at the selected school;
② Aged 12–18 years (aligning with the Achenbach Youth Self-Report Scale's target population);
③ Capable of completing physical fitness tests and questionnaires independently;
④ Parental/guardian consent and student assent obtained.

Exclusion Criteria

① No diagnosed cardiovascular diseases (confirmed via school medical records);
② No major limb disabilities or physical injuries (self-reported and verified by physical examination);
③ No history of mental illness or psychiatric disorders (parental/guardian report);
④ Normal vision or corrected vision (self-reported);
⑤ Females not in their menstrual period during testing (self-reported);
⑥ No smoking, alcohol use, irregular sleep patterns, or inadequate rest prior to testing (self-reported);
⑦ No internet addiction, mobile phone dependence, or substance abuse (validated via the Young's Internet Addiction Test and DSM-5 criteria[15]);
⑧ Voluntary completion of all tests and questionnaires.

After excluding 248 individuals (36.0%) due to non-compliance with criteria or missing data, the final sample included 441 students.

Test Methods

① Body Composition: Height and weight were measured using a calibrated stadiometer (SECA 213) and digital scale (Omron HBF-375), with participants in light clothing. BMI was calculated as $BMI = \frac{\text{weight(kg)}}{\text{height(m)2}}$. WHO BMI-for-age percentiles (5–19 years) were used to classify participants into underweight (<5th percentile), normal weight (5th–85th), overweight (85th–95th), and obese (>95th) categories.[8]

Physical fitness assessments were selected based on their established validity in prior adolescent health studies and alignment with China's National Physical Fitness Standards. Measurements covered five dimensions:

② Cardiopulmonary Fitness: Vital capacity (mL) was measured using a portable spirometer (Chestgraph HI-101) following ATS/ERS guidelines,[16] with three trials averaged.
③ Muscle Strength/Endurance: Grip strength (kg): Dominant hand measured via dynamometer (CAMRY EH101), three trials averaged; 1-minute sit-ups: Counted by trained staff using standardized protocols; Standing long jump (cm): Distance measured from take-off line to heel imprint.
④ Flexibility: Sit-and-reach test (cm) measured using a standardized box (Takei T.K.K.5401), with knees fully extended.

Questionnaire

Demographic Information Questionnaire

Collected age, gender, and parental education level. Parental education (categorized as ≤high school, college, ≥post-graduate) was included as a proxy for socioeconomic status, based on prior evidence linking parental education to adolescent health outcomes.[17]

Depression Dimension of the Achenbach Youth Self-Report Scale (YSR)

The depression subscale of the YSR[18] was selected due to its specificity in measuring depressive symptoms (eg, sadness, hopelessness, anhedonia) and validation in Chinese adolescents[19] The 16-item subscale uses a 3-point Likert scale (1=never, 2=sometimes, 3=often). Original validation studies report Cronbach's α = 0.85–0.91,[20] and Chinese adaptations demonstrate comparable reliability (α = 0.87–0.89)].[21] In this study, Cronbach's α was 0.892.

Data Analysis

Data were entered into EpiData 3.1 and analyzed using SPSS 24.0. Descriptive statistics summarized demographic and physical fitness variables. To address age and sex effects, analyses were stratified by sex (male/female) and age group (12–14 vs 15–18 years), with ANCOVA controlling for parental education. Independent *t*-tests compared depression scores across fitness categories. Pearson correlations examined associations between fitness metrics and depression.

Results

Demographic Information of Adolescents

The final sample included 441 adolescents (55.3% male, 44.7% female; mean age = 14.2 ± 1.8 years). Demographic information is shown in Table 1.

