Health Promotion and Physical Activity
ISSN 2544-9117 ▪ 2024; 28 (3): 17–28
doi: 10.55225/hppa.597

HPPA • 2024; 28 (3): 17-28

The effects of exercise on mental health among college students

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Original article

Abstract

Background: The prevalence of mental health (MH) disorders among college-aged young adults is alarmingly high, with many also experiencing poor physical health and comorbidities. The purpose of this study was to examine the effects of exercise on MH among college students.

Materials and methods: Fifteen participants (60% males, 20.0 ± 2.0 years) participated in this 8-week study. Nine participants completed the exercise (EX) intervention, while 6 formed the non-exercise control (CON) group. The Depression Anxiety Stress Scores (DASS-21) instrument was used to collect data for the dependent variable and analyzed using linear mixed models (LMM).

Results: No statistically significant differences were found in depression ($F = 0.015$, $p = 0.904$), anxiety ($F = 1.038$, $p = 0.327$), and overall MH ($F = 0.266$, $p = 0.615$) scores between groups or over time. The EX group's pre/post scores (mean ± standard deviation) for depression (pre: 1.11 ± 2.62, post: 2.44 ± 5.34), anxiety (pre: 1.00 ± 0.87, post: 3.11 ± 2.52), and overall MH (pre: 3.33 ± 5.34, post: 8.55 ± 13.06). The CON group's pre/post scores for depression (pre: 0.66 ± 1.21, post: 2.32 ± 3.83), anxiety (pre: 1.67 ± 2.40, post: 5.16 ± 6.49), and overall MH (pre: 4.33 ± 4.23, post: 13.33 ± 16.91).

Conclusion: Although there were no statistically significant differences in depression, anxiety, and overall MH scores between the EX and CON groups, the findings may have practical implications. Notably, the anxiety and overall MH scores in the CON group exceeded the *normal* classification on the DASS-21, and the EX group maintained normal scores throughout the 8-week intervention. These findings suggest that regular exercise likely plays a crucial role in sustaining MH status, highlighting its importance as a preventive measure rather than solely a therapeutic intervention.

Approval of ethics committee

East Stroudsburg University Institutional Review Board, Human Research Review. Protocol # ESU-IRB-001-2122. Research conducted August 2021 – May 2022.

Keywords

- anxiety
- depression
- physical activity
- young adults

Contribution

A – Preparation of the research project
B – Assembly of data
C – Conducting of statistical analysis
D – Interpretation of results
E – Manuscript preparation
F – Literature review
G – Revising the manuscript

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Article info

Article history

- Received: 2024-08-12
- Accepted: 2024-11-06
- Published: 2025-01-20

Publisher

University of Applied Sciences in Tarnow
ul. Mickiewicza 8, 33-100 Tarnow, Poland

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Conflict of interest

None declared.

Financing

This research did not receive any grants from public, commercial or non-profit organizations.

Introduction

Mental health (MH) disorders, specifically anxiety and depression, have been a growing cause for concern throughout the world in recent years. Over the last decade, the prevalence of MH disorders has increased by roughly 18%, with approximately 1 in 5 adults worldwide experiencing at least one disorder each year.[1] In 2019, the Global Burden of Disease Collaborative Health Network reported that MH disorders affected approximately 742 million adults (14.6%) globally, with anxiety and depression among the top causes of disability worldwide.[2]

In Europe, this growing burden is particularly pronounced. The World Health Organization (WHO) European Region reports over 125 million people were affected by a MH disorder in 2019, nearly 13% of the population.[3] Moreover, depressive and anxiety disorders accounted for 29% and 18%, respectively, of the total burden caused by MH and substance use disorders.[4] The prevalence of MH disorders is especially high among adults aged 20–54, with more than 50% of cases falling within this age group.[4]

While this European data highlights the significant burden of MH disorders, similar trends are seen globally, especially among younger populations. For example, in the United States, young adults aged 18–25 years, have the highest prevalence of MH disorders (30.6%) compared to other age groups, and these data are believed to be underreported.[5] Notably, approximately 50% of lifetime MH disorders begin by the age of 14 and 75% begin by the age of 24.[5]

MH directly impacts physical health, with approximately 50% of those diagnosed with MH disorders also suffering from poor health, being overweight or obese, and having comorbidities such as cardiovascular diseases (CVD), Alzheimer's disease, metabolic disease, type II diabetes, mortality, and non-compliance with medical treatment.[6,7] While the relationship between obesity and chronic disease is well established, the relationship between obesity and MH disorders requires more attention.

MH disorders negatively affect well-being, relationships, careers, and productivity, especially among undergraduate college students who experience unprecedented amounts of stress. This stress negatively impacts academic performance, relationships, sense of self, and physical and mental health.[6,8] College students may also experience increased sedentary behaviors due to studying, completing homework assignments, attending lectures, and increased screen time usage (smartphone, computer, TV, etc.). Several studies have reported negative physical and mental health-related outcomes associated with increased screen time, including increased risk of anxiety and depression, and decreased well-being.[9]

