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Influence of Exercise Intensity for Improving Depressed Mood in Depression: A Dose-Response Study

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Introduction: Exercise effectively improves mood in major depressive disorder (MDD), but the optimal exercise stimulus to improve depressed mood is unknown.

Purpose: To determine the dose–response relationship of acute exercise intensity with depressed mood responses to exercise in MDD. We hypothesized that the acute response to exercise would differ between light, moderate, and hard intensity exercise with higher intensities yielding more beneficial responses.

Methods: Once weekly, 24 women (age: 38.6 ± 14.0) diagnosed with MDD underwent a 30-minute session at one of three steady-state exercise intensities (light, moderate, hard; rating of perceived exertion 11, 13 or 15) or quiet rest on a stationary bicycle. Depressed mood was evaluated with the Profile of Mood States before, 10 and 30 minutes post-exercise.

Results: Exercise reduced depressed mood 10 and 30 minutes following exercise, but this effect was not influenced by exercise intensity. Participants not currently taking antidepressants (n = 10) had higher baseline depression scores, but did not demonstrate a different antidepressant response to exercise compared to those taking antidepressants.

Conclusions: To acutely improve depressed mood, exercise of any intensity significantly improved feelings of depression with no differential effect following light, moderate, or hard exercise. Pharmacological antidepressant usage did not limit the mood-enhancing effect of acute exercise. Acute exercise should be used as a symptom management tool to improve mood in depression, with even light exercise an effective recommendation. These results need to be replicated and extended to other components of exercise prescription (e.g., duration, frequency, mode) to optimize exercise guidelines for improving depression.

Keywords: depression; exercise; antidepressant response; exercise optimization; symptom management

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By 2030, depression will be one of the three most burdensome diseases worldwide (Mathers & Loncar, 2006). In 2003, it was estimated that depression accounted for $44 billion in lost productivity in the United States alone (Stewart, Ricci, Chee, Hahn, & Morganstein, 2003). Unfortunately, current pharmacological antidepressant approaches are minimally effective with only approximately 30% of patients responding to initial treatment (Trivedi et al., 2006). Given the high level of disease burden, cost to society, and disappointing treatment effectiveness, it is imperative that research focuses on alternative therapies and on improving treatment efficacy.

An alternative to traditionally prescribed pharmacotherapies is exercise. Indeed, the National Institute for Health and Care Excellence in the U.K. recommends exercise therapy for mild depression (NICE, 2009). Chronic exercise training has been shown to be no different than common antidepressant treatments in reducing levels of mild to moderate depression (Barbour, Edenfield, & Blumenthal, 2007; Cooney et al., 2013; Lawlor & Hopker, 2001). However, the optimal dose of exercise is currently unknown. The majority of exercise research designed to improve depression has employed exercise prescriptions based on the American College of Sports Medicine's (ACSM) guidelines to promote and maintain health (Haskell et al., 2007). An elegant example examining the effect of these guidelines to reduce depression was performed by Dunn and colleagues (Dunn, Trivedi, Kampert, Clark, & Chambliss, 2005), who found that an exercise dose consistent with ACSM's guidelines reduced depression more than an exercise dose of roughly half of the guidelines. This research indicated a potential dose–response relationship between the amount of exercise and the reduction in depression. However, as these prescriptions are intended to improve general health, their application may not yield optimal improvements in psychological health.

Accordingly, there have been recent calls for systematic evaluations of the parameters of exercise prescription for patients with major depressive disorder (MDD; Perraton, Kumar, & Machotka, 2010; Rethorst & Trivedi, 2013; Stanton & Reaburn, 2014) to improve efficacy of exercise treatment. To this end, acute exercise studies could be employed to minimize participant burden and cost while allowing for detailed analyses of the moderating effects of specific parameters of exercise (e.g., intensity). Although acute studies cannot definitively determine the optimal parameters for exercise training programs to improve depression, they can probe the exercise-depression relationship and yield relevant information to aid in the design and implementation of training programs. In addition, determining acute exercise-mood relationships will enhance depressed patients' abilities to use acute exercise as a symptom management tool.

We are aware of only one study specifically designed to determine the dose–response relationship of acute exercise intensity on mood in depression. In a published abstract, Nelson and Morgan (1994) tested three intensities of acute exercise on depressed mood (assessed via the Profile of Mood States; POMS) in six women with elevated levels of depression and six healthy controls. The participants were randomly assigned to 40%, 60%, or 80% of their estimated maximal heart rate and cycled for 30 minutes with each participant completing the three intensities on separate days. There was no significant effect of intensity on mood either immediately post-exercise or 15–20 minutes post-exercise, although they found a Time × Group interaction demonstrating that the depressed group had a greater antidepressant response to exercise than the nondepressed group. However, due to the limited sample size and the lack of clinically diagnosed depression, no firm conclusions can be made regarding the intensity-affect relationship in depression from this investigation.

