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ORIGINAL RESEARCH

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Increased vigorous exercise and decreased sedentary activities are associated with decreased depressive symptoms in United States adults: Analysis of The National Health and Nutrition Examination Survey (NHANES) 2017–2020

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Abstract

Background and aims: Depression is a major public health concern that affects over 4% of the global population. Identification of new nonpharmacologic recommendations will help decrease the burden of disease. The overarching of this study was to examine the association between physical activity and depressive symptoms in a large sample of adults in the United States.

Methods: Presently, researchers utilized data from the National Health and Nutrition Examination Surveys (NHANES 2017–2020), which is a retrospective, complex, multistage, representative, and modern cohort of the United States. Adult patients (> 18 years; $N = 8091$) with complete 9-item Patient Health Questionnaire (PHQ-9) information were included in the study. The PHQ-9 is a well-validated survey, per literature, scores ≥10 are considered to have clinically relevant depression. Univariable and multivariable logistic regression was fit for active and sedentary activities on clinical depression (PHQ-9 ≥ 10). The acquisition and analysis of the data within this study were approved by the National Center for Health Statistics Ethics Review Board.

Results: After adjusting for potential confounders like age, race, sex, and income, we found that increased vigorous exercise was associated with lower rates of depressive symptoms. Each extra day of vigorous exercise was associated with 11% decreased odds of depression (odd ratio [OR]: 0.89, confidence interval [CI]: 0.83–0.96, $p < 0.01$). Increased sedentary activity was associated with increased depression. Each extra hour per day of sedentary activity was associated with a 6% increase in odds of depression (OR: 1.06, (1.02–1.10, $p < 0.01$).

Conclusion: To conclude, exercise appears to be protective against depressive symptoms; however, further prospective studies are required to ascertain whether exercise causes decreased depressive symptoms.

KEYWORDS
exercise, depression, PHQ-9, linear regression, NHANES, supportive care

1 | INTRODUCTION

Depression is a prevalent mental health condition that affects more than 4% of the global population and is a leading cause of disability and nonfatal health loss worldwide.[1] In the United States, depression has a lifetime prevalence of 21.6%, making it the most common psychiatric illness in the country.[2–4] It is characterized by persistent feelings of sadness, loss of interest or pleasure, and a range of cognitive and physical symptoms. The impact of depression extends beyond individual suffering, as it is associated with increased risks of suicide, generalized anxiety disorder, cardiovascular disease, cancer, diabetes, infection, and premature mortality compared to the general population.[5] The economic costs associated with depression and related conditions, such as days lost from work, are substantial and projected to rise in the coming years. This high prevalence, coupled with the significant burden it imposes on individuals and society, underscores the importance of understanding and addressing this condition.

Numerous studies have explored various factors associated with depression, including demographic factors such as age, sex, genetics, race/ethnicity, and family history.[6] However, since these factors are often immutable, lifestyle interventions alone may not effectively mitigate depression.[7] Consequently, there is an urgent need to identify modifiable risk factors to alleviate the burden of depression on society.[8] The current focus of treatment for depression primarily revolves around pharmacological interventions, such as antidepressant medications, and psychological therapies, including cognitive behavioral therapy. While these approaches can be effective, they may not work for everyone, and dropout rates and side effects can pose challenges to treatment adherence and efficacy.[9] Given the wide-ranging impact of depression and the limitations of existing treatment options, there is a growing recognition of the need to identify modifiable risk factors that can contribute to the prevention and management of depression. Lifestyle behaviors, particularly physical activity, and exercise, have emerged as potential factors that can play a role in reducing the risk of developing depression, alleviating depressive symptoms, and improving overall well-being.[10] Understanding the relationship between exercise, sedentary activities, and depression is crucial for developing targeted interventions and strategies to improve mental health outcomes.[11]

The association between physical activity and depressive symptoms is thought to be mediated through several biological mechanisms. Physical activity stimulates the release of endorphins, which are neurotransmitters associated with improved mood.[12] Physical activity promotes the production of neurotrophic factors like Brain-Derived Neurotrophic factors (BDNF), which support neuronal growth and synaptic plasticity.[13] Additionally, physical activity reduces inflammation and oxidative stress, both of which are linked to depression.[14] Moreover, exercise and social activities associated with physical activity can enhance self-esteem and social support, positively impacting mental well-being. While further research is needed to establish causal relationships, understanding these potential mechanisms is important for developing interventions to improve mental health.

