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ARTICLE

Exercise, Depression, and Anxiety in Young People: A Cross-Sectional Survey

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ABSTRACT

Background: Depression and anxiety are highly prevalent among adolescents and have multiple negative effects on their physical and mental health. While exercise can reduce the symptoms of depression and anxiety, the relationship between mental disorders among American university students has been rarely reported. Accordingly, this study aimed to explore the association between exercise, depression and anxiety among American university students in the 2018–2019 academic year. **Methods:** In this cross-sectional study, the association between exercise, depression and anxiety was investigated in a large representative sample of American university students. In the 2018–2019 academic year, university students aged 18+ years old from 79 institutions participated in this school-based study. The questionnaire included measurements of demographic characteristics, exercise, and validated screen instructions for depression (PHQ-9) and anxiety (GAD-7). The multivariable logistic regression model was applied to explore the association between exercise, depression and anxiety. **Results:** A total of 62026 individuals (31.9% males) participated in this survey, and the prevalence of exercising at least 5 h each day was 24.6%. The prevalence of depression and anxiety was 25.7% and 22.3%, respectively. In the multivariable logistic regression model, compared to exercise at least 5 h daily, participants whose exercise less than 1 h daily (OR = 1.31 [1.29, 1.33], $p < 0.05$), 2 to 3 h daily (OR = 1.13 [1.11, 1.15], $p < 0.05$), 3 to 4 h daily (OR = 1.04 [1.02, 1.06], $p < 0.05$), were correlated with greater odds of depression, while exercise less than 1 h daily (OR = 1.23 [1.21, 1.25], $p < 0.05$), 2 to 3 h daily (OR = 1.10 [1.08, 1.12], $p < 0.05$) were significantly correlated with greater odds of anxiety. **Conclusion:** Higher levels of exercise are associated with lower risk of depression and anxiety among American university students. Community and school interventions should focus on increasing exercise participation in university populations to promote both physical and mental health.

KEYWORDS

Exercise; depression; anxiety; adolescent; cross-sectional studies

1 Introduction

To cope with the COVID-19 pandemic, 143 countries imposed nationwide mandatory school closures at all levels starting in March 2020, affecting a total of 43,518,726 learners around the world [1,2]. While these lockdown policies protected the vulnerable population, they also brought negative mental impacts on young people, particularly anxiety and depression [3]. A recent meta-analysis illustrated that the prevalence of anxiety and depression for university students during COVID-19 was 31% and 34%, respectively, which

were considerably higher than before the pandemic [4]. Among young adults in the United States (US), the prevalence of depression and anxiety during COVID-19 was 43.3% and 45.4%, respectively [5]. Depression and anxiety could have adverse effects on university students from an individual, family, and social perspective. A cross-sectional study reported that depression predicts less happiness [5], while recent systematic reviews have shown that anxiety and depression are associated with addiction to the Internet and mobile phones among university students [6,7]. Moreover, two studies have proposed that higher levels of anxiety and depression are associated with a diminished quality of life [2,8], while studies from the US and India have reported that university students with high depression and anxiety have a poorer quality of sleep [9,10]. In terms of eating behaviour, previous research has shown that university students are more likely to suffer from eating disorders due to increased depression and anxiety [11,12]. In addition to these lifestyle behaviours, depression and anxiety also predict higher use of alcohol, marijuana, and nicotine [13,14] and greater susceptibility to risky sexual behaviour among university students [15,16]. Furthermore, several studies have even reported a correlation between depression, anxiety, and higher rates of self-harm and parasuicide [17–19]. In terms of academic performance, anxiety, and depression can predict lower grade point averages and a tendency to drop courses among university students [20–22]. Meanwhile, in a study on student-athletes, preseason anxiety was found to predict sports injuries in the prospective season [23]. Anxiety and depression are also interrelated with body image and obesity in general university students [24,25], while previous studies have shown that anxiety and depression are correlated with obesity [26–28].

Multitudinous observational studies have proposed that higher levels of PA or exercise are interrelated with lower levels of depression and anxiety symptoms among university students [29–33]. Moreover, a current meta-analysis demonstrated the effectiveness of exercise intervention, including aerobic exercise, traditional Chinese exercise, mind–body exercise, muscle-strengthening training, and high-intensity interval training, in reducing depression and anxiety symptoms among university students [34–41].