At present, there is mixed evidence for the presence and directionality of the relationship between exercise intensity and improvements in mood. Research that systematically evaluates the influence of exercise intensity and includes a sufficient sample of participants who meet diagnostic criteria for depression is necessary to further elucidate the exercise-depression relationship and begin to optimize exercise stimuli for improving depression in both the short and long term. Therefore, the purpose of this study was to determine if the intensity of exercise influences the acute effect of exercise on depressed mood in a sample of women diagnosed with MDD. According to the plausibility of a dose–response relationship between intensity and mood, we hypothesized that depressed mood following acute exercise would differ between light, moderate, and hard intensity exercise in depressed patients, with higher intensities yielding more beneficial mood changes.

Material and Methods

PARTICIPANTS

Twenty-four participants completed the study and were included for analysis; participant characteristics and baseline physical activity variables are presented in Table 1. Participants were recruited via newspaper advertisements in a local newspaper, a mass email to the campus community, and flyers

Table 1
Sample Characteristics

Sample measure	Whole sample (n = 24)	Not taking antidepressants (n = 10)	Taking antidepressants (n = 14)
Age (years)	38.6 (14.0)	37.3 (14.0)	39.5 (14.4)
BMI (kg/m^2)	29.7 (8.0)	31.6 (9.2)	28.3 (7.0)
EBBS Total	125.2 (13.4)	122.8 (15.9)	126.9 (11.6)
Benefits	85.7 (9.8)	85.6 (11.3)	85.8 (9.1)
Barriers	31.1 (6.7)	34.2 (7.6) [a]	28.9 (5.1)
IPAQ Sitting (min/day)	574.4 (205.1)	512.2 (196.8) [a]	618.7 (200.7)
IPAQ Vigorous (min/day)	8.7 (22.1)	6.9 (14.3)	10.1 (26.3)
IPAQ Moderate (min/day)	68.4 (70.8)	66.4 (54.4)	69.8 (80.8)
IPAQ MVPA (min/day)	77.1 (82.9)	73.3 (59.0)	79.8 (96.8)

Values are mean ± (standard deviation). n = 120 for IPAQ data reported as an average of each of the five visits, 50 total for those not taking antidepressants and 70 total for those taking antidepressants.
BMI = body mass index, EBBS = exercise benefits and barriers scale, IPAQ = international physical activity questionnaire, MVPA = moderate-to-vigorous physical activity, kg/m2 = kilograms per meter squared.
[a] indicates significant difference at $\alpha = .05$ between those taking antidepressants and those who were not.

posted across the University of Wisconsin–Madison campus and immediate surrounding areas that advertised a study looking at the effect of exercise in depression. Interested potential participants underwent a short phone screener to assess initial eligibility. Those who appeared to be eligible following the phone screening were invited for the first day of testing. Participants were (a) female, (b) aged 20–60, (c) diagnosed with MDD, (d) healthy enough to exercise, and (e) on a stable psychiatric treatment regimen (medications or psychotherapy) for the 8 weeks preceding their initial visit. We included participants who were currently on stable doses of antidepressant medications or other therapy as long as they did not change these during the course of the study and as long as they met criteria for current MDD. Because women are diagnosed with depression at much higher rates than men (Bromet et al., 2011), we chose to only include women for this initial investigation. Participants were excluded if they were pregnant, current smokers, diagnosed with concomitant psychological disorders other than generalized anxiety disorder or MDD, currently taking opioid or analgesic medications, or currently abusing alcohol or other drugs. Participants were compensated a total of $100 for completion of all study visits.

PROCEDURES

Participants were tested on 4 separate days, each separated by at least 1 week. Upon arriving for the initial day of testing, participants provided written informed consent and were assessed for major depression and other psychiatric comorbidities via a structured clinical interview. Next, baseline questionnaires measuring mood, depression, anxiety level, perceptions and barriers to exercise, and self-reported physical activity were completed. Participants then completed one of the four experimental conditions. Each session included 30 minutes of exercise at one of three prescribed exercise intensities or a 30-minute quiet rest condition on a cycle ergometer. Experimental sessions were randomly assigned and counterbalanced for order. Immediately following each experimental condition, participants provided visual analog scale ratings (VAS) for depressed mood. The questionnaire battery was completed both 10 and 30 minutes (10 min, 30 min) post-exercise. Blood was drawn before and within 10 minutes of the end of each session (data not reported here). Participants were in the exercise room by themselves during the 30 minutes following exercise. The first session lasted approximately 3 hours, with each subsequent session lasting 2 hours. All procedures were approved by the local Institutional Review Board and informed consent was obtained from each participant.