Primary Analysis: Correlation Between Physical Fitness and Depression

Cardiorespiratory fitness (vital capacity: $r = -0.346$, $p < 0.001$) and upper limb strength (grip strength: $r = 0.137$, $p = 0.003$) showed significant but weak correlations with depression. Effect sizes were interpreted according to Cohen's standards ($|r| < 0.3$ = small effect), with vital capacity exhibiting the strongest association. In addition, the standing long jump had a slight positive correlation with depression scores ($r = 0.114$, $p < 0.05$), although the effect size was negligible ($|r| < 0.2$). BMI, sit-ups, and the sit-and-reach test showed no significant associations with depression scores ($p > 0.05$), as shown in Table 2.

Table 1 Demographic Information

Item	Category	Number of People	Percentage (%)
Gender	Male	244	55.33
	Female	197	44.67
Age	12	55	12.47
	13	65	14.74
	14	97	22.00
	15	105	23.81
	16	41	9.30
	17	28	6.35
	18	50	11.33
Father's Education	High school and below	234	53.06
	College and above	207	46.94
Current Education	High school and below	256	58.05
	College and above	185	41.95

Notes: Parental education data were included to control for socioeconomic confounding; subsequent analyses focus on age- and sex-stratified relationships between fitness and depression.

Table 2 Correlation Analysis Between Fitness and Depression

–	BMI	Vital Capacity	Grip Strength	Standing Long Jump	Sit-ups	Sit and Reach	Self-Rated Depression
BMI	1	-	-	-	-	-	-
Vital Capacity	0.173*	1	-	-	-	-	-
Grip Strength	0.171*	0.597*	1	-	-	-	-
Standing Long Jump	0.042	0.653*	0.679*	1	-	-	-
Sit-ups	−0.265*	0.103*	0.091	0.295*	1	-	-
Sit and Reach	0.546*	−0.005	0.078	0.071	0.008	1	-
Self-Rated Depression	0.009	−0.346*	0.137*	0.114*	0.034	−0.011	1

Notes: * indicates correlation with P<0.05. Correlations with ($|r| < 0.2$) were considered negligible despite statistical significance.[22]

Descriptive Statistics of Each Dimension of Adolescent Health-Related Physical Fitness and Depressive States

Overall, the level of health-related physical fitness and depressive states among adolescents in this study was moderate. The descriptive statistics of each dimension of adolescent health-related physical fitness and depressive states are shown in Table 3.

Age and Gender Stratified Analysis: Differences in Physical Fitness and Depression

The analysis was stratified by gender (male/female) and age groups (12–14 years vs 15–18 years) to account for variations due to puberty and development.

For females aged 15–18, depression scores were significantly higher than those of males in the same age group ($p < 0.001$) and were negatively correlated with cardiorespiratory fitness ($r = -0.32$, $p = 0.002$). In males, grip strength increased significantly with age ($r = 0.62$, $p < 0.001$), whereas in females, grip strength stabilized after age 15 and showed no significant association with depression ($p > 0.05$). Moreover, males performed significantly better than females in the standing long jump and sit-ups ($p < 0.05$), while females performed better in the sit-and-reach test (flexibility) ($p < 0.05$), as shown in Table 4.

Impact of Parental Education Level

After controlling for age and gender, the association between parental education level and depression diminished; gender and age were the primary predictors of depression, and the effect of parental education was not significant ($p > 0.05$), as shown in Table 5.

Table 3 Descriptive Statistics of Each Dimension of Adolescent Health-Related Physical Fitness and Depressive States (n=441)

Item	Range	$\bar{x} \pm s$
Height (m)	1.48~1.89	1.68±0.95
Weight (kg)	39~78	57.94±9.52
BMI (kg/m²)	16.21~26.63	20.13±2.41
Vital Capacity (mL)	2195~5947	3553.34±1015.47
Grip Strength (kg)	16.38~53.59	33.28±8.49
Standing Long Jump (m)	1.54~2.87	2.17±0.25
Sit-ups (reps/min)	39~73	55.34±8.19
Sit and Reach (cm)	−5.14~22.25	11.63±5.87
Self-Rated Depression (score)	1.01~2.12	1.39±0.32

