sciendo

Original Paper

Biomedical Human Kinetics, 17, 78–89, 2025

DOI: 10.2478/bhk-2025-0008

How acute aerobic exercise and social interactions influence mood and cognitive functioning in healthy adults: A pilot study

Douglas J. Oberlin[1], Jacob M. Eubank[1], Lalitha Samuel[2], Jane Ekhtman[3], Emmanuel Egwuonwu[1], Kristine Sabo[4], Ángela Veras[1], Andy Fernandez[1]

[1] City University of New York, Lehman College, Department of Exercise Sciences and Recreation; [2] City University of New York, Lehman College, Department of Health Promotion and Nutrition Sciences; [3] City University of New York, City College, Department of Psychology; [4] City University of New York, Hunter College, Department of Psychology

Abstract

Study aim: Aerobic exercise has many benefits including improvements in mood and cognition. Group exercise has been suggested to better improve mood compared to exercise alone, but there is no consensus and few studies attempting to understand exercise and social influences on mood and cognition. This study's purpose was to begin filling this gap by isolating socialization from exercise to determine how each affect mood and cognitive changes.
Materials and methods: Twenty-five adults (24.2 ± 1.69 years) performed four 30-minute sessions including either acute exercise or sedentary, and either social interaction or limited social interaction. Mood was assessed using a Profile of Mood States and a State-trait Anxiety Inventory Questionnaire. Cognitive assessments were performed using computerized Stroop and Eriksen Flanker tasks. Mood and cognition were assessed prior-to and following each session. Differences in mood and cognitive performance were analyzed for main effects of both exercise and social interactions in a two-by-two within subject design.
Results: Both exercise and social interactions influenced mood parameters, with fatigue being reduced by exercise and social interaction, total mood disturbance approaching significance for exercise, and hostility being reduced by socialization. Vigor approached significance for exercise and had a significant interaction with socialization. No cognitive improvements were observed, likely due to cognitive tasks lacking sufficient sensitivity for cognitively healthy young adults.
Conclusion: Both exercise and social interactions can improve mood parameters, and when performed together there may be an additive effect for some mood parameters. Additional studies are needed to elucidate these acute effects.

Keywords: Acute effect – Exercise – Mood – Socialization

Introduction

Exercise is known to be associated with several positive health benefits related to cardiovascular and metabolic health, such as reduced risk of cardiovascular diseases, type 2 diabetes mellitus, and some cancers (Rao et al., 2022; Ruegsegger & Booth, 2018). While these health-related benefits of exercise are well documented, the effects of exercise on mood and cognition have been less studied, and are not necessarily well known. As an example of mood effects of exercise, individuals who maintain higher levels of physical activity have reduced risks of developing depression (Harvey et al., 2018; Pearce et al., 2022). This reduced risk maybe important, as rates of depression have been increasing in the United States and globally (Goodwin et al., 2022; Moreno-Agostino et al., 2021). Exercise and physical activity are a widely available and affordable means of preventing and possibly treating some mood disorders (Hearing et al., 2016; Mikkelsen et al., 2017). Beyond mood disorders, a single exercise session may reduce levels of depression and anxiety and improve cognition among healthy individuals, with effects lasting several hours (Basso et al., 2015; Basso, 2017; Chase & Hutchinson, 2015; Ishihara et al., 2021). The mood and cognitive benefits of exercise have been observed from adolescents, to young healthy adults, and even among older adults (Basso, 2017; Eubank et al., 2022; Koch et al., 2020). Hence, regular participation in exercise is important for not only metabolic health, but also mental health (Chekroud et al., 2018; Mikkelsen et al., 2017).

Author's address Douglas J. Oberlin, 250 Bedford Park Boulevard West, APEX building Rm. 261, Bronx, New York, United States, 10468 douglas.oberlin@lehman.cuny.edu

Although many people are aware of health benefits from physical activity and exercise, most individuals in the United States and United Kingdom who regularly exercise reported working out alone rather than in groups, despite suggestions that mood and cognitive benefits from group exercise may be greater than exercising alone (Gray, 2021; Internicola, 2013; Yorks et al., 2017). Unfortunately, few studies have directly tested why group exercise may have different effects compared to non-group exercise. A study by Yorks et al. found that individuals who trained for 12-weeks in groups of four or more had greater improvements in quality of life (QOL) and reductions in stress, relative to those who exercised in groups of three or less (Yorks et al., 2017). This raises the question of what about the "group" is affecting these outcomes.

There are other aspects of daily living that may influence mood besides exercise, such as social interactions, which have also been proposed to improve cognitive functioning (Kuczynski et al., 2022; Ybarra et al., 2008). Social interactions occurring during exercise and fitness activities may also be influencing the outcomes of studies of exercise on mood and cognitive function. While studying the effects of exercise on mood and cognition, there can be substantial social interactions. Researchers must engage with the participants to guide them through the study procedures and it is common for social interactions to extend beyond instructional dialog. This may be incidental or to intentionally build rapport among participants in a research study. However, it is not well understood how social interactions experienced during routine exercise sessions, or during exercise research influence mood and cognitive outcomes. This leaves a blind spot in research efforts to understand the role of exercise in enhancing mood, as the social interactions may be acting as a confounding variable in study designs.

Therefore, the current study attempts to examine the effects of both acute socialization and/or acute exercise on mood and cognitive parameters to better understand the role of each in influencing mood and cognition. It was hypothesized that both socialization and exercise would lead to improvements in mood and cognition, and that the combination of the two, similar to group exercise, would yield the greatest improvements.

Materials and methods

To address the research question, participants were recruited for the study via fliers posted around New York City and the campuses of the City University of New York. Individuals who were interested in the study completed a screening questionnaire. Screening questionnaires included basic demographic questions, a physical activity readiness questionnaire (PAR-Q+), and the International Physical Activity Questionnaire (IPAQ) short form (Craig et al., 2017). Criteria for participation included: (a) that they were non-smokers, (b) did not report any cardiometabolic health conditions, and (c) were already moderately active. In addition, the PAR-Q+ questionnaire, which explores potential cardiovascular and metabolic risk factors, verified that participants were healthy enough to engage in moderate to vigorous physical activity. For those qualifying for the study, written informed consent was obtained, but participants were not made aware of the study's socialization aspect during the informed consent process. This omission was an effort to obtain natural responses to the social engagement or lack thereof. Participants were told that multiple sessions were required for validity. After the study's completion, each participant was debriefed and informed of the deception and made aware of the socialization intervention. All documents, including informed consent and study procedures, were approved by the Lehman College Institutional Review Board and in accordance with the Declaration of Helsinki. An *a-priori* power analysis using G*Power3.1.9.7 suggested a sample size of approximately 28 would be adequate to achieve a statistical power of 0.8. This was based on the partial Eta squared of 0.0491 from similar acute mood change data collected prior to and following a similar length aerobic exercise intervention. A total of 29 participants began the study, out of which, four did not perform all four study sessions and were excluded, leaving a total of 25 participants (15 female and 10 male, age 24.2 ± 1.69 years) completing the fitness assessment and all four sessions. The four participants who began the study but did not complete all four sessions did not have complete data sets, so their data were excluded from analyses. Participants that completed the study were all healthy, moderately active adults. Descriptive information for the participants can be seen in Table 1.