University students are undergoing a distinct phase in their lives, where they are obtaining considerable knowledge and skills while also beginning the huge transition from school to society. Consequently, they differ from adolescents and adults in their physical, psychological, and social perspectives. Previous research has proposed that the prevalence of depression and anxiety in university students is high, and both mental disorders have negative psychological, physical, academic performance, and lifestyle impacts, and even suicidal tendencies, in university students [4–13]. Exercise, as a changeable lifestyle behaviour, has been demonstrated in previous systematic reviews to be highly acceptable and effective in reducing depression and anxiety in university student populations [34–41]. Nevertheless, there is a lack of sufficient observational studies to explore the correlation between exercise and depression and anxiety in the university student population, which would provide reliable evidence for subsequent interventions and policy development. Moreover, previous research on the correlation between exercise and depression and anxiety in university students was conducted in China, Iceland, and other countries, with a lack of representative study samples from the massive population of American university students [29–33]. To the best of our knowledge, the Healthy Minds Study (HMS), which is the largest national study of university student mental health in the US, did not contribute to studies on the correlation between exercise and depression and anxiety [42]. Furthermore, the majority of the present studies have focused on the period after the outbreak of COVID-19, and there is a lack of research on pre-pandemic data [4]. The availability of pre-pandemic epidemiological data could contribute to carrying out pre-and post-COVID-19 comparisons of prevalence.

Accordingly, to contribute to the above research gaps, we identified two specific aims for this present study: 1) investigating the prevalence of exercise, depression, and anxiety and 2) exploring the association between exercise, depression, and anxiety among American university students in the 2018–2019 academic year.

2 Methods

2.1 Study Design

This study, which was cross-sectionally designed, secondarily analysed available data from the HMS 2018–2019 academic year (https://healthymindsnetwork.org/). As an annual, countrywide, cross-sectional survey conducted on the Internet, the HMS investigates physical, mental, and social health domains among university students in the United States [42]. Demographics, mental health status, and mental health survey utilization/help-seeking are three mandatory modules for colleges and universities who voluntarily participate in this survey, while additional optional modules are selected by their institutions. In the 2018–2019 HMS survey, researchers from the University of Michigan and Boston University recruited students aged 18 and higher from 79 small universities without any exclusion criteria via email. A sample of 4000 students was randomly recruited in institutions with >= 4000 learners, and all students were recruited in institutions with <4000 learners. The overall response rate was 16%. This survey was managed by Qualtrics, and the signed online consent form was obtained from all the subjects before participation. Ethical approvals for the HMS were provided by the ethics committees of all involved universities. The present study was exempt from the approval of the ethics committee due to its secondary analysis of anonymous data from HMS, a publicly accessible database.

2.2 Measures

2.2.1 Exercise

A single-selection question, whose validity and acceptability in previous waves of the HMS survey has been demonstrated [42], was performed as a self-reported measurement to assess exercise among participants. The question was: “In the past 30 days, how many hours per week on average did you spend exercising?”, while the answers were composed of: “Less than 1 h”, “2–3 h”, “3–4 h”, and “5 or more hours”.

2.2.2 Depression

The Patient Health Questionnaire-9 (PHQ-9), which is a self-administrated tool composed of the *Diagnostic and Statistical Manual of Mental Disorders* (DSM-IV)’s nine criteria for a depressive disorder, was applied to measure depression among participants [43,44]. In the US adult population, the reliability and validity of the PHQ-9 are 0.89 and 0.88, respectively [45]. The PHQ-9 investigates how often participants are troubled over the last two weeks using the nine criteria, such as “Little interest or pleasure in doing things.” Each criterion is rated from “0” (not at all) to “3” (nearly every day). Participants are screened for depression based on their overall scores as either negative (scores 0–9) or positive (scores 10–27) [43,44], thus converting the overall score into a dichotomous variable.

2.2.3 Anxiety

The Generalized Anxiety Disorder 7-Item (GAD-7) scale, which is a self-reported instrument consisting of DSM-IV’s seven criteria for generalized anxiety disorder, was applied to measure anxiety among the participants [45]. The reliability and validity of the GAD-7 in the US adult population are 0.92 and 0.83, respectively [45]. The GAD-7 explores how often participants are troubled over the last two weeks using seven criteria, such as “Trouble relaxing, becoming easily annoyed or irritable, etc.” Each criterion is rated from “0” (not at all) to “3” (nearly every day). Participants are screened for anxiety based on their overall score as either negative (scores 0–9) or positive (scores 10–22) [45], thus converting the overall score into a dichotomous variable.

2.2.4 Covariates

Sociodemographic characteristics, which consisted of age, sexual orientation (male, female, trans male, trans female, genderqueer, and self-identified), international students (Yes or No), race (Black, American Indian or Alaskan Native, Asian, Latino, Native Islander, Middle Eastern, Arab, White, other race), and residence were identified as covariates for further analysis.

2.3 Statistical Analysis

All statistical analyses were performed using SPSS 26.0. The study respondents' characteristics, independent variables, and outcomes were reported using a descriptive approach. The multivariable logistic regression model was employed to explore the association between exercise and depression and anxiety, controlling for age, gender, race/ethnicity, and international students. All results were presented as an odds ratio (OR) with 95% confidence intervals. All statistical analyses considered a weighted sample. Statistical significance was set as $p < 0.05$.

3 Results

3.1 Demographic Characteristics

The demographic characteristics of the participants are presented in Table 1. A total of 62,026 participants, of which 65.9% were female, were included in the final analysis during the 2018–2019 academic year. The majority of participants were in the 18-to-24-year-old age group (77.1%) and non-international students (91.8%), while residence status and race were diversely distributed.