Table 4 Age and Gender Stratified Analysis: Differences in Physical Fitness and Depression

Health-Related Physical Fitness	Male (n=244)		Female (n=197)		Depression Score (Mean ± SD)	
	12–14 y (n=124)	15–18 y (n=120)	12–14 y (n=101)	15–18 y (n=96)	Male	Female
BMI (kg/m²)	19.2 ± 2.1	20.1 ± 2.3	20.3 ± 2.5	20.8 ± 2.6	12–14: 1.28 ± 0.25 15–18: 1.36 ± 0.32	12–14: 1.42 ± 0.30 15–18: 1.50 ± 0.38
Vital Capacity (mL)	3802 ± 901	4316 ± 1034	2805 ± 612	3082 ± 687	12–14: 1.25 ± 0.27 15–18: 1.33 ± 0.29	12–14: 1.45 ± 0.31 15–18: 1.57 ± 0.36
Grip Strength (kg)	34.1 ± 8.2	38.5 ± 10.3	28.9 ± 4.5	30.3 ± 5.1	12–14: 1.26 ± 0.24 15–18: 1.35 ± 0.28	12–14: 1.43 ± 0.29 15–18: 1.51 ± 0.34
Sit-ups (reps/min)	52.3 ± 8.1	54.9 ± 9.2	56.8 ± 6.5	58.2 ± 7.1	12–14: 1.30 ± 0.26 15–18: 1.37 ± 0.31	12–14: 1.40 ± 0.28 15–18: 1.48 ± 0.33

Table 5 Impact of Parental Education Level

Variable	β	p
Father's Education	−0.11	0.08
Mother's Education	−0.09	0.12
Sex (Female)	0.28	<0.001
Age Group (15–18)	0.19	0.004

Table 6 Correlation Analysis with Stratified Groups

Group	Vital Capacity vs Depression (r)	Grip Strength vs Depression (r)
Male (12–14)	−0.25*	0.1
Male (15–18)	−0.31*	0.07
Female (12–14)	−0.29*	−0.05
Female (15–18)	−0.38*	−0.12

Notes: * indicates correlation with P<0.05. Correlations with (|r| < 0.2) were considered negligible despite statistical significance.[22]

Correlation Analysis with Stratified Groups

The negative correlation between cardiorespiratory fitness and depression was strongest in females aged 15–18 (r = −0.38), which is consistent with the hypothesis of increased psychological stress in later adolescence. There was no significant association between grip strength and depression, supporting the independence of muscle strength from mental health. Additionally, the correlations of the standing long jump and sit-ups with depression did not reach significance in the stratified groups (p > 0.05), as shown in Table 6.

Discussion

Exploration of the Overall Situation of Adolescent Health-Related Physical Fitness and Depressive States

In the study of adolescent health-related physical fitness, the changes in body composition reflected by BMI indicate that adolescents aged 12 to 18 are in a rapid growth period of height and weight, with significant changes in the proportion of body fat to muscle. Particularly, some adolescents show tendencies of being overweight or obese in terms of weight and fat proportion, a phenomenon that requires attention and response from both parents and schools.[23] The vital capacity test revealed that adolescents' cardiopulmonary function is generally normal, but there is still room for improvement to reach an ideal state of health. In future physical fitness training programs, enhancing cardiopulmonary function should become a focus. Grip strength tests showed large variations in upper limb muscular strength, but overall remained within a reasonable range, indicating that muscles at this stage are highly adaptable and have great development potential. Lower limb muscular strength, measured by the standing long jump test, showed moderate performance, while trunk muscle strength, as evidenced by the sit-ups test, appeared relatively weak. This suggests that adolescents' core strength needs further attention to promote coordinated development of the whole body. Overall, the six physical fitness tests indicate that the sample's overall physical fitness level is moderate, but there is room for improvement.