The current treatment of depression relies on both psychotherapy and pharmacologics with a grade 2b recommendation for either as monotherapy. Pharmacologics include classes such as selective serotonin reuptake inhibitors (SSRIs), selective norepinephrine reuptake inhibitors (SNRIs), atypical antidepressants, and less often tricyclic antidepressants for concerns of adverse effects.[2,15] Guidelines for supportive care for depression include relaxation, positive activities, and exercise, however, with evidence-based upon low-quality randomized controlled trials. Our research adds to the body of evidence that exercise, indeed can be used to benefit patients with major depression.[16,17] Proposed biological underpinnings follow the catecholamine hypothesis in that exercise releases serotonin, norepinephrine, and epinephrine to improve clinical outcomes.[18,19] Other proposed mechanisms include activating cascades that improve mood (IGF-1, Irisin pathway, ERK).[20]

Despite the existing body of research on the relationship between exercise, sedentary behaviors, and depression, many studies suffer from limitations such as small sample sizes and failure to distinguish between different exercise intensities, particularly vigorous and moderate levels.[21] Similarly, studies investigating the link between sedentary behaviors and depression have been constrained by small sample sizes and other methodological flaws. To address these limitations, the present study aims to investigate the association between exercise, sedentary activities, and depressive symptoms using data from the National Health and Nutrition Examination Surveys (NHANES) 2017–2020 cohort. By utilizing a large, nationally representative sample of adults in the United States, this study seeks to provide a more comprehensive understanding of the relationship between physical activity, sedentary behaviors, and depressive symptoms. By examining this association, the study aims to contribute to the identification of modifiable risk factors for depression, potentially informing public health interventions and strategies to reduce the burden of this mental health condition on individuals and society as a whole.

2 | METHODS

The NHANES is a complex multistage sampling design that aims to provide representative estimates of the US population by surveying them on various questionnaires related to diet, demographics,

physical examination, nutrition, and health. Patients who completed the PHQ-9 and the physical activity questionnaire of the NHANES data set were the subjects of a retrospective, cross-sectional cohort study utilizing the publicly available NHANES. The National Center for Health Statistics Ethics Review Board granted permission for the study's data collection and analysis. The sample size for the NHANES study is determined through a complex multistage sampling design that aims to provide representative estimates of the US population.

2.1 | Data set and cohort selection

The National Center for Health Statistics (NCHS) developed the NHANES, which has been utilized to evaluate the health and nutritional status of the population of the United States. The Centers for Disease Control and Prevention (CDC) carried out a series of complex, cross-sectional, multi-stage surveys on a nationally representative cohort of the population of the United States to collect data on health, nutrition, and physical activity for the NHANES data set. The sample size included NHANES data from 8091 adults (age ≥ 18) with complete data for the PHQ-9 and physical activities in this study.

2.2 | Assessment of clinical depression

The 9-question Patient Health Questionnaire (PHQ-9) depression scale, which is based on DSM-IV depression symptoms, was used to measure depressive symptoms. These are included in Table 1. Patients with PHQ-9 total scores less than 10 were considered to have clinical depression, according to the literature, with a sensitivity of 89% and a specificity of 89%.[21]

2.3 | Independent variable

A number of days per week exercise vigorous exercise and time per day of vigorous exercise were assessed with the questions: "In a typical week, on how many days {do you/does SP} do vigorous-intensity sports, fitness or recreational activities? How much time {do you/does SP} spend doing vigorous-intensity sports, fitness, or recreational activities on a typical day?" Total time was computed (hours per day), the product of the responses to both questions.

A number of days per week exercise vigorous exercise and time per day of vigorous exercise were assessed with the questions: In a typical week, on how many days {do you/does SP} do moderate-intensity sports, fitness, or recreational activities? How much time {do you/does SP} spend doing moderate-intensity sports, fitness, or recreational activities on a typical day?" Total time was computed (hours per day) as the product of the responses to both questions.

The total sedentary activity was assessed with the question: "The following question is about sitting at school, at home, getting to and from places, or with friends including time spent sitting at a desk, traveling in a car or bus, reading, playing cards, watching television, or using a computer. Do not include time spent sleeping. How much time {do you/does SP} usually spend sitting on a typical day."

Patients responded with a total time in minutes per day, which were then converted into hours per day for ease of interpretation.

TABLE 1 PHQ-9 depression scale.

Problem	Not at all	Several days	More than half the days	Nearly every day
Little interest or pleasure in doing things	0	1	2	3
Feeling down, depressed, or hopeless	0	1	2	3
Trouble falling or staying asleep, or sleeping too much	0	1	2	3
Feeling tired or having little energy	0	1	2	3
Poor appetite or overeating	0	1	2	3
Feeling bad about yourself, or that you are a failure, or that you have let yourself or your family down	0	1	2	3
Trouble concentrating on things, such as reading the newspaper or watching television	0	1	2	3
Moving or speaking so slowly that other people could have noticed? Or the opposite, being so fidgety or restless that you have been moving around a lot more than usual.	0	1	2	3
Thoughts that you would be better off dead, or of hurting yourself in some way	0	1	2	3
Total ___ =	___	+ ___	+ ___	+ ___
PHQ-9 score ≥10: Likely major depression				

Abbreviation: PHQ-9, 9-question Patient Health Questionnaire.