Table 1. The baseline demographic information for study participants

Descriptive var.	Mean ± SEM
Sex – n (%)	15 (60%) female / 10 (40%) male
Age – years	24.20 ± 1.69
BMI – kg/m^2	24.56 ± 1.07
Aerobic Fitness – ml O_2/kg/min	41.54 ± 1.93

Upon entry into the study, participants first completed a maximal aerobic capacity test to determine aerobic fitness. Once the aerobic capacity test was completed, an exercise heart rate range was calculated to maintain an intensity of ~50% of heart rate reserve (HRR) ± 5 beats per minute (bpm). Participants were randomly assigned an order to complete all four study sessions which included: exercise with socialization (Ex+/Soc+), exercise without socialization (Ex+/Soc-), no-exercise with socialization (Ex-/Soc+), and no-exercise and no socialization (Ex-/Soc-). Before and after each session, participants would complete mood questionnaires and perform computerized cognitive assessments. Heart rate was monitored throughout to verify the intensity of physical activity versus sedentary activity.

Aerobic capacity testing

Before reporting to the exercise science lab for their aerobic capacity test, participants were told to avoid exercising for 24 hours. Aerobic capacity testing was performed on a motor-driven treadmill using a graded exercise test while monitoring heart rate and collecting ventilatory gases. The graded exercise test followed an Ellestad protocol because the population was healthy, and a jogging/running protocol more closely mimicked the exercise sessions that the study would utilize (Gentile & Tighe, 2019; Mehta & Shah, 2013). Participants had their heart rate, respiratory exchange ratio (RER), and ventilation recorded every 15 seconds. The test continued until the participant asked to stop and confirmed their inability to continue a second time. A test was considered a 'true' maximal effort if the participant achieved at least two of the following criteria: peak exercise heart rate within 10 bpm of their age predicted max heart rate, RER $\geq$ 1.15, rating of perceived exertion (6–20 scale) $\geq$18, or a plateau in VO_2 despite an increase in workload. If a participant requested to stop and the test was deemed a sub-maximal effort, the maximal achieved heart rate was averaged with the age-predicted max heart rate to calculate the HRR for the exercise sessions. If the test was a true maximal effort, the maximal achieved heart rate was used for the exercise prescription. The prescription was verified by comparing the calculated 50%HRR with the graded exercise test heart rate achieved at 50% of the maximal measured VO_2.

Exercise

During exercise sessions, participants walked/jogged on a motor-driven treadmill at a self-selected speed and grade to maintain their heart rate within 5 bpm of their 50% HRR. Their heart rate and rating of perceived exertion were assessed every 5 minutes throughout the 30-minute exercise session. The exercise intensity was adjusted as necessary to maintain a heart rate within the prescribed range. At the completion of 30-minutes of exercise, participants returned to a seated position to recover for 10 minutes before completing post-intervention mood and cognitive assessments.

Alternatively, during no-exercise sessions, the participants were asked to remain seated for a 30-minute period. They were asked not to text, talk on the phone, or use social media during this time. However, they were encouraged to bring homework, reading, or other materials to occupy themselves during the session. During the 30 minutes of inactivity, heart rate was recorded every 5 minutes. Following these 30 minutes of inactivity, the participants remained seated for an additional 10-minute recovery period to match the total duration of the exercise sessions.

Socialization

During a socialization session, regardless of exercise condition, researchers engaged in conversation with the participants. The researchers were instructed to avoid talking about contentious or fraught topics, and instead were encouraged to ask questions about the participants' interests, weekend or vacation plans, music, television, or sport teams which they liked, etc. Alternatively, during non-socialization sessions, the researchers avoided conversation with the participants. The researchers would answer questions or respond if the participants spoke to them, however, they busied themselves around the lab to appear occupied during these sessions. If a participant was continually attempting to talk to a researcher during a non-socialization session, another researcher would ask their colleague to "help them with something" in the lab. This was done to maintain a friendly environment while restricting social engagement. These protocols were followed during either exercise or non-exercise sessions.

Mood and neurocognitive assessments

Before and after each session, participants completed computerized mood questionnaires and neurocognitive tests. The mood questionnaires consisted of a Profile of Mood States (POMS) and a State Trait Anxiety Inventory (STAI) (Berger & Motl, 2000; Ekkekakis et al., 1999; Leunes & Burger, 2000). The neurocognitive tests consisted of the Eriksen Flanker (EF) task and the Stroop task.

The POMS, developed by McNair and colleagues in the 1970s, uses 65 items to assess six sub-scales of mood (tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment) as well as a Total Mood Disturbance (TMD) (McNair D, 1971, 1981, 1992). Total Mood Disturbance is calculated by summing all sub-scales, and then subtracting the vigor-activity sub-scale value. While initially developed for clinical populations, this instrument has been widely used among healthy populations with sensitivity to changes associated with exercise (Berger & Motl, 2000). The State Trait Anxiety Inventory was developed in the 1970s by Spielberger and colleagues to measure more persistent individual differences in anxiety (trait) as well as transient emotional changes in anxiety (state) (Renzi, 1985; Spielberger et al., 1971). For STAI, only state anxiety was examined, as the trait anxiety is unlikely to show acute changes (Ensari et al., 2015). The computerized questionnaires were modified from their original versions in several important ways. The order the items appeared on the questionnaires were randomized each time the participants were assessed. In addition, a visual analog scale with no visible values, besides the maximal and minimal end, was used rather than the standard Likert scales with which these questionnaires were developed. The visual analog scales did retain the same upper and lower bounds of the original Likert scales, but allowed for continuous values between the ends of the scale. These changes were made to avoid participants intentionally reproducing responses during repeated retesting, and to give greater flexibility and precision in responses.

The neurocognitive assessments included a computerized modified Eriksen flanker (EF) task and a Stroop task. The EF task displayed a string of seven letters on the screen, and participants were asked to respond "right" or "left" based on the central letter using the right and left shift keys. There were two letters that were assigned to "right" response and two letters that were assigned to "left" response. The EF task items could be scaled from easier to harder by mixing the cued response, making the string either congruent, neutral, or incongruent. The flanking (non-central) characters could be assigned the same cued response (right or left) as the center letter (congruent) or the opposite cued response (incongruent). The neutral condition occurred if the flanking characters did not match either cued response (right nor left). The participants had a 750 bmillisecond (ms) window to respond to the string with a keyboard input with their right or left hand. A 1,000 ms pause separated the disappearance and reappearance of each string of letters regardless of participant response to avoid mistakenly giving keyboard inputs for a different/previous string. Prior to beginning the task, the participants were given the opportunity to practice the task as long as they wanted. Practice was not scored, but in all other ways was identical to the actual trial. Once they felt ready, participants completed the scored task consisting of 20 different, and randomized strings. The task was scored for both accuracy and response time.

