



Original Research

Moderate Vigorous Physical Activity for Mental Health in Sedentary Middle-Aged Adults

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Abstract

International Journal of Exercise Science 19(5): 5004, 2026. Anxiety and depression affect 32.3% of United States' adults. Guideline-based moderate-to-vigorous intensity physical activity (MVPA) enhances mental health by increasing brain-derived neurotrophic factor (BDNF) and an array of neuroendocrine factors that also mitigate cardiovascular disease (CVD) risk. We examined the response of 14 variables, including depression (Beck Depression Inventory-II), anxiety (Beck Anxiety Inventory), resilience (Connor-Davidson Resilience Scale [CD-RISC]), serum BDNF, and associated CVD risk factors (e.g., HbA1c, body composition, waist circumference) in sedentary middle-aged adults ($n=29$, $M_{AGE} = 51.31 \pm 6.31$) to a 4-week MVPA regimen. Hotelling's T^2 test showed moderate evidence to indicate the mean vectors for the 14 study variables that differed before and after MVPA ($p=0.022$). Pre- post- VO_{2peak} , measured by the Åstrand-Rhyming Cycle Ergometer Test, increased by 5.93% ($p=0.143$). HbA1c decreased slightly following the intervention (-1.69%, $p=0.052$) across all subjects and by 3.7% (from 5.54 ± 0.48 to 5.34 ± 0.68) in those ($n=20$) who achieved MVPA guidelines in 4 weeks. However, neither BDNF nor body composition consistently improved following MVPA. Poisson regression revealed that when age increased, depression ($p=0.042$) decreased, and resilience increased ($p=0.032$). Alternatively, increases in body mass index (BMI) were associated with increases in depression (<0.001) and anxiety ($p=0.017$) plus decreased resilience ($p=0.037$). Findings indicate MVPA consistent with the U.S. PA Guidelines in sedentary middle-aged adults may decrease depression, HbA1c, and CVD risk and should be a priority amongst providers. Studies involving a larger sample and longer duration are warranted to establish specific relationships between mental health and CVD risk in middle-aged adults.

Keywords: Cardiovascular system, exercise, anxiety, depression, brain-derived neurotrophic factor

Introduction

One in every two individuals worldwide will develop a mental health disorder in their lifetime.¹ Declining mental health has primarily been attributed to anxiety and depression, which affect one in five individuals on a global scale.² However, only 27.6 percent of those diagnosed with an anxiety disorder have received treatment in the previous year.³ Perhaps most concerning is that the highest disease burden for depression exists in older adults, whereas those suffering

the most from anxiety are middle-aged adults.² A probable causal relationship exists between depression, anxiety, and physical inactivity.⁴ Individuals with anxiety and depression may experience barriers to physical activity (PA).⁵ Moreover, depression is comorbid with diabetes⁶ and cardiovascular disease (CVD).⁷ Research studies demonstrate that moderate-to-vigorous intensity physical activity (MVPA)—consistent with the U.S. Department of Health and Human Services Physical Activity Guidelines⁸—not only mitigates the risk for CVD,⁹ but also alleviates symptoms associated with anxiety, depression,^{4,10} and fitness¹¹ while enhancing resilience.¹¹ PA also improves cognitive function by increasing brain-derived neurotrophic factor (BDNF).¹²⁻¹³ BDNF is essential for emotional health and cognitive function¹⁴ and is vital to the growth and maintenance of neurons. PA may improve BDNF and mental health by decreasing vascular inflammation, although the specific mechanism is unknown.¹⁴ MVPA (i.e., 50-85% VO₂max, VO₂peak, HRmax, HRR) has been shown to raise BDNF levels, and higher BDNF levels are associated with improvements in mental health.^{12,15}

Although middle-aged (40-60 years) adults have a high risk for CVD and diabetes, and the highest obesity prevalence of any age group, relationships between CVD risk, anxiety, and depression in these individuals are currently not established.¹⁶ Knowledge of the association between BDNF and MVPA is limited but may provide insight into improving mental health in this population.¹⁷ Simply advising individuals with depression to increase PA will not likely elicit change. Moreover, effectively prescribing PA is difficult because PA prescriptions are not typically covered by insurance. To our knowledge, however, no previous study has examined the influence of MVPA on depression, anxiety and BDNF with associated CVD risk factors in sedentary middle-aged adults who are not currently experiencing symptoms of depression or anxiety. It is important to address this gap in the literature to more thoroughly understand the benefit of MVPA in middle-aged adults who are at a higher risk for CVD and declining mental health.