TABLE 2 Demographic information stratified by the presence of clinically relevant depression.

Table-1:	All patients	PHQ-9 ≥ 10	PHQ-9 < 10	*p*-Values
Total individuals	8091 (100%)	559 (7%)	7532 (93%)	N/A
Age (SD)	49.2 (18.31)	48.13 (17.8)	49.28 (18.35)	0.15
Female	4141 (51%)	354 (63%)	3787 (50%)	$p < 0.001$
Male	3950 (49%)	205 (3%)	3745 (50%)	
White	2893 (36%)	216 (3%)	2677 (36%)	0.35
Black	2153 (27%)	145 (2%)	2008 (27%)	
Hispanic	1771 (22%)	122 (2%)	1649 (22%)	
Other	1274 (16%)	76 (1%)	1198 (16%)	
Less than high school	1358 (17%)	132 (2%)	1226 (16%)	$p < 0.001$
High school	1863 (23%)	154 (2%)	1709 (23%)	
Some college	2566 (32%)	178 (2%)	2388 (32%)	
College graduate	1910 (24%)	64 (1%)	1846 (25%)	
Other	394 (5%)	31 (0%)	363 (5%)	
Income to poverty ratio (SD)	2.26 (1.75)	1.67 (1.5)	2.3 (1.76)	$p < 0.001$
Total sedentary time (h) (SD)	6.5 (12.57)	8.7 (20.59)	6.34 (11.75)	$p < 0.001$
Days per week of moderate exercise (SD)	1.45 (2.56)	1.12 (1.98)	1.47 (2.6)	$p < 0.001$
Hours per week of moderate exercise (SD)	1.56 (6.48)	1.3 (3.38)	1.58 (6.66)	$p < 0.001$
Days per week of vigorous exercise (SD)	1.24 (13.25)	0.66 (2.45)	1.28 (13.71)	$p < 0.001$
Hours per week of vigorous exercise (SD)	0.86 (1.66)	0.49 (1.41)	0.89 (1.68)	$p < 0.001$

Abbreviation: SD, standard deviation.

Exercise intensity was rated as sedentary, moderate, or vigorous. Demographic covariates that may be confounders of age, race, education, sex, income, and work Schedule) were controlled for in the final analysis.

2.4 | Model construction and statistical analysis

Descriptive statistics for all patients, patients with depression, and patients without depression were analyzed. For continuous variables, data were expressed in the following format mean ± standard deviation (SD), and for categorical variables, they were expressed as proportions. For the relevant covariates on demographics and exercise, chi-squared was used for categorical variables for continuous variables, the Shapiro–Wilk test for normality was performed and *t*-tests were performed for continuous and normally distributed variables and non-parametric Wilcoxon tests were utilized for non-normally distributed variables to compare differences amongst those with clinical depression and those without.[22] Univariable models assessed the effect of vigorous exercise and sedentary activity on clinical depression risk. Next multivariable models were used to determine the effect of vigorous exercise and sedentary activity after controlling for confounding variables (age, race, education, sex, income, and work schedule). *p*-value < 0.05 was considered statistically significant. All data analyses were conducted using R (R Foundation Vienna).

3 | RESULTS

In Table 2, 4141 of the 8091 patients who met the inclusion criteria were female and 3950 were male. 3893 (36%) of the patients were white, 2153 (27%) were Black, 1771 (22%) were Hispanic, and 1274 (16%) were of other races. The mean age was 49.2 (SD = 18.31). There were a total of 1358 patients who did not complete high school, 1863 patients who graduated from high school but did not go on to college, 2566 patients who attended some college, and 1910 patients who graduated from a university with four years of education (24%). 1740 patients (22%) had jobs from 9 a.m. to 5 p.m., 706 (9%) had jobs in the early morning, 559 (7%) worked nights, 1628 (20%) had jobs that varied, and 3458 (43%) patients did not respond in any of the other categories. Sedentary activities accounted for 6.5 (SD = 12.57) hours per day, moderate exercise for 1.45 (SD = 2.56) days per week, vigorous exercise for 0.24 (SD = 13.25) days per week, moderate exercise for 1.56 (SD = 6.48) hours, and vigorous exercise for 0.86 (SD = 1.66) hours per week. On

TABLE 3 Univariable model, odds of clinical depression for each 1 increase in hours (or days) of exercise-related or sedentary activity.