Table 1: Demographic characteristics

		N	%	Weighted %	95%CI	
Total		**62026**	**100**	/	/	/
Gender						
	Male	19758	31.9	31.9	31.5	32.3
	Female	40900	65.9	66.0	65.7	66.4
	Trans male/Trans man	167	0.3	0.3	0.2	0.3
	Trans female/Trans woman	63	0.1	0.1	0.1	.01
	Genderqueer/Gender non-conforming	671	1.1	1.1	1.0	1.2
	Self-identify	374	0.6	0.6	0.5	0.7
	Missing	93	0.1			
Age group						
	18–24 years	47848	77.1	77.1	76.8	77.5
	25–65 years	14091	22.7	22.7	22.4	23.0
	≥66 years	86	0.1	0.1	0.1	0.2
	Missing	1	0.1			
Residence						
	On-campus housing, residence hall	17152	27.7	28.6	28.2	28.9
	On-campus housing, apartment	5370	8.7	8.9	8.7	9.2
	Fraternity or sorority house	925	1.5	1.5	1.4	1.6
	On- or off-campus cooperative housing	990	1.6	1.6	1.5	.18
	Off-campus, non-university housing	24980	40.3	41.6	41.2	42.0
	With my parents (or relatives)	8968	14.5	14.9	14.7	15.2
	Other	1636	2.6	2.7	2.6	2.9
	Missing	2005	3.2			

(Continued)

Table 1 (continued)

		N	%	Weighted %	95%CI	
Race						
	African American/Black	3535	5.7	6.2	6.0	6.4
	American Indian or Alaskan Native	165	0.3	0.3	0.2	0.3
	Asian American/Asian	7313	11.8	12.9	12.6	13.2
	Hispanic/Latino	4024	6.5	7.1	6.9	7.3
	Native Hawaiian or Pacific Islander	65	0.1	0.1	0.1	0.1
	Middle Eastern, Arab or Arab American	892	1.4	1.6	1.5	1.7
	White	39828	64.2	70.4	70.0	70.8
	Other	767	1.2	1.4	1.3	1.5
	Missing	5437	8.8			
International student						
	Yes	5082	8.2	8.2	8.0	8.4
	No	56657	91.3	91.8	91.6	92.0
	Missing	287	0.5			

Note: CI: confidence interval.

3.2 Prevalence of Exercise and Mental Disorders

From Table 2, it can be seen that 24.6% of the participants exercised at least 5 h daily, while the prevalence of depression and anxiety was 25.7% and 22.3%, respectively.

Table 2: Prevalence of exercise, depression and anxiety

		N	%	Weighted %	95%CI	
Total		**62026**	**100**	/	/	/
Exercise time per week						
	<1 h	16650	26.8	29.4	29.1	29.8
	2–3 h	15318	24.7	27.1	26.7	27.4
	3–4 h	9354	15.1	16.5	16.2	16.8
	≥5 h	15245	24.6	27.0	26.6	27.3
	Missing	5459	8.8			
Depression						
	Yes	15939	25.7	31.0	30.6	31.4
	No	35508	57.2	69.0	68.6	69.4
	Missing	10579	17.1			
Anxiety						
	Yes	13801	22.3	27.0	26,6	27.3
	No	37391	60.3	73.0	72.7	73.4
	Missing	10834	17.5			

Note: CI: confidence interval.

3.3 Association between Exercise and Mental Disorders

We observed that those participants who exercised less were prone to experience depression and anxiety compared with participants who exercised at least 5 h daily. Table 3 shows that exercise times of less than 1 h daily (OR = 1.31 [1.29, 1.33]), 2 to 3 h daily (OR = 1.13 [1.11, 1.15]), and 3 to 4 h daily (OR = 1.04 [1.02, 1.06]) were correlated with greater odds of depression. As for anxiety, it was associated with exercising for less than 1 h daily (OR = 1.23 [1.21, 1.25]) and for less than 2 to 3 h daily.

Table 3: Mental disorders associated with exercise

	Depression (overall score ≥ 10) n = 52626			Anxiety (overall score ≥ 10) n = 52635		
	OR	95%CI		OR	95%CI	
Exercise time per week						
Less than 1 h	**1.31**	**1.29**	**1.33**	**1.23**	**1.21**	**1.25**
2–3 h	**1.13**	**1.11**	**1.15**	**1.10**	**1.08**	**1.12**
3–4 h	**1.04**	**1.02**	**1.06**	1.02	1.00	1.04
5 or more hours	REF			REF		

Note: REF: reference group; All models were controlled for gender, age, international student, race, and residence; Bold numbers: statistically significant at $p < 0.05$.

4 Discussion

To the best of our knowledge, HMS is the largest study on university students in the area of mental health. The present study first explored the correlation between exercise and depression and anxiety in this database. The Results showed that the prevalence of PA is low, while the prevalence of the two mental disorders is high. Prolonged exercise was a protective factor against depression and anxiety, and lower exercise levels were significantly correlated with depression and anxiety. Our study contributes to the growing body of literature investigating the correlation between exercise and mental disorders in university students and provides a reference to compare the prevalence and correlation across countries and time.