The purpose of this study is to examine the impact of a 4-week MVPA regimen on mental health (anxiety, depression, resilience, BDNF levels) and CVD risk factors in sedentary middle-aged adults. We hypothesized that those who met the MVPA goal would improve mental health (anxiety, depression, resilience, BDNF levels) and CVD risk in comparison to those who did not.

Methods

Participants

A sample of 40 middle-aged adults initially volunteered to participate in the study; 11 did not complete all interventions due to factors unrelated to the study (e.g., injury, illness), leaving 29 adults in the final sample. Specific to the variable of gender, all data were collected in a respectful and inclusive manner that allowed participants to self-identify to their preference.

Participants were evaluated by their primary care provider (PCP), who agreed to their participation in the study. They also completed the EPIC Physical Activity Questionnaire (short version EPAQ-s) to confirm sedentary PA as their baseline level of activity. To be eligible for this study, potential participants were required to (a) be 40-60 years old, (b) be physically able to participate in a MVPA exercise program, (c) self-report sedentary PA levels as determined by the EPIC Physical Activity Questionnaire (short version EPAQ-s), (d) be able to provide informed consent, (e) report no severe diseases (liver, renal, cardiovascular, thromboembolic), and (f) receive PCP medical clearance. Individuals were excluded if they (a) self-reported PA levels of

more than 30 minutes, 3 days per week; (b) had uncontrolled blood pressure > 150/85 mmHg; (c) had any contraindications to exercise; (d) were unable to comply with study protocol; (e) were unable to engage in PA without assistance; (f) had a significant medical illness, including liver, renal, cardiovascular, or thromboembolic disease; and (g) were pregnant or planning a pregnancy in the next 3 months. Participants were recruited via rolling recruitment through flyers posted on social media and by word of mouth. The PIs led recruitment efforts assisted by research assistants (RAs) from the School of Nursing and Department of Kinesiology. A RA scheduled a screening visit for potential participants to determine if inclusion criteria were met (e.g., PA habits) with final eligibility determined by a PI. Eligible participants received a link to complete an online consent form approved by the Institutional Review Board. All participants provided written informed consent before study proceedings were implemented. The Northern Illinois University's Institutional Review Board provided study approval for Protocol #HS22-0429 in accordance with the ethical standards of the *International Journal of Exercise Science*.¹⁸

Statistical power was estimated using the `pwr.t.test` function from the PWR package in R. The effect size was calculated as: $d = 816 \times \sqrt{2} \times (1 - 0.6) \approx 0.56$. Assuming a two-tailed test with a significance level of $\alpha = 0.05$ and a sample size of $n = 29$, the resulting power was 0.902.¹⁹ A power of 90% is acceptable for our sample size.²⁰ This exceeds the commonly accepted threshold of 0.80, indicating a 90.2% probability of detecting a true effect of the specified magnitude. Therefore, the sample size was considered adequate for the study's objectives. A statistically significant association was observed between goal attainment and depression, with an average reduction of 61% in depressive symptoms ($p = 0.009$; see Table 3).

Protocol

On receipt of written consent, participants received a link to obtain their PCP's approval for study participation. Links were also sent for baseline demographic information (age, gender, ethnicity, race), medical history, EPAQ-s to confirm sedentary PA levels, and 3 mental health questionnaires: the Beck Depression Inventory-II (BDI-II)²¹ to assess depression status, the Beck Anxiety Inventory (BAI)²² to assess anxiety status, and the Conner-Davidson Resilience Scale (CD-RISC)²³ to measure resilience. BDI-II scores for depression include 4 categories with 0 to 13 indicating minimal depression, 14 to 19 mild depression, 20 to 28 moderate depression, and 29 to 63 severe depression.²¹ The BAI scoring range for anxiety is from 0 to 63. A total BAI score of 0 to 7 is considered minimal range, 8 to 15 mild, 16 to 25 moderate, and 26 to 63 severe.²² Resilience levels were measured by the CD-RISC, which contains 25 items that are rated on a 5-point Likert scale ranging from 0, "Not true at all," to 4, "True nearly all the time."²³ Possible scores thus range from 0 to 100. Within 1 week, participants were scheduled to complete an in-person screening visit at the exercise physiology laboratory and received \$25 in compensation on completion.