The computerized Stroop (color-word) task was performed following the EF task. This task consisted of viewing a series of color words: Red, Green, Blue, or Yellow, and responding based on the color of the typeface rather than responding to the word's meaning. The participants had a custom input device with large red, green, blue, and yellow buttons to respond to the color of the typeface. The words and colors were randomized and could be congruent (matching) or incongruent (mis-matched). Participants had 750 ms to respond to each color word with a 1,000 ms pause between words, like the EF task. Just as with the EF task, the participants were allowed to practice the task until they felt confident of the process. This task was scored based on the response to 20 color words, where both response time and accuracy were recorded.

Statistics

Once data were collected, mood parameters and cognitive task responses were converted to percentages

$$\left(\frac{\text{Score for item}}{\text{Highest possible score for item}}\right).$$

Any parameters that allowed for negative values were offset by the minimum value so that percentage scores were always positive. The post-assessment percentage was subtracted from the pre-assessment percentage for mood parameters to assess the change in mood. The cognitive assessments were scored for response time and the percentage correct/incorrect at each testing session. The difference between the post-assessment and pre-assessment percent correct for each treatment was calculated along with any differences in absolute response time (the average number of milliseconds to respond to cognitive task items).

The analysis included an omnibus 2 × 2 × 6 repeated measures ANOVA (including all six session time points, minutes: 5, 10, 15, 20, 25, and 30) for the heart rate responses to sessions. Pre-session and post session heart rate was also analyzed for differences among session types. The changes between post-assessment and pre-assessment mood and cognitive parameters were used as the dependent variable in a 2 × 2 repeated measures ANOVA with main effects for exercise and socialization condition, and an interaction. An omnibus test including all eight mood parameters (2 × 2 × 8) was also performed before following up with univariate tests for each mood parameter. The same procedure was repeated for the Stroop and Eriksen flanker tasks, but including all task types, response time, and number of non-responses. Any significant mood or cognitive findings were followed-up with main-effects analysis. The alpha for these tests was set *a-priori* at 0.05. All analyses were performed using IBM SPSS Statistics 29.0.2.0 (Armonk, NY).

Results

Heart rate response

There were significant main effects of both exercise ($F_{1,24}$ = 2193.33, p < 0.01) and socialization ($F_{1,24}$ = 5.02, p = 0.04) on HR response between the sessions, and HR significantly changed over the duration of the sessions ($F_{5,20}$ = 6.13, p < 0.01) (HR data shown in Figure 1 below). The only significant interaction when examining HR response was between exercise and time ($F_{5,20}$ = 6.39, p < 0.01). Exploring these differences further showed significant differences in mean %HRR between all non-exercise vs. exercise conditions (7.8±0.6% vs. 52.8±0.8%, p < 0.01), as well as all no socialization vs. socialization conditions: (29.4 ± 0.7% vs. 31.1 ± 0.6%, p = 0.04). Time differences showed that %HRR was lower at the first 5-minute interval compared to all other time points during exercise conditions (all p < 0.05).

Pre-session resting heart rate and post session recovery heart rate were also analyzed. There were no significant differences in resting %HRR prior to exercise sessions or socialization sessions ($F_{1,24}$ = 1.70, p = 0.20 and $F_{1,24}$ = 0.65, p = 0.43 respectively). However, despite equivalent recovery times, there were significant main effects of both exercise and socialization on recovery %HRR ($F_{1,24}$ = 34.33, p < 0.01 and $F_{1,24}$ = 5.74, p = 0.03 respectively). Differences between the exercised versus sedentary session average recovery %HRRs were 12.5 ± 0.8% vs. 6.7 ± 0.7% ($p < 0.01$), while the average difference between social and non-social sessions was 10.5 ± 0.7% vs. 8.8 ± 0.6% ($p = 0.03$). Despite these differences, there was no significant interaction ($F_{1,24} = 0.31$, $p = 0.58$).

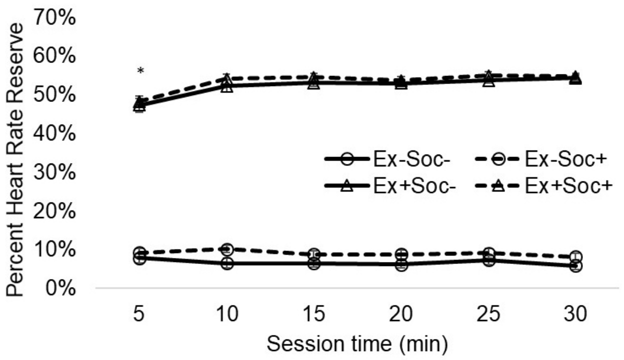

Figure 1. The average percent of heart rate reserve for all participants across 30 minutes for all four conditions

(*) indicates difference from other exercise timepoints. The exercise conditions %HRRs were significantly higher than the sedentary conditions ($p < 0.01$).

Mood changes

The omnibus test showed no significant main effects for exercise ($F_{1,23} = 3.30$, $p = 0.08$), but a significant effect of socialization ($F_{1,23} = 4.70$, $p = 0.04$) on changes across all 8 mood parameters assessed, changes in mood parameters can be seen in Figure 2. BMI was used as a covariate due to the variability amongst the sample (range = 17.95 kg/m^2). Once adjusted for BMI, the effects of exercise were improved ($F_{1,23} = 3.71$, $p = 0.07$), but the effects of socialization were decreased ($F_{1,23} = 3.29$, $p = 0.08$).

Further examination of the individual mood parameters showed that not all sub-scales were equally affected. Exercise did not have a significant main effect on changes in anger-hostility ($F = 3.47$, $p = 0.08$), while social interaction did have a significant main effect for changes in anger-hostility ($F = 5.32$, $p = 0.03$) and a significant interaction with BMI ($F = 4.51$, $p = 0.045$). The percent change in fatigue-inertia was significantly affected by exercise ($F = 10.19$, $p < 0.01$), and significant interactions with BMI ($F = 11.03$, $p < 0.01$). While socialization had significant main effects for fatigue-inertia ($F = 4.75$, $p = 0.04$), but no significant interaction with BMI ($F = 3.20$, $p = 0.09$). Changes in vigor-activity approached significant main effects for the exercise condition ($F = 4.02$, $p = 0.057$), and had a significant interaction with BMI ($F = 5.92$, $p = 0.02$). Socialization showed no significant main effect for changes in vigor-activity ($F = 0.04$, $p = 0.84$), but did show a significant interaction with exercise ($F = 9.20$, $p < 0.01$). Neither exercise nor social interaction had overall significant main effects for TMD ($F = 4.17$, $p = 0.05$ and $F = 2.99$, $p = 0.10$ respectively). However, there was a significant interaction between exercise and BMI ($F = 5.02$, $p = 0.04$), but no other significant interactions. Univariate follow-ups showed no significant effects of acute exercise or social interaction on tension-anxiety, depression-dejection, confusion-bewilderment, nor state anxiety. All main effects and interactions are shown in Table 2.

