Received: 24 April 2020 | Accepted: 4 August 2021

DOI: 10.1002/pchj.485

ORIGINAL ARTICLE

PsyCh Journal

The effect of physical activity on anhedonia in individuals with depressive symptoms

Ching-wen Sun[1,2†] | Ya-jing Wang[3†] | Yu-qi Fang[1] | Yu-qian He[1] | Xuan Wang[1] | Billy C. L. So[4] | David H. K. Shum[4,5,6] | Chao Yan[1,2]

[1]Key Laboratory of Brain Functional Genomics (MOE&STCSM), Affiliated Mental Health Center (ECNU), School of Psychology and Cognitive Science, East China Normal University, Shanghai, China

[2]Shanghai Changning Mental Health Center, Shanghai, China

[3]Department of Psychology, Navy Medical University, Shanghai, China

[4]Department of Rehabilitation Sciences, The Hong Kong Polytechnic University, Hong Kong, China

[5]Neuropsychology and Applied Cognitive Neuroscience Laboratory, CAS Key Laboratory of Mental Health, Institute of Psychology, Chinese Academy of Sciences, Beijing, China

[6]School of Applied Psychology, Griffith University, Gold Coast, Queensland, Australia

Correspondence
Dr. Chao Yan, Key Laboratory of Brain Functional Genomics (MOE&STCSM), Affiliated Mental Health Center (ECNU), School of Psychology and Cognitive Science, East China Normal University, 3663 Zhongshan North Road, Shanghai 200062, China.
Email: cyan@psy.ecnu.edu.cn

Funding information
MOE (Ministry of Education of China) Project of Humanities and Social Sciences, Grant/Award Number: 20YJC190025; National Natural Science Foundation China, Grant/Award Number: 31500894; Fundamental Research Funds for the Central Universities, Grant/Award Numbers: 2018ECNUQKT015, 2019ECNU-HWFW021; Natural Science Foundation of Shanghai, Grant/Award Number: 21ZR142000

Abstract

The therapeutic effect of antidepressants has been demonstrated for anhedonia in patients with depression. However, antidepressants may cause side-effects, such as cardiovascular dysfunction. Although physical activity has minor side-effects, it may serve as an alternative for improving anhedonia and depression. We sought to investigate whether physical activity reduces the level of anhedonia in individuals with depression. Fifty-six university students with moderate depressive symptoms (Beck Depression Inventory total score > 16) were divided into three training groups: the Running Group (RG, $n = 19$), the Stretching Group (SG, $n = 19$), and the Control Group ($n = 18$). We employed the Monetary Incentive Delay (MID) task and the Temporal Experience of Pleasure Scale (TEPS) to evaluate hedonic capacity. All participants in the RG and SG received 8 weeks of jogging and stretching training, respectively. The RG experienced an increase in the level of arousal during anticipation of a future reward and recalled less negativity towards the loss condition. The SG exhibited enhanced scores on the Anticipatory and Consummatory Pleasure subscales of the TEPS after training. Moreover, in the RG, greater improvements in anticipatory arousal ratings for pleasure and remembered valence ratings for negative affect were associated with longer training duration, lower maximum heart rate, and higher consumed calories during training. To conclude, physical activity is effective in improving anticipatory anhedonia in individuals with depressive symptoms.

KEYWORDS
anhedonia, anticipatory pleasure, depressive symptom, physical exercise

Depression is a highly prevalent mental health disorder that affects over 300 million people globally (World Health Organization, 2010). There is high mortality in these patients with depression due to suicidal thoughts and cardiovascular death (Lépine & Briley, 2011; Rugulies, 2002; Whang et al., 2009). To date, various types of interventions, including antidepressant medication and psychological treatment, have been developed to alleviate depressive symptoms.

In the psychopharmacological field, numerous antidepressants have been developed to relieve the depressive symptoms experienced by patients (Boyer et al., 2000; Dewilde et al., 2015; Martinotti et al., 2012; Tomarken et al., 2004).

†These authors equally contributed to this research.

Although many of these medications are considered safe and well-tolerated, various adverse side-effects can occur, including headache, nausea, weight gain, and sexual dysfunction (Anderson et al., 2012; Schuch & Stubbs, 2019; Wan et al., 2015). Evidence has also suggested that only approximately half of patients taking antidepressants achieve a clinically significant response (Pigott, 2015; Rush et al., 2006).

Other than medication, several non-pharmacological therapies with minimal side-effects have been developed to treat depression. Cognitive-behavioral therapy (CBT) is a commonly used treatment that is effective in treating depression. However, individuals with depression who receive CBT have concerns regarding stigmatization, which leads to depression going untreated (Kohn et al., 2004; Webb et al., 2017). An alternative intervention is physical activity, which is less stigmatizing. Common training formats involve running and cycling, whereas other formats also include strength exercise, climbing, hiking, and yoga (Cramer et al., 2017; Ströhle, 2019). The effect of physical activity on depression has been well established in many randomized control trials (RCTs) and meta-analyses, which have indicated a moderate to large effect of improvement in depressive symptoms in clinical and non-clinical depressed populations compared with control conditions (e.g., usual care), and even larger effects (Hedge's $g = -0.97$ to -1.24) compared with no intervention (Josefsson et al., 2014; Knapen et al., 2015; Kvam et al., 2016). The response rate of physical activity has been reported to be 20%–89% (Waters et al., 2011). Currently, studies have focused on individuals with subclinical depression because this population is most likely to be free of antidepressants, which ensures that any antidepressant effects observed have been induced by physical activity only.

The benefits of physical activity extend beyond its antidepressant effects: it also has the potential to alleviate deficits in hedonic capacity, which is regarded as one of the core symptoms (i.e., anhedonia) of major depressive disorder (American Psychiatric Association, 2013). It is widely acknowledged that physical activity is beneficial to the well-being of humans. Previous research has shown that physical activity is associated with fewer symptoms of depression and anxiety and fewer negative and more positive emotions in both healthy populations and individuals with psychiatric disorders (Bernstein & Mcnally, 2017; Garcia et al., 2012; Harris et al., 2006; Ströhle et al., 2007; Tordeurs et al., 2011). Additionally, physical exercise is regarded as a naturally rewarding activity (Brené et al., 2007). Specifically, neurobiological evidence has suggested that physical activity and reward processing activate overlapping brain regions, such as the ventral tegmental area, ventral striatum, hippocampus, and nucleus accumbens, which are closely related to dopaminergic signaling (Craske et al., 2016; Dishman & O'Connor, 2009; Höflich et al., 2018). Based on this evidence, physical activity may be a promising treatment for anhedonia in patients with depression. However, to date, evidence that directly explores the mechanisms underlying the effect of physical activity on hedonic capacity remains limited (Leventhal, 2012; Sigwalt et al., 2011; Toups et al., 2017).

Hedonic capacity is a multi-dimensional concept that involves anticipatory, consummatory, and remembered pleasure. Anticipatory pleasure refers to the prediction or feeling of future rewarding stimuli (Gard et al., 2006; Loas & Krystkowiak, 2010) and comprises two dimensions: prediction and feelings of anticipation. The prediction dimension of anticipatory pleasure is the emotional status while anticipating a forthcoming reward, whereas the feeling dimension of anticipatory pleasure is the forecast of feelings towards future events. Consummatory pleasure is the in-the-moment emotion status towards ongoing positive events (Gard et al., 2007; Kring & Barch, 2014; Kring & Caponigro, 2010; Kring & Elis, 2013). Remembered pleasure refers to an individual's memory of pleasant experiences (Kring & Barch, 2014). Extensive evidence has shown that individuals with depression rate pleasantness of future pleasant events (Hoerger et al., 2012; Yuan & Kring, 2009) and monetary rewards lower (McFarland & Klein, 2009) than do those without depressive symptoms. Similarly, depressed individuals report more blunted positive emotions (Bylsma et al., 2008) as well as weaker physiological responses (e.g., decreased contraction of muscles, less attenuation of the startle–blink reflex, reduced heart rate acceleration, and weaker facial expressions; Larson et al., 2007; Mneimne et al., 2008; Sloan et al., 2001) in response to pleasant stimuli compared with healthy controls. Additionally, depressed patients have a preference for negative over pleasurable materials during memory retrieval and show greater sensitivity towards negative information than do non-depressed individuals (Gotlib & Joormann, 2010; Platt et al., 2017), which may contribute to the persistence of depressive symptoms (Hall et al., 2010). Thus, characterizing these three components of anhedonia by assessing valence and arousal levels can help to further our understanding of the mechanisms underlying the effect of physical training on anhedonia.

The current study aimed to investigate whether physical activity decreases the levels of anhedonia and depression in university students with depressive symptoms. We hypothesized that running and stretching would enhance valence and arousal levels of anticipatory, consummatory, and remembered pleasantness and reduce depressive symptoms in individuals with depressive symptoms. Moreover, running may induce further changes in pleasant experiences and level of depression, which may be associated more strongly with physiological modifications than stretching.