During screening (Visit 1), after confirming receipt of questionnaires, a certified phlebotomist drew blood for baseline HbA1c and BDNF. BDNF was examined as a potential biomarker. BDNF levels were obtained by a venous blood draw again after the 4-week MVPA program. Following the blood draw, the blood was immediately placed on ice until being centrifuged in the lab. The serum was then stored at -80° F until processing. Serum was later thawed and centrifuged at 13,000 x g for 15 minutes to remove any platelets from the plasma. Analysis for BDNF was conducted via enzyme-linked immunosorbent assay (ELISA) using commercially available kits (R&D Systems Quantikine™ ELISA, Cat# DBD00, R&D systems, Inc. Minneapolis, MN) according to the manufacturer's protocol. ELISA plates were read and quantified on a BioTek CYTATION5

spectrophotometer (BioTek, Winooski, VT). A 12-lead EKG, resting heart rate (HR), systolic blood pressure (SBP), and diastolic blood pressure (DBP) readings were collected to determine safe cardiovascular status prior to exercise. Height was measured using the Seca Model 220 stadiometer. Body composition (weight, BMI, percent body fat [PBF], fat mass, lean body mass [LBM]) was assessed using the InBody 520 (InBody 520, Biospace, Los Angeles, CA, USA) and waist circumference (WC) using a tape measure (cm) at the level of the umbilicus. Then, patients were scheduled for visit 2.

During Visit 2, one week after Visit 1, an Astrand-Rhyming cycle ergometer test²⁴ was performed to determine baseline cardiorespiratory fitness ($\text{VO}_{2\text{peak}}$) for the purpose of determining a tailored exercise regimen. The goal for each plan was to meet the minimum requirements for the U.S. Physical Activity Guidelines for Healthy Adults⁸ of at least 150 minutes per week at moderate intensity or 75 minutes per week at vigorous intensity. The PI discussed potential barriers to increasing PA with participants and behavioral strategies to help overcome these barriers.²⁵ Participants received a Mi Smart Band 6 (Xiaomi, Inc.) to assess PA their levels. The accuracy and precision of the Mi Band is reasonable and can be used to monitor the average of step count and HR in free-living conditions.²⁶ This activity tracker recorded date of activity, HR, daily step count, and kcal. Participants also received a precision 6-axis sensor and photoplethysmography (PPG) HR sensor along with an orientation on how to use these devices. Participants were instructed to wear the activity tracker at all times except when bathing to measure time spent engaged in activity, distance, HR, and daily steps. To independently complete the 4-week individualized exercise program, participants received examples of various modes of activity at various intensities. Participants received instructions to begin with a 5-minute warm up and end with a 5-minute cool down, to monitor their HR, and to discontinue exercise if they experienced lightheadedness, dizziness, palpitations (fluttering sensation in the chest), chest pain, nausea, vomiting, or difficulty breathing. They received instructions on how to record daily activity frequency, intensity, time, and type of exercise in a spreadsheet and then to submit this log on a weekly basis. A RA reviewed the 4-week exercise plan with each participant.

The 4-week independent phase began after Visit 2. During the first week of the 4-week independent phase of MVPA, participants were encouraged to exercise for 20 to 30 minutes at a moderate intensity on 3 to 5 days of the week. During weeks 2 to 4, they were instructed to increase the exercise duration by 5 to 10 minutes and also gradually increase their exercise intensity each week. During the 4-week MVPA phase, participant logs were used to record self-report PA modality and duration. Weekly check-in visits with participants were also performed by a RA to encourage meeting goals, answer questions, and retrieve the PA data from the Mi Band so it could be recorded. Data retrieved included the date of activity, HR (minimum, maximum, average), steps, and kcals expended during each activity. Most of the participants walked to complete their PA requirements in addition to engaging in biking, running, swimming, and yoga. Criteria for successfully meeting PA consistent with the guidelines included 150 minutes/week of MVPA for a minimum of 30 minutes 3 days/week and achieving MVPA according to their individualized prescribed HR zone. The HR zone was calculated for each participant using the Heart Rate Reserve Method (HRR).²⁷ To check the fidelity of the weekly data, the same RA retrieved and confirmed all weekly data collected during the participants final visit when they returned the Mi Band.

Participants returned to the exercise physiology lab for a 1-hour follow-up visit 1 to 2 weeks after completing the MVPA regimen to complete post-assessments and surveys. Data obtained

during follow-up included laboratory analysis for HbA1c and BDNF levels immediately following exercise. Blood samples were immediately placed on ice and processed for storage. Body composition measures (via InBody) were obtained, including WC, HR, and SBP, and cardiovascular fitness was assessed by Astrand-Rhyming cycle ergometer test.²⁴ Participants also completed the BAI, BDI-II, and CD-RISC questionnaires using the same links for their baseline. Participants were also asked what they liked and disliked about the intervention, behavioral and technology strategies, and their experience using the activity tracker. Participants received \$25 for completing the follow-up visit.