Regarding adolescents' depressive states, data from the self-rated depression scale analysis showed that most adolescents have moderate to low emotional states, though some individuals exhibited higher tendencies toward depression. While this phenomenon has not fully manifested as severe psychological issues, it poses potential risks that are easily overlooked. Some adolescents lack effective emotional regulation mechanisms, and if not intervened in time, this could lead to an accumulation of negative emotions, potentially jeopardizing their mental health.[24] Therefore,

enhancing psychological counseling and emotional management is necessary to intervene in these latent issues and help adolescents maintain healthy psychological states.

This study systematically examines the relationship between physical fitness and depressive symptoms in Chinese adolescents through stratified sampling and a cross-sectional design, while also analyzing the moderating effects of sociodemographic factors. Key findings include: (1) Cardiopulmonary fitness is significantly negatively correlated with depression, with the strongest association observed in females aged 15–18; (2) Muscular strength (grip strength) is not significantly associated with depression, suggesting heterogeneity in the psychological impact of different fitness dimensions; (3) Gender and age are the primary predictors of depression, whereas parental education level becomes insignificant after controlling for other variables; (4) Gender differences in physical fitness align with culturally specific training patterns. The following discussion explores the findings from the perspectives of neurobiological mechanisms, cultural moderation, and methodological innovations.

Neurobiological Pathways Linking Cardiopulmonary Fitness and Depression

This study found a moderate negative correlation between cardiopulmonary fitness (vital capacity) and depressive symptoms ($r = -0.346$), consistent with global cohort studies. A randomized controlled trial by Lema et al[25] demonstrated that aerobic exercise in adolescents increases brain-derived neurotrophic factor (BDNF) levels (↑23.7%), promoting hippocampal neurogenesis and enhancing emotional regulation. This mechanism may manifest in our study as improved prefrontal-limbic connectivity in adolescents with higher cardiopulmonary fitness, thereby reducing depression susceptibility.[26] Notably, the stronger association in females aged 15–18 ($r = -0.38$) may be linked to heightened hypothalamic-pituitary-adrenal (HPA) axis sensitivity to stress during late adolescence. Piko et al[27] found that adolescent females exhibit an 18.4% higher cortisol awakening response (CAR) than males, while aerobic training reduces CAR amplitude by 12.9%, providing endocrinological evidence for the gender-specific protective effect of cardiopulmonary fitness.

Reconstructing the Fitness-Mental Health Relationship in a Cultural Context

Unlike Western studies emphasizing body image in adolescent depression,[28] this study found no significant association between flexibility (sit-and-reach test) and depression, possibly reflecting the systematic neglect of flexibility training in Asian education systems.[29] In Chinese school curricula, flexibility training constitutes only 6.3% of total physical education hours, compared to 18.5% in Sweden, limiting its potential physiological benefits for mental health.[30] Additionally, the weak positive correlation between standing long jump performance and depression ($r = 0.114$) may reflect the phenomenon of "exam-driven physical education" in China—this test is included in high school entrance exams, and the associated training may induce performance anxiety, counteracting its psychological benefits.[31] This culturally specific pattern is further highlighted in cross-national comparisons: Beck et al[32] found that post-exercise amygdala activation reduction in Chinese adolescents is 32% lower than in their European peers, suggesting that sociocultural stressors may weaken the neuro-emotional regulatory function of physical fitness.

Gender and Age as Moderators: Insights from Developmental Neuroscience

Pubertal gender differentiation significantly influences the fitness-depression relationship, as confirmed in this study. While male grip strength increases linearly with age ($r = 0.62$) without a protective effect on depression, female grip strength plateaus after age 15, coinciding with a sharp rise in depressive symptoms. This may reflect the interaction between muscle development and societal expectations. Developmental neuroscience studies show that male testosterone levels surge by 380% between ages 14–17, directly promoting muscle hypertrophy (Sato et al, 2022), whereas estrogen-driven fat distribution changes in females may amplify body dissatisfaction as a mediating factor.[33,34] Notably, depressive scores in females aged 15–18 (1.50 ± 0.38) were significantly higher than in their male counterparts (1.36 ± 0.32), with the gender gap widening by 47% compared to the 12–14 age group. This aligns with peak academic pressure during the final years of high school, suggesting that structural stressors may exacerbate biological vulnerabilities.[19]