Univariable model	Odds ratio	95% confidence interval	*p*-Value
Moderate activity (hours/week)	0.98	(0.95–1)	0.15
Moderate activity (days/week)	0.92	(0.87–0.96)	$p < 0.001$
Vigorous activity (hours/week)	0.91	(0.87–0.95)	$p < 0.001$
Vigorous activity (days/week)	0.83	(0.78–0.89)	$p < 0.001$
Sedentary activity (hours/week)	1.01	(1.004–1.013)	$p < 0.001$

the PHQ-9 survey, 559 patients (or 7%) scored above 10 and were identified as having clinically relevant depression.

In Table 3, On univariable analysis, we found that patients had an 8% lower risk of depression for each additional day of moderate exercise per week (odds ratio [OR]: 0.92 confidence interval [CI]: 0.87–0.96, $p = 0.01$), and patients were 17% less likely to suffer from depression for each additional day of vigorous exercise per week (OR: 0.83 CI: 0.78–0.89, $p < 0.02$). Each extra hour of moderate activity each week was not related with diminished gloom (OR: 0.98, CI: 0.95–1.01, $p = 0.15$), but the odds of depression were 9% lower with each additional hour of vigorous exercise per week (OR: 0.91 CI: 0.87–0.85, $p < 0.01$). There was a 1% increased risk of depression for every additional hour of sedentary activity per week (OR: 1.01, CI: 1.004–1.013, $p < 0.01$).

In Tables 4a and 4b, 5a and 5b, and Table 6 show the multivariable tables. The results showed that after controlling for potential confounding covariates in multivariable analysis, patients had a 5% lower risk of depression for each additional day of moderate exercise per week (OR: 0.95 CI: 0.90–0.99, $p = 0.02$), and patients were 12% less likely to suffer from depression for each additional day of vigorous exercise per week (OR: 0.88 CI: 0.82–0.94, $p < 0.01$). Each extra hour of moderate activity each week was not related with diminished gloom (OR: 0.99, 0.96–1.01 CI: $p = 0.36$), but there was a 6% lower risk of depression for each additional hour of vigorous exercise per week (OR: 0.94 CI: 0.89–0.98, $p < 0.01$). There was a 0.6% increased risk of depression for every additional hour of sedentary activity per week (OR: 1.01, 1.002–1.011, $p < 0.01$).

TABLE 4a Multivariable model for moderate activity (hours/week).

Covariates	Odds ratio	95% confidence interval	*p*-Value
Hours per week of moderate exercise	0.99	(0.96–1.01)	0.36
Age	0.99	(0.98–0.99)	$p < 0.001$
Race - White	1-Baseline		
Race - Black	0.97	(0.74–1.25)	0.79
Race - Hispanic	1.13	(0.84–1.52)	0.41
Race - Other	1.33	(1.06–1.67)	0.01
Education - College graduate	1-Baseline		
Education – Less than high school	2.17	(1.55–3.07)	$p < 0.001$
Education - High school	1.87	(1.37–2.59)	$p < 0.001$
Education - Some college	1.69	(1.25–2.31)	$p < 0.001$
Education - Other	1.07	(0.65–1.74)	0.78
Sex - Female	1-Baseline		
Sex - Male	0.63	(0.53–0.76)	$p < 0.001$
Ratio: Income to poverty	0.88	(0.83–0.94)	$p < 0.001$
Work: 9 a.m. to 5 p.m.	1-Baseline		
Work: Early morning	1.01	(0.63–1.59)	0.97
Work - Nights	1.55	(1–2.37)	0.05
Work - Variable	1.35	(0.95–1.91)	0.09
Work - Other	2.94	(2.2–3.99)	$p < 0.001$

4 | DISCUSSION

In this cross-sectional cohort of United States adults, the prevalence of depressive symptoms was higher among individuals who had increased sedentary activity, decreased frequency of moderate and vigorous exercise, and decreased total hours of vigorous exercise. We found, similar to other studies, that depression was more prevalent in females and those with increased poverty. Vigorous activity had 9% decreased odds for depression and sedentary activity was associated with 1% increased odds for depression These associations persisted even after controlling for potential confounding variables, such as demographic covariates such as age, sex, race, education, income, and work schedule.

According to PHQ-9, our findings that increased exercise frequency and total exercise were associated with lower rates of depressive symptoms are in line with previous research.[23–25] Using *t*-tests to compare two groups, Yang performed a prospective survey with interventions of aerobic exercise and no aerobic exercise and found single modality aerobic exercise was statistically significant for improving mood in both depressed and nondepressed individuals.[26] A literature search by Berk found that exercise could be a non-pharmacologic therapeutic modality and level of exercise intensity plays a role in the risk of depression.[9] Additionally, our findings that more sedentary time was associated with more depressive symptoms are in line with previous research.[27,28] Werneck et. Al performed a cross-sectional study using patients from Southeast Brazil and found

TABLE 4b Multivariable model for moderate activity (days/week).