For the prevention and treatment of chronic diseases, the American College of Sports Medicine (ACSM) and the World Health Organization (WHO) recommend adults engage in a minimum of 150 minutes (2 hours and 30 minutes) of moderate-intensity aerobic exercise or 75 minutes (1 hour and 15 minutes) of vigorous-intensity aerobic exercise (AE) each week.[10] Adults should also perform moderate or high-intensity resistance training (RT) exercise that involves all major muscle groups at least 2 (or more) days per week.[10] This combination of AE and RT is also known as concurrent training (CT) exercise. It has been well documented that regular exercise is associated with numerous health benefits, including reduced overall mortality, improved muscular strength and endurance, improved ability to manage stress, and decreased risks of CVD, obesity, stroke, and cancer.[11–13] Because of the dose-response relationship between exercise and health, those who wish to improve their fitness level further, reduce their risk for chronic diseases and disabilities, and/or prevent excessive weight gain may benefit from exceeding the minimum recommended amounts of exercise.[10]

Beyond these general guidelines, research emphasizes that exercise provides numerous MH benefits. Exercise is known to positively impact MH through numerous physiological, psychological, and psycho-social mechanisms.[14] Exercise has been shown to improve psychological factors such as self-efficacy, self-esteem, and self-confidence, which is particularly important in those individuals suffering from MH disorders because they generally tend to struggle with these qualities.[15] The relationship between self-esteem and MH disorders appears to be cyclical; whereby poor self-esteem can lead to depressive symptoms, enhancing the pre-existing self-esteem issues.[15] Exercise is known to create a perception of improved physical abilities and mastery of a skill resulting in improved self-efficacy.[15] In addition, psychosocial factors such as social interaction could also potentially assist in the improvement of anxiety and depressive symptoms.[1]

Despite these recommendations, approximately 80% of U.S. adults (ages 18–80) and 70% of young adults (ages 18–24) do not meet the exercise guidelines.[1,16] Previous research has shown that structured exercise is a safe, effective, and inexpensive method to treat and prevent MH disorders in individuals with and without a diagnosed MH disorder.[1,17] However, there are currently no specific exercise guidelines for the treatment and prevention of MH symptoms.[18] The RT recommendations have only recently been added to the ACSM and WHO exercise guidelines within the last decade, which may explain the lack of research on the relationship between RT and CT on MH.[16] In addition, this could explain the lack of understanding among the general public regarding the potential benefits of CT, as previous exercise recommendations focused solely on AE, rather than the combination of AE and RT.[16]

While exercise is widely recognized for its numerous health benefits, young adults, particularly those aged 18–25, face unique MH challenges that require further exploration. The prevalence of MH disorders in this demographic is a significant concern, further exacerbated by the COVID-19 pandemic. Traditional treatment methods for MH disorders include medication and/or psychotherapy; however, there is emerging evidence to support the use of structured exercise for the treatment and prevention of MH disorders in individuals with and without a diagnosed MH disorder.[1] Exercise provides a low-risk, cost-effective approach to improving MH, avoiding the potential side effects of medication and the long waits and expenses associated with psychotherapy.

Emerging evidence suggests that the prevalence of MH symptoms is lower in those who met exercise recommendations for AE and RT, instead of meeting just one or the other.[6] The combination of AE and RT may provide unique benefits over solely AE or RT, but there have been a limited number of studies to explore this.[6] Therefore, the purpose of the present study was to examine the effects of exercise on mental health among college students. In addition, this study investigated the differences in physiological measurements (e.g., body composition, 1.5-mile run, 5RM bench press, and partial curl-ups) between an exercise and non-exercise control group.

Materials and methods

Participants and study design

This study used a pre/post design to examine the effects of an 8-week exercise intervention on MH among college students. Following the approval from the East Stroudsburg University Institutional Review Board, fifteen college-aged participants (60% males, 20.0 ± 2.0 years) volunteered to participate in this 8-week study. Nine participants completed the exercise (EX) intervention, while 6 formed the non-exercise control (CON) group. Participants were recruited via a convenience sample from introductory-level Exercise Science courses, which typically enroll mostly first-year students, and the exercise intervention was embedded into the course requirements. Due to the structure of the course and logistical reasons, participants were not randomly assigned to the EX and CON groups. Each course met 3 times per week for a total of 24 meetings with 20 bouts of exercise performed. Participants were required to attend at least 17 sessions (85%) for compliance. All participants were asked to read and sign an informed consent form before volunteering for the study.

However, participants were excluded from participation in this study under the following conditions: if they had a diagnosed MH disorder or were receiving any form of treatment for one; if they were required to take any prescription medication of any kind; and if they were required to engage in any other structured activity outside of the intervention due to other responsibilities (e.g., sports and recreational activities). Participants who scored in the *severe/extremely severe* categories on the initial DASS-21 assessment were also excluded from the study and referred to the school's Counseling and Psychological Services.

Exercise intervention

During the 8-week intervention, participants engaged in various forms of aerobic, concurrent, and resistance training exercises for approximately 30 to 45 minutes led by a qualified instructor of Exercise Science. Participants performed a standardized 10-minute dynamic warm-up prior to each bout of exercise. The AE component varied between steady-state cardio, intermittent sprints, high-intensity interval training, and Fartlek training. Participants were encouraged to maintain moderate-to-high exercise intensities and used the modified Borg RPE (0–10) scale to quantify exercise intensity (e.g., moderate intensity = 5–6, high intensity = 7–10). For the RT portion, participants were instructed to perform 2–3 sets of 8–12 repetitions at a moderate intensity. Following Gordon et al. (2020), participants were instructed to increase resistance by 5% if they completed 12 repetitions in the previous session or decrease it by 5% if they failed to complete 8 repetitions. Lastly, the CT protocol effectively integrated both AE and RT components. This variety provided a comprehensive exercise intervention, while simultaneously serving to educate participants on the different training methodologies.