METHODS

Participants

We recruited 68 university students (age range 17 to 28 years) with moderate depressive symptoms who scored 16 or above on the Beck Depression Inventory (BDI) from a university in Shanghai. Advertisements were posted on campus, and students who were interested in our study were invited to complete the BDI. Twelve participants were excluded because they met one of the following exclusion criteria: (1) a history of

neurological disorder (e.g., stroke or epilepsy); (2) a history of other psychiatric disorders (e.g., schizophrenia or phobia); (3) a family history of psychosis; (4) suicidal behaviors in the last 2 years; (5) drug or substance abuse (e.g., alcohol or heroin); (6) unwillingness to complete the study assessments or tasks; or (7) failure to complete all training sessions. This study was approved by the ethics committee of East China Normal University. We obtained written informed consent from all participants before the commencement of the study.

A total of 56 individuals with moderate depression (11 males and 45 females) were enrolled in the study and were assigned to one of three groups according to their preferred training method: the Running Group (RG; $n = 19$, 13 females), the Stretching Group (SG; $n = 19$, 16 females), and the Control Group (CG; $n = 18$, 16 females). There were no significant differences in age or sex ratios ($ps > .05$) among the three groups. However, education level was significantly different among the groups ($F[2, 54] = 3.62$, $p = .033$, Table 1), with the SG receiving significantly fewer years of education than the CG ($p = .033$). There were no significant differences in BDI score ($ps > .05$) or Temporal Experience of Pleasure Scale (TEPS) score ($ps > .05$) among the three groups before physical training.

Assessments

Participants' depression levels were evaluated using the amended Beck Depression Inventory (BDI-IA). Both laboratory and self-report approaches were implemented to provide a more comprehensive picture of anticipatory, consummatory, and remembered pleasure and negative affect. The Monetary Incentive Delay (MID) task captures state-like emotional reactions through valence and arousal levels of participants, whereas the TEPS reflects trait-like affect towards daily life pleasurable activities.

MID task

We employed the MID task (Knutson et al., 2001; Yan et al., 2019) to assess the feeling dimension of anticipatory pleasure and consummatory pleasure experiences towards monetary rewards. Participants were required to hit the target as soon as possible to gain monetary rewards or avoid monetary loss. During the task, positive affect was triggered by winning money or avoiding losing money, whereas negative affect was triggered by losing or missing money. Participants rated valence and arousal towards potential future gains/losses before responding to the target and after receiving a monetary outcome. There were four types of outcomes based on participants' responses to the targets: gain, gain omission, loss avoidance, and loss. For each condition (gain or loss), there were three magnitudes of rewards: None (0 Yuan), low (0.5 Yuan), and high (5 Yuan). Baseline movements were captured using a tap-controlling task, where participants simply hit the target as fast as possible without any monetary cues.

Before the MID task, participants were required to complete a prediction questionnaire, which assessed the prediction dimension of anticipatory pleasure towards the gain/loss conditions that would be subsequently encountered during the MID task (e.g., "If you see a cue indicating you will gain 5 Chinese Yuan, how excited would you be?"; see Figure 1). To measure remembered pleasure, participants completed a questionnaire to recall their affective experience towards each condition during the task approximately 30 min after the MID task.

Assessment and questionnaires

The Chinese versions of the following questionnaires were employed to measure participants' affect before and after physical activity training. All questionnaires had acceptable reliability and validity.

The BDI-IA is a 21-item questionnaire that was used to evaluate depressive symptoms (Beck & Steer, 1987; Chan, 1991) and has an acceptable level of reliability (Cronbach's alpha .94; Lu et al., 2002). The score for each item ranged from 0 to 3, with a higher score indicating an elevated level of depressive symptoms. The BDI-IA score is interpreted according to the following guidelines (Beck & Steer, 1987; Smarr, 2003): minimal

TABLE 1 Pre-training means and standard deviations of three groups of participants

	The RG ($n = 19$) Mean (*SD*)	The SG ($n = 19$) Mean (*SD*)	The CG ($n = 18$) Mean (*SD*)	$t/F/\chi^2$	p	Cohen's d/η^2
Age (years)	20.3 (2.58)	19.1 (1.20)	20.7 (2.30)	2.82	.069	.096
Education (years)	14.3 (1.80)	13.3 (1.41)	14.8 (2.18)	3.62	**.033**	.120
Gender (female:male)	13:6	16:3	16:2	2.72	.256	…
Calories	142 (20.8)	72.3 (14.7)	…	12.1	**<.001**	3.92
Average heart rate	141 (9.5)	122 (12.5)	…	5.37	**<.001**	1.74
Maximum heart rate	197 (13.3)	205 (15.8)	…	−1.63	.112	−.528
Total training duration (min)	876 (187)	954 (91.8)	…	−1.64	.110	−0.532

Note: Calories and heart rate were consumed during physical activity. Bold numbers indicate that p values are lower than .05. Post-hoc analyses showed significant difference in years of education between the SG and the CG ($p = .033$, $d = 0.86$), indicating that participants in the SG received less education than those in the CG. No significant differences were found between the RG and the CG, as well as the RG and SG ($ps > .05$).
Abbreviations: CG, the Control group; RG, the Running group; SG, the Stretching group.

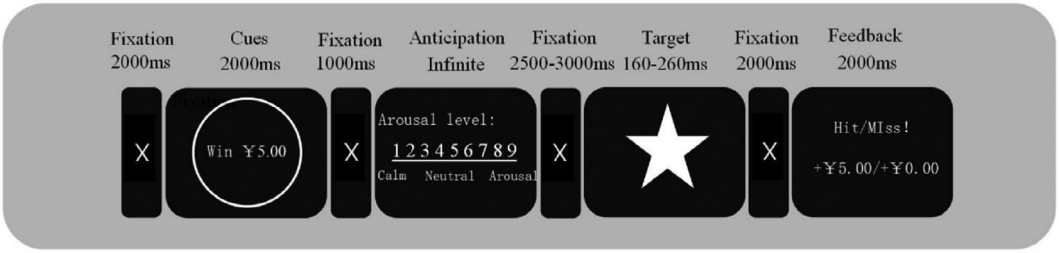

FIGURE 1 The flow chart of MID task. There were four types of blocks: Anticipatory valence block, Anticipatory arousal block, Consummatory valence block, Consummatory arousal block. For Anticipatory valence/arousal block as shown in the figure, the participants were presented with a cue indicating monetary rewards/losses at stake. During the anticipation phase, they were required to rate their subjective experience (e.g., arousal experience) before the presence of the target (e.g., "pentagram"). Then the participant pressed the "space" key as fast as possible to hit the target. Then, the feedback would be delivered to participants by informing whether or not they won the rewards/avoided the losses. Consummatory pleasure was examined in the Consummatory valence/arousal block. Participants were required to rate their valence/arousal rating after receiving the feedback instead of during anticipation phase

depression 0–9, mild depression 10–16, moderate depression 17–29, and severe depression 30–63.

To measure trait-like anhedonia symptoms, we used the TEPS (R. C. Chan et al., 2012; Gard et al., 2006), which is a 20-item scale used to capture self-reported anticipatory and consummatory pleasure. It comprises four factors: abstract and contextual dimensions of anticipatory pleasure and abstract and contextual dimensions of consummatory pleasure. Cronbach's alphas of the four factors were: abstract anticipatory .69, contextual anticipatory .63, abstract consummatory .72, and contextual consummatory .60 (R. C. Chan et al., 2012). Abstract anticipatory pleasure refers to the anticipation of something that is essentially abstract (e.g., "I look forward to a lot of things in life"), whereas contextual anticipatory pleasure refers to the anticipation of something that is concrete (e.g., "When I hear about a new movie starring my favorite actor, I cannot wait to see it"). Similarly, abstract consummatory pleasure is the consummation of an emotional experience that is abstract or less concrete (e.g., "The smell of freshly cut grass is enjoyable to me"), whereas contextual consummatory pleasure is the consummation of an emotional experience with more concrete concepts or scenarios (e.g., "When I think about eating my favorite food, I can almost taste how good it is"). A lower score on the TEPS reflects a higher level of anhedonia.

Training procedures

Each participant in the RG and SG was required to complete 24 individual training sessions within a 2-month period, which equated to an average of three sessions per week. The duration of each session increased from 25 min in the first week to up to 50 min in the last 3 weeks. Instructors were three undergraduate students from the Department of Psychology with experience in physical activity training and leading individual exercise sessions. The instructor-to-participant ratio was 3:56.

