Review

LET'S GET PHYSICAL: A CONTEMPORARY REVIEW OF THE ANXIOLYTIC EFFECTS OF EXERCISE FOR ANXIETY AND ITS DISORDERS

Gordon J. G. Asmundson, Ph.D.,[1]* Mathew G. Fetzner, M.A.,[1] Lindsey B. DeBoer, M.A.,[2] Mark B. Powers, Ph.D.,[2] Michael W. Otto, Ph.D.,[3] and Jasper A. J. Smits, Ph.D.[2]

Research over the past few decades has focused on the therapeutic effects of physical exercise among those affected by mood disorders. Only recently has attention turned to maladaptive and persistent expressions of anxiety, with a growing body of evidence indicating promise for exercise as an effective treatment for some of the anxiety disorders. The current review provides a comprehensive account of contemporary research examining the anxiolytic effects of exercise for anxiety disorders. We synthesize pertinent research regarding the effects of various types of exercise within the different anxiety disorders, consider impact of various types of exercise regimens on anxiety, and examine potential anxiolytic mechanisms responsible for positive mental health gains. We conclude with important considerations for implementing exercise as a treatment for clinically significant anxiety as well as future research directions. Depression and Anxiety 30:362–373, 2013.

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INTRODUCTION

North American guidelines recommend that adults accumulate at least 150 min of moderate-to-vigorous physical activity every week in order to obtain substantial health benefits.[1,2] Only 15% of Canadian adults[3] and 30% of American adults[4] report meeting or exceeding this recommendation, leaving a substantive portion that lead generally sedentary lifestyles. Indeed, 36% of American adults report not being physically active.[4] Epidemiological studies using cross-sectional[5–8] and prospective[8] data from large North American and European samples have consistently found that individuals who engage in regular physical activity are less likely to suffer the same mental health problems as nonactive individuals. More than two decades ago the US National Institute of Mental Health recognized the link between physical activity and emotional well-being and emphasized the need for methodologically sound investigations into the mechanisms that underlie the mental health benefits of exercise.[9]

Anxiety disorders—the most commonly diagnosed mental disorders—exert substantial economic strain on society (e.g., increased health care costs and utilization).[10,11] Those affected are often faced with numerous barriers to treatment (e.g., lack of availability of services).[12] Recent research suggests that anxiety disorders are on the rise;[10] thus, investigations of cost efficient and widely accessible stand-alone or adjunctive interventions may be of benefit. Mounting evidence

[1]**Anxiety and Illness Behaviours Laboratory, Department of Psychology, University of Regina, Regina, Saskatchewan**
[2]**Southern Methodist University, Dallas, Texas**
[3]**Boston University, Boston, Massachusetts**

Dr. Otto serves as consultant for MicroTransponder, Inc. and receives royalties for some of the books mentioned in this review. Dr. Smits receives royalties for some of the books mentioned in this review.

*Correspondence to: Gordon J. G. Asmundson, Anxiety and Illness Behaviours Laboratory, Department of Psychology, University of Regina, Regina, SK S4S 0A2, Canada. E-mail: gordon.asmundson@uregina.ca.

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indicates that exercise may be one such intervention. There is considerable evidence that exercise confers protective effects against the acute effects of anxiety[13–17] and reactivity to stressors.[18–21] Although the therapeutic effects of exercise on anxiety disorders have received comparatively less empirical attention to date, the available evidence is promising. What follows is a comprehensive review of contemporary literature examining the anxiolytic effects of physical activity for specific anxiety disorders as well as the effectiveness of specific exercise paradigms in anxiety reduction, discussion of potential anxiolytic mechanisms responsible for positive mental health gains, important considerations for implementing exercise as a treatment for clinically significant anxiety, and suggested avenues for future research. The effects of exercise on other disorders (e.g., mood disorders) are reviewed elsewhere.[21,22]

Published studies were identified for inclusion in the review using electronic searches of MEDLINE®, PsycInfo®, and the Cochrane Library from 1995 to November 2012. We used the search terms of "anxiety" or full (e.g., "posttraumatic stress disorder" (PTSD)) and abbreviated (e.g., "OCD") anxiety disorder names in combination with "exercise," "aerobic exercise," "anaerobic exercise," "resistance training," "tai chi," or "yoga." Studies that investigated specific anxiety disorders and nonspecific anxiety measures using either self-report or laboratory-measured physical activity were retained. Several additional studies of relevance were identified in reference sections of studies found via the electronic searches and were included in the review.