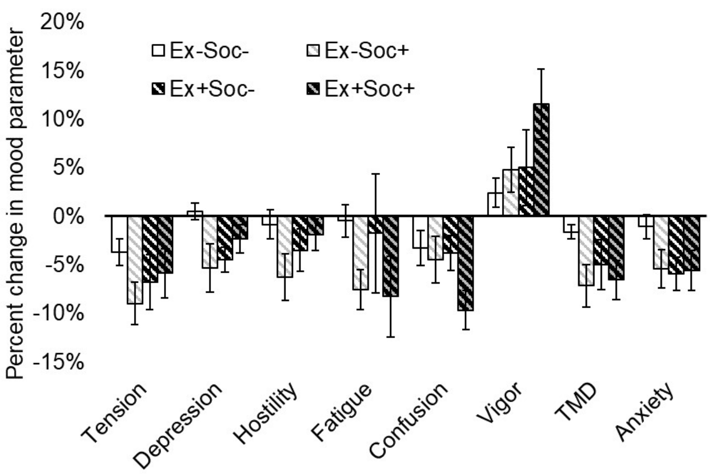

Figure 2. The average percent change in mood parameters following each of the four sessions

(Average values ± the standard error of the mean).

Table 2. The changes in individual mood parameters based on the main effects of exercise, social interaction, and an interaction with BMI as a covariate

Mood parameter	Exercise		Social interaction		Interaction	
	F statistic	p-value	F statistic	p-value	F statistic	p-value
Tension	0.38	0.55	4.06	0.06	0.66	0.43
Depression	0.38	0.54	0.14	0.72	0.21	0.66
Hostility	3.47	0.08	5.32	0.03*	0.75	0.40
Fatigue	10.19	< 0.01*	4.75	0.04*	3.79	0.06
Confusion	0.01	0.94	0.05	0.83	1.19	0.29
Vigor	4.02	0.06	0.04	0.84	9.20	< 0.01*
TMD	4.17	0.05	2.99	0.10	0.92	0.35
Anxiety	2.48	0.13	1.36	0.26	1.55	0.70

* Indicates significant main effect or interaction.

Follow-up analyses showed no significant effects of socialization on changes in anger-hostility when exercise was included, but a significant effect during the sedentary conditions ($t = -1.91$, one-sided $p = 0.03$), and these effects did not change if these pairs were analyzed as repeated measures with BMI as a covariate ($F = 0.91$, $p = 0.35$ and $F = 4.39$, $p = 0.047$ respectively). Follow-up analyses of fatigue-inertia changes showed significant differences for social interactions, but only during the sedentary condition ($t = -2.35$, one-sided $p = 0.01$). Despite no significant effect of exercise during non-social conditions ($t = -0.22$, one-sided $p = 0.42$), when analyzed with BMI as a covariate, differences were detected ($F = 14.34$, $p < 0.01$) with a significant interaction with BMI ($F = 15.46$, $p < 0.01$).

Because vigor-activity approached significance for exercise and interacted with socialization, a follow-up analysis was also performed. This analysis showed significant effects of exercise, but only when social interaction was included ($t = 2.29$, one-sided $p = 0.02$), and significant effects of socialization, but only in the context of exercise ($t = 1.94$, one-sided $p = 0.03$). No differences were detected for exercise in the non-social condition ($t = 0.66$, one-sided $p = 0.26$) nor socialization without exercise ($t = 0.86$, one-sided $p = 0.20$). Interestingly, if BMI were included as a covariate, the effects of exercise in the non-social conditions became significant ($F = 10.33$, $p < 0.01$) with a significant interaction with BMI ($F = 11.96$, $p < 0.01$).

A follow-up was also performed for TMD due to its approaching significance for exercise ($p = 0.053$). Here no differences were observed with exercise unless BMI was included as a covariate ($t = 0.20$, one-sided $p = 0.42$ in the social condition, and $t = -1.29$, $p = 0.11$ in the non-social condition). With BMI included as a covariate in the non-social condition, there was a significant effect of exercise ($F = 6.23$, $p = 0.02$) with a significant interaction with BMI ($F = 8.21$, $p = 0.01$). Surprisingly, social interaction significantly influenced TMD, but only in the sedentary condition ($t = -2.18$, one-sided $p = 0.02$, vs. $t = -0.59$, one-sided p=0.28 for the exercise condition). This was made worse by including BMI as a covariate ($F = 0.27$, $p = 0.61$) although the exercise and socialization effects were improved ($F = 3.62$, $p = 0.07$).

Cognitive changes

When examining the changes in performance on cognitive tasks, percent correct, response times, and response rate were assessed. For both EF and Stroop tasks, neither the percent of correct responses, percent of non-responses, nor average response times showed significant changes (figures 3-5). There were no significant main effects of exercise for EF regardless of whether the test items were congruent, neutral, or incongruent ($F < 0.01$, $p = 0.99$, $F = 0.02$, $p = 0.88$, and $F = 0.51$, $p = 0.48$ respectively) as shown in figure 3. The same was true for social interaction ($F < 0.01$, $p = 0.96$, $F = 0.03$, $p = 0.87$, and $F = 1.81$, $p = 0.19$ respectively), and, likewise, no significant interactions (all $p > 0.05$). There were also no differences in the number of non-responses based on exercise or socialization ($F = 0.22$, $p = 0.64$ and $F = 0.16$, $p = 0.70$ respectively).

Similarly, the Stroop task showed no main effects of either exercise or socialization regardless of trials being congruent ($F = 1.28$, $p = 0.27$ and $F = 0.24$, $p = 0.63$) or incongruent ($F = 0.73$, $p = 0.40$ and $F = 0.50$, $p = 0.49$) as seen in figure 4. There were no differences in the change in number of non-responses based on exercise ($F = 0.14$, $p = 0.71$) or social interaction ($F = 0.12$, $p = 0.74$) for the Stroop task.

Regarding response time, there were no differences in times for the EF task regardless of exercise ($F = 2.48$, $p = 0.13$) or social interaction ($F = 0.59$, $p = 0.45$) as shown in figure 5. Likewise, the Stroop response time changes were not different for exercise ($F = 1.62$, $p = 0.22$) or social interaction ($F = 1.12$, $p = 0.30$).

