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Exercise-based treatments for substance use disorders: evidence, theory, and practicality

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Abstract

Background—Epidemiological studies reveal that individuals who report risky substance use are generally less likely to meet physical activity guidelines (with the exception of certain population segments, such as adolescents and athletes). A growing body of evidence suggests that individuals with substance use disorders (SUDs) are interested in exercising and that they may derive benefits from regular exercise, in terms of both general health/fitness and SUD recovery.

Objectives—The aims of this paper were to: (i) summarize the research examining the effects of exercise-based treatments for SUDs; (ii) discuss the theoretical mechanisms and practical reasons for investigating this topic; (iii) identify the outstanding relevant research questions that warrant further inquiry; and (iv) describe potential implications for practice.

Methods—The following databases were searched for peer-reviewed original and review papers on the topic of substance use and exercise: PubMed Central, MEDLINE, EMBASE, PsycINFO, and CINAHL Plus. Reference lists of these publications were subsequently searched for any missed but relevant manuscripts. Identified papers were reviewed and summarized by both authors.

Results—The limited research conducted suggests that exercise may be an effective adjunctive treatment for SUDs. In contrast to the scarce intervention trials to date, a relative abundance of literature on the theoretical and practical reasons supporting the investigation of this topic has been published.

Conclusions—Definitive conclusions are difficult to draw due to diverse study protocols and low adherence to exercise programs, among other problems. Despite the currently limited and inconsistent evidence, numerous theoretical and practical reasons support exercise-based treatments for SUDs, including psychological, behavioral, neurobiological, nearly universal safety profile, and overall positive health effects.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of this paper.

Keywords

Exercise; review; substance use disorders; theoretical mechanisms

Background

Substance use disorders (SUDs), including alcohol use disorder (AUD), are among the most prevalent mental health disorders. Worldwide, up to 15% of individuals are likely to experience a SUD in their lifetime (1). Approximately 250,000 global deaths per year are attributable to illicit drug use, and 2.25 million are attributable to alcohol use (2). Furthermore, individuals with SUDs face elevated risks of multiple comorbid mental and physical health problems (3-9).

Despite widely available treatment programs, typically incorporating elements such as psychoeducation, social support, medication, and/or a 12-Step program (e.g. Alcoholics Anonymous) (10,11), at least 60% of individuals with SUDs are likely to relapse within one year of treatment (11-13), suggesting a need for innovative approaches to treatment.

Insufficient physical inactivity is a growing global epidemic, with estimates ranging from 33% of adults worldwide who are physically inactive (14) to 82% of adults in the US who fail to meet physical activity guidelines (15). Globally, approximately 9% of premature mortality is attributable to insufficient physical activity (16). Epidemiological studies indicate that physical activity levels are generally inversely related to SUDs. However, epidemiological and prospective studies examining the relationship between physical activity and alcohol use are mixed: some studies have found that individuals who report hazardous levels of drinking also report less physical activity (17,18), but others have found the reverse (19-23) or no relationship between these two risk factors (24). One study showed that those engaging in physical activity or related behaviors (e.g. planning physical activity) during treatment for substance use report lower substance use than those not engaged in these activities (25).

The aims of this paper were to: (i) summarize the research examining the effects of exercise-based treatments for SUDs; (ii) discuss the theoretical mechanisms and practical reasons for investigating this topic; (iii) identify the outstanding relevant research questions that warrant further inquiry; and (iv) describe potential implications for practice. Although it draws upon the exercise and smoking cessation literature, including a recently updated Cochrane review that extensively discussed the mechanisms and theoretical reasons for examining exercise-based interventions for smoking cessation (26), this review focuses primarily on substances other than nicotine. Despite known differences between the effects (i.e. physiological, psychological, biological) of alcohol and the various classes of drugs, the remainder of this review focuses on the broader picture of all substances of misuse, which share much common ground at their core.

Exercise as a treatment for SUDs

A small but growing body of research has examined the potential role of exercise in the treatment of SUDs. Exercise is advocated as an intrinsically rewarding, engaging, healthy, and safe alternative behavior. The acute and chronic effects of exercise have both garnered attention and supporting evidence (27-29); due to this paper's broad scope and the complexities of attempting to disentangle these two areas of research, they will be presented together as necessary. Exercise's broad positive health (30-33), mood-enhancing (34-39), and anxiolytic (40-42) effects; capacity to reduce the acute distress of withdrawal (43-47); and nearly universal safety profile when properly adapted for the individual (30,31) make it an appealing adjunctive intervention to help attain abstinence and prevent relapse among individuals with SUDs.