Mental health assessments

The primary outcome for this study was the Depression Anxiety Stress Scores (DASS-21) instrument, which has shown criterion validity (depression: AUC = 0.77–0.91, anxiety AUC = 0.60–0.83).[6] The DASS-21 consists of

21 Likert-scale questions to measure the participants' depression, anxiety, stress, and overall mental health scores using a 4-point Likert scale (0 to 3) with a maximum total score of 63.[19] The scores were organized and arranged into 5 different categories: *normal*, *mild*, *moderate*, *severe*, and *extremely severe*.[19] Participants identified themselves using coded numbers to ensure confidentiality. This instrument was administered pre- and post-intervention (weeks 1 and 8) to assess changes in depression, anxiety, and overall MH.

Physiological assessments

Physiological assessments included body fat percentage, 1.5-mile run (on an indoor track), 5RM bench press (NSCA protocol), and partial curl-ups (NSCA protocol); served as pre/post measures to monitor health and fitness improvements. These tests were selected based on standardized NSCA protocols to ensure the validity, reliability, and safety of the measures. For example, the 5RM bench press was chosen to prioritize participant safety and its feasibility for novice participants. The partial curl-ups are preferred to the sit-ups test because they eliminate the use of the hip flexors, providing a more accurate measure of core endurance. These physiological tests provided additional data to measure potential associations between fitness levels and MH status. Supplemental data from the exercise program variables (e.g., mean session duration, distance traveled, exercise intensity, number of sets and repetitions performed, and length of rest periods) were collected to provide further insight into the effectiveness of exercise interventions on MH in college students.

Procedures

Participants completed a Physical Activity Readiness Questionnaire (PAR-Q) to obtain medical clearance and identify any risk factors or symptoms that could interfere with their safety or participation in the exercise intervention. The PAR-Q was used as a formal screening process to confirm that the participants were healthy and able to safely engage in exercise without limitations. No data from the PAR-Q were included in the analysis or discussion, as it was used solely to screen for eligibility.

Demographic information, including age, gender, body mass index (BMI = weight [kg] / height [m^2]), and body fat percentage via bioelectrical impedance analysis (BIA) OMRON HBF-306 Fat Loss Monitor (OMRON Healthcare, Inc., Bannockburn, IL, USA) were also collected. Although not directly analyzed, BMI and body fat percentage were intended to provide a comprehensive profile of participant health and fitness status, as previous research has indicated the relationship between poor physical health and MH status.[6,7]

Statistical analysis

The primary dependent variable was derived from the DASS-21 instrument. All data was analyzed using SPSS Version 27.0 (IBM, Armonk, NY, USA). A linear mixed model (LMM) was used to account for repeated measures (pre/post-intervention) and to compare differences between the EX and CON groups over time. A priori alpha of 0.05 was used for all statistical analyses. All data is presented in mean ± standard deviation.

Results

The participant demographic information ($n = 15$) is presented in Table 1. Six additional participants started the study; however, 3 were excluded due to *severe/ extremely severe* baseline MH scores, and 3 did not complete the exercise intervention. Nine males and 6 females participated in this study and the mean age for participants was 20.0 ± 2.0 years.

Table 1. Participant demographics

Parameter	Exercise ($n = 9$)	Non-exercise control ($n = 6$)
Age (years)[a]	19.78 ± 1.56	20.33 ± 3.66
Gender (M/F)	6/3	3/3
Height (m)[a]	1.69 ± 0.08	1.68 ± 0.11
Weight (kg)[a]	83.16 ± 24.61	70.25 ± 11.03
BMI (kg/m^2)[a]	28.76 ± 7.00	24.90 ± 1.31
Body Fat (%)[a]	22.64 ± 11.61	19.58 ± 7.41

[a] Data are presented mean ± SD.

Abbreviations: BMI – body mass index; kg – kilograms; m – meters; % – percentage.

Table 2 represents the descriptive statistics for the pre/post-DASS-21 scores for the EX and CON groups. The cutoff scores for the *normal* classifications for each category were as follows: Depression: 0–9, Anxiety: 0–7, Stress: 0–14, and Overall Mental Health: 0–30. All 15 participants initially scored in the *normal* classifications during the pre-intervention measurement, however, 2 participants scored beyond the *normal* ranges at the post-intervention measurement. One participant from the EX group scored *moderate* for depression (16), *normal* for anxiety (7), *mild* for stress (18), and *moderate* for overall MH (41). In addition, 1 participant from the CON group scored *mild* for depression (10), *severe* for anxiety (18), *moderate* for stress (19), and *moderate* for overall MH (47).

Although stress was not a primary dependent variable in the study, it is important to note that both groups' stress scores remained within *normal* ranges. LMM analysis revealed no significant differences between groups or over time for stress ($F = 0.226$, $p = 0.642$). Notably, the CON group experienced a larger increase in stress, with post-intervention scores increasing from 2.50 ± 2.07 to 5.83 ± 6.85, compared to the EX group, whose scores increased from 1.22 ± 1.72 to 3.00 ± 5.89. These data suggest that, while stress levels increased for both groups, the CON group experienced higher levels of stress throughout the intervention compared to the EX group.