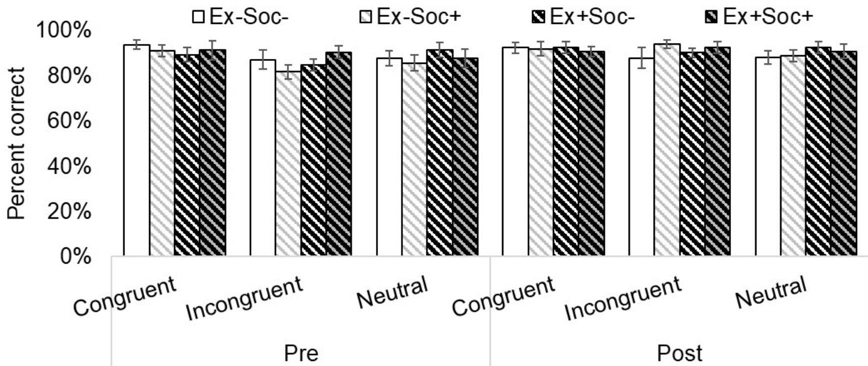

Figure 3. The average percentage of correct responses to the Eriksen flanker task before and after each study session

The figure is divided to show: congruent, incongruent, and neutral task items.

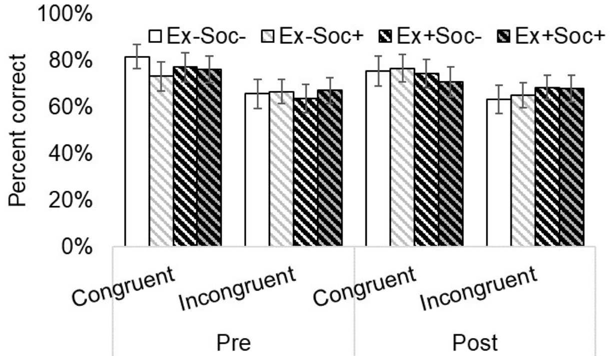

Figure 4. The average percent correct for the Stroop task before and after each study session

The figure is divided to show: congruent and incongruent task items.

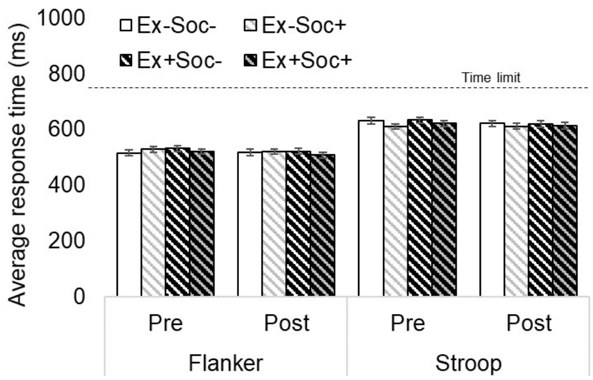

Figure 5. The average response times for both Eriksen Flanker and Stroop tasks before and after each session

The time limit to respond is indicated by the dotted line, occurring at 750ms.

Discussion

The findings from this investigation were mixed. It was hypothesized that mood would improve following acute exercise, and that improvements would be greatest when social interactions were incorporated. Mood was improved following treatment sessions, but it was not necessarily clear that Ex+/Soc+ was always the session which produced the best outcome. Fatigue-inertia seemed to be the parameter most exclusively influenced by exercise, as would be generally expected as it has been noted in many other studies, although with mixed directional responses (Berger & Motl, 2000; Elkington et al., 2017). The current study showed exercise with social interaction led to decreased fatigue-inertia. However, this response could also be related to the social interaction itself which showed significant reductions in fatigue-inertia during the sedentary condition (Ex-/Soc+) and exercise condition (Ex+/Soc+), while the exercise condition without socialization (Ex+/Soc-) did not seem to reduce fatigue-inertia. The notion that the social interactions may be important for fatigue-inertia seems relevant as the mood parameter reflects tiredness and exhaustion, which physical exertion would seemingly exacerbate, but studies of social interactions without physical activity have shown reductions in fatigue-inertia following face-to-face social interactions (Pollock et al., 1979; Watanabe et al., 2016).

In contrast to fatigue-inertia, anger-hostility ratings only seemed to respond to social interactions, and only during sedentary conditions. This was contrary to the hypothesis, as well as the findings of many studies of acute aerobic exercise reducing anger-hostility ratings (Berger & Motl, 2000). The current study's findings may have been due to low average anger-hostility ratings at baseline across all sessions (15.35 ± 1.24%) leading to a "floor-effect" with little room for improvement. An acute exercise and mood study in a group of young healthy adults by Crush et al. measured average baseline anger-hostility rating of 12.9 ± 3.9 (29.32 ± 8.86%), almost double that of the current study (Crush et al., 2018). Similar to what was observed by Crush et al., on average, hostility ratings were reduced at post-assessment in the current study (reduced by 11.98 ± 0.50% vs. 27.95% overall by Crush et al.) (Crush et al., 2018). In both cases there were large reductions, but the low initial anger-hostility ratings in the current study may have limited the ability to achieve statistically significant changes.

Changes in measures of anger-hostility in the current study were driven to the largest extent by the Ex-/Soc+ session. As anger-hostility is a scale sensitive to frustration and irritability, it seems reasonable that social interactions, designed to build rapport and put the participant at ease would be more effective at reducing feelings of anger-hostility than physical activity alone. While studies have shown that acute exercise can reduce anger-hostility, this effect has also been shown in socialization only studies (Berger & Motl, 2000; Elkington et al., 2017; Watanabe et al., 2016). Thus, it may be that social interactions are more important at reducing anger-hostility than solely the act of performing exercise.

Vigor-activity has previously been observed to increase following acute aerobic exercise; however, these effects may be influenced by exercise habituation, exercise intensity, or the type of exercise being performed (Chase & Hutchinson, 2015; Hallgren et al., 2010; Wilson & Yilla, 2021). The vigor-activity sub-scale assesses feelings of energy, alertness, and enthusiasm, which are correlated with elevated HR and potentially the release of endorphins from exercise (Pollock et al., 1979). Data in the current study indicated that the combination of both exercise and social interactions led to the greatest improvements in vigor. This is somewhat surprising as studies examining socialization without exercise have not necessarily shown changes in vigor-activity (Watanabe et al., 2016). Although this may be due to individual differences, as ratings of social interactions with unacquainted individuals has previously been shown to be influenced by the positive and negative affect of the individuals (Berry & Hansen, 1996). On average, it seems that both exercise and social interactions may still exert influence over vigor-activity, and these effects may be additive.