EXERCISE AND THE ANXIETY DISORDERS

Goodwin[5] examined the association between regular physical activity and mental disorders using cross sectional data from a large nationally representative sample of American adults ($N = 8{,}098$). Data indicated that the prevalence of panic attacks (OR = 0.73 [0.56–0.96]), social anxiety disorder (SAD; OR = 0.65 [0.53–0.80]), specific phobia (OR = 0.78 [0.63–0.97]), and agoraphobia (OR = 0.64 [0.43–0.94]) were significantly lower among those reporting regular physical activity than those who did not. Although these findings suggest an association between regular physical activity and lower prevalence of some anxiety disorders, the nature of the investigation precludes conclusion regarding the effectiveness of exercise in the reduction of anxiety symptoms. Table 1 summarizes the details of studies designed to specifically assess the effects of exercise on several distinct anxiety disorders.

MIXED SAMPLES

Martinsen and colleagues[23] examined the effects of 8-week aerobic and nonaerobic exercise programs for inpatients with panic disorder with agoraphobia, SAD, and generalized anxiety disorder (GAD). Patients participated in 30 min of exercise three times weekly. Both exercise programs resulted in significant improvements on clinician-rated and self-report measures of anxiety at posttreatment, with no significant differences between conditions. The small sample and lack of a nonexercise or other control condition are major limitations of this study. Using a somewhat different approach, Merom et al.[24] assessed whether cognitive behavior therapy (CBT) supplemented with exercise was more effective than CBT alone for outpatients with GAD, SAD, or panic disorder. All patients received CBT and were randomized to either a home-based walking group or additional education sessions. The home-based walking condition was not standardized; rather, each patient was instructed to increase walking frequency to five times or more per week for at least 150 min in total. Results demonstrated that those in the home-based walking condition reported significantly greater reductions in anxiety, depression, and stress at posttreatment than did those receiving CBT without exercise.

PANIC DISORDER

Broocks and colleagues[25] used a randomized controlled trail (RCT) design to compare 10 weeks of aerobic exercise to clomipramine and pill placebo in 46 patients with panic disorder. Patients randomized to the exercise condition were asked to complete a 4-mile route three times weekly. Drop out rates were 31, 27, and 0% for the exercise, clomipraimmine, and placebo conditions, respectively. Both treatments resulted in equal reductions in anxiety and outperformed placebo at posttreatment, but clomipramine yielded greater improvements in Clinical Global Impression (CGI[26]) ratings than exercise. Wedekind and colleagues[27] compared 10 weeks of exercise and relaxation, each combined with either paroxetine or pill placebo, in 75 patients with panic disorder with agoraphobia. All groups had reduced panic symptoms at posttreatment, with the paroxetine treated groups showing greater improvement than pill placebo groups. All groups also showed improvements in CGI ratings, with exercise plus paroxetine and relaxation plus paroxetine outperforming relaxation plus placebo, and exercise plus placebo showing a trend to outperform relaxation plus placebo. Most recently, when Hovland and colleagues[28] compared exercise to group CBT in 36 patients with panic disorder, both conditions produced significant reductions in panic disorder symptoms; however, the group receiving CBT experienced greater overall reductions in symptoms at posttreatment and 1-year follow-up than did the group receiving exercise. Collectively, these findings suggest that exercise holds promise as an intervention for panic disorder.

SAD

A more recent RCT compared exercise to mindfulness-based stress reduction (MBSR) and no treatment among 77 adults with SAD.[29] The exercise intervention comprised three weekly aerobic

TABLE 1. Studies examining the effects of exercise protocols on anxiety disorders