Experimental and Control Conditions

There were four experimental conditions: a control condition and three exercise conditions. A quiet rest condition, identical to the exercise condition except for exercise, served as a control matching for time, instrumentation, and interpersonal interactions. Both exercise and quiet rest were performed while seated on the bicycle. For the exercise conditions, three different intensities of exercise were prescribed to the participant. Intensity was standardized across participants by having each individual exercise at a work rate perceived as light, moderate, or hard based on perceived exertion ratings of "11," "13," and "15," respectively (see below; *Perceived Exertion*). Participants were instructed to maintain 60–70 rpm and adjust the resistance to maintain the specified intensity for the session. Over the 5-minute warm-up, participants increased their exertion to achieve the session's intensity at the end of the warm-up period. Participants then maintained that intensity throughout the 20-minute steady-state session and ended with a 5-minute cool-down. Intensity adjustments were measured and intensity maintenance confirmed by an investigator who was present at each session.

Exercise Equipment and Physiological Measurement

Exercise and quiet rest were performed on an electronically braked cycle ergometer (Lode Corival, Lode BV, Groningen, The Netherlands). Seat height and handlebar placement were adjusted for the participant prior to the first bout and maintained for each subsequent session. During exercise, measurements of ventilation (Ve), oxygen consumption (VO_2), carbon dioxide production (VCO_2) and work rate (in Watts; W) were obtained continuously and analyzed with 15-second averaging using a metabolic cart (TrueOne, ParvoMedics, Sandy, Utah) and two-way nonrebreathing valve (Hans-Rudolph, Kansas City, MO). Respiratory exchange ratio (RER) was calculated as the ratio of VCO_2 to VO_2. The flow meter was calibrated prior to each exercise bout by making multiple comparisons to a calibrated 3-l piston syringe. Gas measurements were calibrated by presentation of gases with known concentrations of oxygen, carbon dioxide and nitrogen. Heart rate (Polar, Lake Success, NY) was also recorded throughout the exercise test and during recovery.

Perceived Exertion

Borg's 6–20 rating of perceived exertion (RPE; [Borg, 1962]) scale was used to both prescribe exercise intensity for each session and to assess exertion during exercise. Using perceived exertion to standardize exercise intensity has been shown to be reliable and valid across many different populations (Glass, Knowlton, & Becque, 1992) and similar to heart rate for predicting aerobic capacity (Faulkner, Parfitt, & Eston, 2007). We chose RPE to manipulate exercise intensity for several reasons. First, RPE is easy and efficient to prescribe simplifying translation to the practitioner. Second, to accurately prescribe relative exercise intensity based on aerobic capacity (e.g., 50% of peak oxygen consumption), a maximal exercise test is necessary, a procedure which would require an extra day of strenuous testing and would limit translation of this research to clinical settings. Since RPE is based on an individual's perception, it is inherently relative (Borg, 1962), which allowed participants to work at what they individually perceived as the session's prescribed intensity. Workload was adjusted by the participant as necessary to maintain the prescribed intensity, and perceived exertion was assessed at 5-minute intervals. The RPE scale remained in front of the participant to allow them to easily check their current perceived exertion and adjust the workload whenever necessary throughout the 20 minutes of steady-state exercise.

Questionnaires

At multiple points throughout the study, participants completed sets of questionnaires.

To assess current depressive symptoms, participants filled out the 21-question Beck Depression Inventory–II (BDI), which is a validated measure of assessing depression symptoms in both psychiatric patients and healthy populations, has good reliability (Cronbach's α = .91) and is similar to the BDI-I (Beck, Steer, Ball, & Ranieri, 1996). Scores range from 0 to 63 with 14–19 being considered mild depression, 20–28 moderate, and 29+ severe.

To assess current mood state, in particular current depressed mood, participants filled out the 65-item Profile of Mood States (POMS)—a frequently used and validated scale to assess mood states within a wide range of populations (McNair, Lorr, & Droppleman, 1992; Reddon, Marceau, & Holden, 1985). Adult female norms for this questionnaire are tension—8.2, depression—8.5, anger—8.0, vigor—18.9, fatigue—8.7, confusion—5.8, and total mood disturbance—120.3 (Nyenhuis, Yamamoto, Luchetta, Terrien, & Parmentier, 1999).

The International Physical Activity Questionnaire (IPAQ), a validated 7-day recall measure of physical activity participation in the last week (Craig et al., 2003), was used to measure self-reported physical activity behavior in the last week. This questionnaire measures work, transportation, home-based and leisure-time physical activity as well as sitting time and was completed with one of the study staff.

To measure current state anxiety, participants filled out the State–Trait Anxiety Inventory (STAI; state version only, 20 questions). This is a validated measure to assess state levels of anxiety (Julian, 2011; Spielberger, 1983). The female adult norm for the trait version of this inventory is 36.9 (range 20–80).