Evidence suggests that individuals with SUDs are interested in increasing their exercise levels (48) and that they may derive benefits from regular exercise in terms of both general health/fitness and SUD recovery (27,49). Treatment programs rarely incorporate dedicated time for exercise; however, researchers have evaluated exercise programs for those with SUDs.

A systematic review of studies (including eight alcohol and nine illicit drug studies) examining the effects of exercise-based interventions for SUDs on recovery trajectories, physical fitness, and psychosocial variables was recently published (27). This review (27) revealed that multiple studies using exercise-based treatments for SUDs were reported throughout the 1970s and 1980s; few studies were then reported until recent years. Most of the studies evaluated aerobic exercise or sports that primarily utilize the aerobic energy system, although a few examined strength training in lieu of or in addition to aerobic exercise. The majority of the reviewed studies were poor in quality for multiple reasons, including: small sample sizes, uncontrolled study designs (only one alcohol and no drug studies met randomized controlled trial [RCT] criteria), high attrition rates, low exercise adherence and/or lack of or inadequate exercise adherence measurement, insufficient exercise volume and/or intensity, and inadequate length of intervention and/or follow-up period. Exercise was incorporated as an adjunctive treatment in all of the studies; some studies compared exercise with a standard care control group (with or without an exercise treatment waitlist), whereas others only reported pre-post measurements of the exercise group.

Four of the six alcohol studies that reported substance-related outcomes (50-55) found significantly greater improvements in the exercise group (51-54), whereas two studies did not find any group differences (50,55). Secondary psychological outcomes (e.g. depression, anxiety, stress) improved in four (50,56-58) of the six alcohol studies that examined them, whereas the other two studies did not find group differences (53,55). Eight alcohol studies reported significant fitness improvements (50-57), and another study (58) did not find significant changes in fitness. All six of the drug studies that reported substance-related outcomes (47,59-63) found significant improvements. Likewise, secondary psychological and social outcomes (e.g. depression, anxiety, tension, self-concept) improved in all five of the drug studies that reported them (59-62,64). Three drug studies reported fitness

improvements (59,62,63), four did not report fitness outcomes (47,60,61,65), and one did not find significant changes in fitness (64).

Overall, the results suggested that exercise is a potentially promising adjunctive treatment for SUDs for populations with a wide range of characteristics (e.g. ages, SUD severity, inpatient and outpatient treatment). However, a relative dearth of research, particularly quality studies with well-controlled procedures, has been conducted in this area, making definitive conclusions difficult to draw at this point. The numerous carefully controlled exercise-based treatment studies that have recently been conducted (e.g. 47,54,62,63,66) or are currently underway (e.g. 67,68) will help to improve our understanding of the role exercise may play in recovery from SUDs.

Although well-controlled clinical trials in this area are scarce, several preclinical studies have been conducted. These studies provide evidence supporting the role of exercise for the prevention and treatment of SUDs, particularly regarding the mechanisms through which exercise might exert positive effects on SUDs (49). Multiple mechanisms, including physiological, neurobiological, behavioral, psychological, and possibly even epigenetic pathways, have been identified (49,69). Research has shown that exercise evokes reward pathways and neurochemicals in the brain that are similar to those induced by addictive substances, suggesting that exercise treatment effects may be due to a combination of behavioral and biological/physiological processes (69,70). These mechanisms are currently under further investigation in preclinical trials as well as clinical trials utilizing techniques such as fMRI and PET scans to examine the effects of exercise on changes in brain structure and function in the presence of SUDs (69,71).

Theoretical mechanisms

The primary mechanisms, including psychological, behavioral, and neurobiological pathways, through which exercise may exert positive effects on SUD recovery and relapse prevention have been and continue to be extensively investigated in preclinical (49) and clinical trials (27). These mechanisms, discussed in detail below, are currently under further investigation in trials examining the preconditions and effects of exercise on SUDs.

Psychological

Cravings often contribute to relapse among individuals with SUDs (72,73); alleviating these cravings with exercise may decrease relapse rates. Thus, exercise is hypothesized to help individuals with SUDs both acutely (i.e. immediately after exercise) and in the long term. A large body of research demonstrates that exercise reduces withdrawal symptoms and negative affect among smokers attempting to quit (29,44,74). One study examined the acute effects of a brief bout of exercise on cravings and urges to drink among recently abstinent individuals with AUDs enrolled in an inpatient treatment program (46). Results indicated that, relative to a 10-minute bout of light intensity exercise, a 10-minute bout of moderate intensity exercise reduced alcohol urges during exercise, although this benefit was not evident immediately after exercise or at 5 or 10 minutes post-exercise. However, because urges decreased within both groups, the sample size was small, and a pure control condition

was not tested, the possibility that any exercise, regardless of intensity, reduces alcohol urges to a similar extent cannot be dismissed.