Study	Sample (*n*)	Groups	Exercise type	Duration/ frequency	General findings
Martinsen et al.[23]	Agoraphobia (56) Social phobia (13) GAD (10)	(1) Aerobic (2) Anaerobic	Aerobic versus anaerobic	8 weeks/3 × 60 min/week	Both groups experienced significant reductions in anxiety at posttreatment.
Broocks et al.[25]	Panic disorder (46)	(1) Exercise (2) Clomipramine (3) Placebo	Aerobic (walk/run)	10 weeks/3–4 × no time requirement	Exercise and clomipramine groups had significantly less symptoms compared to placebo group at posttreatment
Hovland et al. 2012[28]	Panic disorder (36)	(1) Group exercise (2) Group CBT	Day 1: walk/run; Day 2: circuit training; Day 3: sports and games	12 weeks/3 × 60 min/week	Both groups reported improved panic disorder symptoms; however, participants in CBT group demonstrated significantly greater improvements
Wedekind et al. 2010[27]	Panic disorder with agoraphobia (75)	(1) Exercise + paroxetine (2) Relaxation + paroxetine (3) Exercise + pill placebo (4) Relaxation + pill placebo	Aerobic (walk/run) and training session with trainer	10 weeks;/4 × 45 min/week (aerobic = 3; trainer = 1)	All groups improved at posttreatment. Paroxetine was superior to placebo. Exercise had a trend toward more improvement compared to relaxation.
Diaz and Motta[34]	PTSD (12)	None	Aerobic (moderate intensity walk)	5 weeks/15 × <23 min	Reduction of PTSD symptoms but not anxiety and depression at posttreatment.
Manger and Motta[35]	PTSD (9)	None	Aerobic (moderate intensity walk)	12 sessions/30 min	Reductions in PTSD, depression, and anxiety symptoms at posttreatment.
Newman and Motta[33]	PTSD (12)	None	Aerobic (60–90% max heart rate)	5 weeks/3 × per week	Reduction in PTSD symptoms at posttreatment.
Brown et al.[36]	OCD (15)	None	Aerobic (moderate intensity)	12 weeks/3–4 × 20–40 min/week	Reduction in OCD symptoms at posttreatment and 6-month follow-up.
Abrantes et al.[38]	OCD (15)	None	Aerobic (treadmill, bike, elliptical)	12 weeks/3–4 × 20–40 min/week	Reduction in obsessions at weeks 1 and 12. Reduction in compulsions at weeks 1 and 12. Reductions at week 1 were stronger than at week 12.
Merom et al.[24]	*N* = 41 GAD* SAD* Panic disorder*	(1) Group CBT + psychoeducation (2) Group CBT + exercise	Aerobic (home-based walk)	8 weeks/increasing physical activity to 5× per week; 150 min total	Reduced depression, anxiety, and stress in CBT + exercise group at posttreatment.
Herring et al.[32]	GAD (30)	(1) Resistance training (2) Aerobic exercise (3) Wait list	Weightlifting versus cycling	Weightlifting: 2 weekly sessions of lower body weight lifting Cycling: 2 weekly sessions of leg cycling	Significant condition-by-time interaction. Significant reductions in worry symptoms for both exercise conditions when compared to wait list.

GAD, generalized anxiety disorder; PTSD, posttraumatic stress disorder; OCD, obsessive compulsive disorder; SAD, social anxiety disorder; CBT, cognitive behavioural therapy.
**n* not reported.

exercise sessions (two individual sessions plus one group session) for eight weeks. Exercise sessions were not monitored to ensure adherence to treatment protocol or intensity of exercise. Aerobic exercise and MBSR resulted in similar, significant improvements on measures of social anxiety, depressive symptoms, and well-being at postintervention and 3-month follow-up. Relative to no treatment, exercise decreased scores (n^2_p = 0.25) on the Social Interaction Anxiety Straightforward Scale (SIAS-S[30]), but there were not

significant differences on the Liebowitz Social Anxiety Scale-Self-Report (LSAS-SR[31]). This study offers preliminary and partial support for the efficacy of aerobic exercise for the treatment of SAD. It is possible that a supervised intervention would have produced more robust effects.

GAD

Herring and colleagues[32] reported on the results of a small-scale RCT comparing 6 weeks of resistance training to 6 weeks of aerobic exercise in 37 adults with GAD. Patients assigned to resistance training completed two weekly sessions of lower-body weight lifting whereas patients assigned to aerobic exercise completed two weekly sessions of leg cycling. Both groups evidenced significant reductions ($d = 0.52$ and $d = 0.54$, respectively) in anxiety as measured by the trait subscale of State-Trait Anxiety Scale and worry as measured by the Penn State Worry Questionnaire, with no significant between-group differences.

PTSD

An 8-week program comprised of three weekly 40-min aerobic sessions resulted in reduced PTSD, depression, and anxiety symptoms among adolescent females diagnosed with PTSD.[33] Likewise, 90% of a sample of adolescents with PTSD who participated in a 5-week aerobic exercise intervention (three sessions weekly at 60–90% maximum heart rate [max HR]) experienced significant reductions in PTSD symptoms at posttreatment and over 50% showed significant reductions in general anxiety symptoms.[34] Similar findings have been reported in a small sample of adults with PTSD following 12 40-min sessions of aerobic exercise (60–86% max HR[35]). In each of these studies, reductions in PTSD symptoms were maintained at 1-month follow up. Notwithstanding, given the small sample sizes and lack of appropriate control groups, the promising findings can only be considered preliminary.