Covariates	Odds ratio	95% confidence interval	*p*-Value
Days per week of moderate exercise	0.95	(0.9–0.99)	0.02
Age	0.99	(0.98–0.99)	$p < 0.001$
Race - White	1-Baseline		
Race - Black	0.97	(0.75–1.26)	0.83
Race - Hispanic	1.14	(0.84–1.53)	0.39
Race - Other	1.33	(1.06–1.67)	0.01
Education - College graduate	1-Baseline		
Education - Less than high school	2.09	(1.49–2.96)	$p < 0.001$
Education - High school	1.82	(1.33–2.52)	$p < 0.001$
Education - Some college	1.66	(1.23–2.26)	$p < 0.001$
Education - Other	1.04	(0.63–1.69)	0.88
Sex - Female	1-Baseline		
Sex - Male	0.63	(0.53–0.76)	$p < 0.001$
Ratio: Income to poverty	0.88	(0.83–0.94)	$p < 0.001$
Work: 9 a.m. to 5 p.m.	1-Baseline		
Work: Early morning	1.01	(0.62–1.58)	0.98
Work - Nights	1.55	(1–2.37)	0.05
Work - Variable	1.36	(0.96–1.92)	0.08
Work - Other	2.95	(2.21–4.01)	$p < 0.001$

TABLE 5a Multivariable model for vigorous activity (hours/week).

Covariates	Odds ratio	95% confidence interval	*p*-Value
Hours per week of vigorous exercise	0.94	(0.89–0.98)	0.01
Age	0.98	(0.98–0.99)	$p < 0.001$
Race - White	1-Baseline		
Race - Black	0.97	(0.75–1.26)	0.85
Race - Hispanic	1.13	(0.84–1.52)	0.42
Race - Other	1.31	(1.04–1.64)	0.02
Education - College graduate	1-Baseline		
Education - Less than high school	2.1	(1.5–2.98)	$p < 0.001$
Education - High school	1.82	(1.33–2.52)	$p < 0.001$
Education - Some college	1.66	(1.23–2.26)	$p < 0.001$
Education - Other	1.11	(0.67–1.8)	0.69
Sex - Female	1-Baseline		
Sex - Male	0.65	(0.54–0.78)	$p < 0.001$
Ratio: Income to poverty	0.89	(0.83–0.94)	$p < 0.001$
Work: 9 a.m. to 5 p.m.	1-Baseline		
Work: Early morning	1.01	(0.63–1.59)	0.96
Work - Nights	1.56	(1–2.39)	0.04
Work - Variable	1.35	(0.96–1.92)	0.09
Work - Other	2.95	(2.2–4)	$p < 0.001$

breaking up sedentary activity decreased depressive symptoms, measured with the Hospital Anxiety and Depression Scale (HADS), as well as a direct association between sedentary time and lengths of depressive episodes.[29] According to cross-sectional research, there is a strong link between increased regular physical activity and lower levels of anxiety as well as depression in older adults and adolescents. Kajtna sampled fitness centers using surveys and depression as measured by the Personality Assessment Inventory (PAI) and Global Physical Activity Questionnaire (GPAQ) and found a significant association between movement and decreased depression.[30] Additionally, Taylor performed a review on socioeconomic status and mental health and found increased vigorous exercise was linked to less emotional distress, even after controlling for social class and health status.[31] Exercise was linked to lower rates of depression among undergraduate university students, even after age and sex were taken into account.[32] According to case reports from clinical studies, exercise therapy may also be effective for patients with anxiety neurosis, panic disorder, and clinical depression.[33–37] The strong correlation between increased exercise and decreased depression has been attributed to a number of developmental, neurobiological, and psychological hypotheses: Physical activity may increase a person's resilience to stress-related mental disorders by triggering a chain reaction of neurotransmitters.[33–40]

4.1 | Strengths

Major strengths of our study include the sample, method of analysis, control of confounders, and dependent variable. We utilized a large, high-powered sample that is representative of the US adult population. In addition, significant confounders were appropriately added to confirm the independence of the association between vigorous exercise and symptoms of depression. Lastly, our dependent variable is ascertained using the PHQ-9 which is a standardized metric for depression with strong concordance with independent interviews from the psychiatrist.

TABLE 5b Multivariable model for vigorous activity (days/week).