For the RG, participants were instructed to run on a track. For the SG, participants were asked to practice a series of flexing or stretching exercises that were selected from the Chinese fitness software Keep (https://www.gotokeep.com/; see Table 2 for details). The training duration of the SG was matched with the RG. The exercise regime of the SG was designed to be lower intensity compared with that of the RG, which was higher intensity aerobic exercise. Higher intensity exercise elicits greater physiological changes than lower intensity exercise, and moderate-to-vigorous exercise tends to be the most effective in reducing depression levels in individuals with major depressive disorder (Schuch et al., 2016). The RG and SG in the current study would indicate the varying effects produced by different intensities of physical activity on depressive symptoms in a subclinical population. For the CG, we did not provide any physical training instructions during the 2 months to ensure that the emotional changes that were observed in the RG or SG but not in the CG would reflect the influence of physical activity. Participants in both the RG and SG had their heart rate recorded by a wearable physical activity tracker (Maisimai monitoring heart rate meter and multi-functional sports watch; China Shenzhen Jianxing Technology Co., Ltd., Shenzhen, China), which consisted of a belt worn around the waist and a watch worn on the wrist during exercise. These physiological data were collected for monitoring participants to ensure they carried out exercise at a sufficient intensity (especially for the RG) to trigger the antidepressant effect of physical activity. Our analysis suggested that the RG consumed more calories and had a higher average heart rate than did the SG ($ps < .001$; see Table 1). However, we did not find any significant group differences in maximum heart rate during exercise or average training time of each session ($ps > .05$; see Table 1).

Data preparation and analyses

All data were analyzed using SPSS Version 23.0 (SPSS Inc., Chicago, IL, USA).

We used one-way analyses of variance (ANOVAs) to compare age and education level between the training groups (i.e., the RG and SG) and the CG. A chi-square test was performed to compare sex ratios between the three groups. We also performed independent samples *t*-tests to compare average/maximum heart rate, consumed calories, and average training time between the RG and SG. For anhedonia and

TABLE 2 The training arrangements for the running and stretching groups

Week	Training time (min)	The running group's training intensity (% maximum heart rate)	The stretching group (classes on KEEP software)	The control group
1	25	65	whole body stretching + stretching after running	No exercise
2	30	65	whole body stretching + horizontal splits	
3	35	70	torso stretching + vertical splits	
4	40	70	torso stretching + yoga flexibility	
5	45	70	whole body stretching + back shaping + legs shaping	
6	50	75	whole body stretching × 2 + hip shaping + introduction to abdominal muscle training	
7	50	75	upper limbs stretching + yoga core strength + lower limbs comprehensive warm-up	
8	50	75	upper limbs stretching + yoga basic strength + introduction to core muscles function	

Note: The Running and the Stretching group totally took part in 24 times of training in 2 months. While the Control group had no required training in this experiment. Data was collected from the heart rate belt and the wristwatch.

depression questionnaire scores, we carried out a 2 (time: pre-training and post-training) × 3 (group: RG, SG, and CG) mixed ANOVA.

We calculated composite ratings for the predicted dimension of anticipatory pleasure by averaging anticipatory and consummatory ratings for each magnitude and condition on the predicted questionnaire (Yan et al., 2019). A similar algorithm was applied to the ratings of the recall questionnaire to estimate remembered pleasure. To determine the effect of physical activity on the feeling dimensions of anticipatory and consummatory affect, we conducted 2 (time: pre-training and post-training) × 3 (group: RG, SG, and CG) × 3 (reward magnitude: none, low, and high) mixed ANOVAs for both the valence and arousal ratings of the MID task. We also applied 2 (time) × 3 (group) × 3 (reward magnitude) mixed ANOVAs for the composite ratings of predicted/recall questionnaires and reaction time (RT). To control for Type I error, Bonferroni correction was used for multiple comparisons.

Finally, we explored the relationship between affect change and training data in the RG and SG separately. We tested whether improvements in anhedonia and depression levels (e.g., anticipatory pleasure/BDI score post-training—anticipatory pleasure/BDI score pre-training) were related to physiological data and training parameters. Correlation analyses were conducted for changes in both anhedonia and depression levels with average heart rate, maximum heart rate, consumed calories, and training duration.

RESULTS

Reaction time in the MID task

Participants' motivation for rewards was reflected by their RT: the faster they hit the target, the more motivated they were towards receiving a reward. There was no significant Time × Group interaction for RT in the MID task for either the reward or loss condition (*p*s > .05). All three groups responded significantly faster after training compared with pre-training, which was reflected by a significant main effect of time (reward: $F[1, 53] = 6.19$, $p = .016$, partial $\eta^2 = .105$; loss: $F(1, 52) = 4.76$, $p = .034$, partial $\eta^2 = .084$; Table S1). We also observed a significant main effect of reward magnitude (*p*s < .001), which indicated that participants responded faster towards higher rewards or losses compared with no rewards/losses. Results were similar after controlling for years of education.

Changes in anticipatory affect

Pleasure

As expected, we observed a significant Time × Group interaction for arousal rating in anticipation of a future reward (feeling dimension: $F[2, 51] = 3.58$, $p = .035$, partial $\eta^2 = .123$; predictive dimension: $p > .05$; Figure 2). Simple effects analyses indicated that the RG displayed a higher level of arousal during the post-training period compared with the pre-training period ($F[1, 51] = 9.23$, $p = .004$, partial $\eta^2 = .153$). The interaction remained significant after education was included as a covariate ($p = .036$). No significant results were found for the other two groups (*p*s > .05). For valence ratings, we did not find a significant Time × Group × Reward magnitude interaction or group or time main effect for either the feeling or predictive dimension (*p*s > .05). Results remained non-significant after controlling for years of education (*p*s > .05). The main effects of reward magnitude were significant for all anticipatory pleasure ratings (*p*s < .001).

Negative affect

The main effect of group was marginally significant for predicted arousal ratings (predicted dimension: $F[2, 53] = 3.10$, $p = .053$, partial $\eta^2 = .105$). The RG predicted less arousal towards future loss compared with the CG ($p = .017$, Cohen's

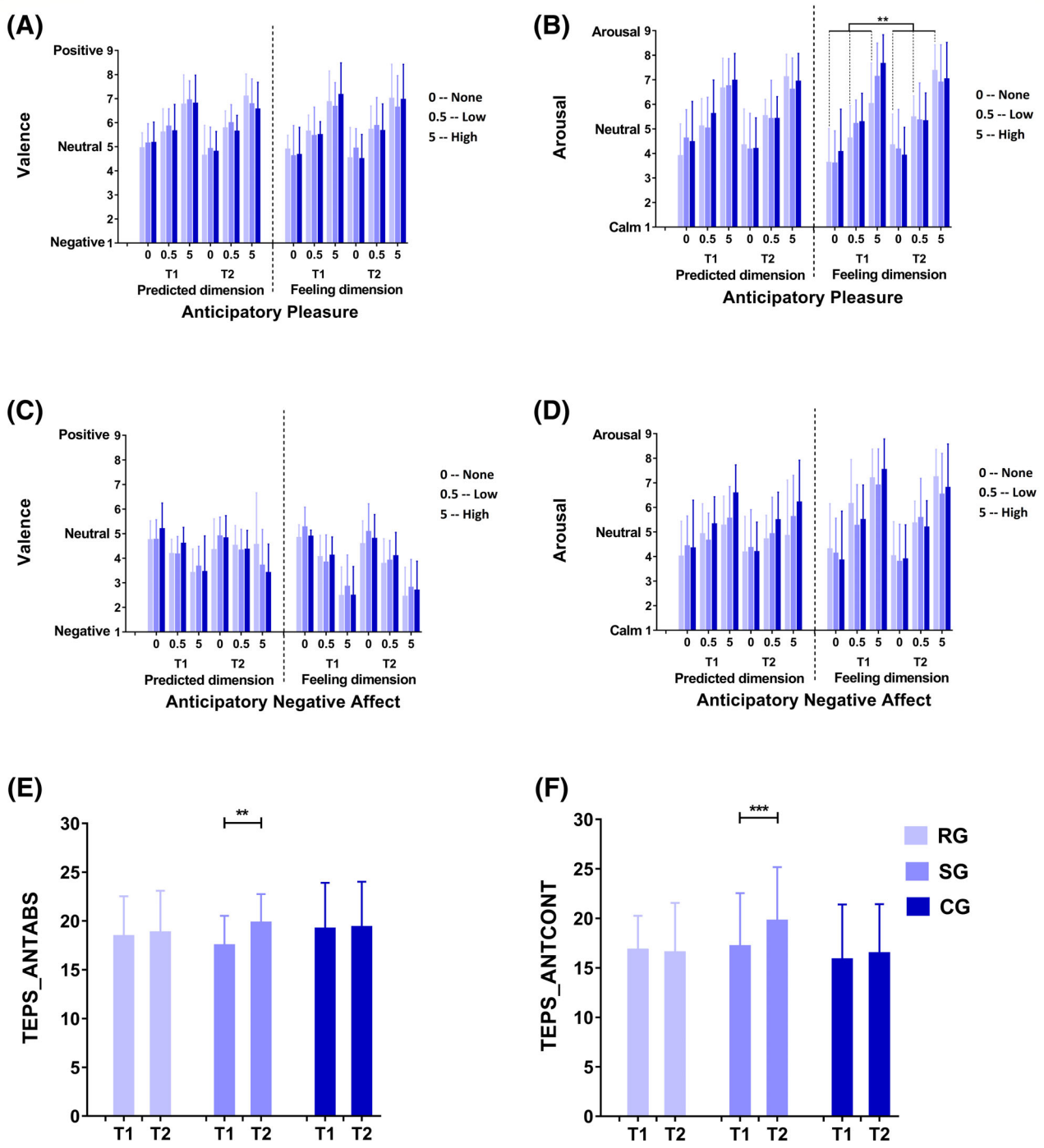

FIGURE 2 Training effect on anticipatory affective ratings in the MID task and TEPS scores among three groups. (A) and (B) represent the valence and arousal ratings of anticipatory pleasure. (C) and (D) represent the valence and arousal ratings of anticipatory negative affect. (E) and (F) refer to the scores changed on the Abstract and Contextual Anticipatory subscales of the TEPS. RG = Running Group; SG = Stretching Group; CG = Control Group. *$p < .05$, **$p < .01$, ***$p < .001$

$d = -.700$). However, we did not observe significant Time × Group or Time × Group × Reward magnitude interaction for arousal or valence ratings ($ps > .05$). For the feeling dimension, we found no significant group main effect or Group × Time × Reward magnitude interaction ($ps > .05$). Results were similar after controlling for education level. Finally, there were significant main effects of reward magnitude for both valence and arousal ratings ($ps < .001$).