OCD

Brown and colleagues[36] enrolled 15 patients with OCD in a 12-week moderate-intensity (55–69% max HR) aerobic exercise program that included weekly CBT-based exercise counseling.[36] Patients exercised three to four times weekly and increased from 20-min to 40-min sessions as treatment progressed. Patients reported significant improvement in overall sense of well-being and significant reductions in OCD symptoms on the Yale–Brown Obsessive Compulsive Scale (Y-BOCS[37]) from baseline to posttreatment ($d = 1.69$). Gains were maintained at 6-month follow-up ($d = 1.11$), and clinically significant changes were observed for 69% of patients at posttreatment and 50% at 6-month follow-up. In a follow-up study of the same sample, the authors examined the acute effects of exercise on anxiety, obsessions, and compulsions.[38] They found large effects for reductions in pre- to postexercise anxiety ($d = -0.73$) and compulsions ($d = -0.77$), and a medium effect for reductions in obsessions ($d = 0.62$) in the first week of exercise. Smaller acute effects for all three measures were found at week 12, suggesting that although exercise resulted in significant reductions in anxiety, obsessions, and compulsions throughout treatment, the greatest reductions occurred earlier in treatment. These positive open trial findings await replication and extension in large RCTs.

SUMMARY

There is, unfortunately, only a small number of studies assessing the effects of exercise as a treatment strategy for the anxiety disorders. As described above, the majority of studies are characterized by small samples, lack of adequate controls, lack of systematic attention to possible dose–response relationships, limited consideration of maintenance of gains following treatment, and primary focus on aerobic activity. These issues are to be expected in an emerging area of inquiry and provide opportunity for future investigation. Notwithstanding, there is work emerging from the investigation of individuals who do not meet diagnostic criteria for an anxiety disorder, but are characterized by significant anxiety, that have informed understanding of the extent to which anxiety symptoms change with different exercise modalities and does (i.e., length if intervention, intensity, duration).

EFFECTIVENESS OF SPECIFIC EXERCISE MODALITIES AND DOSES

Exercise protocols emphasizing walking or running[24,25,34,36] as well as gym-based programs of exercise (e.g., resistance training, yoga, tai chi) have been related to reduced anxiety (see Table 2). Typically, aerobic exercise protocols engender temporary feelings of psychological distress following an initial bout of exercise, oftentimes precipitating greater nonadherence to treatment protocols than that which is seen in control groups;[25] however, with time, positive psychological states[36] and reduced anxiety ensue.[24,25] Likewise, resistance training appears to result in a temporary increase in state anxiety immediately following the exercise, which is followed by a return to baseline levels 20 to 60 min postexercise.[39,40] Long-term resistance training programs, on the other hand, are associated with reductions in state and trait anxiety.[41–44] For example, one study[43] compared the effects of a high intensity/low volume (two sets of 8–10 repetitions at 75–80% at one repetition maximum [1RM]) and a low intensity/high volume (two sets of 14–18 repetitions at 55–65% 1RM) to a no exercise control condition among 42 older adults (mean age = 68 years). Both resistance-training conditions consisted of three weekly sessions for 12 weeks. The two intensities (low and high) showed similar reductions in tension and trait anxiety at posttreatment, and both were greater than those in the no treatment control.[43] Similar effects were

TABLE 2. Studies examining the effectiveness of different types of exercise for individuals without a mental disorder

Study	Sample (*n*)	Exercise type	Duration/frequency	General findings
Broman-Fulks and Storey[50]	University students with high AS (24)	Aerobic exercise (treadmill) versus no exercise	2 weeks/6 × 20 min/week	AS among exercisers reduced significantly, whereas AS among nonexercisers did not significantly change.
Smits et al.[51]	University students with high AS (60)	Aerobic exercise (treadmill) versus aerobic exercise (treadmill) plus cognitive restructuring versus waitlist	2 week/6 × 20 min/week	Both exercise conditions had reduced AS compared to waitlist; cognitive restructuring did not add to the effects of exercise
Raglin et al.[17]	Healthy collegiate athletes (26)	Resistance training versus aerobic exercise	Single session/ 30 min	Reductions in state anxiety were significantly associated with aerobic exercise but not with resistance training.
Tsutsumi et al.[43]	Healthy but sedentary older women (36)	High versus moderate resistance training versus control	12 weeks/3 days per week	Both groups improved on positive affect compared to control and reduced tension and anxiety postexercise period. Moderate intensity group had significantly reduced trait anxiety compared to control.
Bartholomew and Linder[44]	Healthy university students (20)	Resistance training	3 sessions separated by ≥ 3 days/20 min/session	Both males and females reported increases in anxiety following 20 min of high-intensity exercise (75–85% of 1RM), as well as significant decreases in anxiety following low-intensity exercise (40–50% of 1RM).
Tsutsumi et al.[42]	Healthy but sedentary older adults (42)	High- versus low-intensity resistance training	12 weeks/3 days/week	Improved positive and negative mood, trait anxiety, and perceived confidence for physical capability for both groups.
Hale and Raglin[14]	Healthy collegiate athletes (16)	Cross training	2 sessions with 1 week between sessions	Reduced state anxiety.
Broman-Fulks et al.[49]	University students with high AS (54)	High-intensity aerobic versus low-intensity aerobic exercise	2 weeks/6 × 20 min/week	Both conditions had significant reductions in AS; however, the high-intensity condition had a more rapid reduction.
Feild et al.[45]	Healthy adults (38)	Tai chi/yoga	Single session/ 20 min	Increased relaxation and decreased anxiety during class.
Streeter et al.[46]	Healthy adults (34)	Yoga versus walking	12 weeks/3 × 60 min/week	Greater improvements in mood and decreased anxiety in the yoga group
Bibeau et al.[85]	Healthy university students (104)	Resistance training: Control versus 4 groups (high/low intensity and long/short rest).	8 weeks/2 × 90 min/week	Significant main effect for condition (low-long group reported significantly higher positive affect than control). Significant effect for time on anxiety (highest anxiety detected at 5 min postexercise; significant reductions in anxiety at both 20 and 40 min post exercise).