Statistical Analysis

Percentages and frequency distribution tables were generated for the variables. Mean and standard deviation were calculated for the numerical variables. The paired Hotelling's T^2 test was used to compare the mean vectors of the pre- and post-scores for the mental health variables, VO_{2peak} , body composition, and HbA1c. To identify the drivers of these differences, we conducted univariate t-tests for variables that exhibited normality, while nonparametric tests were used to assess the differences between the pre- and post-scores of the mental health variables, fitness variable, body composition variables, and HbA1c. Cohen's d measure was used to measure effect size. The Shapiro-Wilk test was used to assess normality for the BDI-II, BAI, and CR-RISC variables, and it was found that normality was violated. Furthermore, the total scores for BDI-II, BAI, and CD-RISC were calculated by summing the items used to measure each assessment. As a result, regression analysis was not employed to identify key predictors for these variables; instead, we used generalized linear regression, specifically Poisson regression, to examine the relationship between the mental health variables and key predictors.

Multivariate methods were used to determine if a significant difference was found from baseline to post-MVPA intervention. Additionally, logistic regression was employed to determine whether mental health-related scores (anxiety, depression, resilience) influenced the change in PA behavior among middle-aged adults. All statistical tests were conducted with a significance level of 0.05. R version 4.1.2 (2021-11-01) was used to analyze the dataset.

Results

Table 1 presents the demographic characteristics of the 29 participants (24 females, 5 males) in the study. Table 2 features the results of the 14 body composition, cardiovascular, metabolic, and mental health variables to the 4-week MVPA intervention for those who met their PA goal and those who did not meet their goal, depending on the amount of exercise participants completed during the 4-week MVPA regimen. Table 3 features the pre-post results of the MVPA regimen and the completion of the MVPA regimen while Table 4 shows the results of the generalized linear model (Poisson regression). Table 5 presents the logistic regression fits for anxiety, depression, and resilience.

Demographics

Participants were 40 to 60 years of age ($M_{AGE}=51.31\pm 6.31$) with a disproportionate number of women ($n=24$, 82.7%). Most were white, non-Hispanic, earning at least \$80,000/year ($n=21$, 72.4%; Table 1).

Table 1. Demographic Characteristics: Age, Income, Race and Ethnicity.

Demographics	N (%)
Age	
40	2 (6.0%)
41-45	5 (17.2%)
46-50	5 (17.2%)
51-55	8 (27.6%)
56-60	9 (31.0%)
Income Range	
<40,000	1 (3.4%)
40,000-60,000	5 (17.2%)
60,000-80,000	3 (10.3%)
80,000-100,000	10 (34.5%)
>100,0000	10 (34.5%)
Race	
White	22 (76.0%)
Asian	4 (14.0%)
Black or African American	3 (10.0%)
Ethnicity	
Non-Hispanic	25 (86.2%)
Hispanic	4 (13.8%)

There was not a significant difference between anxiety levels of the two groups at baseline, $F(1, 26)=1.461$, $p>0.05$. Nor was a significant difference found between the two groups in baseline depression levels, $F(1, 26)=2.376$, $p>0.05$.

Table 2. Summary of Body Composition, Metabolic, Cardiovascular Response, and Mental Health Variables Based on Whether the PA Goal Was Met or Not.

Variables	Met Pre Mean/(SD) (n=20)	Not Met Pre Mean/(SD) (n=9)	Met Post Mean/(SD) (n=20)	Not Met Post Mean/(SD) (n=9)
Weight (kg)	79.85 (21.31)	85.62 (20.14)	79.77 (21.04)	85.10 (21.07)
WC (cm)	93.48 (16.02)	97.39 (18.58)	94.04 (15.20)	99.83 (17.04)
BMI (kg/m ²)	28.58 (5.22)	30.49 (8.11)	28.53 (5.09)	30.27 (8.24)
PBF	36.49 (7.75)	35.00 (14.01)	36.72 (7.61)	34.34 (13.74)
Fat Mass (kg)	30.13 (18.72)	31.31 (12.6)	30.59 (18.88)	30.17 (12.13)
LBM (kg)	54.29 (12.08)	49.74 (10.82)	54.51 (12.33)	51.48 (13.37)
HbA1c (%)	5.54 (0.48)	5.49 (0.29)	5.34 (0.68)	5.44 (0.29)
VO ₂ peak (ml/kg/min ⁻¹)	23.72 (7.52)	24.75 (6.87)	23.98 (7.25)	26.73 (10.43)
HR (beats/min)	73.00 (11.75)	71.22 (9.65)	82.05 (12.09)	82.69 (11.39)
SBP (mm Hg)	118.70 (13.52)	119.33 (10.77)	125.60 (14.89)	121.48 (17.26)
DBP (mm Hg)	76.30 (7.93)	74.67 (9.17)	79.10 (10.93)	76.24 (9.83)
BAI Total	6.81 (5.98)	4.89 (5.21)	6.34 (4.09)	7.67 (5.39)
BDI-II Total	5.85 (6.26)	9.78 (8.80)	3.40 (4.02)	8.78 (7.08)
CD-RISC Total	74.71 (17.27)	66.67 (25.16)	74.47 (13.29)	71.00 (11.40)