The 43-item Exercise Benefits and Barriers Scale (EBBS; Sechrist, Walker, & Pender, 1987) was employed to measure participants' views of exercise and its barriers. The benefits scale range is 29–116 with a norm of 87 and the barriers scale ranges 14–56 with a norm of 41.

In addition to the above questionnaires, participants also were administered the Mini International Neuropsychiatric Interview 6.0.0 (MINI), a mental health interview designed to diagnose DSM-IV mood disorders (Sheehan et al., 1998). Along with a preexisting diagnosis of major depressive disorder and a score of at least 11 on the BDI at the first visit, meeting current criteria for major depressive disorder on the MINI was required for inclusion in the study. A score of zero on the Physical Activity Readiness Questionnaire, indicative that repeated bouts of submaximal exercise would be safe to undertake, was also required for participation.

Participants completed the MINI and EBBS pre-session on the first day only. For each session, participants filled out the BDI, IPAQ, POMS and STAI pre-exercise and the POMS and STAI again at 10 and 30 min post-exercise. Ratings on VASs for exercise and anxiety were also taken at each of the these measurement points (pre, 10 min and 30 min post) as well as immediately prior to the post-exercise blood draw to determine whether the blood draw may have influenced mood responses post-exercise. The primary dependent variable for assessing the acute effect of exercise on depressed mood was the depression score from the POMS.

DATA ANALYSIS

Pre-exercise values for mood were analyzed with one-way analysis of variance (ANOVA) to assess baseline differences across the sessions and across the visits. Averages across the 20-minute steady-state exercise session for heart rate, RPE, work, RER, VO_2 and ventilation were compared across the four sessions via one-way ANOVA.

For all statistical tests and each family-wise set of comparisons, the level of significance (α) was set to 0.05. All analyses were conducted with SPSS version 22.0. Cohen's *d* (Cohen, 1969) was used to demonstrate effect sizes. Data are reported as means and standard deviations or standard errors where appropriate.

Primary Analysis

The primary outcome was depressed mood as measured by the POMS depression score. The primary hypothesis to be tested was that POMS depression scores following exercise would be significantly different between the three intensities. Data were analyzed using a session (quiet rest, light, moderate, hard) by measurement (pre, 10 min, 30 min) repeated-measures ANOVA. Following a significant interaction, simple effects of session at each measurement were calculated.

Planned Comparisons

To analyze the primary hypothesis, pairwise comparisons were performed at 10 min and 30 min post-exercise among the three intensities in the simple effects analysis using Fisher's LSD to control for multiple comparisons. To assess the presence of an improvement in depressed mood due to exercise above the control session (quiet rest), pairwise comparisons for the simple effects of quiet rest were compared to each exercise session at each measurement. Comparisons were assessed with family-wise α at each measurement for the three comparisons (quiet rest vs. light, moderate and hard) with Holm corrections for multiple comparisons (Holm, 1979).

Antidepressant Usage

Due to the relatively even split in participants based on antidepressant use (10 not taking vs. 14 taking 1 or more antidepressants), secondary subgroup analyses were performed. To assess differences in baseline depression in participants who were taking antidepressant medications, an independent samples *t*-test comparing BDI scores at baseline was performed. To evaluate the influence of antidepressant usage on the effect of exercise, a repeated-measures measurement (pre, 10 min, 30 min) by group (no antidepressants vs. one or more antidepressants) ANOVA was performed on an average of the POMS depression scores across the three exercise sessions.

Results

Fourteen participants were currently taking a selective serotonin reuptake inhibitor or serotonin antagonist/inhibitor (SSRI or SARI), three participants were also taking an additional antidepressant medication and three were taking an anxiety medication. None of the participants changed their medication over the course of the study. Ten participants were not taking any antidepressant medications. There was a single participant who had an external event that significantly impacted her mood between 10 min and 30 min after her light intensity session that was unrelated to the study; her 10 min mood ratings were carried forward to the 30 min measurement for that session. Two participants did not report VAS ratings for their first visit. There was no significant impact of the blood draws on the VAS ratings (VAS 10 min – immediately post; $p > 0.05$).

Participant characteristics are presented in Table 1. The average age of participants was 38.6 ± 14.0 years, and their body mass index was 29.67 ± 8.0 kg/m^2. Average EBBS scores for benefits (85.7) were similar to published median scores for adults (87) as were barriers (31.1 vs. 41) and total (125.2 vs. 129; Sechrist et al., 1987). Participants taking antidepressants self-reported significantly more barriers to exercise, but also reported significantly fewer minutes sitting each day ($p < .05$).