As a modifiable lifestyle behaviour, many organizations and countries have promoted PA through the development of PA guidelines due to its benefits to individuals and all of society [28,46]. The 2018 PA Guidelines for Americans recommends that, every week, university students should perform 150 to 300 min of moderate-intensity aerobic exercise, 75 to 150 min of high-intensity aerobic exercise per week, or an equivalent combination of moderate-and high-intensity aerobic exercise [46]. In this study, nearly half of the participants met the recommended PA level, which is higher than the findings in US adolescent population research before the outbreak of COVID-19 [47,48]. One possible explanation for the exercise conflict is that the measurement applied in this study is different from the ones used in other observational studies. In large-scale observational studies, self-reported questionnaires, particularly the international PA questionnaire, are often applied to assess the level of PA, taking into account reliability, validity, and cost-effectiveness [49,50]. IPSQ-SF can explore time costs in different PA intensities and, thus, compare the results with the majority of PA guidelines. On the contrary, the measurement used in this study did not distinguish specific time costs at different PA intensities. Therefore, some participants who exercise 2–3 h a week may not meet the equivalent combination of moderate-and high-intensity aerobic exercise, leading to an overestimation of the prevalence of students meeting PA levels. Moreover, participants may overestimate their PA due to the 30-day-long recall period, as well as the influence of social desirability and social approval [51,52].

The prevalence of depression in this study resembles the results of the 2005–2018 HMS academic year, as well as pre-COVID-19 studies among university students in other regions [53–55]. Whilst the PHQ-9 cannot be used as an instrument for the clinical diagnosis of depression, it helps to detect the prevalence of depression at the population level. As part of a national cohort study using the same measurement, the prevalence of depression in the 2005–2018 HMS academic year was similar to the results of this study, which may be due to controlling for inclusion criteria and confounding factors. External factors such as the participants' geographical location, sociocultural background, and other factors can significantly influence the prevalence of mental disorders at a population level.

In this study, the prevalence of anxiety resembles the results of the 2015–2017 HMS academic year [56], whereas there were increases of 7.0% to 27.0% compared with the prevalence in the 2007 and 2009 HMS academic years [53]. Even considering the growing trend in the prevalence of anxiety disorders in university students [11,57], it is also possible that such considerable growth, even after controlling for inclusion criteria and confounding factors, may be the result of differences in measurement instruments. The anxiety measurements for the 2007 and 2009 HMS academic years were concise screens using the PHQ, whereas this study used GAD-7. However, in the 2015–2017 HMS academic year, which also used the GAD-7, the prevalence of anxiety was similar to that of this study, indicating that different measurement instruments can reduce the comparability of mental disorders.

To the best of our knowledge, this study, which investigated data from the 2018–2019 HMS academic year, is the first to explore the correlation between exercise and depression and anxiety in the HMS. Our study reported that university students who exercise less than five hours a week had a significantly greater risk of depression compared with those who exercise more than five hours per week. As for anxiety, those who exercise less than three hours per week have a significantly higher risk of anxiety compared with those who exercise more than five hours per week. Our findings are consistent with extant meta-analyses that have found that higher levels of exercise correlate with lower levels of depression and anxiety in university students [58,59]. Moreover, the association between more exercise and lower levels of anxiety and depression has also been reported in studies conducted after the COVID-19 outbreak [60]. As a specific group, university students are transitioning from adolescence to adulthood; thus, different mechanism hypotheses may exist to explain the effectiveness of PA intervention on the mental health of university students, such as neurobiological, psychosocial, or behavioural factors [61]. The neurobiological mechanism hypothesis suggests that PA promotes mental health by altering the function and structure of the brain, particularly neuroimaging changes in frontal lobe area activation and electrophysiological parameters [62]. A study by Gondoh showed that exercise training maintains grey matter volume in the left insula of university students and enhances their mental health [63]. Moreover, monoamine and neurotrophin hypotheses have also been proposed [64]. The possible psychosocial mechanisms include positive variations in physical self-concept and the positive effects of acute exercise on transient mood [65,66]. According to the behavioural mechanism hypothesis, PA can contribute to mental health through effective self-regulation and physical self-regulation [61].

4.1 Limitations and Further Recommendations

Several limitations inevitably exist in this study. First, exclusion criteria for participants were not identified (e.g., participants with a physical disability or clinically diagnosed mental disorders), which may introduce bias. Second, the cross-sectional study design was incapable of verifying causal inferences. Third, the exercise measures in this study did not differentiate between different PA intensities, and the correlation between different PA intensities and mental disorders varied. Therefore, the unsegmented exercise measurement may cause bias in this study. Fourth, exercise was subjectively measured based on a long-term recall period of 30 days, which may cause bias due to a social desirability effect and memory error. Finally, depression and anxiety were measured by using standardised questionnaires, which are

valid and reliable but are not a substitute for clinical diagnosis. Accordingly, future studies need to identify exclusion criteria for participants, apply longitudinal and retrospective designs, and objectively measure the appropriate variables to provide more precise evidence.

