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Associations between physical activity and mental health among bariatric surgical candidates

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Abstract

Objective—This study aimed to examine associations between physical activity (PA) and mental health among adults undergoing bariatric surgery.

Methods—Cross sectional analysis was conducted on pre-operative data of 850 adults with class 2 obesity. PA was measured with a step activity monitor; mean daily steps, active minutes, and high-cadence minutes (proxy for moderate-vigorous intensity PA) were determined. Mental health functioning, depressive symptoms and treatment for depression or anxiety were measured with the Medical Outcomes Study 36-item Short Form, Beck Depression Inventory, and a study-specific questionnaire, respectively. Logistic regression analyses tested associations between PA and mental health indicators, controlling for potential confounders. Receiver operative characteristic analysis determined PA thresholds that best differentiated odds of each mental health indicator.

Results—Each PA parameter was significantly ($P < .05$) associated with a decreased odds of depressive symptoms and/or treatment for depression or anxiety, but not with impaired mental health functioning. After controlling for sociodemographics and physical health, only associations

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Competing Interest Statement

All authors have completed the Unified Competing Interest form at http://www.icmje.org/coi_disclosure.pdf and have no competing interests to report.

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with treatment for depression and anxiety remained statistically significant. PA thresholds that best differentiated those who had vs. had not recently received treatment for depression or anxiety were <191 active minutes/day, <4750 steps/day, and <8 high-cadence minutes/day. Utilizing high-cadence minutes, compared to active minutes or steps, yielded the highest classification accuracy.

Conclusion—Adults undergoing bariatric surgery who meet relatively low thresholds of PA (e.g., 8 high-cadence minutes/day, representative of approximately one hour/week of moderate-vigorous intensity PA) are less likely to have recently received treatment for depression or anxiety compared to less active counterparts.

Keywords

anxiety; bariatric surgery; depressive symptoms; exercise; Roux-en-Y gastric bypass; severe obesity

INTRODUCTION

Mental disorders, such as depression and anxiety, have become the leading cause of disability in the developing world (1). National survey results indicate that adults with obesity, and in particular severe obesity (body mass index [BMI] ≥ 40 kg/m²), are disproportionately affected (2-8). This is especially true for women (2;7;9;10), who appear to suffer more psychological consequences from obesity, such as body image dissatisfaction, stigmatization, and discrimination (11-14).

Studies of clinical populations suggest that a sizeable portion of adults seeking bariatric surgery, the majority of whom are severely obese females, have current depression or anxiety disorders. For example, Kalarchian and colleagues, who assessed Axis I disorders (i.e., Mood, Anxiety, Eating and Substance disorders) with structured interviews independent of the surgery approval process in consecutive bariatric surgery cases (n=288), reported that 10.4% of preoperative patients had current major depressive disorder (42.0% lifetime), while almost a quarter (24.0%) had a current anxiety disorder (37.5% lifetime) (15). In comparison, using similar assessment methods Muhlhans and colleagues (n=146) reported a higher rate of major depressive disorder (25.3%; 50.7% lifetime), but a lower rate of anxiety disorders (15.1%; 21.5% lifetime) (16). These estimates straddle the prevalence of current major depressive disorder and anxiety disorders (13.3% and 19.6%, respectively) reported in a national sample of adults with severe obesity, and are almost two-fold higher than in normal weight adults (7.2% and 10.2%, respectively) (6).

There is evidence to suggest that depressive symptoms and the prevalence of major depressive disorder decrease after bariatric surgery (10;17;18). However, the same has not been consistently shown for symptoms of anxiety and anxiety disorders (17-19). In addition, preoperative depression and anxiety increase risk of their counterpart postoperative conditions (18;20), and have been shown to have a negative impact on long-term surgically induced weight loss (18;21;22). These findings underscore the importance of providing appropriate mental health care to pre- and post-operative patients with depression and anxiety disorders.

Typical management of depression and anxiety by clinical professionals involves counseling and/or antidepressant or anti-anxiety medication (23). In the past decade research has focused on whether physical activity (PA) may also help in the prevention or treatment of depression and anxiety. Recent meta-analyses and systematic reviews have concluded that exercise 1) is effective as a standalone treatment in reducing depressive symptoms among adults without clinical depression (24); 2) reduces depressive symptoms among patients with chronic illness (25); 3) compares favorably to antidepressant medications as a first-line

treatment for mild to moderate depression (26); 4) alleviates depressive symptoms among adults with major depression (27), with comparable results to psychotherapy or antidepressant medications (28-30); and 5) improves depressive symptoms when used as an adjunct to medication (26). However, only a handful of studies have investigated whether exercise improves depressive symptoms in obese adults, with mixed results (31-33), and to our knowledge there are no published studies testing PA interventions to treat depression or anxiety in adults with severe obesity.