BASELINE MOOD AND EFFECT OF VISIT

Baseline ratings of depression on the initial visit were in the mild to severe range (26.3 ± 8.2, range

Table 2
Baseline Mood Ratings by Visit and Exercise Session

Visit	N	Beck Depression Inventory [a]	POMS Depression [a]	POMS Confusion	POMS Total Mood Disturbance	State–Trait Anxiety Inventory	Anxiety Visual Analog Scale	Depression Visual Analog Scale
First	21	26.3 (8.2)	20.2 (12.8)	10.2 (5.2)	155.6 (33.8)	48.2 (8.6)	40.2 (24.7) #	40.3 (24.7) #
Second	21	20.2 (8.2)	14.4 (8.9)	9.1 (3.9)	141.0 (22.2)	48.6 (8.4)	41.4 (22.9)	41.4 (22.9)
Third	18	22.6 (7.8)	12.7 (8.6)	8.6 (3.3)	136.9 (21.8)	47.6 (8.3)	38.4 (23.7)	38.4 (23.7)
Fourth	19	21.1 (7.20	9.8 (8.1)	7.8 (4.2)	131.7 (25.8)	46.0 (8.0)	37.6 (23.1)	37.6 (23.1)
Fifth	17	20.4 (10.0)	11.1 (12.6)	7.7 (4.5)	135.2 (36.3)	46.8 (8.6)	37.5 (30.9)	37.5 (30.9)

Exercise Session	Beck Depression Inventory	POMS Depression [range]	POMS Confusion	POMS Total Mood Disturbance	State–Trait Anxiety Inventory	Anxiety Visual Analog Scale	Depression Visual Analog Scale
Quiet Rest	22.4 (8.4)	15.5 (12.2) [0–49]	9.8 (4.9)	146.8 (32.8)	48.9 (7.1)	38.8 (20.5)	44.0 (25.3)
Light	20.2 (7.2)	13.4 (8.7) [2–30]	8.8 (3.5)	139.0 (21.0)	46.8 (7.8)	36.1 (29.2)	48.2 (24.3)
Moderate	22.6 (9.1)	14.5 (12.0) [0–44]	7.9 (3.8)	138.7 (29.3)	48.2 (9.8)	41.1 (24.5)	47.2 (22.8)
Hard	21.1 (9.6)	12.0 (10.5) [1–45]	8.6 (4.9)	137.9 (32.9)	46.1 (8.4)	40.5 (26.0)	40.8 (27.2)

Values are mean (standard deviation).
[a] indicates $p > .05$ for one-way ANOVA across visit.
[#] indicates N = 19 due to missing data. For each exercise session, N = 24.

11–40 on visit 1). There was a significant effect of visit on BDI score indicating that participants were experiencing worse depressive symptoms in the 2 weeks preceding the initial visit than in the subsequent visits ($p = .045$; Table 2). There was also a significant effect of visit on baseline POMS Depression score indicating higher scores at baseline on the first visit, although there was no significant effect of exercise session (intensity) on baseline score (Table 2). There were no significant differences at baseline for any of the exercise sessions on initial mood ratings ($p > .05$), indicating that the randomization and counterbalancing distributed the effect of the first visit across exercise intensity and quiet rest conditions.

RESPONSES TO EXERCISE SESSIONS

Consistent with the intended design of the study, participants exercised at significantly different intensities across conditions (all $p < .05$; Table 3). There was a clear effect of exercise intensity for RPE, workload, heart rate, and RER.

DOSE RESPONSE

Due to the violation of the assumption of sphericity for measurement (Mauchly's W = .159, $p < .001$) and the Session × Measurement interaction (Mauchly's W = .008, $p < .001$), depression scores were analyzed using a multivariate, repeated-measures ANOVA. There was a significant Session × Measurement interaction, Wilks'

Table 3
Averages for Exercise Variables Across Exercise Sessions

Exercise Session	Work (Watts)	RPE	Heart Rate (bpm)	Respiratory Exchange Ratio	Ventilation (L/min)	VO_2 (L/min)
Quiet Rest	0 (0)	6.2 (0.5)	82.9 (11.1)	0.86 (.05)	9.9 (2.1)	0.26 (0.06)
Light	45.6 (23.8)	10.9 (0.3)	113.8 (20.8)	0.93 (.04)	26.6 (7.5)	0.85 (0.29)
Moderate	72.8 (32.9)	13.2 (0.5)	130.8 (22.1)	0.96 (.05)	32.7 (8.2)	1.06 (0.31)
Hard	93.0 (34.3)	15.1 (0.2)	149.4 (22.9)	1.00 (.04)	44.0 (16.8)	1.30 (0.35)

Values are mean (standard deviation).
For each one-way ANOVA performed on each exercise variable across sessions, all $p < .05$.
Due to metabolic cart malfunctions, average ventilation, $V0_2$ and respiratory exchange ratio data are from 22 (quiet rest), 20, (light and moderate) and 23 (hard) participants.
bpm = beats per minute; L/min = liters per minute.