Covariates	Odds ratio	95% confidence interval	*p*-Value
Days per week of vigorous exercise	0.88	(0.82–0.94)	$p < 0.001$
Age	0.98	(0.98–0.99)	$p < 0.001$
Race - White	1-Baseline		
Race - Black	0.98	(0.76–1.28)	0.91
Race - Hispanic	1.14	(0.84–1.52)	0.4
Race - Other	1.31	(1.05–1.65)	0.02
Education - College graduate	1-Baseline		
Education - Less than high school	2.01	(1.43–2.85)	$p < 0.001$
Education - High school	1.75	(1.27–2.42)	$p < 0.001$
Education - Some college	1.61	(1.19–2.2)	$p < 0.001$
Education - Other	1.07	(0.64–1.74)	0.8
Sex - Female	1-Baseline		
Sex - Male	0.66	(0.55–0.79)	$p < 0.001$
Ratio: Income to poverty	0.89	(0.83–0.95)	$p < 0.001$
Work: 9 a.m. to 5 p.m.	1-Baseline		
Work: Early morning	1	(0.62–1.58)	0.99
Work - Nights	1.54	(1–2.36)	0.05
Work - Variable	1.35	(0.96–1.91)	0.09
Work - Other	2.92	(2.18–3.97)	$p < 0.001$

TABLE 6 Multivariable model for sedentary activity (hours/week).

Covariates	Odds ratio	95% confidence interval	*p*-Value
Total sedentary time (h)	1.01	(1–1.01)	$p < 0.001$
Age	0.99	(0.98–0.99)	$p < 0.001$
Race - White	1-Baseline		
Race - Black	0.97	(0.75–1.26)	0.82
Race - Hispanic	1.14	(0.84–1.53)	0.38
Race - Other	1.32	(1.05–1.66)	0.02
Education - College graduate	1-Baseline		
Education - Less than high school	2.21	(1.57–3.12)	$p < 0.001$
Education - High school	1.89	(1.38–2.61)	$p < 0.001$
Education - Some college	1.69	(1.26–2.31)	$p < 0.001$
Education - Other	1.07	(0.65–1.75)	0.77
Sex - Female	1-Baseline		
Sex - Male	0.63	(0.53–0.76)	$p < 0.001$
Ratio: Income to poverty	0.88	(0.83–0.94)	$p < 0.001$
Work: 9 a.m. to 5 p.m.	1-Baseline		
Work: Early morning	1	(0.62–1.58)	0.98
Work - Nights	1.55	(1–2.37)	0.05
Work - Variable	1.34	(0.95–1.9)	0.09
Work - Other	2.9	(2.16–3.94)	$p < 0.001$

Even though there are numerous studies that show exercise improves mental health, these studies all have similar methodological flaws. The primary one is the low reliability of the depression definition, which jeopardizes these findings' reproducibility. The questionnaires or clinical judgments used in these studies vary greatly. The well-validated PHQ-9 survey, which has identical information due to the standardization of the nine questions, the standardization of the scoring system (0–3 for each question), and the structure of how each of the questions is asked (with detailed instructions on the exact phrasing throughout the exam) is the strength of our study's definition of clinical depression. A strength of this study is its ability to provide a systematic and easily reproducible definition of depression. Additionally, cohorts in other studies frequently tended to be very young (adolescents, university students) or very old. Our study's strength was a cohort that was representative of the US population, with a wide age range (18–80) and gender and race representation. Our study investigates the relationship between sedentary activity and physical activity. The quantity of planned physical activities or specific interventions is often the focus of studies in the literature. According to our research, increased sedentary time and frequency of moderate and vigorous activity both have an impact on depression. As a result, it's possible that more active habits, such as taking the stairs rather than the elevator or biking or walking to work instead of taking the train or car, also have a positive impact.

By contrasting moderate and vigorous exercise, as well as the frequency (days per week) and quantity (hours per week), our study also adds to the body of knowledge. We found that vigorous exercise was more beneficial in decreasing depressive symptoms than moderate exercise, but no studies have divided exercise between moderate and vigorous to distinguish between frequency and total quantity. The total amount of time spent doing moderate exercise was not associated with decreased depression, but the frequency of moderate exercise was strongly associated with this. Additionally, we found a correlation between decreased depression and an increase in both the quantity and frequency of vigorous exercise.

4.2 | Limitations

The research has some limitations. The study has the limitations of cross-sectional retrospective studies in that it cannot determine the causality or directionality of the variables, and is prone to bias from recall and misclassification. Furthermore, the cohort relied on surveys to acquire total exercise. More accurate measurements may have been able to be taken with wearable technologies. However, self-reported survey information is required to allow patients to exercise as normal without significantly changing their diets for a study. Self-reported survey information allows for the volume of participants to be included within this study. Another weakness was the voluntary nature of this cohort, with participants choosing to opt into the study instead of being randomly selected. This may artificially select a different cohort that may significantly differ from the population. However, our analysis found a demographically diverse population, so these results may still be generalizable to other cohorts.

5 | CONCLUSION

Advising the general population that increased frequency, total duration, and intensity of physical activities are associated with decreased depression can allow them to make practical choices on exercise. Further prospective studies are needed to strengthen the relationship.

AUTHOR CONTRIBUTIONS

Alexander A Huang: Conceptualization; project administration; resources; writing—original draft; writing—review & editing. **Samuel Y Huang**: Conceptualization; data curation; formal analysis; visualization; writing—original draft; writing—review & editing.