For example, a control group with no measurable decrease in urges may make the apparent differences between the moderate and light intensity exercise statistically similar. This hypothesis needs to be explored more before any conclusions can be drawn about the acute effects of exercise on urges to drink among individuals with AUDs. Also, if exercise is to have clinical implications for managing urges for alcohol it will need to show benefits not only during exercise but also during the period after exercise.

In the general population, evidence is also strong for both the acute and chronic effects of exercise on positive emotional well-being (38-40,75-79). Research suggests that exercise may reduce the likelihood of relapse among individuals with SUDs by decreasing negative mood/affect and/or increasing positive mood/affect (28,80-83), two related but independent constructs influencing drug and alcohol use (84). Furthermore, engaging in exercise increases exercise self-efficacy, which encourages continued exercise (85), and it may increase self-efficacy for attaining and maintaining abstinence from substance use (86).

The literature also supports an inverse relationship between regular engagement in exercise and mental health problems (87-90), particularly depression and negative mood/ affect (38,39,76,77,89), anxiety (40,76,89,91), and comorbid mental health disorders or symptoms that directly or indirectly influence SUD outcomes and are common among those with SUDs (8,92,93). RCTs have demonstrated significant effects of exercise on reductions in symptoms of depression (39,77) and anxiety (40), although a causal relationship has been questioned (94), and many of the RCTs using exercise as an adjunctive treatment for SUDs have reported improvements in psychological variables (27). The optimal dose (e.g. type, duration, intensity) of exercise required to maximize its acute effects on mood/affect is the topic of ongoing research (79). Studies thus far suggest that the most advantageous dose varies substantially across individuals, depending on personal preferences as well as baseline physical fitness levels (78). Results of these studies will inform interventions for SUD populations.

Behavioral

Numerous environmental cues, psychological responses, and real or anticipated rewards trigger and reinforce substance use. Although treatments for SUDs address overarching behavioral patterns, the individual in recovery must avoid the automatic behavior (i.e. drinking or using the drug of choice) each time a craving or desire to use arises. The myriad places, activities, times of day, etc., associated with misused substances become environmental cues to use and thus increase the risk of relapse (95,96). Therefore, engaging in a safe, immediately rewarding, easily accessible, and sustainable behavior, such as physical activity, in lieu of drinking or using drugs in the moment when urges arise, may help reduce relapse among individuals with SUDs.

In a broader behavioral sense, exercise tends to be one component of a generally healthy lifestyle that is largely incompatible with substance misuse. Indeed, regular exercise often

goes hand-in-hand with other positive health behaviors such as a healthy diet, good sleep hygiene, as well as with moderate alcohol use and absence of problematic use of illicit and prescription drugs (18,97). Although some individuals with SUDs may lead otherwise healthy lifestyles, substance misuse is strongly associated with other unhealthy lifestyle behaviors (98). For example, individuals with SUDs often report poor dietary habits, such as frequent consumption of unhealthy foods or inadequate intake of food related to appetite loss and/or disinterest in eating (99-101). In contrast, engaging in regular exercise often leads to feelings of enhanced well-being, vitality, energy, and motivation to adopt an overall healthier lifestyle (102).

However, a causal behavioral pathway connecting exercise with decreased substance use has not been drawn. Furthermore, exercise has also been positively associated with alcohol consumption, and some reports have suggested that individuals who engage in competitive sports and other intense exercise behaviors may drink as much or more alcohol than other populations (23,97,103). Thus, a closer look into this potential mechanistic pathway is necessary before any conclusions can be drawn.

Psychobiological

Although theories positing the brain's role in addictive behaviors have existed for centuries, only relatively recently has technology enabled neuroscientists to actually examine the neurotransmitters, neurocircuitry, and basic structure and function of the various parts of the human brain implicated in addiction research (104-107). For example, neuroimaging techniques such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) have been used to examine the brain reward pathways activated upon administration of psychoactive substances (108-112). These techniques have also been utilized to examine the brain's response to exercise behavior (113-116). A relatively small but growing body of literature reporting results from human studies (71,117-119) thus far supports the extensive body of psychobiological research on laboratory animals (49,120-122) demonstrating that exercise and commonly abused substances (e.g. drugs, alcohol) activate similar reward pathways in the brain (43,49,69,122). Collectively, these studies have provided objective data supporting the proposed similarities between psychobiological responses to substance use and exercise behavior, suggesting that these otherwise disparate behaviors may illicit similar responses that make certain individuals prone to abusing or becoming dependent upon them (49,69,95,122-124).