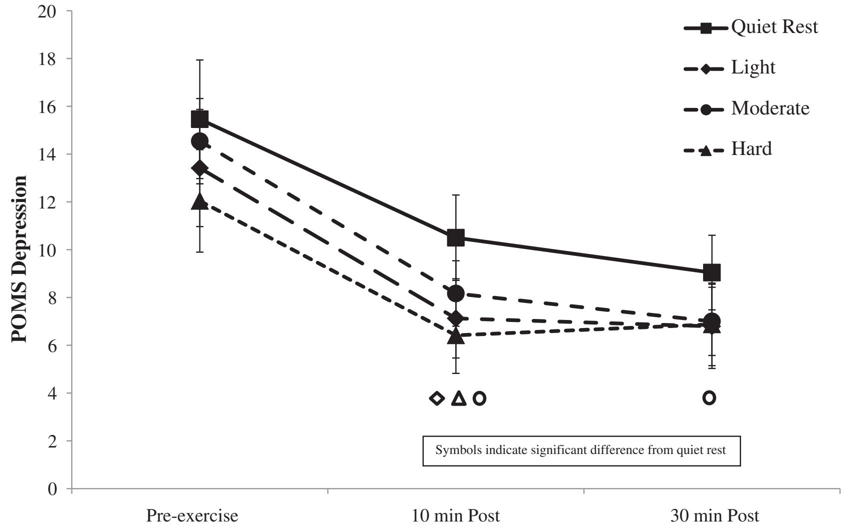

FIGURE 1 POMS Depression ratings across measurements and exercise intensities. Values are mean ± standard error of the mean. DM ratings changed significantly over measurement points indicating an improvement in mood following the sessions. Pre-session, no significant differences existed among all four sessions. At 10 minutes post-session, each exercise session was significantly different from quiet rest after controlling for multiple comparisons ($p < .05$). No significant differences existed among light, moderate, and hard exercise sessions at 10 min post-session. At 30 minutes post-session, only the moderate session was significantly different from quiet rest after controlling for multiple comparisons ($p < .05$). No significant differences existed among light, moderate, and hard exercise sessions at 30 min post-session.

$\lambda = .501$, $F(6, 18) = 2.98$, $p = .033$ (Figure 1), indicating that the depression scores across measurements were differentially affected by session.

Pre- and post-exercise (10m and 30m) POMS depression ratings are listed in Table 4 and illustrated in Figure 1. The three planned contrasts comparing light to moderate, light to hard, and moderate to hard at each measurement were not significant ($p > 0.05$), indicating no significant effect of exercise intensity on depressed mood at either 10 min or 30 min post-exercise.

COMPARISON TO QUIET REST

Following a simple effects analysis to compare sessions at each measurement point, POMS depression scores were significantly lower for light intensity exercise (quiet rest minus light difference: 3.4, $p = .012$), moderate intensity exercise (difference: 2.3, $p = .021$), and hard intensity exercise (difference: 4.1, $p = .016$) than scores following quiet rest at 10 min post-exercise (Table 4 and Figure 1). At 30 min, only the difference between quiet rest and moderate intensity exercise remained

Table 4
Mean POMS Depression Across Measurements and by Session

Exercise session	Pre-session				10 min post-session				30 min post-session			
	Mean (SD)	Diff from quiet rest Mean (SE)	Diff p-value	Diff ES	Mean (SD)	Diff from quiet rest Mean (SE)	Diff p-value	Diff ES	Mean (SD)	Diff from quiet rest Mean (SE)	Diff p-value	Diff ES
Quiet Rest	15.4 (12.2)				10.5 (8.8)				9.0 (7.6)			
Light	13.4 (8.7)	2.04 (1.78)	.262	.20	7.1 (6.7)	3.38 (1.24) [a]	.012	$d = -.44$	6.8 (7.0)	2.25 (0.99)	.033	$d = -.22$
Moderate	14.5 (12.0)	0.92 (1.98)	.648	.08	8.2 (8.1)	2.33 (0.94) [a]	.021	$d = -.39$	7.0 (8.6)	2.04 (0.73) [a]	.010	$d = -.33$
Hard	12.0 (10.5)	3.40 (2.76)	.228	.30	6.4 (7.8)	4.10 (1.58) [a]	.016	$d = -.48$	6.9 (8.5)	2.17 (1.30)	.108	$d = -.12$

The comparison between light and quiet rest at 30 minutes post-session was not significant following the multiple comparison procedure. There were no significant differences among the light, moderate, and hard sessions at any of the measurement points. There were no significant differences among the exercise sessions at any time point.
Diff = difference; ES = effect size (Cohen's *d*); SD = standard deviation; SE = standard error.
[a] indicates significance at α of .05 for pair-wise comparison between quiet rest and the exercise session (after controlling type I error rate for multiple comparisons).

significant (difference: 2.0, $p = .010$). The light difference at 30 min was associated with a p-value of .033, but following the multiple comparison procedure was not statistically significant.