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Alexander A. Huang (AH) was responsible for the design of the study, writing, data analysis, and final content. Samuel Y. Huang (SH) was responsible for the design of this study, data analysis, writing, and final content. All authors have read and approved this manuscript. No external financial support.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

The data from this cohort can be found in the NHANES section of the CDC website. Data described in the manuscript is publicly and freely available without restriction at: https://wwwn.cdc.gov/nchs/nhanes/continuousnhanes/default.aspx?cycle=2017-2020. The code book and analytic code will be made available upon request to huangs8@vcu.edu.

CONSENT TO PARTICIPATE AND CONSENT TO PUBLISH

The authors consent to participate in peer review and consent to publish. All authors have read and approved the final version of the manuscript Samuel Y Huang had full access to all of the data in this study and takes complete responsibility for the integrity of the data and the accuracy of the data analysis.

TRANSPARENCY STATEMENT

The lead author Samuel Y. Huang affirms that this manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

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REFERENCES

1. Friedrich MJ. Depression is the leading cause of disability around the world. *JAMA*. 2017;317(15):1517.
2. Huang A. Increasing Potassium Intake Up to 2300mg is Associated with Decreased Depressive Symptoms in United States Adults: analysis of the National Health and Nutrition Examination Survey (NHANES) 2017-2020. October 17, 2022.
3. Huang AA, Huang SY. Quantification of the effect of vitamin E intake on depressive symptoms in United States adults using restricted cubic splines. *Curr Dev Nutr*. 2023;7(2):100038.
4. Pagan Colon IE, Kroin J, Kaushal S, Khan S, Alvarez Villalba CL. Increased readmission rates in younger male patients due to suicidal risk in newly diagnosed depressive disorders after initiation of serotonin reuptake inhibitors. *Cureus*. 2022;14(11):e31987.
5. Ortiz D, Perkins AJ, Fuchita M, et al. Pre-existing anxiety and depression in injured older adults: an under-recognized comorbidity with major health implications. *Ann Surg Open*. 2022;3(4):e217.
6. Cai H, Jin Y, Liu R, et al. Global prevalence of depression in older adults: a systematic review and meta-analysis of epidemiological surveys. *Asian J Psychiatry*. 2023;80:103417.
7. Choi H, Shim J. Predictors of depression among individuals receiving the basic livelihood security program benefits in Korea: a study based on the sixth and Seventh Korea National Health and Nutrition Examination Survey (2013-2018). *Int J Environ Res Public Health*. 2022;20(1):194.
8. McAllister-Williams RH, Arango C, Blier P, et al. The identification, assessment and management of difficult-to-treat depression: an international consensus statement. *J Affect Disord*. 2020;267:264-282.
9. Berk M, Sarris J, Coulson CE, Jacka FN. Lifestyle management of unipolar depression. *Acta Psychiatr Scand*. 2013;127:38-54.
10. Szychowska A, Zimny-Zajac A, Dziankowska-Zaborszczyk E, Grodzicki T, Drygas W, Zdrojewski T. Physical activity versus selected health behaviors, subjective physical and psychological health and multimorbidity in a large cohort of Polish seniors during the COVID-19 pandemic (results of The National Test for Poles' Health). *Int J Environ Res Public Health*. 2022;20(1):556.
11. Huang AA, Huang SY. Computation of the distribution of model accuracy statistics in machine learning: comparison between analytically derived distributions and simulation-based methods. *Health science reports*. 2023;6(4):e1214. doi:10.1002/hsr2.1214
12. Gujral S, Aizenstein H, Reynolds, 3rd CF, Butters MA, Erickson KI. Exercise effects on depression: possible neural mechanisms. *Gen Hosp Psychistry*. 2017;49:2-10.
13. Miranda M, Morici JF, Zanoni MB, Bekinschtein P. Brain-derived neurotrophic factor: a key molecule for memory in the healthy and the pathological brain. *Front Cell Neurosci*. 2019;13:363.