5 Conclusion

The present study suggests that the prevalence of exercising for more than 5 h daily is low among American university students, and the prevalence of depression and anxiety is high. Moreover, within this population, higher levels of exercise may be positively associated with lower levels of depression and anxiety. Community and school interventions should prevent or reduce anxiety and depression by increasing exercise participation among university students, thereby promoting both physical and mental health.

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Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.

References

1. UNESCO (2022). Education: From disruption to recovery 2022. https://en.unesco.org/covid19/educationresponse?fbclid=IwAR34xtgjsaJtaDBgstsWRUHan9RnPJsHWAka_8YCmJ5S51hBy700rDtcQ2M.
2. Gan, G. G., Yuen, L. H. (2019). Anxiety, depression and quality of life of medical students in Malaysia. *The Medical Journal of Malaysia, 74(1),* 57–61.
3. Onyeaka, H., Anumudu, C. K., Al-Sharify, Z. T., Egele-Godswill, E., Mbaegbu, P. (2021). COVID-19 pandemic: A review of the global lockdown and its far-reaching effects. *Science Progress, 104(2),* 00368504211019854. DOI 10.1177/00368504211019854.
4. Chang, J. J., Ji, Y., Li, Y. H., Pan, H. F., Su, P. Y. (2021). Prevalence of anxiety symptom and depressive symptom among college students during COVID-19 pandemic: A meta-analysis. *Journal of Affective Disorders, 292,* 242–254. DOI 10.1016/j.jad.2021.05.109.
5. Tan, M. N., Mevsim, V., Pozlu Cifci, M., Sayan, H., Ercan, A. E. et al. (2020). Who is happier among preclinical medical students: The impact of chronotype preference. *Chronobiology International, 37(8),* 1163–1172. DOI 10.1080/07420528.2020.1761373.
6. Li, Y., Li, G., Liu, L., Wu, H. (2020). Correlations between mobile phone addiction and anxiety, depression, impulsivity, and poor sleep quality among college students: A systematic review and meta-analysis. *Journal of Behavioral Addictions, 9(3),* 551–571. DOI 10.1556/2006.2020.00057.
7. Seki, T., Hamazaki, K., Natori, T., Inadera, H. (2019). Relationship between internet addiction and depression among Japanese university students. *Journal of Affective Disorders, 256,* 668–672. DOI 10.1016/j.jad.2019.06.055.
8. Leong Bin Abdullah, M. F. I., Mansor, N. S., Mohamad, M. A., Teoh, S. H. (2021). Quality of life and associated factors among university students during the COVID-19 pandemic: A cross-sectional study. *BMJ Open, 11(10),* e048446. DOI 10.1136/bmjopen-2020-048446.
9. Becker, S. P., Jarrett, M. A., Luebbe, A. M., Garner, A. A., Burns, G. L. et al. (2018). Sleep in a large, multi-university sample of college students: Sleep problem prevalence, sex differences, and mental health correlates. *Sleep Health, 4(2),* 174–181. DOI 10.1016/j.sleh.2018.01.001.