Table 2. Descriptive statistics for DASS-21 mental health scores

Mental health scores	Exercise ($n = 9$)	Non–exercise control ($n = 6$)
Depression		
Pre[a,b]	1.11 ± 2.62 (0–8)	0.66 ± 1.21 (0–3)
Post[a,b]	2.44 ± 5.34 (0–16)	2.32 ± 3.83 (1–10)
Anxiety		
Pre[a,b]	1.00 ± 0.87 (0–2)	1.67 ± 2.40 (0–6)
Post[a,b]	3.11 ± 2.52 (0–7)	5.16 ± 6.49 (1–18)
Stress		
Pre[a,b]	1.22 ± 1.72 (0–5)	2.50 ± 2.07 (0–5)
Post[a,b]	3.00 ± 5.89 (0–18)	5.83 ± 6.85 (0–19)
Overall MH		
Pre[a,b]	3.33 ± 5.34 (0–10)	4.33 ± 4.23 (0–11)
Post[a,b]	8.55 ± 13.06 (0–41)	13.33 ± 16.91 (1–47)

[a] Data are presented mean ± SD. [b] Data are presented in a range, from high to low.

Abbreviations: DASS-21 – Depression, Anxiety, Stress Scales-21; MH – mental health.

Figures 1–3 represent the pre/ post scores for depression, anxiety, and overall MH (mean ± standard deviation) for the EX and CON groups. LMM analysis revealed no significant differences between groups or across time for depression ($F = 0.015$, $p = 0.904$), anxiety ($F = 1.038$, $p = 0.327$), and overall MH ($F = 0.266$, $p = 0.615$). Although no statistical significance was found, it is important to note that the CON group showed an increase in anxiety scores above the *normal* ranges (5.16 ± 6.49) (Figure 2) and an increase in overall MH scores above the *normal* ranges (13.33 ± 16.91) (Figure 3). These findings may indicate practical significance as the EX group maintained *normal* scores for overall MH with the exercise intervention.

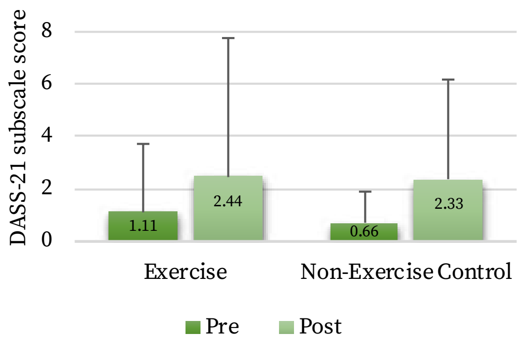

Figure 1. DASS-21 depression scores

Figures 1–3. The mean DASS-21 mental health scores for the exercise and non-exercise control groups are shown. The error bars represent the standard deviation. Although no statistically significant differences were observed, $^{*}p < 0.05$ denotes statistical significance. Abbreviations: DASS-21 – Depression, Anxiety, Stress Scales-21.

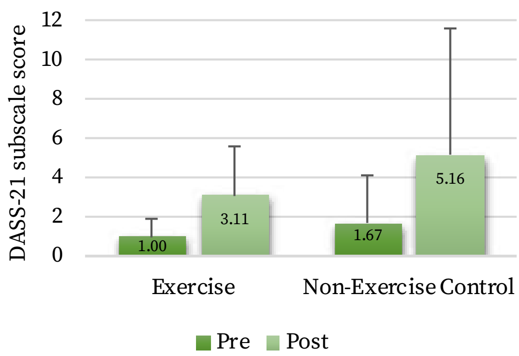

Figure 2. DASS-21 anxiety scores

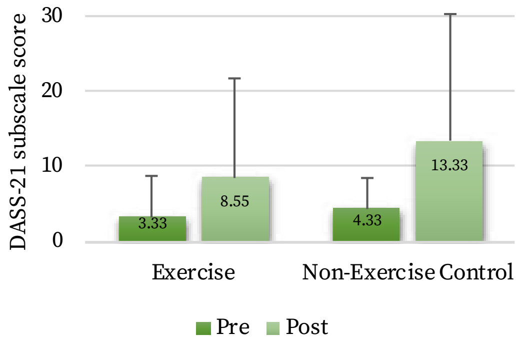

Figure 3. DASS-21 overall mental health scores

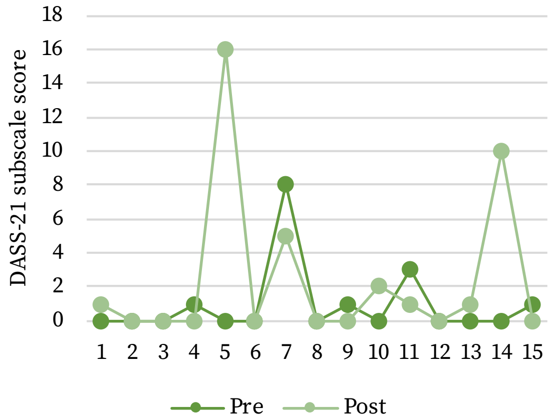

Figure 4. Pre/post DASS-21 depression scores

Note: Figures 4–6. The pre/post-DASS-21 mental health scores for the exercise and non-exercise control groups are shown. Participants 1–9 represent the exercise group, 10–15 represent the non-exercise control group. Each dot corresponds to an individual participant's score, where the dark green dot represents the pre-DASS-21 scores and the light green dot represents the post-DASS-21 score. Although no statistically significant differences were observed, $^{*}p < 0.05$ denotes statistical significance. Abbreviations: DASS-21 = Depression, Anxiety, Stress Scales-21.