Anticipatory factor scores on the TEPS

As shown in Figure 2, we found a significant Time × Group interaction for the contextual sub-scores of the TEPS ($F[2, 53] = 4.55$, $p = .015$, partial $\eta^2 = .146$) and a marginally significant interaction effect for the abstract sub-scores of the TEPS ($F[2, 53] = 3.10$, $p = .054$, partial $\eta^2 = .105$). Further simple effects analyses showed that the SG had higher scores

on both the Abstract and Contextual Anticipatory subscales of the TEPS post-training compared with those pre-training (Abstract: $F(1, 53) = 11.9$, $p = .001$, partial $\eta^2 = .184$; Contextual: $F(1, 53) = 14.3$, $p < .001$, partial $\eta^2 = .212$). However, there were no significant differences for anticipatory factor scores between pre- and post-training in the RG or CG ($ps > .05$). Similar results were revealed after controlling for education. During both the pre- and post-training periods, no significant differences for anticipatory factor scores were observed among the three groups in terms of Contextual and Abstract Anticipatory TEPS subscale scores ($ps > .05$).

Changes in consummatory affect

Pleasure

For loss avoidance, we observed a main effect of group ($F[2, 46] = 3.44$, $p = .040$, partial $\eta^2 = .130$). Both the RG and SG reported higher pleasantness than the CG (RG vs. CG, $p = .049$, Cohen's $d = .763$; SG vs. CG, $p = .016$, Cohen's $d = .958$, Table s3a). There was no significant main effect of group or interaction effects of group for other subjective ratings towards reward received ($ps > .05$). Significant main effects of reward magnitude were observed for pleasure experience in terms of valence and arousal for both reward received and loss avoidance outcomes ($ps < .003$). Similar results were found after controlling for years of education.

Negative affect

We did not find any significant main effects or a Group × Time interaction effect for either valence or arousal ratings towards outcomes of reward omission and loss ($ps > .05$, Table s3c and Table s3d). The main effects of reward magnitude were significant for valence and arousal for both outcomes ($ps < .005$). Similar results were found after controlling for education.

Consummatory scores of the TEPS

The SG showed an increase in scores for both the Abstract and Contextual Consummatory subscales of the TEPS after training (abstract: $F(1, 53) = 21.1$, $p < .001$, partial $\eta^2 = .285$; contextual: $F(1, 53) = 15.1$, $p < .001$, partial $\eta^2 = .221$), which was reflected by the Time × Group interaction (abstract: $F(2, 53) = 7.49$, $p = .001$, partial $\eta^2 = .220$; marginal significant interaction for contextual: $F(2, 53) = 2.45$, $p = .096$, partial $\eta^2 = .085$; Figure 3). The simple effects analysis revealed that the Abstract and Contextual Consummatory scores of the three groups did not significantly differ between before and after physical activity ($ps > .05$). We observed similar results after controlling for education.

Improvements in remembered pleasure and negative affect

For negative affect, we found a significant Time × Group × Reward magnitude interaction ($F[4, 104] = 4.21$, $p = .003$, partial $\eta^2 = .139$) and a significant Time × Group interaction ($F[2, 52] = 4.74$, $p = .013$, partial $\eta^2 = .154$) for remembered valence ratings. Further simple effects analyses revealed that the RG recalled less negativity towards loss conditions post-training compared with pre-training ($F[1, 52] = 16.7$, $p < .001$, partial $\eta^2 = .243$). The SG and CG did not show significant changes between the pre- and post-training periods ($ps > .05$). For pleasure, there was no significant main effect of group or interaction effect of group and valance or arousal ratings ($ps > .05$; Figure 4). The main effects of reward

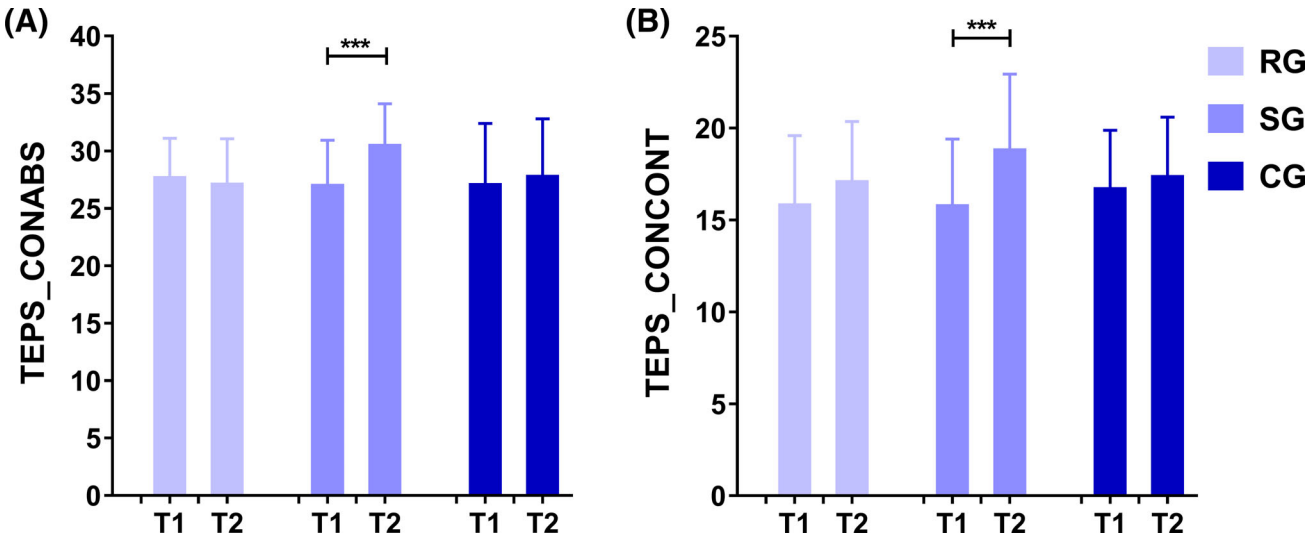

FIGURE 3 Training effect on the TEPS scores among three groups. (A) and (B) represent the scores changed on the Abstract and Contextual Consummatory subscales of the TEPS. RG = Running Group; SG = Stretching Group; CG = Control Group. *$p < .05$, **$p < .01$, ***$p < .001$

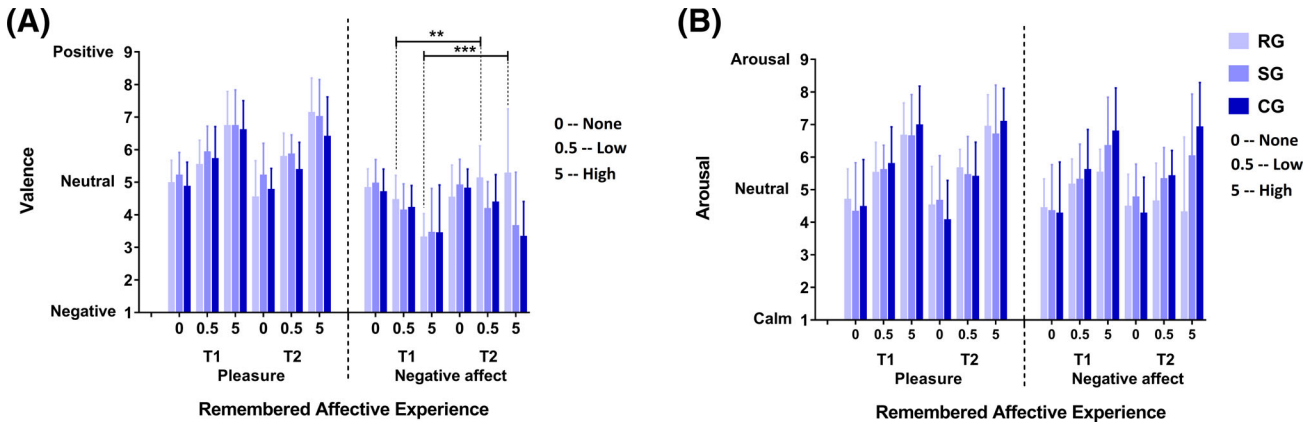

FIGURE 4 Training effect on the remembered affective experience in the MID task among three groups. (A) and (B) refer to valence and arousal ratings, respectively. RG = Running Group; SG = Stretching Group; CG = Control Group. * = $p < .05$, ** = $p < .01$, *** = $p < .001$