AS, Anxiety sensitivity; 1RM, One repetition maximum.

found following a 24-week weight machine intervention consisting of three 1-hr sessions per week.[41] Elderly participants who were randomized to the resistance condition reported significant decreases in both state and trait anxiety at posttreatment compared to the no exercise control. Likewise, a 20-min class combining tai chi movements and yoga postures resulted in significant reductions in state anxiety from pre- to postexercise in 38 healthy participants.[45] Another recent study compared the effects of a 12-week yoga intervention to a metabolically matched walking control condition among 34 healthy participants.[46] Both conditions consisted of three 60-min sessions per week. By week 12, those in the yoga condition showed significantly greater reductions in state anxiety as well as greater improvements in tranquility and revitalization, compared to those in the walking condition. Together, these results suggest that resistance training, yoga, and tai chi, may serve as an alternative exercise treatment for anxiety, which may be important for individuals unable to participate in more vigorous or high-impact exercise such as jogging.

Few studies have examined the dose–response relation of exercise and anxiety reduction. One meta-analysis of 104 published and unpublished studies revealed that the strength of anxiolytic effects varies by the length of the exercise intervention.[16] Programs lasting 16 weeks or more showed the largest effects for reducing trait anxiety ($d = 0.63$), whereas those lasting 10 to 15 weeks had medium effects ($d = 0.50$ for 10–12 weeks; $d = 0.36$ for 12–15 weeks), and those under 10 weeks had small effects ($d = 0.17$). This suggests that exercise interventions should be at least 10 weeks in order to produce meaningful reductions in trait anxiety. Data from the meta-analysis also revealed that duration of exercise sessions affect the magnitude of anxiety reductions. Bouts of exercise shorter than 20 min resulted in significantly lower effect sizes ($d = 0.04$) for state and trait anxiety reduction than exercise lasting 21 to 30 min ($d = 0.41$); however, a more recent review suggests that exercise session duration is not predictive of anxiety reduction beyond the effects explained by the degree of exercise intensity.[47] Intensity was inversely related to changes in positive affect during and immediately following acute bouts of exercise, such that higher intensities resulted in reduced positive affect. In nonclinical samples, higher intensity exercise was linked with greater reductions in anxiety in physically fit participants relative to unfit participants, indicating that the degree of acute benefit may be linked to fitness level.[47] This finding contrasts with earlier work suggesting that reductions in anxiety were independent of cardiovascular fitness.[23] Finally, a recent meta-analysis of 49 studies suggests that an exercise frequency of three to four times weekly elicits significantly larger anxiolytic effects than both less frequent and more frequent regimens;[48] however, the limited number of studies with exercise frequencies of one to two or greater than five sessions per week may have resulted in uncharacteristically low effects in those frequency groups.

POTENTIAL MECHANISMS

Although the utility of physical exercise has received preliminary support for ameliorating anxiety and anxiety disorder symptoms, little research has empirically tested mechanisms potentially responsible for anxiolytic effects. Several hypotheses have emerged. These, along with emerging empirical evidence, are reviewed below.

REDUCTIONS IN ANXIETY SENSITIVITY AND EXPOSURE TO FEARED BODILY SENSATIONS

Several studies[49–51] have demonstrated short bouts of aerobic exercise as effective in reducing high levels of anxiety sensitivity (AS; the propensity to fear anxiety sensations based on the appraisal that they will lead to catastrophic consequences[52]), a trait characteristic of most anxiety disorders.[53] Each study used a similar protocol comprising six sessions of aerobic exercise over a 2-week period. Exercise resulted in significant AS reductions compared to nonexercising[50] and waitlist control,[51] and significant AS reductions among both high- and low-intensity exercisers.[49] Moreover, the magnitude of AS reduction was comparable among those who participated in aerobic exercise alone and those who did so in conjunction with cognitive restructuring.[51] The therapeutic effects of aerobic exercise may be, in part, attributable to the direct targeting of AS; accordingly, in addition to the general benefits on anxiety reduction exercise, may also serve as a means of natural exposure to feared bodily sensations.