Figures 4–6 represent the pre/post DASS-21 scores for depression, anxiety, and overall MH for all 15 participants. Participants 1–9 were derived from the EX group, and participants 10-15 were from the CON group. Notably, in Figure 4, one participant from each of the EX and CON groups exceeded the *normal* range for depression (0–9). Participant 5 from the EX group reported a *moderate* depression score of 16, and Participant 14 from the CON group had a *mild* depression score of 10. Figure 5 highlights that Participant 14 also reported a *severe* anxiety score of 18 post-intervention, an outlier that may have skewed the data. There is a noticeable increase in anxiety scores from pre- to post-intervention among most of the participants, which can likely be attributed to the stressors associated with the semester, final/midterm exams, and continued disruptions to normal life due to the COVID-19 pandemic. Similarly in Figure 6, Participant 5 from the EX group and Participant 14 from the CON group reported overall MH scores of 41 and 47, respectively. Both scores are well beyond the *normal* cutoff score of 30, indicating significant MH concerns.

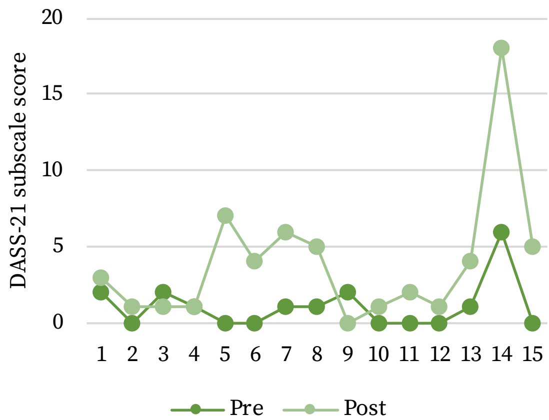

Figure 5. Pre/post DASS-21 anxiety scores

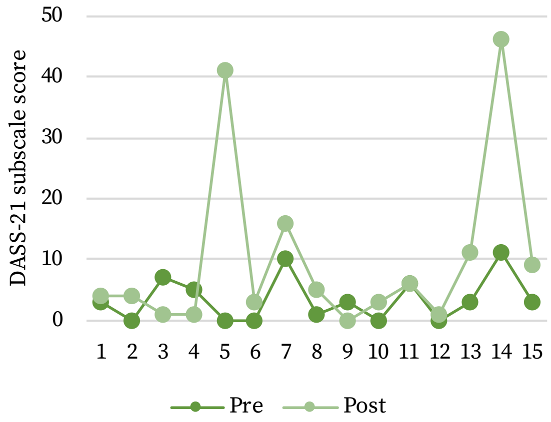

Figure 6. Pre/post DASS-21 overall mental health scores

Table 3 displays the descriptive statistics for the pre/post-physiological indices for the EX and CON groups. LMM analysis reveals no significant differences between groups or across time for body composition ($F = 0.058$, $p = 0.813$), 1.5-mile run ($F = 0.522$, $p = 0.483$), 5RM bench press ($F = 0.002$, $p = 0.968$), or partial curl-ups ($F = 0.299$, $p = 0.594$) between EX and CON groups over the 8-week intervention.

Table 3. Descriptive statistics for physiological indices

Physiological indices	Exercise ($n = 9$)	Non-exercise control ($n = 6$)
Body fat (%)		
Pre[a]	23.93 ± 9.62	19.58 ± 7.41
Post[a]	23.26 ± 9.60	18.60 ± 8.45
1.5-mile run (min: sec)		
Pre[a]	16:32 ± 3:43	14:53 ± 5:27
Post[a]	16:30 ± 3:39	14:19 ± 5:14
5RM bench press (kg)		
Pre[a]	59.87 ± 38.70	58.33 ± 26.77
Post[a]	61.87 ± 40.26	60.21 ± 31.35
Partial curl-up (# of reps)		
Pre[a]	51.89 ± 21.29	59.50 ± 24.60
Post[a]	51.56 ± 15.86	52.33 ± 19.89

[a] Data are presented mean ± SD.

Abbreviations: kg – kilograms; min: sec – minutes: seconds; # of reps – number of repetitions; 5RM – 5 repetition maximum.

Discussion

The pre/post-DASS-21 data did not reveal a statistically significant difference in depression scores between groups over the 8-week intervention. There were, however, minimal increases in depression scores among both EX and CON groups, which was likely attributed to the the timing of the pre/post-assessments during the academic calendar. Specifically, the pre-assessments were conducted during the first week of a new semester, while the post-assessments took place during midterms and final exams. Therefore, it is plausible that this slight increase in depression scores over the 8-week intervention was due to the stressors associated with being a college student.

According to the American College Health Association (ACHA), 52% of college students ($n = 96{,}489$) reported academics (e.g., class, homework, projects, exams) as one of the most common causes to negatively impact MH during the Fall 2021 semester. Of those who reported, approximately 90% of college students indicated that academic stressors caused moderate-to-high levels of psychological distress.[20] Consistent with previous research, academic pressures were likely a key contributor to the elevated depression scores observed in this study.