In recent years, a few studies have examined associations between PA and mental health in severely obese adults, and more specifically in bariatric surgery candidates. In 2006, Bond et al., administered the International Physical Activity Questionnaire-Short form (IPAQ-S) and the Medical Outcomes Study 36-item Short-Form (SF-36) to adults seeking Roux-en-Y gastric bypass (RYGB). No difference in mental health functioning, as assessed with the Mental Component Summary (MCS) score, or any of the SF-36 mental domain scores, was found between adults who reported sufficient PA (defined as reporting at least 30 minutes of moderate intensity PA for at least 5 days in the past week; n=31) vs. those who reported less PA (n=58) (32). In 2009, Bond et al., found some support for a relationship between postoperative PA participation, assessed with the IPAQ-S, and change in mental health functioning following RYGB. Specifically, improvement in the MCS score from pre- to 1 year postoperative was significantly higher among those who were active (defined in this study as reporting at least 200 minutes of moderate intensity PA in the past week) pre- and post-operative (n=68) or only postoperative (n=83), compared to those who reported less PA pre- and postoperative (n=39) (33). However, there was not a significant correlation between change in self-reported PA and change in SF-36 MCS score from pre- to 1 year postoperative, making interpretation of results difficult. More compelling evidence for a link between PA and mental health among bariatric patients was reported by Rosenberger et al. in 2011. Based on the 4-item Godin Leisure Time Questionnaire, PA frequency and intensity 1 year post-RYGB were independently associated with better mental health functioning, as measured by the SF-36 MCS score, and fewer depressive symptoms, as measured with the Beck Depression Inventory (BDI), at that same time point, after controlling for sex, age, ethnicity, preoperative body mass index, and preoperative SF-36 and BDI scores (n=131) (34). Similarly, Larson et al, found a significant association between a composite physical exercise score from the Sport Index of the Baecke Questionnaire, and mental health functioning (SF-36 MCS score) in 157 adults who were 1 to 6 years post-laparoscopic adjustable gastric banding (35). While these studies provide some evidence of a link between PA and mental health among bariatric surgery patients, they all rely on self-reported PA and do little to inform preoperative PA recommendations.

To address shortcomings in the literature, this study sought to determine whether objectively-measured PA was associated with mental health in a large (n=850) cohort of adults undergoing bariatric surgery. Specifically, we examined associations between ambulatory PA and three mental health indicators: impaired mental health functioning, depressive symptoms, and treatment for depression and/or anxiety. We aimed to determine whether associations 1) differed by various parameters of PA (i.e., active minutes, an inverse to sedentary time, high-cadence minutes, a proxy for minutes of moderate-vigorous intensity PA, and steps, a measure of total ambulatory PA), and 2) were independent of the effects of sociodemographics and physical illness and disability. In addition, we attempted to determine thresholds of PA that best differentiated mental health status.

METHODS

Sample

The Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) is an observational study designed to assess the risks and benefits of bariatric surgery (38). Between February, 2006 and February, 2009 patients at least 18 years old seeking bariatric surgery by participating surgeons at ten hospitals throughout the United States were asked to participate if they had not had previous weight loss surgery. By study enrollment closure (April 2009), 2458 participants attended a research visit prior to undergoing a bariatric surgical procedure as part of clinical care. The current analysis is limited to participants with preoperative PA and mental health data (n=850) (Figure).

The study was carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki) for experiments involving humans. All participating centers had institutional review board approval and all participants provided informed consent. The study, #NCT00465829, is registered at www.clinicaltrials.gov.

Measures

Measures were collected independently of the surgery approval process and clinical care. Participants were informed that their responses were confidential, although the informed consent document specified that investigators could take steps to prevent serious harm (e.g., if suicidal ideation were reported).