TABLE 3 The post-training means and standard deviations of questionnaires in three groups

		The RG ($n = 19$) Mean (*SD*)	The SG ($n = 19$) Mean (*SD*)	The CG ($n = 18$) Mean (*SD*)
BDI	Pre-training	21.2 (5.87)	21.8 (8.48)	21.2 (8.47)
	Post-training	11.5 (6.87)	14.3 (10.9)	17.1 (10.5)
TEPS_ANTABS	Pre-training	18.4 (4.11)	17.5 (3.06)	19.2 (4.74)
	Post-training	18.8 (4.30)	19.8 (2.96)	19.3 (4.69)
TEPS_ANTCONT	Pre-training	16.8 (3.47)	17.2 (5.39)	15.8 (5.58)
	Post-training	16.5 (5.03)	19.7 (5.45)	16.4 (5.00)
TPES_CONABS	Pre-training	27.6 (3.47)	27.0 (3.98)	27.0 (5.39)
	Post-training	27.1 (3.99)	30.4 (3.69)	27.7 (5.06)
TEPS_CONCONT	Pre-training	15.8 (3.81)	15.7 (3.66)	16.7 (3.22)
	Post-training	17.1 (3.31)	18.8 (4.16)	17.3 (3.27)

Abbreviations: ANTABS, Abstract Anticipatory Pleasure subscale; ANTCONT, Contextual Anticipatory Pleasure subscale; BDI, the Beck Depression Inventory; CG, the Control group; CONABS, Abstract Consummatory Pleasure subscale; CONCONT, Contextual Consummatory Pleasure subscale; RG, the Running group; SG, the Stretching group; TEPS, the Temporal Experience of Pleasure Scale.

magnitude were significant for all the remembered subjective ratings (*p*s < .001). Similar results were observed after controlling for years of education.

Improvement in depressive symptoms

Our analysis showed a significant main effect of time for total BDI score ($F[1, 54] = 28.9$, $p < .001$, partial $\eta^2 = .348$), which indicated that the level of depression decreased following training. However, the Time × Group interaction was not significant ($F[2, 53] = 1.48$, $p = .238$, partial $\eta^2 = .053$). Table 3 shows the descriptive statistics for the BDI and TEPS scores.

The relationships between affective improvements and training parameters

When we explored the relationships within the RG group, there was a significant negative correlation between improvement in anticipatory arousal ratings for pleasure and maximum heart rate ($r = -.50$, $p = .027$) and a positive correlation between improvement in anticipatory arousal ratings for pleasure and total training duration ($r = .46$, $p = .048$). Improvement in remembered valence ratings for negative affect towards low reward magnitude was significantly correlated with consumed calories ($r = .50$, $p = .030$), whereas improvement in remembered valence ratings for negative affect towards high reward magnitude was significantly negatively correlated with both maximum heart rate ($r = -.66$, $p = .002$) and consumed calories ($r = .52$, $p = .024$). Within the SG group, improvement in remembered negative affect was negatively correlated with average heart rate. No other significant results were observed.

DISCUSSION

The objective of this study was to examine the effect of physical activity on anticipatory pleasure, consummatory pleasure, remembered pleasure, and depression in university students with

moderate depressive symptoms. We found that, compared with stretching training and no training, running training increased arousal levels significantly more during the anticipation of a future reward but also decreased remembered negative affect towards loss condition more. In contrast, stretching training reduced trait-like anticipatory and consummatory pleasure, which was not observed in the RG or CG. Specifically, in the RG, greater anticipatory pleasure and remembered negative affect improvements were related to lower maximum heart rate, higher calories consumed, and longer total training duration, whereas in the SG, greater remembered negative affect improvements were related to lower average heart rate.

Effect of physical activity on anticipatory pleasure

After training, the RG showed a significant increase in arousal level towards a future reward during the MID task, which was not observed in the other groups. This indicated that running exercise improves anticipatory pleasure in terms of arousal in individuals with depressive symptoms. In addition, compared with the RG and SG, stretching exercise led to a significant increase in Abstract and Contextual Anticipatory Pleasure scores on the TEPS, which indicated that stretching improves trait-like anticipatory pleasure. These findings are in line with previous studies that examined the relationship between physical activity and anticipatory pleasure. Neuroimaging studies have found that physical exercise modulates the activity of brain regions involved in anticipatory reward processing by altering dopaminergic signaling in the ventral striatum, amygdala, and thalamus (Bothe et al., 2013; Saanijoki et al., 2018). In another study, researchers employed the effort expenditure for rewards task to detect individuals' effort expenditure for monetary stimuli, which reflects motivation towards rewards (Wardle et al., 2018). They found that participants who were more accustomed to physical exercise tended to experience increased motivation following physical activity, whereas those who exercised less did not. These outcomes raise the issue of participants' initial status, such as familiarity with exercising and baseline emotions, which may moderate the effect of exercise on anhedonia.

Effect of exercise on consummatory pleasure

The SG showed an increase in their Abstract and Contextual Consummatory Pleasure scores of the TEPS following physical activity, which supports its therapeutic effect on consummatory pleasure. These results were unexpected because high-intensity running exercise did not positively impact TEPS scores, whereas stretching, a low-intensity exercise, enhanced TEPS scores. There is limited research on the effect of stretching on hedonic well-being because stretching is primarily used as a control condition. However, the present findings of the TEPS score align with the findings of one study that concluded that the SG experienced an increase in pleasant affect over time (Follador et al., 2019). Moreover, inconsistently with the TEPS data, the SG did not experience significant changes in hedonic emotion during the MID task. Stretching training in the current study contained some yoga-based gestures, which are associated with improved positive affect and psychological well-being (Impett et al., 2006; Ivtzan & Papantoniou, 2014; Jadhav & Havalappanavar, 2009). Stretching improved TEPS scores but not performance on the MID task, which may be due to the specific components of yoga. The items of the TEPS assess the severity of trait anhedonia, which reflects general beliefs of pleasant life experiences involving interactions with the surrounding environment (e.g., "When I think about eating my favorite food, I can almost taste how good it is."); these are addressed during yoga practice and contribute to its promotion of happiness (Eggleston, 2008; Ivtzan et al., 2013; Singleton, 2010). Therefore, the SG in the current study was more likely to rate higher for trait hedonic capacity because of their raised spiritual awareness, whereas the increase in arousal during the MID task in the RG may be more likely to improve state anhedonia.

Effect of exercise on remembered pleasure

We also assessed remembered pleasure to explore the influence of physical activity training on emotional memory in depressed individuals. Compared with the other groups, the RG reported less negativity towards unfavorable outcomes. Depressed individuals tend to think of more negative memories and recall fewer positive memories (Bianchi et al., 2018; Hertel & Paula, 1998), and this memory bias is associated with depression severity (Archer et al., 2014; Marchetti et al., 2018). Because past experiences influence anticipation of the future (Schacter & Addis, 2007; Schacter et al., 2008), impaired memories of pleasure may hinder subsequent pleasant experiences and predict depressive symptoms (Everaert et al., 2015; Johnson et al., 2007; Marchetti et al., 2018). Several studies examining the relationship between physical exercise and memory have been conducted in populations without mental illness. In healthy adults, physical exercise heightens arousal levels, which facilitates memory storage and consolidation (Coles & Tomporowski, 2008; Mcgaugh, 2006). In depressed populations, memory abilities have also been shown to improve following physical activity, in addition to reducing depressive symptoms (Brondino et al., 2017; Krogh et al., 2009; Krogh et al., 2012). It has been speculated that physical activity promotes emotional memory via changes in affective responses, psychological attention (Scudder et al., 2012; Wade & Loprinzi, 2018), and norepinephrine, which plays a role in the modulation of emotional memory (Hamann, 2001; Segal et al., 2012). This finding extends the effect of exercise from the simple affect level to a more complex cognitive processing level.

The relationships between affective improvements and training parameters

As previously mentioned, participants' intensity of physical activity may moderate the effect of exercise on emotion. This is supported by our finding that changes in anhedonia level in

the RG were strongly correlated with maximum heart rate, calories consumed, and total training duration. In contrast, in the SG, only changes in remembered negative affect were linked to average heart rate. It seems reasonable that running induces more physiological modulation than stretching, given that it is a higher intensity exercise. Physical activity studies targeting neurobiological changes have suggested that higher intensity exercise tends to generate more neuroplasticity than moderate-intensity exercise and trigger a greater reduction in depressive symptoms (Kandola et al., 2019; Schuch et al., 2016). Sufficient exercise intensity is thought to be one of the critical factors for inducing an effective antidepressant effect with exercise.