In addition to the academic stressors, lack of exercise and sedentary behaviors have been identified as risk factors for the development of MH disorders such as anxiety and depression.[21] As previously discussed, college students experience an increase in sedentary behaviors from studying, completing homework assignments, and attending lectures.[9] However, previous research has shown the protective effects of exercise against the development of depression in healthy adults, as well as the reduction in depressive symptoms in those with diagnosed depression.[1,14,15]

Other important variables to consider when examining the relationship between exercise and depression include exercise intensity, the dose-response relationship, and the modality of exercise. Pearce et al. (2022) found that 2.5 hours of low-intensity physical activity (e.g., brisk walking) per week was associated with a 25% lower risk of depression than adults who did not report any activity.[22] Even half the dose (75 minutes) was associated with an 18% lower risk of depression.[22] A 2018 meta-analysis by Gordon et al. indicated that RT was associated with a significant reduction in depressive symptoms ($\Delta = 0.66$, $p < 0.001$) regardless of age, gender, and/or health status. This significant reduction in depressive symptoms was found independent of the RT program, session duration, intensity, frequency, or total volume.[7]

There is also emerging evidence in support of CT, or the combination or AE and RT exercise. Bennie et al. demonstrated that adults who met both AE and RT exercise guidelines were associated with the lowest likelihood of reported depressive symptoms.[1] Although this combination of AE and RT exercise did not produce statistically significant reductions in depression scores in the present study, previous research suggests that CT exercise may provide unique MH benefits. This approach is especially relevant for college students, as this combination of AE and RT exercise can improve resilience against stress and depressive symptoms to support both mental and physical health.

It is also important to highlight that 11 of the 15 participants reported a pre-intervention score of zero for depression on the DASS-21. This is significant because a baseline depression score of zero did not allow for any room to improve throughout the 8-week intervention. It is also plausible that some participants did not accurately report any pre-existing depressive symptoms at baseline, and these symptoms remained elevated at the post-measurement, which may have falsely skewed the data.

Moreover, given that the participants in this study were mostly first-year Exercise Science students, they may have had greater awareness of the benefits of exercise, potentially leading to higher baseline engagement in exercise than the general population. This may have contributed to the lack of significant findings in depression scores.

The pre/ post-DASS-21 data did not reveal a statistically significant difference in anxiety scores between groups. However, the scores (mean ± standard deviation) for anxiety increased from *normal* to *moderate* pre- to post-8-week intervention in the CON group, whereas the EX group maintained *normal* scores. Although these data did not result in statistical significance, these findings may indicate practical significance as exercise appeared to help maintain or prevent anxiety scores from exceeding the *normal* classification for the EX group.

Numerous studies support these findings as evidence has indicated that both AE and RT exercise have anxiolytic effects on individuals both with and without diagnosed anxiety disorders and/or symptoms.[23–26] A 2019 meta-analysis by Schuch et al. (n = 75,831 followed for 357,424 person-years) found that higher self-reported levels of exercise were associated with a decreased risk of anxiety symptoms and anxiety disorders in people free of anxiety at baseline. Specifically, these data suggest that people with higher levels of self-reported exercise have a 27% and 21% lower risk for developing anxiety when compared with lower levels of self-reported exercise, even after adjusting for potential confounders such as age, sex, BMI, and smoking, in adjusted odds ratios and odds ratios, respectively.[23]

However, despite these promising findings from previous studies, the relatively short duration of the present study (8 weeks) was likely insufficient to produce statistically significant improvements in anxiety scores. Future studies could benefit from longer intervention periods or larger volumes of exercise to fully assess the anxiolytic effects of exercise.

Furthermore, a narrative review by Kandola et al. (2018) revealed those who engaged in more exercise had a decreased risk of experiencing anxiety symptoms and frequency, as well as developing an anxiety disorder in the general population. Exercise interventions were also shown to be effective in reducing anxiety symptoms in individuals with and without a diagnosed anxiety disorder both as standalone and/or adjunctive therapies.[21] These findings suggest that exercise appears to provide protective effects for anxiety symptoms and disorders.[21]

Similarly, Gordon et al. (2020) reported a significant reduction in anxiety symptoms (mean difference = −7.89, $p \leq 0.001$) over an 8-week RT intervention in a non-anxiety-disordered sample of young adults. The large reduction in anxiety symptoms (d = 0.85) was larger than previous meta-analytic evidence from Gordon et al. (2018) on the effects of RT on anxiety symptoms in healthy adults (Δ = 0.50).[18] In addition, these data are greater than the effects of AE in healthy adults (Δ = 0.45) by Conn (2010), and the effects of RT among women with generalized anxiety disorder (d = 0.52) by Herring et al. (2011).[18]

Importantly, Gordon et al. (2020) found immediate improvements in anxiety symptoms upon beginning an RT intervention (d = 0.51, 95% CI: −0.25–1.28) from initial familiarization to week 1, and further improvement from week 4 to post-intervention (d = 0.42, 95% CI: 0.35–1.18). Similarly, Ensari et al. (2015) performed a meta-analysis on 36 RCTs and found a small (Hedge's g = 0.16, SE = 0.06), but statistically significant ($p < 0.05$) improvement in anxiety symptoms with a single bout of exercise compared with a control group.[27] This supports the notion that AE and RT both have immediate and long-term benefits on anxiety symptoms, which aligns with the findings from the present study.