10. Ghrouz, A. K., Noohu, M. M., Dilshad Manzar, M., Warren Spence, D., BaHammam, A. S. et al. (2019). Physical activity and sleep quality in relation to mental health among college students. *Sleep & Breathing = Schlaf & Atmung, 23(2),* 627–634. DOI 10.1007/s11325-019-01780-z.
11. Coakley, K. E., Le, H., Silva, S. R., Wilks, A. (2021). Anxiety is associated with appetitive traits in university students during the COVID-19 pandemic. *Nutrition Journal, 20(1),* 45. DOI 10.1186/s12937-021-00701-9.
12. Eck, K. M., Byrd-Bredbenner, C. (2021). Disordered eating concerns, behaviors, and severity in young adults clustered by anxiety and depression. *Brain and Behavior, 11(12),* 2367. DOI 10.1002/brb3.2367.
13. Bierhoff, J., Haardörfer, R., Windle, M., Berg, C. J. (2019). Psychological risk factors for alcohol, cannabis, and various tobacco use among young adults: A longitudinal analysis. *Substance use & Misuse, 54(8),* 1365–1375. DOI 10.1080/10826084.2019.1581220.
14. Masaki, K., Taketa, R. M., Nakama, M. K., Kawamoto, C. T., Pokhrel, P. (2022). Relationships between depressive symptoms, anxiety, impulsivity and cigarette and E-cigarette use among young adults. *Hawai'i Journal of Health & Social Welfare, 81(3),* 51–57.
15. Ramrakha, S., Caspi, A., Dickson, N., Moffitt, T. E., Paul, C. (2000). Psychiatric disorders and risky sexual behaviour in young adulthood: Cross sectional study in birth cohort. *BMJ, 321(7256),* 263–266. DOI 10.1136/bmj.321.7256.263.
16. Agardh, A., Cantor-Graae, E., Ostergren, P. O. (2012). Youth, sexual risk-taking behavior, and mental health: A study of university students in Uganda. *International Journal of Behavioral Medicine, 19(2),* 208–216. DOI 10.1007/s12529-011-9159-4.
17. Patsali, M. E., Mousa, D. V., Papadopoulou, E. V. K., Papadopoulou, K. K. K., Kaparounaki, C. K. et al. (2020). University students' changes in mental health status and determinants of behavior during the COVID-19 lockdown in Greece. *Psychiatry Research, 292,* 113298. DOI 10.1016/j.psychres.2020.113298.
18. Ali, M., Uddin, Z., Amran Hossain, K. M., Uddin, T. R. (2022). Depression, anxiety, stress, and suicidal behavior among Bangladeshi undergraduate rehabilitation students: An observational study amidst the COVID-19 pandemic. *Health Science Reports, 5(2),* e549. DOI 10.1002/hsr2.549.
19. Lew, B., Huen, J., Yu, P., Yuan, L., Wang, D. F. et al. (2019). Associations between depression, anxiety, stress, hopelessness, subjective well-being, coping styles and suicide in Chinese university students. *PLoS One, 14(7),* e0217372. DOI 10.1371/journal.pone.0217372.
20. Gorman, E. L., Burke, H. H., Rubino, L. G., Vargas, I., Haeffel, G. J. (2020). Teasing apart the effect of depression specific and anxiety specific symptoms on academic outcomes. *Clinical Psychology and Special Education, 9(3),* 91–104. DOI 10.17759/cpse.2020090307.
21. Awadalla, S., Davies, E. B., Glazebrook, C. (2020). A longitudinal cohort study to explore the relationship between depression, anxiety and academic performance among Emirati university students. *BMC Psychiatry, 20(1),* 448. DOI 10.1186/s12888-020-02854-z.
22. Andrews, B., Wilding, J. M. (2004). The relation of depression and anxiety to life-stress and achievement in students. *British Journal of Psychology, 95,* 509–521. DOI 10.1348/0007126042369802.
23. Li, H., Moreland, J. J., Peek-Asa, C., Yang, J. (2017). Preseason anxiety and depressive symptoms and prospective injury risk in collegiate athletes. *The American Journal of Sports Medicine, 45(9),* 2148–2155. DOI 10.1177/0363546517702847.
24. Edlund, K., Johansson, F., Lindroth, R., Bergman, L., Sundberg, T. et al. (2022). Body image and compulsive exercise: Are there associations with depression among university students? *Eating and Weight Disorders–Studies on Anorexia, Bulimia and Obesity, 27,* 2397–2405. DOI 10.1007/s40519-022-01374-x.
25. Pritchard, M., Brasil, K., McDermott, R., Holdiman, A. (2021). Untangling the associations between generalized anxiety and body dissatisfaction: The mediating effects of social physique anxiety among collegiate men and women. *Body Image, 39,* 266–275. DOI 10.1016/j.bodyim.2021.10.002.
26. Nogueira, M., de Assis, B. D. S., Ferreira, C. C. D., Franco-Sena Siqueira, A. B., Leão, L. et al. (2021). Is level of anxiety associated with overweight and obesity risk in university students? The NUTSAU study. *Nutricion Hospitalaria, 38(3),* 488–494. DOI 10.20960/nh.03376.