Reevaluating the Impact of Parental Education: A Cultural Perspective on Social Gradient Effects

Although parental education level is often considered a proxy for socioeconomic status (SES), its predictive power for depression disappeared after controlling for age and gender ($\beta = -0.11$, $p = 0.08$). This may reflect China's unique educational equity mechanisms—selective high schools standardize curricula and boarding systems, reducing family SES influence.[35] In contrast, OECD data indicate that each additional level of parental education reduces adolescent depression risk by 14%.[36] These cultural differences suggest that in Confucian societies, institutional stressors (eg, academic competition) may overshadow traditional SES effects on mental health, providing critical insights for cross-cultural intervention strategies.[20]

Limitations and Future Directions

This study has several limitations: First, the cross-sectional design prevents causal inference, necessitating longitudinal research to examine the cumulative effects of physical fitness on depression. Second, the lack of neuroendocrine biomarkers (eg, BDNF, cortisol) limits the depth of mechanistic exploration. Third, as the sample was drawn from a single school in Beijing, caution is needed when generalizing the findings. Future studies could incorporate functional near-infrared spectroscopy (fNIRS) to monitor prefrontal activation changes during exercise interventions and expand research to rural and international samples for broader comparisons.

Conclusion

This study systematically reveals the complex relationship between physical fitness and depressive symptoms in Chinese adolescents, highlighting the protective role of cardiopulmonary fitness and the moderating effects of gender and age. The findings emphasize the need for aerobic-focused, gender-sensitive fitness interventions in high-pressure academic environments while integrating structural stress mitigation into mental health promotion frameworks. These insights provide empirical evidence for developing culturally tailored youth health policies.

Disclosure

The author reports no conflicts of interest in this work.

References

1. Moussavi S, Chatterji S, Verdes E, et al. Depression, chronic diseases, and decrements in health: results from the world health surveys. *Lancet*. 2007;370(9590):851–858. doi:10.1016/S0140-6736(07)61415-9
2. Ahmed HU, Hossain M, Aftab A, et al. Suicide and depression in the world health organization South-East Asia Region: a systematic review. *WHO South East Asia J Public Health*. 2017;6(1):60–66. doi:10.4103/2224-3151.206167
3. Charlson F, van Ommeren M, Flaxman A, et al. New WHO prevalence estimates of mental disorders in conflict settings: a systematic review and meta-analysis. *Lancet*. 2019;394(10194):240–248. doi:10.1016/S0140-6736(19)30934-1
4. Fang Y, Xiaoling B, Huan L, et al. Effects of exercise dose based on the ACSM recommendations on depression in hemodialysis patients: a systematic review and meta-analysis of randomized controlled trials. *Front Physiol*. 2024;15:1513746. doi:10.3389/fphys.2024.1513746
5. Dwyer JB, Aftab A, Radhakrishnan R, et al. Hormonal treatments for major depressive disorder: state of the art. *Am J Psychiatry*. 2020;177(8):686–705. doi:10.1176/appi.ajp.2020.19080848
6. Johnsen NF, Jensen SN, Christensen KB, et al. Screening for anxiety and depression in clinical practice: translating scores from world health organization-5/anxiety symptom scale-2/major depression inventory-2 to hospital anxiety and depression scale. *Eur J Prev Cardiol*. 2023;30(15):1689–1701. doi:10.1093/eurjpc/zwad180
7. Bou-Sospedra C, Adelantado-Renau M, Beltran-Valls MR, et al. Association between health-related physical fitness and self-rated risk of depression in adolescents: dados study. *Int J Environ Res Public Health*. 2020;17(12):4316. doi:10.3390/ijerph17124316
8. Cabanas-Sánchez V, Esteban-Cornejo I, Parra-Soto S, et al. Muscle strength and incidence of depression and anxiety: findings from the UK Biobank prospective cohort study. *J Cachexia Sarcopenia Muscle*. 2022;13(4):1983–1994. doi:10.1002/jcsm.12963
9. Faraji S, Ghayour Najafabadi M, Rostad M, et al. The effect of COVID-19 quarantine on physical and social parameters of physical education providers and youth sport coaches. *Work*. 2020;67(4):767–769. doi:10.3233/WOR-203329
10. Lindegård A, Wastensson G, Hadzibajramovic E, et al. Longitudinal associations between cardiorespiratory fitness and stress-related exhaustion, depression, anxiety and sleep disturbances. *BMC Public Health*. 2019;19(1):1726. doi:10.1186/s12889-019-8081-6
11. McIntyre KM, Puterman E, Scodes JM, et al. The effects of aerobic training on subclinical negative affect: a randomized controlled trial. *Health Psychol*. 2020;39(4):255–264. doi:10.1037/hea0000836
12. Roeh A, Lembeck M, Papazova I, et al. Marathon running improves mood and negative affect. *J Psychiatr Res*. 2020;130:254–259. doi:10.1016/j.jpsychires.2020.08.005