SECONDARY ANALYSES FOR ANTIDEPRESSANT STATUS

Average depression ratings as a function of antidepression status are presented in Table 5. Participants not taking antidepressants had moderately greater POMS depression ratings at each measurement ($d = .50, .47, .59$). Again, Mauchly's test of sphericity was significant, so the multivariate test was used. There was a significant effect of measurement, Wilks' $\lambda = .296$, $F(2, 21) = 24.95$, $p < .001$, but no Measurement × Group interaction, Wilks' $\lambda = .971$, $F(2, 21) = 0.31$, $p = .736$, indicating a significant overall decrease in depressed mood but no differential effect based on antidepressant usage.

Discussion

The primary results of this study demonstrate an acute improvement in depressed mood after exercise, but this effect was not influenced by exercise intensity (i.e., not dose dependent). When directly compared, light exercise was as effective as moderate exercise and both were as effective as hard exercise in reducing depressed mood at both 10 and 30 minutes following exercise. This study supports the conclusions from Nelson and Morgan's preliminary report (Nelson & Morgan, 1994) that found no effect of exercise intensity in six participants who had elevated depression levels. This research extends and strengthens those conclusions by replicating and extending results in a larger sample of women clinically diagnosed with major depressive disorder.

In this sample, there were 10 participants who were not taking antidepressant medications of any kind and 14 who were taking at least one antidepressant medication. The participants not currently taking antidepressants had higher baseline depression scores (BDI of 24.7 vs. 18.9), indicating that the participants who were not on medications were more severely depressed. However, the nonmedicated patients did not demonstrate a significantly different depressed mood response to exercise compared to those who were taking antidepressant medications (Table 5). This result suggests that, regardless of antidepressant status, depressed patients depressed mood improved following an acute bout of exercise.

Unsurprisingly, there was a large effect of measurement indicating that all sessions (including the quiet rest session) led to lower post-session depressed mood although the interaction demonstrated that post-session depressed mood was not the same for all sessions (Figure 1 and Table 4). At 10 min post-exercise, the quiet rest session was significantly different than each of the exercise sessions, although at 30 min there was no longer a significant difference between the quiet rest and the light or hard sessions. This is similar to published data demonstrating an effect of quiet rest and meditation on mood in both healthy people and those with MDD (Bahrke & Morgan, 1978; Bartholomew, Morrison, & Ciccolo, 2005). Despite instructions to simply rest quietly, some participants reported meditating or using the time to plan out their week, which could have resulted in improved mood. However, the significant interaction indicates that the effect of the exercise sessions were greater than that of the quiet rest session. The large variance in mood ratings at 30 min following hard intensity exercise suggests that, for some patients, high intensity exercise may not be as effective at improving mood, and this could explain why the mean was not significantly different from quiet rest. It is also possible that the harder exercise may have had a shorter effect than the other sessions (it was the only one to begin to rebound

Table 5
Effects of Antidepressant Usage on the DM Effect of Exercise

Antidepressant usage	Measurement	Average POMS depression across prescribed sessions	Effect size difference between antidepressant usage subgroups (Cohen's d)
None	Pre	16.8 (12.7)	.50
	10 min	9.9 (10.5)	.47
	30 min	9.7 (11.1)	.59
One or more	Pre	10.9 (10.7)	
	10 min	5.3 (8.9)	
	30 min	4.9 (9.4)	

Values are mean (standard deviation).
There was a significant effect of measurement ($p < .05$), no effect of group and no significant group by measurement interaction ($p > .05$).
DM = depressed mood; POMS = profile of mood states.

after the initial drop at 10 min). Although this study was not specifically designed to analyze the decay in the mood-enhancing effects of exercise, this may be a relevant consideration when prescribing exercise to patients.

Previous literature demonstrates that a greater dose of exercise can produce greater reductions in depressive symptoms over the course of an exercise training program (Dunn et al., 2005). Dunn and colleagues compared a dose consistent with ACSM's guidelines for healthy adults (Garber et al., 2011) to a dose slightly less than half as large (17.5 kcal/kg/wk. vs. 7.0 kcal/kg/wk) with a stretching group used as a control. They reported that the greater dose yielded better depression outcomes than either of the other groups. However, the exercise programs in this investigation were prescribed in terms of caloric expenditure and participants could accumulate their weekly prescribed energy expenditure through exercise bouts of various durations and intensities. This limits conclusions about the relative importance of either exercise intensity or exercise duration for the antidepressant effect of exercise. Because of differences in research design and the presence of confounding factors (e.g., simultaneous manipulation of more than one parameter of exercise), comparison across currently published trials is inherently difficult and potentially misleading. The significant costs and time associated with conducting a clinical trial decreases the feasibility of systematically manipulating a single parameter in this study design.