27. Kaufman, C. C., Thurston, I. B., Maclin-Akinyemi, C., Hardin, R. N., Decker, K. M. et al. (2020). Risk and protective factors associated with depressive symptoms in young adults with overweight and obesity. *Journal of American College Health, 68(2),* 148–154. DOI 10.1080/07448481.2018.1536057.
28. Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P. et al. (2020). World health organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine, 54(24),* 1451–1462. DOI 10.1136/bjsports-2020-102955.
29. Cahuas, A., He, Z., Zhang, Z., Chen, W. (2020). Relationship of physical activity and sleep with depression in college students. *Journal of American College Health, 68(5),* 557–564. DOI 10.1080/07448481.2019.1583653.
30. Chi, X., Liang, K., Chen, S. T., Huang, Q., Huang, L. et al. (2021). Mental health problems among Chinese adolescents during the COVID-19: The importance of nutrition and physical activity. *International Journal of Clinical and Health Psychology, 21(3),* 100218. DOI 10.1016/j.ijchp.2020.100218.
31. Hrafnkelsdottir, S. M., Brychta, R. J., Rognvaldsdottir, V., Gestsdottir, S., Chen, K. Y. et al. (2018). Less screen time and more frequent vigorous physical activity is associated with lower risk of reporting negative mental health symptoms among Icelandic adolescents. *PLoS One, 13(4),* e0196286. DOI 10.1371/journal.pone.0196286.
32. El Ansari, W., Salam, A. (2021). Physical activity and mental health. is achieving the physical activity guidelines associated with less depressive symptoms among undergraduates at the University of Turku, Finland? *Central European Journal of Public Health, 29(3),* 201–208. DOI 10.21101/cejph.a6813.
33. Rodriguez-Ayllon, M., Cadenas-Sánchez, C., Estévez-López, F., Muñoz, N. E., Mora-Gonzalez, J. et al. (2019). Role of physical activity and sedentary behavior in the mental health of preschoolers, children and adolescents: A systematic review and meta-analysis. *Sports Medicine, 49(9),* 1383–1410. DOI 10.1007/s40279-019-01099-5.
34. Carter, T., Pascoe, M., Bastounis, A., Morres, I. D., Callaghan, P. et al. (2021). The effect of physical activity on anxiety in children and young people: A systematic review and meta-analysis. *Journal of Affective Disorders, 285,* 10–21. DOI 10.1016/j.jad.2021.02.026.
35. Huang, J., Nigatu, Y. T., Smail-Crevier, R., Zhang, X., Wang, J. (2018). Interventions for common mental health problems among university and college students: A systematic review and meta-analysis of randomized controlled trials. *Journal of Psychiatric Research, 107,* 1–10. DOI 10.1016/j.jpsychires.2018.09.018.
36. Song, J., Liu, Z. Z., Huang, J., Wu, J. S., Tao, J. (2021). Effects of aerobic exercise, traditional Chinese exercises, and meditation on depressive symptoms of college student: A meta-analysis of randomized controlled trials. *Medicine, 100(1),* e23819. DOI 10.1097/MD.0000000000023819.
37. Guo, S., Liu, F., Shen, J., Wei, M., Yang, Y. (2020). Comparative efficacy of seven exercise interventions for symptoms of depression in college students: A network of meta-analysis. *Medicine, 99(47),* e23058. DOI 10.1097/MD.0000000000023058.
38. Chi, X., Curtin, K., Kastelic, K., Huang, L., Clark, C. et al. (2021). Muscle-strengthening exercise and depression in Chinese young adults. https://www.researchsquare.com/article/rs-154416/v1.
39. Faro, J., Wright, J. A., Hayman, L. L., Hastie, M., Gona, P. N. et al. (2019). Functional resistance training and affective response in female college-age students. *Medicine and Science in Sports and Exercise, 51(6),* 1186–1194. DOI 10.1249/MSS.0000000000001895.
40. Eather, N., Riley, N., Miller, A., Smith, V., Poole, A. et al. (2019). Efficacy and feasibility of HIIT training for university students: The Uni-HIIT RCT. *Journal of Science and Medicine in Sport, 22(5),* 596–601. DOI 10.1016/j.jsams.2018.11.016.
41. Mailey, E. L., Wójcicki, T. R., Motl, R. W., Hu, L., Strauser, D. R. et al. (2010). Internet-delivered physical activity intervention for college students with mental health disorders: A randomized pilot trial. *Psychology, Health & Medicine, 15(6),* 646–659. DOI 10.1080/13548506.2010.498894.
42. Healthy Minds Network (2022). Healthy minds study among colleges and universities, year (HMS 2018–2019). Healthy minds network, University of Michigan, University of California Los Angeles, Boston University, and Wayne State University. https://healthymindsnetwork.org/reserach/data-for-researchers.
43. Spitzer, R. L., Kroenke, K., Williams, J. B. (1999). Patient health questionnaire primary care study group, & patient health questionnaire primary care study group. Validation and utility of a self-report version of PRIME-MD: The PHQ primary care study. *JAMA, 282(18),* 1737–1744. DOI 10.1001/jama.282.18.1737.