Physical activity—Preoperative PA was assessed in one half (n=1228; 50.0%) of LABS-2 participants with the StepWatch™ 3 Activity Monitor (OrthoCare Innovations, Washington, D.C.) (Figure). The StepWatch is a small (75×50×20 mm), lightweight (38g) microprocessor-controlled biaxial activity monitor, worn above the ankle that combines acceleration, position, and timing information to count strides per time interval. It is accurate in lean and obese individuals at “slow” (i.e. 1 mph) and “purposeful walking” (i.e. 2 and 3 mph) paces and with a variety of gait styles, with accuracy typically exceeding 98% (39). Trained research staff programmed the StepWatch to double count strides (i.e. to equal steps) in 1 minute intervals with sensitivity settings appropriate to participant’s height, cadence, and gait speed. Settings were verified at slow, normal and fast walking speeds. Participants were asked to wear the StepWatch for the seven consecutive days following their research visit. Raw StepWatch data from the manufacturer software were exported to a SAS version 9.2 database (SAS Institute Inc, Cary, NC). Step counts at the minute level were screened for signs of monitor malfunction. Non-wear periods were identified by intervals of at least 120 minutes with no activity (40). Daily wear time was calculated as 24 hours minus the duration of non-wear periods. Days with at least 10 hours of monitor wear time were considered valid. Algorithms developed in SAS used steps per minute data from valid days of participants with at least three such days (n=927; 75.6%) to calculate average daily values for the following PA parameters: steps; minutes of activity (number of 1-minute intervals with step count greater than 0); and high cadence minutes (number of 1-minute intervals with step count greater than 80).

Impaired mental health functioning—Self-reported functional health and well-being over the past four weeks was assessed with the Medical Outcomes Study 36-item Short-Form (SF-36), a widely used instrument with well-established validity and reliability (41). Items are used to generate a score in four physical health (physical functioning, role limitations due to physical problems, bodily pain, and general health) and four mental health (vitality, social functioning, role limitations due to emotional problems, and mental health) scales, as well as two summary scores: the Physical Component Summary (PCS) and the

Mental Component Summary (MCS). Scores range from 0 to 100, with lower scores indicating greater impairments. Scores were standardized to a population normal distribution (mean=50, standard deviation=10) (42). Individuals whose MCS score was below 40 (i.e. at least one standard deviation below the national mean) were classified as having impaired mental health functioning (42).

Depressive symptoms—Symptoms of depression over the past week was assessed using the Beck Depression Inventory (BDI), version 1 (43), which has well-established validity and reliability (44) and is one of the most widely used instruments in psychological evaluations of bariatric surgery candidates (45). The 21 item test is scored by assigning a value of 0 (absence of the symptom) to 3 (severe symptoms) to each response resulting in a total score ranging from 0 to 63; higher scores indicate greater depressive symptomatology. Because many patients are advised to lose weight in preparation for bariatric surgery, no points were assigned to the one BDI item that assesses weight loss (I have lost more than 5 pounds) for participants who endorsed the statement, “I am purposefully trying to lose weight by eating less,” which was added as a yes/no item to the LABS-2 BDI form (38). The following cut-offs for the BDI were applied to the total score: 0-9, 10-18, 19-29 and 30-63, reflecting minimal (sub-clinical), mild, moderate and severe symptomatology, respectively. Due to the distribution of responses categories were collapsed [mild-severe symptoms (BDI score 10) and moderate-severe symptoms (BDI score 19)] for analysis.

Treatment for depression and anxiety—Participants self-reported history of treatment for psychiatric or emotional problems including reason(s) for treatment, hospital admissions, counseling with a mental health professional, and psychotropic medication use with the LABS-2 Psychiatric and Emotional Test Survey (38). Recent treatment for depression or anxiety was defined as counseling or hospitalization in the past 12 months for depression or anxiety, or current antidepressant medication (e.g., Fluoxetine, Paroxetine) or benzodiazapine anxiolytics (e.g., Lorazepam, Diazepam) use for “psychiatric or emotional problems.”

Covariates—Selection of potential confounders and mediators was based on the published literature (5;46;47). Waist circumference, height, and weight measurements were made by certified research staff. BMI was calculated as weight (kg) divided by height squared (m^2). Demographics, smoking status, use of recreational drugs and walking aid use were assessed with LABS-2 questionnaires (38). The Alcohol Use Disorders Identification Test (48) was used to assess symptoms of alcohol use disorder experienced over the past year (49). Chronic medical conditions (hypertension, history of stroke, ischemic heart disease, congestive heart failure, hyperlipidemia, diabetes, sleep apnea, pulmonary hypertension, asthma, abnormal renal function, venous edema with ulcerations and urinary incontinence) were determined using a combination of clinical assessment, self-report, and medical chart review by trained researchers. The number of chronic medical conditions was summed (range: 0-12) to provide a rough estimate of disease burden, as disease severity was not taken into account and all diseases were weighted equally. Three of the four SF-36 physical scales were also utilized as measures of physical health: 1) physical functioning, which assesses ability to complete activities of daily living; 2) role limitations due to physical problems, which measures physical limitations in fulfilling social and occupational roles; and 3) bodily pain, which measures both the frequency and severity of physical pain. The fourth physical scale, general health perception, was not included because it measures both physical and mental health (50).