Several factors likely influenced the stress outcomes observed in this study. As previously mentioned, college students face a unique set of stressors that can negatively affect both their mental and physical health, including academic overload, pressure to succeed, competition with peers, financial concerns, and limited leisure time.[28] These factors are compounded by additional issues such as increased sedentary time from prolonged periods of studying, completing assignments, and attending lectures. Research shows that this sedentary lifestyle, common among college students, limits the opportunities for physical activity and exercise, further exacerbating MH concerns.[8,9,13] The culmination of these factors is known to have negative impacts on academic performance, relationships, self-perception, as well as mental and physical health.[8]

In line with these findings, both groups in the present study reported increased stress scores at the post-intervention assessment. However, the CON group experienced a slightly larger increase in stress compared to the EX group, which suggests that exercise may have helped alleviate some of the stressors typically encountered during the semester. These findings are consistent with previous research, which has demonstrated that exercise can provide protective effects against stress, particularly in college students.[14,21]

The timing of the post-intervention assessments, conducted during midterm and final exams, likely contributed to elevated stress levels. Academic pressures, such as exams and assignments, are significant stressors for college students, with 52% reporting academic stress as a major cause of psychological distress and 90% indicating moderate-to-high levels of distress.[20] These pressures often lead to sedentary behaviors, including prolonged studying and attending lectures, which are risk factors for MH issues like anxiety and depression.[9] Given that lack of physical activity is a known contributor to poor MH outcomes, it is possible that the increase in stress scores in the CON group was exacerbated by the absence of structured exercise.

The pre/post-DASS-21 data for overall MH did not reveal a statistically significant difference between groups. Similarly, overall MH scores (mean ± standard deviation) increased from *normal* to *mild* pre- to post-8-week intervention in the CON group, whereas the EX group maintained *normal* scores for overall MH. Although these data are not statistically significant, they may indicate practical significance as exercise appeared to maintain or prevent overall MH scores from exceeding the *normal* classification for the EX group.

These findings are consistent with previous research, as AE and RT exercise have been shown to independently benefit MH via anti-depressive and anxiolytic effects.[1,6,14,26,29] The dose-response relationship between exercise frequency and the prevalence of MH disorders also appears to play an essential role in the prevention and/or management of symptoms. A 2020 cross-sectional study by Hallgren et al. of 36,595 adults found those who exercised 1–2 times per week were associated with a decreased risk of depression and anxiety.[30] Specifically, those who exercise 1–2 times per week and ≥3 times per week had 0.67 (95% CI: 0.62–0.74) and 0.56 (95% CI: 0.52–0.62) lower odds of reporting frequent symptoms of depression and anxiety, respectively, compared with those who never/sometimes exercised.[30] Furthermore, those with medium to high cardiorespiratory fitness levels also had lower odds of reporting frequent symptoms of depression and anxiety.[30] Although the key finding of exercising 1–2 times per week was beneficial for symptoms of depression and anxiety, it is quite broad. Prospective data from the British Whitehall II study (n = 9,309) with an 8-year follow-up demonstrated that regular moderate-intensity exercise, of at least 2.5 hours per week, was associated with lower odds of future depression and anxiety symptoms.[31]

Similarly, Oftedal et al. (2019) provided evidence that meeting both AE and RT guidelines was associated with a lower risk of depression and co-occurring depression and anxiety in middle-aged Australian women. These findings demonstrated that 150 minutes of AE was associated with a lower risk of depression and co-occurring depression and anxiety than individuals who met neither AE nor RT guidelines.[6] Exercise intensity may also play an important role in MH benefits, as the AE + RT group reported higher total vigorous intensity MET minutes and higher leisure MET minutes.[6] These findings are consistent with Benne et al. (2019) and suggest the synergistic relationship between AE and RT exercise and the benefits of depression, anxiety, and overall MH.[6]

Lastly, because this population of college students/young adults is at a higher risk for developing MH disorders and/or experiencing symptoms, the use of exercise interventions during this stage in their lives is critical. Gordon et al. (2020) stated that intervening at this point in the severity spectrum, from elevated subclinical symptoms to a diagnosed MH disorder, could alleviate future burdens through the preventive effects of exercise.[18]

Although physiological adaptations were anticipated with the 8-week exercise stimulus, previous studies have demonstrated that improvements in strength were not required to achieve MH benefits and reductions in anxiety symptoms.[18] However, the 8-week RT intervention by Gordon et al. (2020) found significant increases in strength by 23.4% ± 14.7% in young adults, which raises questions about the exercise stimulus in the present study. In addition, a 2009 meta-analysis of 57 exercise interventions (35.7% of participants were college/university students) found improvements in self-esteem and body image with exercise, regardless of changes in fitness levels and/or body composition.[32]

Limitations and recommendations for future studies

While this study offers valuable insights into the effects of exercise on MH among college students, several limitations may have impacted the findings of this study. The recruitment of participants was based on a convenience sample and was limited to a small group of participants, which may have impacted the generalizability of the results. In addition, participants were not randomized into EX and CON groups due to the course structure, which may have influenced the findings. However, since both groups consisted of Exercise Science students, potential differences between groups were minimized. Future studies should focus on a randomized selection of participants and group assignments to strengthen results.

Another major limitation includes the use of the Borg RPE scale as a measure, or indicator, of exercise intensity. Despite being well-established in measuring physical activity, this scale is dependent upon subjective feedback from the participants. Therefore, it may not accurately reflect the physiological state of participants during exercise, particularly in cases of fatigue and recovery. Although the Borg RPE scale is acceptable for preliminary studies like this, objective measures, such as monitoring heart rate before, during, and after exercise, could provide a more reliable measure of exercise intensity. Using these measures in future research could increase the reliability of our findings and offer a clearer understanding of the effects of exercise intensity on MH.