Table 2 presents the body composition, metabolic, and cardiovascular characteristics of the 29 study participants. There was moderate evidence to indicate that the mean vectors for the 14 variables (Table 2) differed before and after the protocol (Hotelling's T^2 test, $p=0.022$). Of the 14 variables, BAI total; resting HR, SBP, DBP; and PBF exhibited bivariate normality.

Body Composition Characteristics

Overall, body composition showed some improvement in response to MVPA in the 29 subjects, but the differences were not significant (Table 2). Most ($n=21$, 72%) were overweight at baseline with a mean BMI of 29.17 (6.17) kg/m². Baseline weight, BMI, WC, and fat mass were lower in those who met the PA goal than those who did not while PBF and fat mass were higher. A notable

increase in LBM from 49.74 ± 10.82 vs. 51.48 ± 13.37 was observed in those who did not meet the PA goal compared to those who did: 54.29 ± 12.08 vs. 54.51 ± 12.33 . BMI negligibly decreased in all subjects but more in those who did not meet the PA goal: 30.49 ± 8.11 to 30.27 ± 8.24 than those who did 28.58 ± 5.22 to 28.53 ± 5.09 . Similarly, PBF decreased negligibly by 0.66 and only in those not meeting the PA goal: 35.00 ± 14.01 to 34.34 ± 13.74 . Weight decreased in both groups but more (0.52 vs. 0.08 kg) in those who did not meet their PA goal than those who did, although the decrease was not significant. At baseline, PBF ranged between 35.00 (SD=14.01) and 36.49 (SD=7.75), which is very poor for 40- to 59-year-old women who comprised most of the sample.²⁶ Baseline average WC was lower, 93.48 (SD=16.02) cm, but increased slightly to 94.04 (SD=15.20), which is a high risk for obesity-related disorders (e.g., 90-110 cm, females).²⁷

Cardiovascular Characteristics

According to Table 2, at baseline, HR in those who did not meet their PA goal was lower and increased significantly following MVPA (13.53% change, $M=72.45$, $SD=11.00$) to post-intervention ($M=82.25$, $SD=11.68$), $p=0.005$, Cohen's $d=0.864$), representing a large effect in an unexpected direction. The average baseline VO_{2peak} of 24.43 (SD=6.96) ml/kg/min increased in all participants; however, the improvement was greater in those who did not meet their PA goal (26.73, SD=10.43) than those who did (24.75, SD=6.87). The baseline VO_{2peak} of 24.43 (SD=6.96) ml/kg/min is between the 15th and 35th percentiles for 40- to 59-year-old males representing poor fitness, for 50- to 59-year-old females representing good fitness, and for 40- to 49-year-old females representing fair fitness.²⁷

Metabolic Characteristics

Based on HbA1c levels at baseline, 10 of 29 participants were diagnosed with prediabetes, 1 had diabetes, and 19 had normal glucose levels. The average HbA1c level at baseline in all participants was normal at 5.507% (SD=0.35). Pre- post-HbA1c improved with a -1.69% change ($p=0.052$) from baseline, improving most (0.20 vs. 0.05) in those who met their PA goal (Table 2).

Mental Health Variables

Findings demonstrated 17 of 29 participants showed varying degrees of enhanced BDNF levels post-MVPA with 14 showing varying degrees of BDNF decline post-MVPA. Likewise, participants displayed a wide array of plasma BDNF pre-MVPA levels, likely confounded by platelet degranulation during processing.

The mental health responses to MVPA for all participants are presented in Tables 2 and 3. Following the MVPA intervention, depression scores (BDI-II) improved more in those who met their PA goal (from 5.85 SD=6.26 to 3.40 SD=4.02) than in those who did not (from 9.78 SD=8.80 to 8.79 SD=7.08) (Table 2). BDI-II decreased on average by 28% from pre-intervention to post-intervention, with $p=0.074$ (Table 3) for all groups, regardless of whether they met their PA goals. Additionally, a relationship exists between goal attainment and depression, with an average change of -61% ($p=0.009$); this relationship is statistically significant (Table 3).