Statistical analysis

Characteristics of LABS-2 participants in the current analysis versus those who were excluded due to missing PA or mental health data (Figure) were compared with Pearson's chi-square test for categorical variables and the Wilcoxon rank-sum test for continuous variables. Pearson's chi-square test was also used to test for associations between mental health indicators. Logistic regression analyses were used to assess associations between PA parameters (entered as continuous variables) and 1) impaired mental health functioning, 2a) mild-severe depressive symptoms, 2b) moderate-severe depressive symptoms, and 3) recent treatment for depression or anxiety. For ease of interpretation, continuous PA parameters were entered with the following units: 100 active minutes/day, 1000 steps/day and 10 high-cadence minutes/day.

Next, we constructed multivariable logistic regression models adjusting for sex as well as any of the following factors that reached statistical significance (defined as $P < .05$): age, race, ethnicity, marital status, education, employment status, household income, smoking status, alcohol use disorder symptoms, recreational drug use, BMI, waist circumference, number of chronic medical conditions, walking aid use, and physical functioning, role limitations due to physical problems, and bodily pain scores. Use of antidepressant or anxiolytic medication was also considered as a covariate in models of impaired mental health functioning and depressive symptoms. Initial analyses with race, education, income, and employment led to collapsing categories when relationships did not differ significantly between all categories. Continuous measures were centered. All potential interactions between variables in the final models were tested.

Receiver operative characteristic (ROC) analysis was used to determine the threshold of each PA parameter that best differentiated odds of each mental health indicator. Analyses were repeated with categorical PA measures based on these thresholds. The C-statistic was used to compare the classification accuracy of competing models. Associations from logistic regression models are reported using odds ratios with 95% confidence intervals. Analyses were conducted using SAS, version 9.2.

RESULTS

Description of the sample

Characteristics of the analysis sample ($n=850$) are shown in table 1. LABS-2 participants who were excluded from analysis ($n=1608$) were similar ($p > .05$) for the most part. However, a greater proportion of the analysis sample was younger (median age 45 vs. 46 years; $p = .01$), Caucasian (88.6% vs. 84.4%; $p < .01$), employed full-time (74.1% vs. 65.6%; $p < .0001$), and had a household income $\leq \$25,000$ (86.0% vs. 79.2%; $p < .0001$), while fewer had impaired mental health functioning (19.7% vs. 30.3%; $p < .0001$). In addition, fewer used a walking aid (12.0% vs. 16.6%; $p < .01$), reflecting the exclusion criteria for PA assessment (i.e. exclusive wheel chair use and medical condition other than obesity that limits walking, such as multiple sclerosis).

Associations between mental health indicators

A higher percentage of those reporting recent treatment for depression or anxiety reported impaired mental health functioning (31.1% vs. 11.6%; $p < .0001$), mild-severe depressive symptoms (46.0% vs. 22.6%; $p < .0001$) and moderate-severe depressive symptoms (14.5% vs. 3.4%; $p < .0001$), than those who did not report having received recent treatment.

Physical activity and mental health indicators

None of the PA parameters were related to impaired mental health functioning ($p > .05$ for all analyses; data not shown). In unadjusted analyses, a lower PA level, as measured by steps, active minutes, or high-cadence minutes, was significantly associated with an increased likelihood of having mild-severe depressive symptoms (Table 2), but not moderate-severe symptoms, which were less common and thus required a large effect size in order for an association to be detected ($p > .05$ for all analyses; data not shown). After controlling for bodily pain and physical role limitations (which were significantly associated with less PA and greater likelihood of depressive symptoms; data not shown), PA parameters were no longer significantly associated with depressive symptoms. Income and antidepressant or anxiolytic medication use also had lesser confounding effects, while sex and age, which also entered the multivariable models (Table 2) did not appear to influence the relationship between PA and depressive symptoms.

Fewer daily steps and high-cadence minutes, but not active minutes, were significantly associated with an increased odds of recent treatment for depression or anxiety in unadjusted analyses. However, after controlling for significant confounders and mediators (i.e., employment status, education, bodily pain and physical role limitations) only high-cadence minutes remained statistically significant (Table 2). There was a significant interaction between high-cadence minutes and physical role limitations such that the association between high-cadence minutes and recent treatment for depression or anxiety was stronger for those with fewer limitations. For example, for those whose physical role limitations score was 60 (indicating few limitations), every 10 high-cadence minutes per day decrease in PA was associated with 87% higher odds of recent treatment for depression or anxiety, whereas the same decrease in PA was associated with 30% higher odds of recent treatment for those whose physical role limitations score was 40 (indicating impairment).