Limitations

Although the findings of the present study contribute to our understanding of the relationship between physical activity and anhedonia, several limitations must be mentioned. Firstly, only 56 participants were recruited in this study and the sex ratio was unbalanced, with significantly more women, which limited the power of the study. Secondly, the CG was passive; although we did not offer any physical training, we had difficulty preventing participants from carrying out their own activities. Thirdly, both researchers and participants were not blinded to the study objectives. There may have been an expectation effect because the investigators and participants had knowledge of their situation and may have responded or performed in line with the treatment, which may have influenced the outcome (Curry et al., 2006). Moreover, participants were not randomly assigned to exercise groups. Instead, they chose to participate in either running or stretching. Although self-selection may promote autonomy and decrease the withdrawal rate, it may also bias the outcome. The blinding of intention and random group assignment were considered initially. However, it was deemed impractical for the current study because the training process was relatively long, and it would have been difficult to recruit participants without informing them of the aim of the study. We allowed participants to choose the type of physical activity to promote motivation and compliance.

CONCLUSION

Running positively impacted the arousal level of anticipatory pleasure and recall of negative affect. In contrast, stretching enhanced pleasant affect, which was based on individuals' beliefs and spirit. Both running and stretching may be promising for reducing the severity of depression. The findings of this study suggest that different types of physical exercise promote improvements in various dimensions of anhedonia and provide a more complex picture of depression treatment. Developing an exercise intervention that targets a specific depressive symptom, such as anhedonia, may provide insight into treatment effectiveness for clinical major depressive disorder.

ACKNOWLEDGMENTS

This study was supported by grants from the National Natural Science Foundation China (31500894), the MOE (Ministry of Education of China) Project of Humanities and Social Sciences (20YJC190025), Natural Science Foundation of Shanghai (21ZR142000) and the Fundamental Research Funds for the Central Universities (2018ECNUQKT015, 2019ECNUHWFW021).

CONFLICT OF INTEREST

The authors report no conflict in interest.

ORCID

Ching-wen Sun https://orcid.org/0000-0002-6536-6308
Ya-jing Wang https://orcid.org/0000-0003-0359-4548
Chao Yan https://orcid.org/0000-0002-0327-9321

REFERENCES

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders: DSM-5* (5th ed.). American Psychiatric Association.

Anderson, H. D., Pace, W. D., Libby, A. M., West, D. R., & Valuck, R. J. (2012). Rates of 5 common antidepressant side effects among new adult and adolescent cases of depression: A retrospective US claims study. *Clinical Therapeutics*, *34*(1), 113–123. https://doi.org/10.1016/j.clinthera.2011.11.024

Archer, T., Josefsson, T., & Lindwall, M. (2014). Effects of physical exercise on depressive symptoms and biomarkers in depression. *CNS & Neurological Disorders-Drug Targets*, *13*(10), 1640–1653. https://doi.org/10.2174/1871527313666141130203245

Beck, A. T., & Steer, R. A. (1987). *Manual for the Beck depression inventory*. The Psychological Corporation.

Bernstein, E. E., & McNally, R. J. (2017). Acute aerobic exercise helps overcome emotion regulation deficits. *Cognition and Emotion*, *31*(4), 834–843. https://doi.org/10.1080/02699931.2016.1168284

Bianchi, R., Laurent, E., Schonfeld, I. S., Bietti, L. M., & Mayor, E. (2018). Memory bias toward emotional information in burnout and depression. *Journal of Health Psychology*, *25*, 1567–1575. https://doi.org/10.1177/1359105318765621

Bothe, N., Zschucke, E., Dimeo, F., Heinz, A., Wüstenberg, T., & Ströhle, A. (2013). Acute exercise influences reward processing in highly trained and untrained men. *Medicine and Science in Sports and Exercise*, *45*(3), 583–591. https://doi.org/10.1249/MSS.0b013e318275306f

Boyer, P., Tassin, J. P., Falissart, B., & Troy, S. (2000). Sequential improvement of anxiety, depression and anhedonia with sertraline treatment in patients with major depression. *Journal of Clinical Pharmacy and Therapeutics*, *25*(5), 363–371. https://doi.org/10.1046/j.1365-2710.2000.00302.x

Brené, S., Bjørnebekk, A., Åberg, E., Mathé, A. A., Olson, L., & Werme, M. (2007). Running is rewarding and antidepressive. *Physiology & Behavior*, *92*(1–2), 136–140. https://doi.org/10.1016/j.physbeh.2007.05.015

Brondino, N., Rocchetti, M., Fusar-Poli, L., Codrons, E., Correale, L., Vandoni, M., Barbui, C., & Politi, P. (2017). A systematic review of cognitive effects of exercise in depression. *Acta Psychiatrica Scandinavica*, *135*(4), 285–295. https://doi.org/10.1111/acps.12690

Bylsma, L. M., Morris, B. H., & Rottenberg, J. (2008). A meta-analysis of emotional reactivity in major depressive disorder. *Clinical Psychology Review*, *28*(4), 676–691. https://doi.org/10.1016/j.cpr.2007.10.001

Chan, D. W. (1991). The Beck depression inventory: What difference does the Chinese version make. *Psychological Assessment*, *3*, 616–622. https://doi.org/10.1037/1040-3590.3.4.616

Chan, R. C., Shi, Y. F., Lai, M. K., Wang, Y. N., Wang, Y., & Kring, A. M. (2012). The temporal experience of pleasure scale (TEPS): Exploration and confirmation of factor structure in a healthy Chinese sample. *PLoS One*, *7*(4), e35352. https://doi.org/10.1371/journal.pone.0035352

Coles, K., & Tomporowski, P. D. (2008). Effects of acute exercise on executive processing, short-term and long-term memory. *Journal of Sports Sciences*, *26*(3), 333–344. https://doi.org/10.1080/02640410701591417

Cramer, H., Anheyer, D., Lauche, R., & Dobos, G. (2017). A systematic review of yoga for major depressive disorder. *Journal of Affective Disorders*, *213*, 70–77. https://doi.org/10.1016/j.jad.2017.02.006

Craske, M. G., Meuret, A. E., Ritz, T., Treanor, M., & Dour, H. J. (2016). Treatment for anhedonia: A neuroscience driven approach. *Depression and Anxiety*, *33*(10), 927–938. https://doi.org/10.1002/da.22490

Curry, J., Rohde, P., Simons, A., Silva, S., Vitiello, B., Kratochvil, C., … March, J. (2006). Predictors and moderators of acute outcome in the treatment for adolescents with depression study (TADS). *Journal of the American Academy of Child and Adolescent Psychiatry*, *45*(12), 1427–1439. https://doi.org/10.1097/01.chi.0000240838.78984.e2

DeWilde, K. E., Levitch, C. F., Murrough, J. W., Mathew, S. J., & Losifescu, D. V. (2015). The promise of ketamine for treatment-resistant depression: Current evidence and future directions. *Annals of the New York Academy of Sciences*, *1345*(1), 47–58. https://doi.org/10.1111/nyas.12646

Dishman, R. K., & O'Connor, P. J. (2009). Lessons in exercise neurobiology: The case of endorphins. *Mental Health and Physical Activity*, *2*(1), 4–9. https://doi.org/10.1016/j.mhpa.2009.01.002

Eggleston, B. (2008). Psychosocial determinants of attending yoga classes: An application of the theory of planned behavior. ProQuest Dissertations. https://doi.org/10.1017/CBO9781107415324.004

Everaert, J., Duyck, W., & Koster, E. H. (2015). Emotionally biased cognitive processes: The weakest link predicts prospective changes in depressive symptom severity. *PLoS One*, *10*(5), e0124457. https://doi.org/10.1371/journal.pone.0124457

Follador, L., Alves, R. C., Ferreira, S. D. S., Silva, A. C., & Silva, S. G. D. (2019). Perceived exertion and affect from tai chi, yoga, and stretching classes for elderly women. *Perceptual and Motor Skills*, *126*(2), 223–240. https://doi.org/10.1177/0031512518823661

Garcia, D., Archer, T., Moradi, S., & Andersson-Arntén, A. C. (2012). Exercise frequency, high activation positive affect, and psychological well-being: Beyond age, gender, and occupation. *Psychology*, *3*(4), 328–336. https://doi.org/10.4236/psych.2012.34047

Gard, D. E., Gard, M. G., Kring, A. M., & John, O. P. (2006). Anticipatory and consummatory components of the experience of pleasure: A scale development study. *Journal of Research in Personality*, *40*(6), 1086–1102. https://doi.org/10.1016/j.jrp.2005.11.001

Gard, D. E., Kring, A. M., Gard, M. G., Horan, W. P., & Green, M. F. (2007). Anhedonia in schizophrenia: Distinctions between anticipatory and consummatory pleasure. *Schizophrenia Research*, *93*(1–3), 253–260. https://doi.org/10.1016/j.schres.2007.03.008

Gotlib, I. H., & Joormann, J. (2010). Cognition and depression: Current status and future directions. *Annual Review of Clinical Psychology*, *6*, 285–312. https://doi.org/10.1146/annurev.clinpsy.121208.131305

Hall, J., O'Carroll, R. E., & Frith, C. D. (2010). Neuropsychology. In E. C. Johnstone, D. C. Owens, S. M. Lawrie, A. M. McIntosh, & M. Sharpe (Eds.), *Companion to psychiatric studies* (pp. 121–140). Churchill Livingstones.