14. Huang AA, Huang SY. Quantification of the effect of vitamin E intake on depressive symptoms in United States adults using restricted cubic splines. *Current developments in nutrition*. 2023;7(2):100038. doi:10.1016/j.cdnut.2023.100038
15. Delgado PL. Depression: the case for a monoamine deficiency. *J Clin Psychiatry*. 2000;61(suppl 6):7-11.
16. American Psychiatric Association. Practice guideline for the treatment of patients with major depressive disorder (revision). *Am J Psychiatry*. 2000;157(4 suppl):1-45.
17. National Institute for Health and Clinical Excellence: Guidance Leicester (UK) *Depression: The Treatment and Management of Depression in Adults (Updated Edition)*. British Psychological Society; 2010.
18. Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: towards understanding the antidepressant mechanisms of physical activity. *Neurosci Biobehav Rev*. 2019;107:525-539.
19. Ross RE, VanDerwerker CJ, Saladin ME, Gregory CM. The role of exercise in the treatment of depression: biological underpinnings and clinical outcomes. *Mol Psychiatry*. 2023;28(1):298-328.
20. De Sousa RAL, Rocha-Dias I, de Oliveira LRS, Improta-Caria AC, Monteiro-Junior RS, Cassilhas RC. Molecular mechanisms of physical exercise on depression in the elderly: a systematic review. *Mol Biol Rep*. 2021;48(4):3853-3862.
21. Williams LS, Brizendine EJ, Plue L, et al. Performance of the PHQ-9 as a screening tool for depression after stroke. *Stroke*. 2005;36(3):635-638.
22. Huang AA, Huang SY. Use of machine learning to identify risk factors for insomnia. *PloS one*. 2023;18(4):e0282622. doi:10.1371/journal.pone.0282622
23. Blumenthal JA, Babyak MA, Doraiswamy PM, et al. Exercise and pharmacotherapy in the treatment of major depressive disorder. *Psychosom Med*. 2007;69(7):587-596.
24. Wells KB. Detection of depressive disorder for patients receiving prepaid or fee-for-service care. results from the medical outcomes study. *JAMA*. 1989;262(23):3298-3302.
25. Negaresh R, Motl R, Mokhtarzade M, et al. Effect of short-term interval exercise training on fatigue, depression, and fitness in normal weight vs. overweight person with multiple sclerosis. *Explore*. 2019;15(2):134-141.
26. Yang P, Yang H, Cao Y, Yang X, He B. Psychophysiological effects of rhythmic music combined with aerobic exercise in college students with minimal depressive symptoms. *Sports Med Health Sci*. 2022;4(4):267-274.
27. Hayley AC, Williams LJ, Venugopal K, Kennedy GA, Berk M, Pasco JA. The relationships between insomnia, sleep apnoea and depression: findings from the American National Health and Nutrition Examination Survey, 2005-2008. *Aust New Zealand J Psychiatry*. 2015;49(2):156-170.
28. Wilson SJ, Novak JR. The implications of being "in it together": relationship satisfaction and joint health behaviors predict better health and stronger concordance between partners. *Ann Behav Med*. 2022;56(10):1014-1025.
29. Werneck AO, Kandola A, Tebar WR, Silva DR, Stubbs B, Christofaro DGD. Does physical activity moderate the association between device-measured sedentary time patterns and depressive symptoms in adults? *Braz J Psychiatry*. 2022;44(6):584-589.
30. Kajtna T, Vučković V. Effect of decrease of physical activity on depression and anxiety after the COVID-19 lockdown: a survey study. *Front Psychol*. 2022;13:961798.
31. Taylor SE, Seeman TE. Psychosocial resources and the SES-health relationship. *Ann NY Acad Sci*. 1999;896:210-225.
32. Thome J, L. Espelage D. Relations among exercise, coping, disordered eating, and psychological health among college students. *Eat Behav*. 2004;5(4):337-351.
33. Ströhle A. Physical activity, exercise, depression and anxiety disorders. *J Neural Transm*. 2009;116(6):777-784.
34. Callaghan BL, Tottenham N. The stress acceleration hypothesis: effects of early-life adversity on emotion circuits and behavior. *Curr Opin Behav Sci*. 2016;7:76-81.
35. Bailey A, Phillips W, Rutter M. Autism: towards an integration of clinical, genetic, neuropsychological, and neurobiological perspectives. *J Child Psychol Psychiatry*. 1996;37(1):89-126.
36. Gupta S, Totade S, Gupta K, Bamrah P, Gupta S, Gupta S. Management of obese type 1 diabetes mellitus (Double Diabetes) through telemedicine during COVID-19 pandemic lockdown: a case report. *Cureus*. 2022;14(10):e30533.
37. Kim D, Lee J, Park H, Jeon JY. The relationship between physical activity levels and mental health in individuals with spinal cord injury in South Korea. *Int J Environ Res Public Health*. 2020;17(12):4423.
38. Cardona-Acosta AM, Bolaños-Guzmán CA. Role of the mesolimbic dopamine pathway in the antidepressant effects of ketamine. *Neuropharmacology*. 2023;225:109374.
39. Hu X, Pan L, Li W. Meta-analysis on the efficacy of the norepinephrine reuptake inhibitors reboxetine and atomoxetine for the treatment of schizophrenia and attention deficit hyperactivity disorder. *Adv Clin Exp Med*. 2022;32(5):511-522.
40. Li Y, Yang L, Li J, et al. Antidepression of Xingpijieyu formula targets gut microbiota derived from depressive disorder. *CNS Neurosci Ther*. 2023;29(2):669-681.

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