Using ROC analysis the following cut points in PA parameters were determined to best differentiate those who did vs. did not report mild-severe depressive symptoms: <287 active minutes, <5740 steps, and <5 high cadence minutes per day; PA cut points for differentiating between those who did vs. did not receive recent treatment for depression or anxiety were: <191 active minutes, <4750 steps, and <8 high cadence minutes per day. Participants who did not meet each threshold of PA (10-45% of participants depending on the measure) had significantly increased odds of depressive symptoms and recent treatment for depression or anxiety (Table 3). After adjusting for potential confounders and mediators, categorical PA measures were no longer significantly associated with depressive symptoms. However, all three categorical PA measures were significantly independently related to recent treatment for depression and anxiety, (e.g., compared to being active at least 191 minutes/day, not being at least this active was associated with a 125% higher odds of recent treatment for depression and anxiety) (Table 3). Classification accuracy of models predicting treatment for depression and anxiety was highest when high-cadence minutes was entered as a continuous measure (Table 2), followed by high-cadence minutes entered as a dichotomous variable (Table 3).

DISCUSSION

Key findings

The results of this LABS-2 study confirm and extend previous research by demonstrating an inverse association between PA and indicators of poor mental health, in a large cohort of adults with class 2 and class 3 (i.e., severe) obesity prior to undergoing bariatric surgery. Specifically, individuals who were active for more minutes each day, who accumulated more daily steps, and who achieved more high-cadence minutes, had a lower odds of

depressive symptoms and a lower odds of recent treatment for depression or anxiety. Our study also confirms that a sizeable portion of patients undergoing bariatric surgery are affected by mental health issues. Approximately two in five participants (39.2%) reported recent treatment for depression or anxiety, the majority (91.2%) of whom reported current antidepressant medication or anxiolytic use for psychiatric or emotional problems. Compared to those not reporting treatment for depressive or anxiety, a greater percentage of those reporting treatment reported impaired mental health functioning and depressive symptoms, indicating that they may benefit from alternative or supplemental treatment modalities, such as PA.

Dose-response relationship

All three PA parameters were significantly related to depressive symptoms and two of three PA parameters (steps and high-cadence minutes) were significantly related to treatment for depression and anxiety when evaluated as continuous measures, indicating a dose-response relationship with PA. These findings are in line with results from the National Comorbidity Survey (n=8098), in which frequency of PA (without regard for duration) showed a dose-response relationship with current major depression and anxiety disorders (51); a randomized control trial of adults with elevated depressive symptoms (n=23), in which high-frequency aerobic exercise (i.e. 3-5 sessions/week) was more efficacious in reducing depressive symptoms compared to low-frequency aerobic exercise (of the same duration) (52); as well as a study of adults with major depressive disorder (n=53) who had larger increases in their positive affect after longer duration and/or higher intensity PA compared to short duration and/or lower intensity PA (53). However, given the cross sectional nature of this study, it is unclear whether greater volumes of PA resulted in better mental health (i.e., fewer depressive symptoms, less need for treatment for depression and anxiety) or whether poor mental health resulted in less PA.

PA intensity

Some, but not all, studies suggest that more intense PA leads to greater antidepressant effects compared to less intense PA (54). Thus, an important feature of this study was the inclusion of several parameters of PA, which differed by PA intensity. The classification accuracy (as shown by the C statistic) in predicting depressive symptoms and treatment for depression and anxiety was highest with high-cadence minutes, a proxy measure for moderate-vigorous intensity PA, compared to active minutes or steps, which do not account for PA intensity. Therefore, this study provides support that the association between PA and depression and anxiety may be stronger with higher-intensity PA.

Confounders/mediators

After controlling for bodily pain and role limitations due to physical problems, associations between PA parameters and depressive symptoms were no longer significant. It is possible that they confounded the relationship (i.e., pain and physical health factors may have limited PA, while also independently increasing depressive symptoms (55). However, it is also possible that pain and physical role limitations mediated the relationship between PA and depressive symptoms, given that PA participation can decrease pain and improve physical health, thereby lessening role limitations due to physical problems (56).