Hamann, S. (2001). Cognitive and neural mechanisms of emotional memory. *Trends in Cognitive Sciences*, *5*(9), 394–400. https://doi.org/10.1016/S1364-6613(00)01707-1

Harris, A. H., Cronkite, R., & Moos, R. (2006). Physical activity, exercise coping, and depression in a 10-year cohort study of depressed patients. *Journal of Affective Disorders*, *93*(1–3), 79–85. https://doi.org/10.1016/j.jad.2006.02.013

Hertel, P. T., & Paula, T. (1998). Relation between rumination and impaired memory in dysphoric moods. *Journal of Abnormal Psychology*, *107*(1), 166–172. https://doi.org/10.1037/0021-843X.107.1.166

Hoerger, M., Quirk, S. W., Chapman, B. P., & Duberstein, P. R. (2012). Affective forecasting and self-rated symptoms of depression, anxiety, and hypomania: Evidence for a dysphoric forecasting bias. *Cognition & Emotion*, *26*(6), 1098–1106. https://doi.org/10.1080/02699931.2011.631985

Höflich, A., Michenthaler, P., Kasper, S., & Lanzenberger, R. (2018). Circuit mechanisms of reward, anhedonia, and depression. *International Journal of Neuropsychopharmacology*, *22*(2), 105–118. https://doi.org/10.1093/ijnp/pyy081

Impett, E. A., Daubenmier, J. J., & Hirschman, A. L. (2006). Minding the body: Yoga, embodiment, and well-being. *Sexuality Research & Social Policy*, *3*(4), 39–48. https://doi.org/10.1525/srsp.2006.3.4.39

Ivtzan, I., Chan, C. P., Gardner, H. E., & Prashar, K. (2013). Linking religion and spirituality with psychological well-being: Examining self-actualisation, meaning in life, and personal growth initiative. *Journal of Religion and Health*, *52*(3), 915–929. https://doi.org/10.1007/s10943-011-9540-2

Ivtzan, I., & Papantoniou, A. (2014). Yoga meets positive psychology: Examining the integration of hedonic (gratitude) and eudaimonic (meaning) wellbeing in relation to the extent of yoga practice. *Journal of Bodywork and Movement Therapies*, *18*(2), 183–189. https://doi.org/10.1016/j.jbmt.2013.11.005

Jadhav, S. G., & Havalappanavar, N. B. (2009). Effect of yoga intervention on anxiety and subjective well-being. *Journal of the Indian Academy of Applied Psychology*, *35*(1), 27–31. http://medind.nic.in/jak/t09/i1/jakt09i1p27.pdf

Johnson, S. L., Joormann, J., & Gotlib, I. H. (2007). Does processing of emotional stimuli predict symptomatic improvement and diagnostic recovery from major depression? *Emotion*, *7*(1), 201–206. https://doi.org/10.1037/1528-3542.7.1.201

Josefsson, T., Lindwall, M., & Archer, T. (2014). Physical exercise intervention in depressive disorders: Meta-analysis and systematic review. *Scandinavian Journal of Medicine & Science in Sports*, *24*(2), 259–272. https://doi.org/10.1111/sms.12050

Kandola, A., Ashdown-Franks, G., Hendrikse, J., Sabiston, C. M., & Stubbs, B. (2019). Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neuroscience and Biobehavioral Reviews*, *107*, 525–539. https://doi.org/10.1016/j.neubiorev.2019.09.040

Knapen, J., Vancampfort, D., Moriën, Y., & Marchal, Y. (2015). Exercise therapy improves both mental and physical health in patients with major depression. *Disability and Rehabilitation*, *37*(16), 1490–1495. https://doi.org/10.3109/09638288.2014.972579

Knutson, B., Adams, C. M., Fong, G. W., & Hommer, D. (2001). Anticipation of increasing monetary reward selectively recruits nucleus accumbens. *Journal of Neuroscience*, *21*(16), RC159. https://doi.org/10.1523/jneurosci.21-16-j0002.2001

Kohn, R., Saxena, S., Levav, I., & Saraceno, B. (2004). The treatment gap in mental health care. *Bulletin of the World Health Organization*, *82*, 858–866. http://S0042-96862004001100011

Kring, A. M., & Barch, D. M. (2014). The motivation and pleasure dimension of negative symptoms: Neural substrates and behavioral outputs. *European Neuropsychopharmacology*, *24*(5), 725–736. https://doi.org/10.1016/j.euroneuro.2013.06.007

Kring, A. M., & Caponigro, J. M. (2010). Emotion in schizophrenia: Where feeling meets thinking. *Current Directions in Psychological Science*, *19*(4), 255–259. https://doi.org/10.1177/0963721410377599

Kring, A. M., & Elis, O. (2013). Emotion deficits in people with schizophrenia. *Annual Review of Clinical Psychology*, *9*, 409–433. https://doi.org/10.1146/annurev-clinpsy-050212-185538

Krogh, J., Saltin, B., Gluud, C., & Nordentoft, M. (2009). The DEMO trial: A randomized, parallel-group, observer-blinded clinical trial of strength versus aerobic versus relaxation training for patients with mild to moderate depression. *Journal of Clinical Psychiatry*, *70*(6), 790–800. https://doi.org/10.4088/JCP.08m04241

Krogh, J., Videbech, P., Thomsen, C., Gluud, C., & Nordentoft, M. (2012). DEMO-II trial. Aerobic exercise versus stretching exercise in patients with major depression—A randomised clinical trial. *PLoS One*, *7*(10), e48316. https://doi.org/10.1371/journal.pone.0048316

Kvam, S., Kleppe, C. L., Nordhus, I. H., & Hovland, A. (2016). Exercise as a treatment for depression: A meta-analysis. *Journal of Affective Disorders*, *202*, 67–86. https://doi.org/10.1016/j.jad.2016.03.063

Larson, C. L., Nitschke, J. B., & Davidson, R. J. (2007). Common and distinct patterns of affective response in dimensions of anxiety and depression. *Emotion*, *7*(1), 182–191. https://doi.org/10.1037/1528-3542.7.1.182

Lépine, J. P., & Briley, M. (2011). The increasing burden of depression. *Neuropsychiatric Disease and Treatment*, *7*(Suppl 1), 3–7. https://doi.org/10.2147/NDT.S19617

Leventhal, A. M. (2012). Relations between anhedonia and physical activity. *American Journal of Health Behavior*, *36*(6), 860–872. https://doi.org/10.5993/AJHB.36.6.12

Loas, G., & Krystkowiak, P. (2010). The measurement of anhedonia in Parkinson's disease: Psychometric properties of the Snaith-Hamilton Pleasure Scale (SHAPS) and the relevance to distinguish anticipatory and consummatory anhedonias. *Movement Disorders*, *25*(4), 523–524. https://doi.org/10.1002/mds.22972

Lu, M. L., Che, H. H., Chang, S. W., & Shen, W. W. (2002). Reliability and validity of the Chinese version of the Beck depression inventory-II. *Taiwanese Journal of Psychiatry*, *16*, 301–310.

Marchetti, I., Everaert, J., Dainer-Best, J., Loeys, T., Beevers, C. G., & Koster, E. H. (2018). Specificity and overlap of attention and memory biases in depression. *Journal of Affective Disorders*, *225*, 404–412. https://doi.org/10.1016/j.jad.2017.08.037

Martinotti, G., Sepede, G., Gambi, F., Di Iorio, G., De Berardis, D., Di Nicola, M., … Di Giannantonio, M. (2012). Agomelatine versus venlafaxine XR in the treatment of anhedonia in major depressive disorder: A pilot study. *Journal of Clinical Psychopharmacology*, *32*(4), 487–491. https://doi.org/10.1097/JCP.0b013e31825d6c25

McFarland, B. R., & Klein, D. N. (2009). Emotional reactivity in depression: Diminished responsiveness to anticipated reward but not to anticipated punishment or to nonreward or avoidance. *Depression and Anxiety*, *26*(2), 117–122. https://doi.org/10.1002/da.20513

McGaugh, J. L. (2006). Make mild moments memorable: Add a little arousal. *Trends in Cognitive Sciences*, *10*(8), 345–347. https://doi.org/10.1016/j.tics.2006.06.001

Mneimne, M., McDermut, W., & Powers, A. S. (2008). Affective ratings and startle modulation in people with nonclinical depression. *Emotion*, *8*(4), 552–559. https://doi.org/10.1037/a0012827