44. Kroenke, K., Spitzer, R. L., Williams, J. B. (2001). The PHQ-9: Validity of a brief depression severity measure. *Journal of General Internal Medicine, 16(9),* 606–613. DOI 10.1046/j.1525-1497.2001.016009606.x.
45. Spitzer, R. L., Kroenke, K., Williams, J. B., Löwe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166(10),* 1092–1097. DOI 10.1001/archinte.166.10.1092.
46. US Department of Health and Human Services (2018). *Physical activity guidelines for americans*, 2nd edition. DC: US Department of Health and Human Services.
47. Office of Disease Prevention and Health Promotion UDoHaHS (2020). Healthy people 2020: Data search—Physical activity 2020. https://www.healthypeople.gov/2020/data-search/search-the-data#topic-area=3504.
48. Armstrong, S., Wong, C. A., Perrin, E., Page, S., Sibley, L. et al. (2018). Association of physical activity with income, race/ethnicity, and Sex among adolescents and young adults in the United States: Findings from the national health and nutrition examination survey, 2007–2016. *JAMA Pediatrics, 172(8),* 732–740. DOI 10.1001/jamapediatrics.2018.1273.
49. Welk, G. (2002). *Physical activity assessments for health-related research*. USA: Human Kinetics.
50. Lee, P. H., Macfarlane, D. J., Lam, T. H., Stewart, S. M. (2011). Validity of the international physical activity questionnaire short form (IPAQ-SF): A systematic review. *International Journal of Behavioral Nutrition and Physical Activity, 8(1),* 1–11. DOI 10.1186/1479-5868-8-115.
51. Adams, S. A., Matthews, C. E., Ebbeling, C. B., Moore, C. G., Cunningham, J. E. et al. (2005). The effect of social desirability and social approval on self-reports of physical activity. *American Journal of Epidemiology, 161(4),* 389–398. DOI 10.1093/aje/kwi054.
52. Sallis, J. F., Saelens, B. E. (2000). Assessment of physical activity by self-report: Status, limitations, and future directions. *Research Quarterly for Exercise and Sport, 71(sup2),* 1–14. DOI 10.1080/02701367.2000.11082780.
53. Eisenberg, D., Hunt, J., Speer, N. (2013). Mental health in American colleges and universities: Variation across student subgroups and across campuses. *The Journal of Nervous and Mental Disease, 201(1),* 60–67. DOI 10.1097/NMD.0b013e31827ab077.
54. Goodwill, J. R., Zhou, S. (2020). Association between perceived public stigma and suicidal behaviors among college students of color in the U.S. *Journal of Affective Disorders, 262,* 1–7. DOI 10.1016/j.jad.2019.10.019.
55. Ramón-Arbués, E., Gea-Caballero, V., Granada-López, J. M., Juárez-Vela, R., Pellicer-García, B. et al. (2020). The prevalence of depression, anxiety and stress and their associated factors in college students. *International Journal of Environmental Research and Public Health, 17(19),* 7001. DOI 10.3390/ijerph17197001.
56. Lipson, S. K., Raifman, J., Abelson, S., Reisner, S. L. (2019). Gender minority mental health in the U.S.: Results of a national survey on college campuses. *American Journal of Preventive Medicine, 57(3),* 293–301. DOI 10.1016/j.amepre.2019.04.025.
57. Kosic, A., Lindholm, P., Järvholm, K., Hedman-Lagerlöf, E., Axelsson, E. (2020). Three decades of increase in health anxiety: Systematic review and meta-analysis of birth cohort changes in university student samples from 1985 to 2017. *Journal of Anxiety Disorders, 71,* 102208. DOI 10.1016/j.janxdis.2020.102208.
58. Schuch, F. B., Vancampfort, D., Firth, J., Rosenbaum, S., Ward, P. B. et al. (2018). Physical activity and incident depression: A meta-analysis of prospective cohort studies. *American Journal of Psychiatr, 175(7),* 631–648. DOI 10.1176/appi.ajp.2018.17111194.
59. Schuch, F. B., Stubbs, B., Meyer, J., Heissel, A., Zech, P. et al. (2019). Physical activity protects from incident anxiety: A meta-analysis of prospective cohort studies. *Depression and Anxiety, 36(9),* 846–858. DOI 10.1002/da.22915.
60. Wolf, S., Seiffer, B., Zeibig, J. M., Welkerling, J., Brokmeier, L. et al. (2021). Is physical activity associated with less depression and anxiety during the COVID-19 pandemic? A rapid systematic review. *Sports Medicine, 51(8),* 1771–1783. DOI 10.1007/s40279-021-01468-z.
61. Lubans, D., Richards, J., Hillman, C., Faulkner, G., Beauchamp, M. et al. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics, 138(3)*. DOI 10.1542/peds.2016-1642.
62. Heinze, K., Cumming, J., Dosanjh, A., Palin, S., Poulton, S. et al. (2021). Neurobiological evidence of longer-term physical activity interventions on mental health outcomes and cognition in young people: A systematic review of randomised controlled trials. *Neuroscience and Biobehavioral Reviews, 120,* 431–441. DOI 10.1016/j.neubiorev.2020.10.014.

63. Gondoh, Y., Sensui, H., Kinomura, S., Fukuda, H., Fujimoto, T. et al. (2009). Effects of aerobic exercise training on brain structure and psychological well-being in young adults. *The Journal of Sports Medicine and Physical Fitness, 49(2),* 129–135.
64. Chen, M. J. (2013). The neurobiology of depression and physical exercise. In: *Routledge handbook of physical activity and mental health*, pp. 191–206. UK: Routledge.
65. Annesi, J. J. (2005). Improvements in self-concept associated with reductions in negative mood in preadolescents enrolled in an after-school physical activity program. *Psychological Reports, 97(2),* 400–404. DOI 10.2466/pr0.97.2.400-404.
66. Ekkekakis, P., Dafermos, M. (2012). Exercise is a many-splendored thing, but for some it does not feel so splendid: Staging a resurgence of hedonistic ideas in the quest to understand exercise behavior. https://www.semanticscholar.org/paper/Exercise-Is-a-Many-Splendored-Thing%2C-but-for-Some-a-Ekkekakis-Dafermos/6ebf67c1a3ba15d2a5078e1c71858e3dd578717d.