Mechanisms

There are several physiological mechanisms that may account for a positive association between PA and mental health in adults with severe obesity. Exercise stimulates serotonin release (53) and reduces the stress hormone cortisol (57), both of which can positively influence mood states. Exercise may also stimulate growth of new nerve cells and release of

proteins known to improve health and survival of nerve cells, such as brain-derived neurotrophic factor messenger ribonucleic acid in the hippocampus, an important brain area for behavioral regulation (58;59). It has also been hypothesized that exercise attenuates the hypothalamic-pituitary-adrenal axis response to physical and mental stress (60). Additional physiological or biochemical explanations for how PA may improve aspects of mental health include endogenous opiates, endocannabinoids, anti-inflammatory cytokines, and cerebral blood flow (61). Psychological factors associated with PA participation may also reduce symptoms of depression or anxiety in adults with severe obesity. For example, exercise participation is associated with greater confidence in the capacity of one's body, perceptions of competence, self-efficacy and improved body image (61;62). Thus, exercise may influence depression through enhanced self-esteem. Exercise may also provide patients, who may be lacking a sense of control, with a sense of self-determination (61), thereby reducing anxiety. Exercise may also serve as a distraction from worries and negative thoughts (63). These mechanisms are not mutually exclusive; the effects of PA might stimulate a complex system, trigger a cascade of physiological and neurobiological events (23).

Threshold effect

Although the 2008 PA guidelines for Americans recommend that adults participate in at least 150 minutes/week of moderate-vigorous intensity PA to gain general health benefits, they recognize that "the specific amounts and types of activity that benefit each [health] condition vary" (64). Thus, we sought to determine thresholds of PA parameters that best differentiated those with versus without indication of poor mental health using ROC analysis. None of the PA parameters we evaluated were associated with impaired mental health functioning, as measured by the SF-36, perhaps because the amount and/or type of PA that may be required to impact mental health functioning was not represented in this observational study. Thus, this analysis was limited to depressive symptoms and treatment for depression and anxiety. The thresholds of PA identified in this study were quite low. For example, daily step thresholds were 5740 steps and 4750 steps for depressive symptoms and recent treatment for depression or anxiety, respectively, which are indicative of "low" and "sedentary" PA levels, respectively (65). Similarly, the thresholds of high-cadence minutes for depressive symptoms and treatment for depression and anxiety (4.7 minutes/day and 8.1 minutes/day, respectively, which translate into approximately 30 minutes and 1 hour of moderate-vigorous intensity PA/week, respectively), were far lower than the minimum level of moderate-vigorous intensity PA recommended for adults (64). However, the low thresholds identified in this study may be an artifact of the low representation of higher levels of PA in this observational study. It is also important to recognize that the thresholds of PA that we identified are not necessarily sufficient for treating major depressive disorder or an anxiety disorder. A randomized clinical trial would be required to test the efficacy of various doses of PA for reducing symptoms of depression and anxiety in adults with severe obesity.

Strengths and limitations

Major strengths of this study were its use of a high-quality PA monitor that is reliable and valid in obese populations, and inclusion of three PA parameters that measured different aspects of ambulatory PA. However, it should be noted that this study was unable to investigate whether non-ambulatory "mindful" exercise, such as yoga, were related to mental health. A major limitation of this study is its cross sectional design, which limits us from deducing causality. Although the observed associations between PA and mental health indicators could reflect the beneficial effects of greater amounts of PA, they could also reflect that patients with more severe depressive symptoms or who require more treatment for depression and anxiety are less likely to be physically active. For example depression or

anxiety may cause people to be more socially isolated and less motivated to engage in PA. In addition, while validated surveys allowed for assessment of mental health functioning and depressive symptoms, this study lacked clinical diagnosis of depression or anxiety. Recent treatment for depression or anxiety was used as a proxy for having depression or anxiety, although severity of symptoms does not necessarily dictate whether treatment is sought by patients, offered by health professionals or accepted by patients, and may be representative of better access to mental health care or increased effort to prepare for bariatric surgery. Finally, it is possible that counseling for depression or anxiety (reported by 46.5% of those who received treatment) included advice to increase PA. However, such advice would presumably decrease the strength of the associations found in this study.