The TMD seems to be influenced by a combination of exercise and social engagement, which is reasonable as both interventions influenced the variables from which it is calculated. Total Mood Disturbance (TMD) has been shown in previous studies to respond to both acute exercise and acute social engagement (Berger & Motl, 2000; Elkington et al., 2017; Watanabe et al., 2016). Despite this, the current study did not show strong interactions between these interventions. This suggests that social interactions and acute exercise may have some shared variability in mood parameter changes, but are likely complementing one another and accounting for unique changes in mood. Thus, changes shown in most acute exercise studies may be due to both the exercise and the social interactions that often accompany the exercise.

As with any study involving physical activity or social interactions, many protocol variations could be affecting outcomes. It is possible that performing higher intensity and/or longer duration exercise would have independently improved mood parameters regardless of social interactions. Although most evidence suggests that moderate to vigorous intensity exercise of sessions lasting between 10 and 60 minutes are effective for acute mood enhancement (Chan et al., 2019; Crush et al., 2018; Meyer et al., 2016). Similarly, if individuals were observed in a more naturalistic setting, and/or were interacting with others with whom they have pre-established relationships, mood parameters may have been more robustly influenced (Yorks et al., 2017).

The current study also observed that BMI was often significantly interacting with mood outcomes, but only during exercise conditions. This has not been thoroughly examined previously but aligns with previous studies where there were exercise related mood differences when comparing groups by BMI (Hoffman & Hoffman, 2008). Although the current protocol prescribed exercise at the same relative intensity across all individuals, it is possible that some relationship between exercise preference/enjoyment and BMI exists regardless of the relative intensity. This may have influenced the outcomes as there was a wide range of BMIs among the current study sample (range = 17.95 kg/m^2).

The current study adds additional data and context to the findings by Yorks et al. (Yorks et al., 2017). Yorks showed improved mental and emotional QOL following 12 weeks of fitness classes (group exercise) compared to working out for 12 weeks in groups of 3 or less, which only improved mental QOL (Yorks et al., 2017). The average mental and emotional QOL across the 12 weeks of the study was higher in the group exercise compared to those exercising in groups of 3 or less and the control group (Yorks et al., 2017). In addition, only the group exercisers had a trend of decreasing perceived stress over the 12-week period (Yorks et al., 2017). The current study standardized the exercise and social interactions for all participants and exposed every participant to all conditions, accounting for individual variability. In addition, POMS and STAI were used to assess mood changes, as they have been used in several acute exercise studies (Berger & Motl, 2000; Ensari et al., 2015). The mood parameters from the current study and Yorks et al. are not identical, however they reveal something of how people are influenced by exercise and social interactions. Certain parameters such as vigor-activity or confusion-bewilderment seem to have an additive effect while other mood parameters may be equally influenced by exercise or social interactions, such as state anxiety. Alternatively, certain parameters, such as anger-hostility or depression-dejection may benefit more from the social aspects of engaging in physical activity than the physical activity itself.

There were no cognitive changes in response to acute exercise for either of the cognitive tasks performed in the current study. This contrasts with other studies which have shown acute enhancements of prefrontal cortex-dependent tasks, such as EF and Stroop, following acute aerobic exercise sessions (Basso et al., 2015; Chang et al., 2012; McMorris & Hale, 2012; McSween et al., 2019). It seems as if the tasks were too easy to challenge the young healthy participants in the current study. When cognitive intervention responses were evaluated, on average, participants scored 88.40% correct pre, and 90.95% correct post for the EF (as shown in Figure 3) or 71.43% correct pre vs. 70.20% correct post for the Stroop task. This high rate of correct responses leaves little room to improve. A similar effect was observed for the response times on the cognitive tasks. The response window for both EF and Stroop tasks was set at 750 ms, however the average response time for Eriksen flanker (across all trials) was 519.88 ms, and 619.66 ms for Stroop. Simple response time to a visual stimulus for healthy young adults may be as low as 250 ms (Jain et al., 2015). However, previous studies using EF and Stroop tasks to measure the effects of aerobic exercise on young healthy adults have reported response times between 700 – 1,000 ms (Basso et al., 2022). Thus, the participants in the current study could not improve much further as their response times were already below the low end of previously observed results (~700 ms). Therefore, the number of non-responses were also examined to determine if participants could respond to more items before the response window closed but, there were no statistical differences in the number of non-responses across any of the conditions.

Limitations and future directions

There were limitations to the current study's design. While social interactions influence mood and cognition, there is likely variability among individuals regarding introversion/extroversion and other personality traits which were not accounted for. Additionally, the type of social interaction, familiarity of individuals involved in social interactions, and a group's number, dynamics, and composition may all acutely influence how social interactions affect individuals' moods and cognitive states. Because it is difficult to control these variables, the current study attempted to hold as many variables constant as possible. However, future studies may attempt to control or measure more of these potentially confounding variables and better account for their influence on mood changes. Besides variability among individuals, various mood and cognitive assessments are used in research. While POMS, STAI, EF, and Stroop have all shown effectiveness in acute aerobic exercise trials, they may not have been sensitive enough for this population and intervention. In particular, the cognitive assessments were likely not sensitive enough for the young and cognitively healthy population as evidenced by the fast response times and high percent accuracy across all tasks and conditions. Moving forward, other mood questionnaires, or neuropsychologic assessments may be employed to find other, or more nuanced, changes. Finally, the initial power analysis for the current study used data collected from acute effects of group exercise classes on mood in healthy adults. However, if both exercise and social interactions are sharing explanatory variance in mood changes, the effect size of each may be smaller, thus requiring a larger sample if the true extent of exercise and social influences on mood are to be distinguished.

Conclusions

The current study is a first step in examining the interaction of acute exercise and acute social interactions on changes in mood and cognition. These data suggest that social interactions may play a larger role in certain mood changes, such as anger-hostility or depression-dejection. Meanwhile exercise and social interactions may have a more additive effect for mood parameters such as vigor-activity or confusion-bewilderment. This is important for a better understanding of when exercise is directly involved in mood improvements, and when it may be acting as a mediator for social interactions. This study's data on cognitive function were counter to current understanding of acute exercise and prefrontal cortex dependent cognitive functions. However, this was most likely due to high cognitive capacity of young individuals and a need to develop more sensitive cognitive tasks to assess these individuals.

Future research

Research examining the effects of physical activity/exercise on changes in mood and cognition, may benefit from including methods accounting for, or simply describing the social interactions of the participants. Further mechanistic studies would be valuable in determining what areas of the brain are being engaged during these different circumstances. In addition, humoral changes following exercise and/or social interactions may help to determine whether changes in circulating factors produced during exercise correlate to the changes measured in mood.