Pigott, H. E. (2015). The STAR*D trial: It is time to reexamine the clinical beliefs that guide the treatment of major depression. *Canadian Journal of Psychiatry*, *60*(1), 9–13. https://doi.org/10.1177/070674371506000104

Platt, B., Waters, A. M., Schulte-Koerne, G., Engelmann, L., & Salemink, E. (2017). A review of cognitive biases in youth depression: Attention, interpretation and memory. *Cognition and Emotion*, *31*(3), 462–483. https://doi.org/10.1080/02699931.2015.1127215

Rugulies, R. (2002). Depression as a predictor for coronary heart disease: A review and meta-analysis. *American Journal of Preventive Medicine*, *23*(1), 51–61. https://doi.org/10.1016/S0749-3797(02)00439-7

Rush, A. J., Trivedi, M. H., Wisniewski, S. R., Nierenberg, A. A., Stewart, J. W., Warden, D., Niederehe, G., Thase, M. E., Lavori, P. W., Lebowitz, B. D., McGrath, P. J., Rosenbaum, J. F., Sackeim, H. A., Kupfer, D. J., Luther, J., & Fava, M. (2006). Acute and longer-term outcomes in depressed outpatients requiring one or several treatment steps: A STAR*D report. *The American Journal of Psychiatry*, *163*(11), 1905–1917. https://doi.org/10.1176/ajp.2006.163.11.1905

Saanijoki, T., Nummenmaa, L., Tuulari, J. J., Tuominen, L., Arponen, E., Kalliokoski, K. K., & Hirvonen, J. (2018). Aerobic exercise modulates anticipatory reward processing via the μ-opioid receptor system. *Human Brain Mapping*, *39*(10), 3972–3983. https://doi.org/10.1002/hbm.24224

Schacter, D. L., & Addis, D. R. (2007). Remembering the past to imagine the future: A cognitive neuroscience perspective. *Nature Reviews Neuroscience*, *8*, 657–661. http://doi.org/10.1080/08995600802554748

Schacter, D. L., Addis, D. R., & Buckner, R. L. (2008). Episodic simulation of future events - concepts, data, and applications. *Annals of the New York Academy of Sciences*, *1124*(1), 39–60. http://doi.org/10.1196/annals.1440.001

Schuch, F. B., & Stubbs, B. (2019). The role of exercise in preventing and treating depression. *Current Sports Medicine Reports*, *18*(8), 299–304. https://doi.org/10.1249/JSR.0000000000000620

Schuch, F. B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P. B., & Stubbs, B. (2016). Exercise as a treatment for depression: A meta-analysis adjusting for publication bias. *Journal of Psychiatric Research*, *77*, 42–51. https://doi.org/10.1016/j.jpsychires.2016.02.023

Scudder, M. R., Drollette, E. S., Pontifex, M. B., & Hillman, C. H. (2012). Neuroelectric indices of goal maintenance following a single bout of physical activity. *Biological Psychology*, *89*(2), 528–531. https://doi.org/10.1016/j.biopsycho.2011.12.009

Segal, S. K., Cotman, C. W., & Cahill, L. F. (2012). Exercise-induced noradrenergic activation enhances memory consolidation in both normal aging and patients with amnestic mild cognitive impairment. *Journal of Alzheimer's Disease*, *32*(4), 1011–1018. https://doi.org/10.3233/JAD-2012-121078

Sigwalt, A. R., Budde, H., Helmich, I., Glaser, V., Ghisoni, K., Lanza, S., … De Matos, F. J. (2011). Molecular aspects involved in swimming exercise training reducing anhedonia in a rat model of depression. *Neuroscience*, *192*, 661–674. https://doi.org/10.1016/j.neuroscience.2011.05.075

Singleton, M. (2010). *Yoga body: The origins of modern posture practice*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780195395358.001.0001

Sloan, D. M., Strauss, M. E., & Wisner, K. L. (2001). Diminished response to pleasant stimuli by depressed women. *Journal of Abnormal Psychology*, *110*(3), 488–493. https://doi.org/10.1037/0021-843X.110.3.488

Smarr, K. L. (2003). Measures of depression and depressive symptoms: The Beck depression inventory (BDI), Center for Epidemiological Studies-Depression Scale (CES-D), geriatric depression scale (GDS), hospital anxiety and depression scale (HADS), and primary care evaluation of mental disorders-mood module (PRIME-MD). *Arthritis Care & Research*, *49*(S5), S134–S146. https://doi.org/10.1002/art.11410

Ströhle, A. (2019). Sports psychiatry: Mental health and mental disorders in athletes and exercise treatment of mental disorders. *European Archives of Psychiatry and Clinical Neuroscience*, *269*(5), 485–498. https://doi.org/10.1007/s00406-018-0891-5

Ströhle, A., Höfler, M., Pfister, H., Müller, A. G., Hoyer, J., Wittchen, H. U., & Lieb, R. (2007). Physical activity and prevalence and incidence of mental disorders in adolescents and young adults. *Psychological Medicine*, *37*(11), 1657–1666. https://doi.org/10.1017/S003329170700089X

Tomarken, A. J., Dichter, G. S., Freid, C., Addington, S., & Shelton, R. C. (2004). Assessing the effects of bupropion SR on mood dimensions of depression. *Journal of Affective Disorders*, *78*(3), 235–241. https://doi.org/10.1016/S0165-0327(02)00306-3

Tordeurs, D., Janne, P., Appart, A., Zdanowicz, N., & Reynaert, C. (2011). Effectiveness of physical exercise in psychiatry: A therapeutic approach? *L'Encephale*, *37*(5), 345–352. https://doi.org/10.1016/j.encep.2011.02.003

Toups, M., Carmody, T., Greer, T., Rethorst, C., Grannemann, B., & Trivedi, M. H. (2017). Exercise is an effective treatment for positive valence symptoms in major depression. *Journal of Affective Disorders*, *209*, 188–194. https://doi.org/10.1016/j.jad.2016.08.058

Wade, B., & Loprinzi, P. D. (2018). The experimental effects of acute exercise on long-term emotional memory. *Journal of Clinical Medicine*, *7*(12), 486. https://doi.org/10.3390/jcm7120486

Wan, L. B., Levitch, C. F., Perez, A. M., Brallier, J. W., Losifescu, D. V., Chang, L. C., … Murrough, J. W. (2015). Ketamine safety and tolerability in clinical trials for treatment-resistant depression. *Journal of Clinical Psychiatry*, *76*(3), 247–252. https://doi.org/10.4088/JCP.13m08852

Wardle, M. C., Lopez-Gamundi, P., & LaVoy, E. C. (2018). Effects of an acute bout of physical exercise on reward functioning in healthy adults. *Physiology & Behavior*, *194*, 552–559. https://doi.org/10.1016/j.physbeh.2018.07.010

Waters, L. A., Galichet, B., Owen, N., & Eakin, E. (2011). Who participates in physical activity intervention trials? *Journal of Physical Activity & Health*, *8*(1), 85–103. https://doi.org/10.1123/jpah.8.1.85

Webb, C. A., Rosso, I. M., & Rauch, S. L. (2017). Internet-based cognitive behavioral therapy for depression: Current progress & future directions.

Harvard Review of Psychiatry, *25*(3), 114–122. https://doi.org/10.1097/HRP.0000000000000139

Whang, W., Kubzansky, L. D., Kawachi, I., Rexrode, K. M., Kroenke, C. H., Glynn, R. J., Garan, H., & Albert, C. M. (2009). Depression and risk of sudden cardiac death and coronary heart disease in women: Results from the Nurses' Health Study. *Journal of the American College of Cardiology*, *53*(11), 950–958. https://doi.org/10.1016/j.jacc.2008.10.060

World Health Organization. (2010). *International Statistical Classification of Diseases and Related Health Problems: Instruction manual, Family practice management*. Retrieved March 15, 2021, from https://www.who.int/classifications/icd/ICD10Volume2_en_2010.pdf

Yan, C., Lui, S. S. Y., Zou, L. q., Wang, C. Y., Zhou, F. C., Cheung, E. F. C., … Chan, R. C. K. (2019). Anticipatory pleasure for future rewards is attenuated in patients with schizophrenia but not in individuals with schizotypal traits. *Schizophrenia Research*, *206*, 118–126. https://doi.org/10.1016/j.schres.2018.12.003

Yuan, J. W., & Kring, A. M. (2009). Dysphoria and the prediction and experience of emotion. *Cognition and Emotion*, *23*(6), 1221–1232. https://doi.org/10.1080/02699930802416453

SUPPORTING INFORMATION

Additional supporting information may be found in the online version of the article at the publisher's website.

How to cite this article: Sun, C., Wang, Y., Fang, Y., He, Y., Wang, X., So, B. C. L., Shum, D. H. K., & Yan, C. (2022). The effect of physical activity on anhedonia in individuals with depressive symptoms. *PsyCh Journal*, *11*(2), 214–226. https://doi.org/10.1002/pchj.485