Conclusion

This study revealed an inverse association between rather modest levels of PA and depressive symptoms and recent treatment for depression or anxiety, in a large cohort of adults with class 2 and 3 obesity undergoing bariatric surgery at one of 10 hospitals throughout the U.S. Although causality cannot be established, our findings are encouraging and should leverage further investigation of the role of PA in prevention and treatment of depression and anxiety in adults with class 2 and 3 obesity, as PA may prove to be a comparatively safe and cost-effective treatment option. Future research investigating the clinical effects of PA in this population should investigate the optimal type, intensity, frequency and duration of PA. In particular, it would be worthwhile to determine whether increasing the PA level of bariatric surgery candidates from sedentary to low active (e.g., meeting the thresholds of PA identified in this study) has an impact on symptoms of depression or anxiety, or whether, as has been found in some other populations, a higher dose of PA is required. Future research should also evaluate both short and long-term changes in symptoms, as well as changes in weight loss and quality of life following bariatric surgery.

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Role of the Sponsor

NIDDK scientists contributed to the design and conduct of the study, which included collection, and management of data. The Project Scientist from NIDDK served as a member of the Steering Committee, along with the Principal Investigator from each clinical site and the Data Coordinating Center (DCC). The DCC housed all data during the study and performed data analyses according to a pre-specified plan developed by the DCC biostatistician and approved by the steering committee and independent Data Safety Monitoring Board. This report was written without input from the sponsor. The decision to publish was made by the LABS steering committee, with no restrictions imposed by the sponsor.

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Figure.
Recruitment and Data Collection in the Longitudinal Assessment of Bariatric Surgery-2 (LABS-2) Study.

Table I

Characteristics of Study Participants (n=850).

	n=850 ^a
Sex	
Male	177 (20.8)
Female	673 (79.2)
Age, years, median (IQR) [range]	45 (36-53) [18-78]
Race	
White	749 (88.6)
Black	66 (7.8)
Other	30 (3.6)
Ethnicity	
Hispanic	49 (5.8)
Non-Hispanic	801 (94.2)
Marital status	
Married/regular partnership	546 (64.5)
Single	142 (16.8)
Divorced/Separated	145 (17.1)
Widowed	14 (1.7)
Education	
High school	177 (20.9)
Some college	341 (40.3)
College degree	329 (38.8)
Employment status	
Employed	628 (74.1)
Unemployed	35 (4.1)
Homemaker	43 (5.1)
Retired	37 (4.4)
Disabled	96 (11.3)
Other	9 (1.1)
Household income	
< \$25,000	116 (14.0)
\$25,000-\$49,000	224 (27.0)
\$50,000-\$74,999	211 (25.5)
\$75,000-\$99,999	140 (16.9)
\$100,000	138 (16.7)
Smoking	
Never	481 (56.7)
Former	255 (30.0)
Current/recent	113 (13.3)
Alcohol use disorder symptoms	60(7.1)
Recreational drug use	33(3.9)

n=850 ^d	
Body mass index, ^b median (IQR) [range]	45.8 (42.0-51.3) [33.7-81.0]
Waist circumference, cm, median (IQR) [range]	130.0 (120.2-141.1) [94.9-194.4]
Number of chronic medical conditions ^c , %	
0	41 (5.1)
1	110 (13.6)
2	160 (19.8)
3	145 (18.0)
4	108 (13.4)
5	113 (14.0)
6	130 (16.1)
Walking aid use	100 (12.0)
Select SF-36 physical scores, median (IQR) [range]	
Bodily pain	39.6 (35.4-48.5) [18.0-60.4]
Physical functioning	37.1 (28.4-45.8) [13.1-56.8]
Role-physical	40.8 (33.4-55.6) [26.0-55.6]
Physical activity, median (IQR) [range]	
Steps/day	7321.0 (5563.0-9460.0) [1443.5-21618.0]
Active minutes/day	304.5 (245.4-374.7) [73.8-591.2]
High-cadence minutes/day	9.3 (4.7-16.3) [0.0-132.0]
SF-36 Mental Composite Summary score, median (IQR) [range]	51.6 (42.6-57.2) [17.7-71.0]
Poor Mental Health Functioning (< 40)	167 (19.7)
Beck Depression Inventory score, median (IQR) [range]	6 (3-11) [0-37]
Depressive symptoms	
Minimal (0-9)	580 (68.2)
Mild (10-18)	207 (24.4)
Moderate (19-29)	56 (6.6)
Severe (30-63)	7 (0.9)
Recent treatment for depression or anxiety ^d	333 (39.2)
Medication	302 (91.2)
Counseling	154 (46.5)
Hospitalization	8 (2.4)

Abbreviations: BMI, body mass index, cm, centimeters, SF-36, Medical Outcomes Study 36-item Short Form.

^aValues are expressed as No. (%) unless otherwise indicated. The number of participants across categories may not sum to the total number of participants because of missing data.

^bCalculated as weight in kilograms divided by height in meters squared.