Conflict of interest: Authors state no conflict of interest

References

1. Basso, J. C., Oberlin, D. J., Satyal, M. K., O'Brien, C. E., Crosta, C., Psaras, Z., Metpally, A., & Suzuki, W. A. (2022). Examining the Effect of Increased Aerobic Exercise in Moderately Fit Adults on Psychological State and Cognitive Function [Original Research]. *Frontiers in Human Neuroscience*, *16*. https://doi.org/10.3389/fnhum.2022.833149
2. Basso, J. C., Shang, A., Elman, M., Karmouta, R., & Suzuki, W. A. (2015). Acute Exercise Improves Prefrontal Cortex but not Hippocampal Function in Healthy Adults. *J Int Neuropsychol Soc*, *21*(10), 791–801. https://doi.org/10.1017/S135561771500106X

3. Basso, J. C. S., Wendy A. (2017). The Effects of Acute Exercise on Mood, Cognition, Neurophysiology, and Neurochemical Pathways: A Review. *Brain Plasticity*, *2*(2), 127–152. https://doi.org/10.3233/BPL-160040
4. Berger, B. G., & Motl, R. W. (2000). Exercise and mood: A selective review and synthesis of research employing the profile of mood states. *Journal of Applied Sport Psychology*, *12*(1), 69–92. https://doi.org/10.1080/10413200008404214
5. Berry, D. S., & Hansen, J. S. (1996). Positive affect, negative affect, and social interaction. *Journal of personality and social psychology*, *71*(4), 796.
6. Chan, J. S. Y., Liu, G., Liang, D., Deng, K., Wu, J., & Yan, J. H. (2019). Special Issue – Therapeutic Benefits of Physical Activity for Mood: A Systematic Review on the Effects of Exercise Intensity, Duration, and Modality. *The Journal of Psychology*, *153*(1), 102–125. https://doi.org/10.1080/00223980.2018.1470487
7. Chang, Y. K., Labban, J. D., Gapin, J. I., & Etnier, J. L. (2012). The effects of acute exercise on cognitive performance: a meta-analysis. *Brain Res*, *1453*, 87–101. https://doi.org/10.1016/j.brainres.2012.02.068
8. Chase, R., & Hutchinson, J. (2015). The effects of acute aerobic exercise versus resistance exercise on mood state. *J Multidisciplinary Res*, *7*(2), 15–16.
9. Chekroud, S. R., Gueorguieva, R., Zheutlin, A. B., Paulus, M., Krumholz, H. M., Krystal, J. H., & Chekroud, A. M. (2018). Association between physical exercise and mental health in 1·2 million individuals in the USA between 2011 and 2015: a cross-sectional study. *The Lancet Psychiatry*, *5*(9), 739–746. https://doi.org/10.1016/S2215-0366(18)30227-X
10. Craig, C., Marshall, A., Sjostrom, M., Bauman, A., Lee, P., Macfarlane, D., Lam, T., & Stewart, S. (2017). International physical activity questionnaire-short form. *J Am Coll Health*, *65*(7), 492–501.
11. Crush, E. A., Frith, E., & Loprinzi, P. D. (2018). Experimental effects of acute exercise duration and exercise recovery on mood state. *Journal of Affective Disorders*, *229*, 282–287. https://doi.org/10.1016/j.jad.2017.12.092
12. Ekkekakis, P., Hall, E. E., & Petruzzello, S. J. (1999). Measuring state anxiety in the context of acute exercise using the State Anxiety Inventory: An attempt to resolve the brouhaha. *Journal of Sport and Exercise Psychology*, *21*(3), 205–229.
13. Elkington, T. J., Cassar, S., Nelson, A. R., & Levinger, I. (2017). Psychological Responses to Acute Aerobic, Resistance, or Combined Exercise in Healthy and Overweight Individuals: A Systematic Review. *Clinical Medicine Insights: Cardiology*, *11*, 1179546817701725. https://doi.org/10.1177/1179546817701725
14. Ensari, I., Greenlee, T. A., Motl, R. W., & Petruzzello, S. J. (2015). Meta-Analysis of Acute Exercise Effects on State Anxiety: An Update of Randomized Controlled Trials over the Past 25 Years. *Depress Anxiety*, *32*(8), 624–634. https://doi.org/10.1002/da.22370
15. Eubank, J. M., Oberlin, D. J., Alto, A., Sahyoun, N. R., Asongwed, E., Monroe-Lord, L., & Harrison, E. A. (2022). Effects of Lifestyle Factors on Cognition in Minority Population of Older Adults: A Review [Review]. *Frontiers in Nutrition*, *9*. https://doi.org/10.3389/fnut.2022.841070
16. Gentile, B. A., & Tighe, D. A. (2019). Exercise Stress ECG Test Protocols. In *Pocket Guide to Stress Testing* (pp. 53–66). https://doi.org/10.1002/9781119481737.ch5
17. Goodwin, R. D., Dierker, L. C., Wu, M., Galea, S., Hoven, C. W., & Weinberger, A. H. (2022). Trends in U.S. Depression Prevalence From 2015 to 2020: The Widening Treatment Gap. *Am J Prev Med*, *63*(5), 726–733. https://doi.org/10.1016/j.amepre.2022.05.014
18. Gray, C. (2021). Solo vs group workouts: do women prefer exercising alone or with other people? *Stylist*. https://www.stylist.co.uk/fitness-health/workouts/exercising-alone-vs-group-training/575301
19. Hallgren, M., Moss, N. D., & Gastin, P. (2010). Regular exercise participation mediates the affective response to acute bouts of vigorous exercise. *J Sports Sci Med*, *9*(4), 629–637.
20. Harvey, S. B., Øverland, S., Hatch, S. L., Wessely, S., Mykletun, A., & Hotopf, M. (2018). Exercise and the Prevention of Depression: Results of the HUNT Cohort Study. *American Journal of Psychiatry*, *175*(1), 28–36. https://doi.org/10.1176/appi.ajp.2017.16111223
21. Hearing, C. M., Chang, W. C., Szuhany, K. L., Deckersbach, T., Nierenberg, A. A., & Sylvia, L. G. (2016). Physical Exercise for Treatment of Mood Disorders: A Critical Review. *Current Behavioral Neuroscience Reports*, *3*(4), 350–359. https://doi.org/10.1007/s40473-016-0089-y
22. Hoffman, M. D., & Hoffman, D. R. (2008). Exercisers Achieve Greater Acute Exercise-Induced Mood Enhancement Than Nonexercisers. *Archives of Physical Medicine and Rehabilitation*, *89*(2), 358–363. https://doi.org/10.1016/j.apmr.2007.09.026
23. Internicola, D. (2013, September 23, 2013). Americans say they're creatures of simple, solo exercise habits. *Reuters*. https://www.reuters.com/article/lifestyle/americans-say-theyre-creatures-of-simple-solo-exercise-habits-idUSBRE98M0KP/