Exercise increases the concentration of certain neurotransmitters, including beta-endorphins, epinephrine, norepinephrine, serotonin, and dopamine (70,119,125,126), which contribute to the experience of exercise-induced reward. The influence of exercise on the serotonergic system may at least partially explain the positive effects exercise has on stress-related psychiatric disorders such as depression and anxiety (127). In addition, exercise evokes hippocampal neurogenesis, a process that also reduces the impact of stress and related psychiatric disorders (118). Drugs and alcohol also activate these and other neurotransmitters (106,107,109,110,128), lending more support to the psychobiological mechanism by which exercise may serve as a replacement for substance use.

Preclinical and clinical research examining the neurobiological mechanisms underlying the proposed relationship between exercise and SUD recovery has acquired the most recent interest among all of the proposed mechanisms (49,69). Due to advances in knowledge, technology, equipment, and other available resources, the currently available and continuously increasing knowledge about the neurobiological mechanisms supports and guides the relatively nascent field of adjunctive, exercise-based interventions for SUDs (27,49,69).

Outstanding research questions

Based on the evidence reviewed so far, as well as practical considerations, this section discusses the research needs in the area.

Which types, frequencies and intensities of exercise are best?

Which intensities and types of exercise are best for individuals with SUDs is not clear. Individuals with SUDs are often extremely sedentary; therefore, an initial program of light to moderate intensity activity is likely to be preferable to more vigorous activity, and adherence may be greater for moderate exercise (45,48,129), but this has yet to be established, Comorbidities and stage of recovery from their SUD also needs to be considered. Individuals who abuse amphetamines or cocaine are often undernourished, and those who misuse alcohol often have weak muscles. With such persons, studies may need to consider integrating nutritional advice (130,131). Some of the studies reviewed found benefits with more vigorous exercise (e.g. 127, 49) and a progression to vigorous exercise is often recommended in exercise programs.

However, how easily individuals with SUDs can progress to more vigorous exercise has yet to be determined, and studies that compare the effect of interventions with different exercise intensities and among different SUD populations are needed. Studies also need to examine preferences for exercise, the effect of tailoring the program to these preferences, and the comparative benefits of different modes of exercise. For example, most previous studies have focused on cardiovascular-type exercise, but resistance (i.e. weight) training, yoga, and isometric exercise have all been successfully piloted as aids to smoking cessation and need to be tested in larger trials and with SUDs (26).

As regards the frequency and volume of exercise, research has yet to address the optimum dose of exercise for assisting rehabilitation (27). Substantial evidence supports the acute effects of brief exercise bouts, of as little as 5 minutes duration, on reduced urges to smoke (29,44,74), and research is needed to establish the effects of various durations of exercise for other SUD populations and to determine how regular brief bouts of exercise (e.g. on an “as needed” basis) might be combined with longer, scheduled exercise sessions.

Is supervised exercise necessary?

The majority of intervention studies have entailed group-based supervised exercise (27), and all the interventions showing a significant impact on long-term abstinence from alcohol or smoking have entailed supervised exercise (27). Among novice exercisers an element of supervised exercise may be useful to ensure initial adoption of regular exercise and to

provide information about safe exercise (e.g. warm-up) and exercise intensities (e.g. using heart-rate monitors). Counseling towards pursuing home-based exercise is also likely to be important for encouraging patients to maintain exercise levels after the initial exercise program ends. Furthermore, integrating exercise into psychoeducational groups or psychotherapy might enhance positive treatment outcomes. For example, therapists could help their patients improve their self-awareness and body perception, exercise safely to cope with negative emotions and cravings, and overcome psychological barriers/resistance.

Individuals with SUDs are likely to have specific barriers to exercise, and these need to be addressed (48,86). In the general population cognitive behavioral techniques are effective for overcoming barriers and for increasing exercise adherence (140). Few SUD studies have entailed cognitive behavioral counseling (60). Techniques such as self-monitoring (e.g. diaries), goal-setting, contingency management, and relapse prevention planning are common strategies (25,141,142). Pedometers and other wearable devices that track physical activity are now commonly used as a motivational tool; these and other motivational aids (e.g. financial incentives), need to be tested with exercise interventions for SUD populations (143,144).