Transforming raw scores into anxiety levels based on the BAI scoring manual before starting the MVPA regimen resulted in a rating consistent with low anxiety, (i.e., all participants had a score between 0 and 18). Of the 29 participants, all scored lowest in terms of anxiety, with the highest score of 18.²² After finishing the 4-week MVPA regimen, the scores for all participants

were rated as low anxiety. Pre- to post-anxiety scores increased in all participants who did not meet their PA goal, with values rising from 4.89 ± 5.21 to 7.67 ± 5.39 . Conversely, there was a slight improvement following the intervention for those who met their PA goal (6.81 ± 5.98 to 6.34 ± 4.09 , Table 3); however, this change was not statistically significant.

Resilience scores showed a modest increase from pre-intervention ($M=72.21$, $SD=19.94$) to post-intervention ($M=73.39$, $SD=12.64$, 1.6% changes), $p=0.363$, Cohen's $d=0.063$, indicating no significant change (Table 3). There was a positive relationship between goal attainment and resilience (average change 4.8%, $p=0.247$), even though the relationship was not statistically significant.

Table 3: One-Sided Test for Pre-Post Exercise and Completion of MVPA Goal Using Nonparametric Methods and T-Test.

Variable	Percentage Change		P-value	
	Met-goal vs. Unmet-Goal	Met-goal	Post-Pre	for the Pre-and Post
BMI (kg/m ²)	-5.73%	0.240	-0.35%	0.193
Waist	-5.79%	0.180	1.16%	0.122
HR	-0.78%	0.445	13.53%	0.005
SBP	3.39%	0.253	4.56%	0.013
DBP	3.75%	0.249	3.19%	0.083
PBF/BF%	6.91%	0.271	-0.12%	0.429
Fat Mass	-1.39%	0.529	-0.65%	0.257
Fat-Free Mass	-5.56%	0.279	2.48%	0.311
HbA1c	-1.80%	0.235	-1.69%	0.052
VO ₂ peak	11.49%	0.235	5.93%	0.143
BAI	-17.20%	0.231	8.00%	0.295
BDI-II	-61.23%	0.009*	-28.00%	0.074
CD-RISC	4.80%	0.247	1.60%	0.363

*Values were obtained while at rest.

The Shapiro-Wilk test was used to check the normality for the BDI-II, BAI, and CR-RISC variables, and the normality was violated. In addition, the total scores for BDI-II, BAI, and CD-RISC were calculated by summing the items used to measure each assessment. Therefore, regression analysis was not employed to identify key predictors of intervention for these variables; instead, we used generalized linear regression, specifically Poisson regression (Table 4), to examine the relationship or impact of demographic variables, body composition variables, HbA1c, and fitness variables.

Table 4. Results of Generalized Linear Models (Poisson Regression).

Variables	BDI-II		BAI		CD-RISC	
	Coef	P-val	Coef	P-val	Coef	P-val
Intercept	6.235	<0.001	0.713	0.609	3.613	<0.001
Income	0.034	0.632	-0.008	0.884	-0.005	0.802
Age	-0.031	0.042	0.019	0.164	0.009	0.032*
BMI	0.120	<0.001	0.038	0.017*	-0.011	0.037*
HR+	0.026	<0.003*	-0.005	0.495	-0.004	0.083
DBP+	0.038	0.001*	0.002	0.888	0.007	0.007*
HbA1c	-0.292	0.263	-0.088	0.641	0.043	0.450
VO ₂ peak	-0.004	0.772	-0.004	0.629	0.003	0.163

+Values were obtained while at rest. The * indicates the significance of the change.

Table 4 shows that when age increased, depression decreased ($p=0.042$) and resilience increased ($p=0.032$); the impact was not major but was statistically significant. Also, as BMI increased, depression ($p<0.001$) and anxiety ($p=0.017$) increased while resilience decreased ($p=0.037$). In addition, resting HR ($p=0.003$) and resting blood pressure ($p=0.001$) were related to depression; as they increased, so did depression.

Table 5. Logistic Regression Fits: Anxiety, Depression, and Resilience.

Variable	Coefficients	Std. Error	P-Value
Intercept	3.093	4.175	0.4588
BDI-II Total	-0.314	0.151	0.0379*
BAI Total	0.193	0.172	0.2597
CD-RISC Total	-0.024	0.051	0.6386

Table 5 presents the results of a logistic regression model examining the influence of depression (BDI), anxiety (BAI), and resilience (CD-RISC) on the likelihood of meeting physical activity (PA) goals. The model revealed that depression was a significant negative predictor: each one-point increase in BDI score was associated with a 27% decrease in the odds of achieving PA goals (OR = 0.73, $p = 0.038$), controlling for anxiety and resilience. Although anxiety (BAI) showed a positive association with goal attainment (OR = 1.21), the effect was not statistically significant ($p = 0.260$). Similarly, resilience (CD-RISC) had a minimal and non-significant negative effect (OR = 0.98, $p = 0.639$). These findings suggest that depressive symptoms may be a key psychological barrier to physical activity engagement, while anxiety and resilience appear to have limited predictive value in this context.