The immediate therapeutic effects of exposure to feared bodily sensations through aerobic exercise was tested by Ströhle and colleagues.[20,21] Patients with panic disorder participated in either aerobic exercise for 30 min at 70% maximum oxygen consumption or quiet rest. Results suggested that those who engaged in aerobic exercise had fewer instances of experimentally induced panic attacks than those who rested quietly. Ströhle and colleagues[20,21] suggest that exercise-based exposure to feared bodily was therapeutic because it may have served to demonstrate the nonthreatening nature of physical sensations. Esquivel and colleagues[18] also found that single sessions of moderate/hard aerobic exercise, compared to light/very light exercise, corresponded with significantly fewer experimentally induced panic attacks (i.e., 35% CO_2 inhalation) in patients with panic disorder. Additionally, participants in the moderate/heavy group reported less distress to feared bodily sensations than did those in the light/very light group, suggesting a dose–response relationship wherein larger (i.e., more intense) single doses of exercise are more effective at precipitating therapeutic effects.

Similar to the anxiety reduction techniques often employed in CBT, such as interoceptive exposure (i.e., systematic and controlled exposure to feared bodily sensations), aerobic exercise has been shown to engender reductions in all three AS dimensions (fear of physical sensations, cognitive dyscontrol, and socially observable symptoms[54]). Aerobic exercise may, therefore,

constitute a type of interoceptive exposure, evoking physiological changes (e.g., elevations in HR, muscle tension, shortness of breath, sweating) that mimic the anxiety responses of those with clinically significant anxiety. Like other interoceptive exposure strategies, exposure to exercise-induced bodily sensations may facilitate discovery that the sensations are discomforting but not catastrophic. As described in the next section, routine exercise also changes physiology such that arousal becomes less marked during stressful situations, further reducing the likelihood of catastrophic interpretations of bodily sensations.

PHYSIOLOGICAL ADAPTATIONS

Strenuous physical exercise has been found to provide physiological resilience to stressful mood states.[55] Specifically, neuroendocrine adaptations,[56] increases in body temperature,[57] changes in central serotonergic systems,[58] and increases in endorphin production[59] following exercise have been posited as mechanisms by which physical exercise regulates negative psychological states. Although detailed review is beyond the scope and intent of this review, general details of physiological effects may aid in understanding potential therapeutic mechanisms.

Thermoregulatory mechanisms are known to influence homeostasis, which becomes threatened during physiological arousal (for reviews see[60,61]). Exercise increases metabolic heat production and exposure to sublethal homeostatic changes that mimic anxiety-induced neurochemical processes. Repeated exposure to such changes through exercise may, therefore, facilitate tolerance to arousal and stress.[61] Similarly, production of β-endorphins, adrenocorticotropic hormone, and endogenous opioid peptide neurotransmitters with analgesic properties serve to reduce arousal at the neuronal level.[62] Research examining peripheral blood levels has found elevations in β-endorphins and adrenocorticotropic hormones after various types of exercise and associated reductions in anxiety.[63] Finally, exercise down-regulates the hypothalamic–pituitary–adrenal axis and sympathetic nervous system—systems that tend to become dysregulated as a function of chronic stress—thereby normalizing release of cortisol and catecholamines and reducing arousal and distress (for reviews see[64,65]).

There is preliminary evidence suggesting that exercise may augment CBT for anxiety disorders by optimizing systems for extinction learning. In a recent study, Peters and colleagues[66] found that the consolidation of extinction memory within the infralimbic medial prefrontal cortex is mediated by brain-derived neurotrophic factor (BDNF), an established molecular mediator of memory consolidation.[67] These findings indicate that increasing hippocampal BDNF may be a useful target for augmenting extinction-based psychotherapies such as CBT. Indeed, baseline serum BDNF levels among persons with panic disorder have been shown to be predictive of response to exposure-based treatment, such that those with higher serum BDNF levels show greater response compared to those with lower serum BDNF levels.[68] These findings are particularly interesting considering that individuals with anxiety disorders have been shown to have relatively low levels of BDNF.[18] Ströhle and colleagues[69] compared individuals with panic disorder to normal controls before and after a 30-min bout of moderate-intensity exercise. They found that patients with panic disorder had significantly reduced BDNF concentrations relative to normal controls at baseline. Moreover, 30 min of moderate-intensity exercise significantly increased BDNF concentrations in those with panic disorder, whereas no changes in BDNF concentrations were observed in the control participants.