Research studies examining interventions that integrate supervised exercise with physical activity consultations are needed.

Do interventions need to be tailored to different stages of SUD treatment?

Early recovery from drug and alcohol dependence is a major transition, impacting upon close relationships and employment and involving numerous treatment sessions. An exercise program should ideally complement these changes.

Most exercise interventions to date have required patients to alter their substance/alcohol misuse behavior and exercise simultaneously, yet whether or not this strategy is optimal is unclear (132,133). For some individuals the challenge of changing two health behaviors simultaneously may be too demanding, whereas others may prefer to make multiple health behavior changes at once (134,135). Whether involvement in physical activity increases motivation toward managing substance intake or vice versa is also currently unclear.

Among smokers, exercise has often been introduced several weeks before a quit attempt, thereby allowing people to adjust to the demands of increased exercise before starting to quit smoking (26). This timing also allows exercise to play a role in managing cravings during the crucial early days of abstinence, when relapse rates are highest (136,137). Empirical work is required to determine the relative benefits of initiating exercise at different points in the SUD treatment process. For example, those with a severe SUD may not feel able to exercise until they reduce or cease their substance use.

How can exercise be integrated with standard SUD treatments?

Studies assessing whether greater integration between SUD and exercise programs enhances abstinence rates are needed (68). For instance, rather than just proposing exercise as a means for getting fitter and managing weight, exercise could be presented more as a self-control strategy for managing withdrawal symptoms, as well as a way of addressing psychological

and physical harms caused by the SUD (67,138). Exercise may also be used in combination with pharmaceutical interventions, and where these interventions focus on reducing withdrawal symptoms or managing mood, whether exercise further enhances the management of these symptoms needs to be determined (37,139). Integrating exercise into inpatient and outpatient treatment programs as an additional component of standard treatment would enable exercise to be supervised in a well-controlled setting, increasing researchers' ability to examine its efficacy and effectiveness.

Are different interventions needed for different sub-groups?

Exercise interventions need to be tested among SUD populations who might especially benefit from such an intervention. Given the high prevalence of SUDs among people with mental illness, and the established benefits of regular physical activity for mental health, research is needed to examine the role that physical activity may play with this population (140).

Exercise interventions might be particularly appealing to adolescents (141), and controlled trials are needed with young people. Individuals with SUDs who are overweight may have a need for weight control interventions such as exercise, and we have yet to see a trial focusing on this population. Lastly, gender needs to be considered, as men and women may have different preferences for types and intensities of activity (142).

Is "exercise addiction" a significant concern for SUD populations?

Excessive levels of exercise, which has been termed exercise "addiction", may be detrimental to other aspects of life (e.g. career, social relationships) (123,124). Psychobiological mechanisms underlie the rewarding properties of both SUDs and exercise engagement (123,124,143), and studies examining the extent and nature of exercise addiction among those with SUDs who undergo exercise treatment regimens are needed.

Is exercise adherence a problem?

Despite the known effects of exercise on reward systems in the brain that typically facilitate repeated behavior, maintaining a regular exercise schedule is challenging for the majority of the population, including those with SUDs, suggesting that the interactions among individual psychobiological reactions to exercise, genetics and traits, and social and environmental variables, among others, interact to determine each individual's unique level of motivation to exercise regularly (144-146). In effect, responsiveness to an exercise program examined as a treatment for SUDs would therefore be expected to vary significantly across individuals. Adherence to exercise, then, is the major issue necessary to address in future research with SUD populations, as with most others.

Conclusions

Collectively, the existing body of literature, theoretical support, and practical reasoning suggest that exercise is a potentially promising adjunctive behavioral treatment for SUDs. Alternative and adjunctive treatments for SUDs are particularly warranted since traditional treatment approaches do not always resonate with individuals seeking help and relapse rates

are high (10). Because exercise is a healthy lifestyle behavior that prevents, reduces, and/or treats a wide variety of mental and physical health problems with few negative side-effects, prescribing exercise as a treatment for SUDs is low-risk and potentially helpful for a variety of problems commonly associated with SUDs (30,32,33). However, based on the studies included in a recently published review (27), relatively minimal evidence from well-controlled trials for exercise being effective as an adjunctive treatment for SUDs exists so far. Studies with larger sample sizes, novel techniques to improve exercise adherence, and improved strategies for measuring outcomes are needed to support the relatively strong theoretical and practical reasons to promote the use of adjunctive exercise-based treatments for SUDs.

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