Future studies should consider expanding physical fitness assessments to include additional measures such as lower-body strength, flexibility, and recovery indicators to provide a more comprehensive view of participants' physical fitness and functional abilities. Lower-body strength is essential for daily activities such as walking and standing and could be assessed with beginner-friendly exercises for those new to RT. Flexibility is also essential for functional movement and injury prevention and can be evaluated using simple tests like the sit-and-reach. In addition, monitoring heart rate post-exercise and during recovery could offer valuable insights into cardiorespiratory fitness, adding more information to the understanding of physical fitness status. Including these assessments in future studies could offer a more complete perspective on how exercise impacts both physical and mental health, particularly among novice participants.

The duration of the intervention was only 8 weeks, coinciding with midterm and final exams, potentially affecting post-intervention data due to increased academic stress. Additionally, the short duration may not have provided a long enough stimulus to elicit both psychological and physiological improvements.

As previously mentioned, participants were excluded from participating in the study if they had a diagnosed MH disorder or were receiving any form of treatment for one; if they were required to take any prescription medication of any kind; and if they were required to engage in any other structured activity outside of the intervention due to other responsibilities. Participants who scored in the *severe/extremely severe* categories were eliminated from the study and referred to the school's Counseling and Psychological Services. Since the participants were free from MH disorders at baseline, this may have a ceiling effect on potential improvements in MH with a short-term intervention.

Lastly, the study's reliance on self-reported data for MH assessments poses a limitation. Participants with undisclosed MH disorders may have resulted in non-compliance or dropout. In addition, Hallgren et al. (2020) state that assessing symptoms of anxiety and depression together may not be optimal due to the unique etiologies, potentially complicating the interpretation of the findings.

The majority of current research consists of observational and cross-sectional studies, therefore future research should include more well-designed prospective cohort studies[1,30] and randomized controlled trials[21] to gain a better understanding of the relationship between exercise and MH. Researchers should also incorporate more frequent follow-up assessments and qualitative interviews to determine the efficacy of the exercise interventions after the intervention has ended. Follow-up assessments can provide insight regarding the sustainability of mental and physical improvements in response to exercise, if habitual exercise is maintained, and determine the changes/fluctuations in MH over an extended period of time. Qualitative interviews could also provide valuable insight into which elements of the intervention participants found most beneficial (e.g., the exercise stimulus, the education, or social interactions). These interviews can supplement self-reported MH instruments, which have limitations such as recall bias, over/under-reporting, and reliance on participants to disclose sensitive information.

There is continued interest in the comparative effects of AE, CT, and RT on MH, and more research is needed to clarify the specific biological and psychosocial mechanisms that modulate these improvements.[7] Therefore, future research should match AE, CT, and RT exercise modes on relevant features of the exercise stimulus (e.g., frequency, intensity, and duration) to allow for more rigorous and controlled comparisons.[7]

Researchers should also examine the dose-response relationship (e.g., exercise frequency, intensity, and duration) to determine causality and/or reverse causality on the impact of exercise on MH.[30] Given the emerging evidence to support the additional benefits of CT exercise on MH, there is a growing need for more well-designed CT protocols. It would also be interesting to examine the differences among various CT program designs, for example, same session vs. same week protocols to identify any strengths or weaknesses.

In addition, future research should aim to recruit individuals with diagnosed MH disorders across various levels of severity (e.g., *mild*, *moderate*, *severe*, *extremely severe*). As stated by Ensari et al., "The research is plagued by floor effects associated with recruiting persons with normal or lower levels of anxiety [and depression], and this should be overcome in subsequent trials."[27(624)] Further, more research is needed among individuals with co-occurring anxiety and depression because approximately half of those diagnosed with one condition also experience the other.[6,33] However, if researchers are limited to a healthy population like in the present study, future research should measure well-being rather than dysfunction. Measures of dysfunction such as the DASS-21 cannot determine changes in MH status if the baseline scores are too low at the start of the intervention, therefore, this should prevent the aforementioned floor effects.

Lastly, due to the global burden associated with MH disorders, future research should examine the cost-effectiveness of exercise interventions in the treatment and prevention of MH disorders.[14,26] Perhaps of the utmost importance, future research should establish specific exercise guidelines and minimum dosages for treating and preventing MH disorders and symptoms.

Conclusion

Although there were no statistically significant differences in depression, anxiety, and overall MH scores between the EX and CON groups, the findings may reveal practical implications. Notably, the scores for anxiety and overall MH in the CON group exceeded the *normal* classification, and the EX group maintained *normal* scores throughout the 8-week intervention. These findings suggest that regular exercise likely plays a crucial role in sustaining MH status, highlighting its importance as a preventive measure rather than solely a therapeutic intervention.

Future research should explore longer intervention periods, larger sample sizes, and the combination of AE and RT exercise to more fully understand the relationship between exercise and MH among college student populations.

Acknowledgments

We would like to thank all the participants for participating in this study. Special thanks to Shala E. Davis for overseeing the entire study and to Kyle Beyer and Anthony Drago for being part of my dissertation committee. We also extend our gratitude to Brandon Snyder for being the point person and organizing the data at East Stroudsburg University. Additionally, we appreciate Caitlin Cheruka for her assistance with the publication process.

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