^cThe following chronic medical conditions were considered: hypertension, history of stroke, ischemic heart disease, congestive heart failure, hyperlipidemia, diabetes, sleep apnea, pulmonary hypertension, asthma, abnormal renal function, venous edema with ulcerations and urinary incontinence.

^dCounseling or hospitalization in past year or current use of antidepressant or anxiolytic medication for "psychiatric or emotional problems."

Table 2

Odds Ratios of Mental Health Indicators for Each Unit Decrease in Physical Activity Parameters.

	Unadjusted odds ratio (95% CI)	C Statistic	Adjusted odds ratio (95% CI)	C Statistic
Depressive Symptoms ^a				
Mean active minutes (100/day)	1.18 (1.01, 1.38)	.55	1.06 (0.89-1.27) ^c	.77
Mean steps (1000/day)	1.08 (1.02, 1.13)	.56	1.03 (0.97-1.09) ^c	.77
Mean high cadence minutes (10/day)	1.22 (1.05, 1.41)	.58	1.04 (0.89-1.22) ^c	.77
Treatment^b for depression or anxiety				
Mean active minutes (100/day)	1.13 (0.98, 1.31)	.53	1.08 (0.91-1.29) ^d	.71
Mean steps (1000/day)	1.06 (1.01, 1.11)	.55	1.06 (1.00-1.12) ^d	.72
Mean high cadence minutes (10/day)	1.31 (1.14, 1.51)	.59		.72
Physical role limitations SF-36 score=40	-		1.30 (1.10-1.55) ^{d,e}	
Physical role limitations SF-36 score=50	-		1.56 (1.25-1.96) ^{d,e}	
Physical role limitations SF-36 score=60	-		1.87 (1.34-2.62) ^{d,e}	

Abbreviations: CI, confidence interval, SF-36, Medical Outcomes Study 36-item Short Form.

^aBeck Depression Inventory score - 10.^bCounseling or hospitalization in past year or current use of antidepressant or anxiolytic medication for "psychiatric or emotional problems."^cAdjusted for sex, age, income, antidepressant or anxiolytic medication use, and bodily pain and physical role limitations problems SF-36 scores.^dAdjusted for sex, race, education, employment status, recreational drug use, waist circumference, and bodily pain and physical role limitations SF-36 scores.^eThere was a significant interaction between high cadence minutes and the physical role limitations SF-36 score, such that the magnitude of the association between high cadence minutes and treatment for depression and anxiety was greater among those with fewer limitations.

Table 3

Associations Between Not Meeting Physical Activity Thresholds and Mental Health Indicators Presented with Logistic Regression Derived Odds Ratios (ORs) and 95% Confidence Intervals.

	Proportion not meeting PA threshold	Unadjusted odds ratio (95% CI)	C statistic	Adjusted odds ratio (95% CI)	C statistic
Depressive Symptoms ^a					
Mean active minutes (<287/day)	43.3%	1.52 (1.14-2.04)	.55	1.27 (0.90-1.78) ^c	.77
Mean steps (<5740/day)	27.4%	1.65 (1.20-2.27)	.55	1.19 (0.82-1.73) ^d	.77
Mean high cadence minutes (<4.7/day)	24.7%	1.87 (1.21-2.26)	.56	1.15 (0.78-1.70) ^d	.77
Treatment^b for depression or anxiety					
Mean active minutes (<191/day)	9.8%	2.32 (1.47-3.67)	.54	2.25 (1.31-3.86) ^e	.72
Mean steps (<4750/day)	16.8%	1.79 (1.25-2.57)	.54	1.81 (1.17-2.82) ^e	.72
Mean high cadence minutes (<8.1/day)	44.7%	1.94 (1.47-2.57)	.58	1.92 (1.38-2.67) ^e	.73

Abbreviations: CI, confidence interval, PA, physical activity, SF-36, Medical Outcomes Study 36-item Short Form.

^a Beck Depression Inventory score - 10.

^b Counseling or hospitalization in past year or current use of antidepressant or anxiolytic medication for "psychiatric or emotional problems."

^c Adjusted for sex, income, antidepressant medication or anxiolytic use, and bodily pain and physical role limitations SF-36 scores.

^d Adjusted for sex, age, income, antidepressant medication or anxiolytic use, and bodily pain and physical role limitations SF-36 scores, and an interaction between age and the physical role limitations SF-36 score.

^e Adjusted for sex, race, education, employment status, recreational drug use, waist circumference, and bodily pain and physical role limitations SF-36 scores.