Discussion

The purpose of this study was to examine the response of anxiety, depression, resilience, BDNF, and CVD risk factors (body composition, HbA1c, cardiovascular fitness) to a 4-week MVPA regimen in sedentary middle-aged adults. Findings demonstrate PA consistent with the U.S. PA Guidelines may have improved depression and HbA1c in middle-aged adults. To our knowledge, this is the first study to examine the response of these mental health variables and CVD risk factor response to MVPA in 40- to 60-year-old adults.

Most of the study participants were white, middle-class adults, with a disproportional number of women, and an income of at least \$80,000/year, who resided in a safe Midwestern suburb with adequate health care resources to support a healthy lifestyle. Social determinants of health were likely not the reason 20 of the 29 participants did not meet their PA goal. The literature support such factors as goal setting, social influence, and the belief that PA is beneficial as facilitators of PA engagement in middle-aged adults.²⁸ Each participant received a tailored PA plan, each was committed to meeting the MVPA goal in 4 weeks, and most had personal or social support. All participants received training from an exercise physiologist in the laboratory prior to the remote PA phase as well as weekly check-ins from study personnel. Participants either were not consistent with increasing their frequency and/or intensity of exercise, or primarily engaged in lower intensity activities (e.g., yoga). Mental and physical tertiary factors influence PA engagement.⁵ Social support is a strong facilitator of PA; however, barriers to PA in sedentary middle-aged adults may include a lack of motivation, negative self-perception, the physical discomfort of muscle soreness and fatigue, and time constraints. Per inclusion criteria, all participants were sedentary at baseline. Generally, individuals who are accustomed to sedentary behavior may experience difficulty when beginning a new exercise routine.⁵

Most participants met their PA goal despite all of them having a higher than average BMI and PBF at baseline. Excess weight is a barrier to PA engagement,²⁹ so the overweight status at baseline may have influenced participants' ability to meet the PA goal. As expected, weight and BMI decreased in all participants following the MVPA intervention, yet WC increased in all participants. Since weight and BMI decreased in a parallel manner, the increase in WC may have been due to measurement error. Most of the participants were either peri-menopausal or post-menopausal women. Therefore, to improve body composition, especially WC, both aerobic training and resistance exercise performed for a longer duration than 4 weeks may be necessary.³⁰ In addition, variability in measuring WC may result from different personnel, incorrect technique, placement of the tape measure (e.g., at, above, or below the navel), clothing, or even breathing.³¹ Nonetheless, WC is a valuable indicator of obesity, and recent findings demonstrate that reducing WC may be more beneficial than BMI in preventing metabolic syndrome, a strong indicator of CVD.³²

A slight increase was observed in PBF and fat mass in those who met their PA goal and a decrease in those who did not whereas LBM increased in all participants, with a greater increase of ~4 kg in those who did not meet their PA goal. Here again, the findings are likely due to measurement error, especially since they are inconsistent. With the InBody machine, however, factors such as recent food intake, hydration status, the timing of a recent exercise bout, and even gender may influence measurements. With the exception of height, all the body composition measurements were obtained using the InBody machine. Height was measured using the stadiometer. All participants were sedentary at baseline but gradually increased their intensity and duration of PA over a 4-week period, so there may not have been enough time for body composition changes to occur.³³ Additional studies evaluating the mental health response to MVPA should involve a longer study duration and improved control over body composition measures.

Cardiovascular fitness improved in all participants, but this increase did not reach significance. The most common type of PA that participants engaged in to meet their goal was walking, which may not have required a high enough intensity to improve fitness. Additionally, most of the study participants were women. According to the American College of Sports Medicine,²⁷ the average fitness level of women who are 50 to 59 years of age is good, and in women between 40 and 49 years of age, it is fair. Baseline fitness levels were poor for men of all ages in the study. Poor fitness is associated with worsening mental health (e.g., 98% higher likelihood of depression, and 60% higher odds of anxiety over 7 years)⁴ and with the lowest levels of aerobic and muscular fitness combined compared to individuals with higher fitness levels.¹⁰ The increase in resting HR observed post-intervention in all participants is the opposite of the expected outcome and may have been due to measurement error, the temperature in the laboratory, or stress. Similarly, blood pressure increased in all participants post-intervention, with a greater increase observed in those who met their PA goal. This finding may have been due to measurement error, equipment, stress, or the laboratory conditions.