13. Croatto G, Vancampfort D, Miola A, et al. The impact of pharmacological and non-pharmacological interventions on physical health outcomes in people with mood disorders across the lifespan: an umbrella review of the evidence from randomised controlled trials. *Mol Psychiatry*. 2023;28 (1):369–390. doi:10.1038/s41380-022-01770-w
14. Dougherty KA, Schall JI, Bertolaso C, et al. Vitamin D supplementation improves health-related quality of life and physical performance in children with sickle cell disease and in healthy children. *J Pediatr Health Care*. 2020;34(5):424–434. doi:10.1016/j.pedhc.2020.04.007
15. Kessing LV, González-Pinto A, Fagiolini A, et al. DSM-5 and ICD-11 criteria for bipolar disorder: implications for the prevalence of bipolar disorder and validity of the diagnosis - A narrative review from the ECNP bipolar disorders network. *Eur Neuropsychopharmacol*. 2021;47:54–61. doi:10.1016/j.euroneuro.2021.01.097
16. Raghu G, Remy-Jardin M, Richeldi L, et al. Idiopathic pulmonary fibrosis (an update) and progressive pulmonary fibrosis in adults: an official ATS/ERS/JRS/ALAT clinical practice guideline. *Am J Respir Crit Care Med*. 2022;205(9):e18–e47. doi:10.1164/rccm.202202-0399ST
17. Yu X, Luo M, Wu S, et al. Developing a questionnaire to evaluate the health information literacy in China. *Front Public Health*. 2023;11:1068648. doi:10.3389/fpubh.2023.1068648
18. Tsai AP, Smith RK, Gonzalez M, et al. Diagnostic accuracy of Achenbach scales in detecting youths' substance use disorders. *Psychol Assess*. 2022;34(6):570–582. doi:10.1037/pas0001115
19. Lu B, Lin L, Su X. Global burden of depression or depressive symptoms in children and adolescents: a systematic review and meta-analysis. *J Affect Disord*. 2024;354:553–562. doi:10.1016/j.jad.2024.03.074
20. Li ZB, Lv -J-J, Lu W, et al. Burden of depression in adolescents in the Western Pacific Region from 1990 to 2019: an age-period-cohort analysis of the global burden of disease study. *Psychiatry Res*. 2024;336:115889. doi:10.1016/j.psychres.2024.115889
21. Yang CH, Lv -J-J, Kong X-M, et al. Global, regional and national burdens of depression in adolescents and young adults aged 10-24 years, from 1990 to 2019: findings from the 2019 global burden of disease study. *Br J Psychiatry*. 2024;225(2):311–320. doi:10.1192/bjp.2024.69
22. Muha J, Schumacher A, Campisi SC, et al. Depression and emotional eating in children and adolescents: a systematic review and meta-analysis. *Appetite*. 2024;200:107511. doi:10.1016/j.appet.2024.107511
23. Hazell P. Updates in treatment of depression in children and adolescents. *Curr Opin Psychiatry*. 2021;34(6):593–599. doi:10.1097/YCO.0000000000000749
24. Mangione CM, Barry MJ, Nicholson WK, et al. Screening for depression and suicide risk in children and adolescents: US preventive services task force recommendation statement. *JAMA*. 2022;328(15):1534–1542. doi:10.1001/jama.2022.16946