24. Ishihara, T., Drollette, E. S., Ludyga, S., Hillman, C. H., & Kamijo, K. (2021). The effects of acute aerobic exercise on executive function: A systematic review and meta-analysis of individual participant data. *Neuroscience & Biobehavioral Reviews*, *128*, 258–269. https://doi.org/10.1016/j.neubiorev.2021.06.026
25. Jain, A., Bansal, R., Kumar, A., & Singh, K. (2015). A comparative study of visual and auditory reaction times on the basis of gender and physical activity levels of medical first year students. *International Journal of Applied and Basic Medical Research*, *5*(2), 124–127. https://doi.org/10.4103/2229-516x.157168
26. Koch, E. D., Tost, H., Braun, U., Gan, G., Giurgiu, M., Reinhard, I., Zipf, A., Meyer-Lindenberg, A., Ebner-Priemer, U. W., & Reichert, M. (2020). Relationships between incidental physical activity, exercise, and sports with subsequent mood in adolescents. *Scandinavian Journal of Medicine & Science in Sports*, *30*(11), 2234–2250. https://doi.org/10.1111/sms.13774
27. Kuczynski, A. M., Halvorson, M. A., Slater, L. R., & Kanter, J. W. (2022). The effect of social interaction quantity and quality on depressed mood and loneliness: A daily diary study. *Journal of Social and Personal Relationships*, *39*(3), 734–756. https://doi.org/10.1177/02654075211045717
28. Leunes, A., & Burger, J. (2000). Profile of Mood States Research in Sport and Exercise Psychology: Past, Present, and Future. *Journal of Applied Sport Psychology*, *12*(1), 5–15. https://doi.org/10.1080/10413200008404210
29. McMorris, T., & Hale, B. J. (2012). Differential effects of differing intensities of acute exercise on speed and accuracy of cognition: A meta-analytical investigation. *Brain and Cognition*, *80*(3), 338–351. https://doi.org/10.1016/j.bandc.2012.09.001
30. McNair D, M. (1971, 1981, 1992). Profile of mood states. *Educational and industrial testing service*. https://cir.nii.ac.jp/crid/1573950399047802368
31. McSween, M.-P., Coombes, J. S., MacKay, C. P., Rodriguez, A. D., Erickson, K. I., Copland, D. A., & McMahon, K. L. (2019). The Immediate Effects of Acute Aerobic Exercise on Cognition in Healthy Older Adults: A Systematic Review. *Sports Medicine*, *49*(1), 67–82. https://doi.org/10.1007/s40279-018-01039-9
32. Mehta, H. B., & Shah, C. J. (2013). Predicted Maximal Oxygen Consumption (VO2MAX) Values Obtained During The Maximal Treadmill Test Using Different Protocols. *National Journal of Integrated Research in Medicine*, *4*(2), 149–155.
33. Meyer, J. D., Koltyn, K. F., Stegner, A. J., Kim, J.-S., & Cook, D. B. (2016). Influence of Exercise Intensity for Improving Depressed Mood in Depression: A Dose-Response Study. *Behavior Therapy*, *47*(4), 527–537. https://doi.org/10.1016/j.beth.2016.04.003
34. Mikkelsen, K., Stojanovska, L., Polenakovic, M., Bosevski, M., & Apostolopoulos, V. (2017). Exercise and mental health. *Maturitas*, *106*, 48–56. https://doi.org/10.1016/j.maturitas.2017.09.003
35. Moreno-Agostino, D., Wu, Y.-T., Daskalopoulou, C., Hasan, M. T., Huisman, M., & Prina, M. (2021). Global trends in the prevalence and incidence of depression:a systematic review and meta-analysis. *Journal of Affective Disorders*, *281*, 235–243. https://doi.org/10.1016/j.jad.2020.12.035
36. Pearce, M., Garcia, L., Abbas, A., Strain, T., Schuch, F. B., Golubic, R., Kelly, P., Khan, S., Utukuri, M., Laird, Y., Mok, A., Smith, A., Tainio, M., Brage, S., & Woodcock, J. (2022). Association Between Physical Activity and Risk of Depression: A Systematic Review and Meta-analysis. *JAMA Psychiatry*, *79*(6), 550–559. https://doi.org/10.1001/jamapsychiatry.2022.0609
37. Pollock, V., Cho, D. W., Reker, D., & Volavka, J. (1979). Profile of Mood States: The Factors and Their Physiological Correlates. *The Journal of Nervous and Mental Disease*, *167*(10), 612–614. https://journals.lww.com/jonmd/fulltext/1979/10000/profile_of_mood_states__the_factors_and_their.4.aspx
38. Rao, P., Belanger, M. J., & Robbins, J. M. (2022). Exercise, Physical Activity, and Cardiometabolic Health: Insights into the Prevention and Treatment of Cardiometabolic Diseases. *Cardiol Rev*, *30*(4), 167–178. https://doi.org/10.1097/crd.0000000000000416
39. Renzi, D. A. (1985). State-Trait Anxiety Inventory. *Measurement and Evaluation in Counseling and Development*, *18*(2), 86–89. https://doi.org/10.1080/07481756.1985.12022795
40. Ruegsegger, G. N., & Booth, F. W. (2018). Health Benefits of Exercise. *Cold Spring Harb Perspect Med*, *8*(7). https://doi.org/10.1101/cshperspect.a029694
41. Spielberger, C. D., Gonzalez-Reigosa, F., Martinez-Urrutia, A., Natalicio, L. F., & Natalicio, D. S. (1971). The state-trait anxiety inventory. *Revista Interamericana de Psicologia/Interamerican journal of psychology*, *5*(3 & 4).
42. Watanabe, J.-i., Atsumori, H., & Kiguchi, M. (2016). Informal Face-to-Face Interaction Improves Mood State Reflected in Prefrontal Cortex Activity [Original Research]. *Frontiers in Human Neuroscience*, *10*. https://doi.org/10.3389/fnhum.2016.00194
43. Wilson, J., & Yilla, A. (2021). The immediate effects of maximal aerobic and anaerobic exercise on mood. *Journal of Psychology & Psychiatry Research*, *1*(1), 1–9.

44. Ybarra, O., Burnstein, E., Winkielman, P., Keller, M. C., Manis, M., Chan, E., & Rodriguez, J. (2008). Mental Exercising Through Simple Socializing: Social Interaction Promotes General Cognitive Functioning. *Personality and Social Psychology Bulletin*, *34*(2), 248–259. https://doi.org/10.1177/0146167207310454
45. Yorks, D. M., Frothingham, C. A., & Schuenke, M. D. (2017). Effects of Group Fitness Classes on Stress and Quality of Life of Medical Students. *Journal of Osteopathic Medicine*, *117*(11), e17–e25. https://doi.org/doi:10.7556/jaoa.2017.140

Received 25.09.2024
Accepted 26.02.2025

Acknowledgements

The authors thank Elizabeth Arias, Adam Mohan, and Justin English for their assistance in carrying out exercise and/or socialization sessions. We also thank John T. Edwards for assistance in proofreading the manuscript.