IMPROVEMENTS IN SLEEP

There is a strong relationship between exercise and sleep improvements (for review see[67]). Sleep disturbances, daytime sleepiness, nightmares, and poor sleep quality are prevalent among individuals with anxiety disorders[70–75]. Researchers have posited that central nervous system adaptations to anxiety lead to increases in startle response[76] and dysfunctional rapid eye movement (REM) sleep.[74] Exercise has been shown to improve sleep in individuals affected by anxiety and depression[77] by enhancing physiological consequences that promote sleep (e.g., depleting energy stores, breaking down tissue, elevating body temperature (for review see[78]) which, in turn, reduces depressive symptoms and trait anxiety.[77]

MASTERY AND SELF-EFFICACY

Successful completion of an exercise regimen, especially at higher intensities, may engender a sense of mastery; that is, exercise may reinforce adaptive beliefs that one has the power to influence his or her environment and bring about desired outcomes.[79] Mastery has been shown to moderate negative consequences of set-backs and restore hope;[80] indeed, an increased sense of mastery is associated with positive psychological states.[81] In essence, mastery stemming from exercise-related successes appear to counteract catastrophic thinking characteristic of anxious individuals, further increasing feelings of mastery and self-efficacy that reduce psychological distress. Steptoe and colleagues[82] observed parallel increases in perceived coping and anxiety reduction in anxious individuals who initiated an exercise program. There is also evidence that some forms of exercise may be more effective than others in this regard; specifically, Bodin and Martinsen[83] found that exercise-targeting self-efficacy (e.g., 45 min of martial arts) corresponded with significantly greater improvements in state anxiety. Exercise may also teach persistence in the presence of negative somatic and emotional states,[84] thereby increasing sense of mastery and self-efficacy. By training persistence with exercise, exercise interventions may

have more general effects on returning participants to adaptive activity.

CHANGES IN AFFECTIVE STATUS

Improvements in positive affect[85] and reduction in negative affect[86] have been found to immediately follow bouts of anaerobic and aerobic exercise and persist for up to 4 hr following exercise cessation.[16] Notably, maximal affective benefits of exercise are activated almost immediately upon beginning an exercise regimen.[16] Persistent changes in affective status, including improvements in physical self-concept and global self-esteem[87]), have also been recognized when exercise regimens are made routine (e.g., 10 weeks or greater[16]). These finding suggest a near immediate yet potentially long-lasting effect precipitated by exercise if maintained. Findings are, nonetheless, mixed regarding the relative contribution of exercise intensity to acute changes in affective status;[39] for example, on beginning an exercise regimen, individuals have been known to report discomfort and increases in negative affect immediately after exercise. As such, an emphasis on light-intensity exercise programs for patients new to exercise may help to enhance psychological benefits that, in turn, may increase compliance and adherence to prescribed protocols.[39]

DISTRACTION AND INTERRUPTING SOCIAL WITHDRAWAL

The social interactions and interrupted social isolation brought on by the behavioral activation aspect of physical activity among those with anxiety disorders has also been posited as an important therapeutic effect (for review see[64,88]). Indeed, it is well established that modification of self-perpetuating patterns such as social withdrawal and inaction may be critical to therapeutic change,[89–91] whereas behavioral activation is recognized as an efficacious treatment for anxiety disorders such as PTSD.[92] Exercise may provide an opportunity to become engaged in an activity that distracts from negative thoughts, providing an escape from daily stresses and concerns.[21,64,93,94] There are, however, important caveats regarding the use of exercise as distraction. In particular, if therapeutic effects of exercise are primarily a function of interoceptive exposure, then use of exercise as a distraction may diminish overall effectiveness as an anxiolytic. Although researchers often remind participants to focus on their bodily sensations during exercise to ensure that they receive sufficient interoceptive exposure,[51] further research is needed to establish whether these instructions produce greater gains than instructions geared toward distraction.

SUMMARY

A number of mechanisms have been hypothesized to explain the anxioltyic effects of physical exerice. Despite growing empirical scrutiny, our understanding of these mechanisms remains in its infancy. Additional research is needed to elucidate potential mechanisms as well as their impact on pscyhological well-being, biological systems, and the interaction between these.