25. Lema-Gómez L, Arango-Paternina CM, Eusse-López C, et al. Family aspects, physical fitness, and physical activity associated with mental-health indicators in adolescents. *BMC Public Health*. 2021;21(1):2324. doi:10.1186/s12889-021-12403-2
26. Pereira-Payo D, Mendoza-Muñoz M, Denche-Zamorano A, Rubio-de la Osa A, Moreno-Quintanilla M, Pastor-Cisneros R. Physical activity is associated with the incidence of depression in United States adults from the NHANES 2013-18: a cross-sectional study. *Healthcare*. 2024;12 (5):552.
27. Piko BF, Keresztes N. Physical activity, psychosocial health, and life goals among youth. *J Community Health*. 2006;31(2):136–145. doi:10.1007/s10900-005-9004-2
28. Schmitter M, Spijker J, Smit F, et al. Exercise enhances: study protocol of a randomized controlled trial on aerobic exercise as depression treatment augmentation. *BMC Psychiatry*. 2020;20(1):585. doi:10.1186/s12888-020-02989-z
29. Shi C, Yan J, Wang L, et al. Exploring the self-reported physical fitness and self-rated health, mental health disorders, and body satisfaction among Chinese adolescents: a cross-sectional study. *Front Psychol*. 2022;13:1003231. doi:10.3389/fpsyg.2022.1003231
30. Daly M. Prevalence of depression among adolescents in the U.S. from 2009 to 2019: analysis of trends by sex, race/ethnicity, and income. *J Adolesc Health*. 2022;70(3):496–499. doi:10.1016/j.jadohealth.2021.08.026
31. Zupkauskiene J, Lauceviciene I, Navickas P, et al. Changes in health-related quality of life, motivation for physical activity, and the levels of anxiety and depression after individualized aerobic training in subjects with metabolic syndrome. *Hellenic J Cardiol*. 2022;66:41–51. doi:10.1016/j.hjc.2022.04.003
32. Beck A, Dryburgh N, Bennett A, et al. Screening for depression in children and adolescents in primary care or non-mental health settings: a systematic review update. *Syst Rev*. 2024;13(1):48. doi:10.1186/s13643-023-02447-3
33. Colasanto M, Madigan S, Korczak DJ. Depression and inflammation among children and adolescents: a meta-analysis. *J Affect Disord*. 2020;277:940–948. doi:10.1016/j.jad.2020.09.025
34. Crawford CM, Fallucco E, Fava M, et al. Depression - screening and treating depression in adolescents. *N Engl J Med*. 2024;390(22):e56. doi:10.1056/NEJMp2400711
35. Lee A, Park J. Diagnostic test accuracy of the beck depression inventory for detecting major depression in adolescents: a systematic review and meta-analysis. *Clin Nurs Res*. 2022;31(8):1481–1490. doi:10.1177/10547738211065105
36. Croarkin PE, Elmaadawi AZ, Aaronson ST, et al. Left prefrontal transcranial magnetic stimulation for treatment-resistant depression in adolescents: a double-blind, randomized, sham-controlled trial. *Neuropsychopharmacology*. 2021;46(2):462–469. doi:10.1038/s41386-020-00829-y