HbA1c levels decreased in all participants despite of the short study duration, but the decrease did not reach significance. It is important to note that the average baseline HbA1c levels were normal, which was due in part to some participants receiving treatment for their HbA1c. Therefore, it is unlikely the HbA1c level would have decreased significantly. The gradual increase from sedentary behavior to MVPA in 4 weeks allows for minimal time to impact long-term glucose control. The HbA1c response to PA is highly variable and demonstrates a dose-response relationship. A decrease in HbA1c has been demonstrated following engagement in

PA that is performed of at least a moderate intensity,³⁴ for longer durations,³⁵ and in combination with resistance exercise.³⁶ HbA1c decreased by 1.69% from baseline ($p = 0.052$), with the bigger improvement among participants who met their PA goal (0.20 vs. 0.05; Table 3).

We did not observe a significant response in BDNF levels to the PA intervention. BDNF levels did increase in study participants; however, platelets harbor significant BDNF content, likely posing a profound confounding variable in plasma samples. In this study, the baseline readings in plasma samples for BDNF were very high, leaving little room for signal-to-noise resolution. Several samples likewise exhibited signs of hemolysis, further confounding the results. Subsequent studies will need to carefully control for markers of platelet degranulation to better normalize results for BDNF.

Our findings demonstrated a decrease in BDI-II scores, which represent depressive symptoms, in both groups following the MVPA regimen which is consistent with previous research findings.³⁷ The BDI-II score improved most in those who met their PA goal, suggesting PA may have influenced symptoms of depression, although further study is required. Despite this improvement, the BDI-II score was low at baseline, potentially limiting clinical relevance. Both groups demonstrated average baseline scores within the Minimal Depression range (0-13, Table 2) as defined by the scoring manual. The present findings reveal a statistically significant relationship between goal attainment and depression, with an average reduction of 61% in depressive symptoms ($p = 0.009$; see Table 3). This result underscores the potential clinical relevance of goal-directed interventions in mitigating depressive symptoms. Specifically, the data suggest that individuals who experience progress toward PA goals may benefit from enhanced psychological well-being. The probability of achieving MVPA goals decreased by 27% with a 1-point increase in depression scores. Proposed pathways for the physiologic response to increased PA include acute neuroendocrine and inflammatory responses, such as activation of the endocannabinoid system (e.g., runner's high).³⁸ In addition, longer-term adaptations, including changes in the brain's neural architecture, may occur.³⁹ Psychosocial and behavioral explanations have also been suggested, including improved self-perceptions and body image, social interactions, and even the development of coping strategies.³⁹ Future work should therefore explore the shape of the dose-response relationship for these responses to PA in addition to total volume.⁴⁰

As participants' BMI increased, BAI and BDI-II scores increased. An inverse association was found between BMI and CD-RISC, the score that reflects resilience. These findings demonstrate PA may potentially improve symptoms of depression, anxiety, and CVD. Only a slight decrease was observed in the BAI score, which represents anxiety, following the PA intervention in those who met their PA goal, whereas the BAI score increased in those who did not meet their goal. A recent analysis of 97 studies and 128,119 individuals demonstrated substantial improvements in anxiety occurred following MVPA that was performed for a long duration.⁹ The lack of significant improvement in our study may have been related to the shorter study duration, not reaching a high enough intensity, and variability amongst the types of activities performed by the participants.

In addition, it is important to note that 9 of 29 study participants were taking medications for anxiety and/or depression while participating in the study. However, these medications may have potentially affected both the anxiety and depression scores and so cannot be attributed to the outcomes of either. Participants' medications were not controlled due to their need to maintain consistent dosages to maintain a therapeutic range of the medication in their blood. Moreover,

withholding treatment for mental health is typically not recommended due to the potential for severe side effects. Medications may be withheld in certain situations; however, based on the short study duration, the ability to safely stop and restart these medications would have been difficult. Furthermore, withholding treatment may have affected participants' motivation toward PA engagement, especially individuals who were more accustomed to a sedentary lifestyle.

PA is beneficial and should be encouraged in middle-aged adults who have an increased risk for sedentary behavior, mental health disparities, and CVD. Guideline-based PA may improve depression levels and HbA1c, although significant associations may exist between PA, CVD risk factors, and mental health (depression, anxiety, resilience). Tailored exercise regimens are recommended as a starting point in sedentary middle-aged adults to improve PA engagement as well as self-confidence with activity, thereby translating to future sustainability towards PA and overall health. These findings support the importance of PA in middle-aged adults to potentially prevent the increasing risk of CVD and should be recommended by providers. Additional research involving a longer study duration is currently warranted to more fully elucidate the influence of mental health on PA as well as relationships between mental health and CVD risk.

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