An alternative strategy is to evaluate select parameters of exercise prescription in an acute exercise setting. This approach allows for the determination of dose–response characteristics of exercise (e.g., exercise intensity) on psychological outcomes in a time- and cost-effective manner, and if found to be effective, could then be tested in chronic exercise training environments. By determining which parameters are the most influential for improving mood, exercise recommendations that are based on improving psychological health can be determined and implemented. From this study, it was demonstrated that depressed mood response to activity was not directly related to how intense the exercise was. Thus, other parameters of exercise, such as duration, may be more relevant to the salubrious response to exercise.

One potential explanation of the similarity in the depressed mood responses to the different intensities is that each session was prescribed to the participants. This resulted in each session having a defined goal to accomplish during the session (i.e., maintaining the prescribed intensity). Indeed, after their final session some participants reported that even the light intensity felt helpful because they were accomplishing the goal that was set for them before the session began. This is consistent with Morgan's discussion of goal accomplishment as a potential mechanism for the improvement in depressed mood following exercise (W. Morgan & Goldston, 1987; W. P. Morgan, Roberts, Brand, & Feinerman, 1970). Depressed patients do not always feel in control of their mood. Accomplishing a goal and thereby improving their mood may allow these patients to feel more in control of both their behavior and their depression. Other potential mechanisms whereby exercise can increase mood have been put forward (distraction, increased self-efficacy, increased brain-derived neurotrophic factor, norepinephrine, serotonin or dopamine), although no definitive psychological or biological explanations have been proven (Dishman et al., 2006; Eyre & Baune, 2012; Matta Mello Portugal et al., 2013; Wegner et al., 2014). Mechanistic research will benefit from a better understanding of the dose–response relationship between exercise and psychological health.

This study highlights an important difficulty in exercise research—the translation of acute to chronic exercise responses. The acute exercise setting allows for strict control of a number of different parameters and the ability to perform within-subjects designs, which permits detailed analysis of a specific manipulation (e.g., exercise intensity). Because examining multiple frequencies, intensities, or durations of exercise in an exercise training paradigm (a) involves large participant numbers and burden, (b) is extremely costly, and (c) comes with the inherent difficulties of adherence to training over time, information from systematically designed acute studies can provide preliminary data for larger intervention trials. Therefore, acute exercise research provides potentially relevant information to predict chronic adaptations but appreciation of the assumption of similarity is necessary.

This prompts one to consider the potential mechanisms through which these individual sessions could acutely affect mood. It is possible that some of the benefit of participating in this study was realized prior to the actual session, such that going to the appointment and being involved in the study provided some of the short-term mood benefit. This is consistent with the behavioral activation element of CBT, which appears to be a large component of the treatment effectiveness of CBT (Jacobson et al., 1996). The process of improving mood could have been initiated before the pre-session questionnaires were taken, leading to some very low baseline values (Table 2), and could have accounted for some of the effects seen post-session. This would have occurred in each of the sessions, potentially explaining some of the large effect of the quiet rest session with additional mood enhancement related to the exercise itself being realized following the actual exercise sessions (e.g., differences at 10 min post). The present study's quiet rest results and large day-to-day variability in depressed mood in a depressed population highlight the need to design future investigations that parse out improvements in mood related to nonexercise components of study participation to more selectively capture the effect of exercise participation.

The results of this study should be considered in light of its limitations. The entire sample was female, which limits generalizability. Although it is not expected that men would react differently, cross-sex conclusions cannot be drawn from this study. The benefit of the within-subjects design was that a low total number of participants were necessary, but it also led to a large amount of data being collected on a relatively small sample. There was a main effect of visit on baseline mood. On the first visit, the participants were more depressed on both their baseline BDI and POMS than they were on the other visits. This may have been due to the completion of the MINI immediately prior to the baseline questionnaires or to subject expectations about inclusion criteria. Randomization and counterbalancing helped to control for the first day mood effects, resulting in there being no significant differences in baseline mood across the four sessions. Finally, it is difficult to draw conclusions about how these mood results will relate to effects from exercise training programs as the translatability from short-term acute effects to chronic effects is not yet known.

Conclusions

This investigation found that the short-term effect of acute exercise on depressed mood was not intensity dependent. Similar post-session depressed mood ratings were found for single sessions of light, moderate, and hard intensity exercise, suggesting that even relatively mild physical activity could have useful therapeutic effects in depression. Pharmacological antidepressant medications did not limit this effect, demonstrating exercise's wide-reaching potential within the depressed population. Acute exercise should be used as a symptom management tool to improve mood in depression, with even light exercise as effective recommendation. Additional systematic evaluations are needed on other parameters of exercise (e.g., duration) to optimize exercise prescriptions for depression. These results should be applied to future exercise training trials to assess how acute mood responses relate to chronic exercise adaptations.

Conflict of Interest Statement

The authors declare that there are no conflicts of interest.

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