CHALLENGES OF IMPLEMENTATION

In the Spring of 2012, major media headlines trumpeted the failure of exercise to treat depression. The source of these headlines was the publication of the UK TREAtment of Depression with physical activity (TREAD) study.[94] This large-scale RCT examined the benefit of an exercise intervention relative to usual care for 361 adults in general practice in Bristol and Exeter. Although no differences between the treatment groups were found for Beck Depression Inventory scores, a striking feature of the study is the failure to achieve the targeted exercise outcomes among the study participants. In fact, at the 4-month outcome, there was only a 9% difference in rates of exercise among the treatment groups (52% meeting a self-report exercise criterion for the exercise condition compared to 43% for the usual care condition), with no treatment by time interaction for exercise over the follow-up period. Also, the original article and subsequent widespread dissemination of these null results occurred with little mention of the large number of exercise treatment trials demonstrating efficacy for depression[21,22] or related conditions, such as the anxiety disorders. Whereas it is hard to imagine the successful refutation of antidepresant efficacy in a single RCT with only a 9% difference in the use of the targeted medication, major media outlets quickly reported the failure of mood effects for the exercise intervention, raising questions whether there is a general resistance to the notion of using exercise as a treatment for mood or anxiety disorders. On one hand, exercise is a broad spectrum (efficacious for both depression and anxiety) and affordable treatment strategy that has the additional benefits of reduced morbidity and mortality[95–97] and improved cognitive function.[98,99] On the other hand, both providers and patients may be aware of the widespread failure of exercise adoption for fitness goals[1] and may be skeptical about the efficacy and feasibility of this intervention more generally. What is undeniable is that there is great variability in adherence to exercise interventions across trials, with the relative failure of exercise promotion in the UK TREAD study and successful adoption of exercise in other trials.[25,44,100,101]

To meet the challenge of this variability, the science of exercise adherence is growing.[102] One central factor for adherence is pleasure during exercise, with pleasure ratings predicting amount of exercise 6 to 12 months later.[103] Pleasure and comfort during exercise is affected by at least two cognitive risk factors relevant to those with anxiety disorders. The first, AS, is, as described above, successfully reduced by regular exercise,[51] but may prevent individuals from attempting this exercise; that is, feelings of exhertion mimic the feared sensations of anxiety that are AS and,

accordingly, elevated AS scores predict fear during exercise as well as lower rates of exercise.[104,105] The second cognitive risk factor is social physique anxiety, a construct related to anxiety regarding one's figure or physique,[106,107] and conceptually similar to fears of negative evaluation as applied to the exercise environment. Social physique anxiety has been found to predict negative affect during exercise, particularly among overweight individuals.[108] Both of these cognitive risk factors—AS and social physique anxiety—may be important targets for intervention to help anxious individuals have a better experience as an exercise routine is established.

Aside from these specific risk factors, providers may need to address any of a number of motivational issues when prescribing exercise. Like any treatment, patients bring to the session their expectations about what sort of interventions are preferred or efficacious,[109–111] and these preferences shape the acceptability of interventions and, to some degree, treatment outcome.[112] With regard to exercise interventions, expectancies may be shaped by a patient's history of exercise attempts and failures. Accordingly, although an exercise prescription for anxiety or mood is fairly straightforward (e.g., working up to four or five 40-min sessions of moderate exercise per week), schedule and motivation management interventions may need to be applied for establishing and maintaining an exercise intervention.[113] Regardless of approach, the available data suggest that adding on time to standard sessions is sufficient to help patients with anxiety disorders adopt a program of exercise; for example, Merom et al.[24] prescribed exercise in the context of 15- to 30-min meetings that followed group CBT sessions and found a significant increment in anxiolytic efficacy. In the initial meeting patients were given pedometers and log books, and subsequently the benefits of exercise and a home walking program was discussed and monitored over time. Therapist guides,[114] patient workbooks,[115] and self-help books[116] are now available to facilitate this process, if desired.

FUTURE DIRECTIONS AND CONCLUSIONS

There are numerous research directions and opportunities, highlighted in the preceding sections, which warrant further empirical inquiry. Within each of the anxiety disorders there is a need for additional systematic evaluation of the effects of various exercise protocols using larger samples, adequate controls, attention to varying exercise paramenters (e.g., different intensities and durations, different exercise modailities, group versus individual programs, with and without psychotherapy or pharmacotherapy), and evaluation of maintenance of gains over longer follow-up periods. Developing strategies to maximize adherence to exercise protocols may be particularly important in the context of maintaining gains. Knowledge and understanding of the mechanisms through which exercise is effective as an anxiolytic remains limited; thus, more research on putative psychological and biological mechanisms and their interactions is warranted. Notwithstanding, available evidence generally supports patient-appropriate prescription of exercise (i.e., tailored to current fitness and physical health) as a promising addition to psychosocial and/or pharmacologic treatment of clinically significant anxiety.

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