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Exercise training – A beneficial intervention in the treatment of alcohol use disorders?

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Abstract

Background: A growing body of evidence suggests that exercise training may have multiple beneficial effects in individuals with mental health or substance use disorders. Yet, relatively little knowledge exists regarding the benefits of exercise training to augment treatment for alcohol use disorders (AUDs).

Purpose: The purpose of this narrative review is to present a summary of the growing body of published literature supporting exercise training as a treatment strategy for individuals with AUDs. We will provide evidence on the myriad of ways in which exercise may exert a positive effect on AUD outcomes including stress, anxiety, impulsivity, and depression. Further, we will explore how these mechanisms share common neurobiological pathways. The role of exercise in enhancing the social environment and increasing individual self-efficacy to reduce excess and/or inappropriate alcohol consumption will also be discussed.

Discussion: We will conclude with a description of completed investigations involving exercise training and provide suggestions for next steps in this innovative field of study.

Keywords

Alcohol; Anxiety; Depression; Exercise; Impulsivity; Neurobiology; Stress

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1. Introduction

Alcohol use disorders (AUDs) affect approximately 18 million people in the United States (Center for Behavioral Health Statistics and Quality, 2013), with nearly 88,000 deaths per year occurring from alcohol-related causes (Stahre et al., 2014). One in 10 deaths per year, as well as an average of 30 years of potential life lost, can be attributed to excessive drinking among working-age adults (CDC, 2014). Injuries, violence, risky sexual behavior, and fetal alcohol spectrum disorders can occur with short-term alcohol consumption, while long-term use can lead to increased anxiety and depression, unemployment, and is associated with cardiovascular and circulatory diseases (CDC, 2014; Shield et al., 2014). As such, AUDs are an important public health concern and necessitate effective treatment options to best help affected individuals.

A substantial level of attention has been dedicated to developing efficacious treatments for AUDs, including medication, behavioral therapy, and mutual-help groups, that can be offered in both outpatient treatment settings, as well as in short- and long-term residential treatment facilities (National Institute on Alcohol Abuse and Alcoholism, 2010). Treatments are often combined, such as behavioral and pharmacological therapy, to better help patients establish behavioral and coping strategies that aid in recovery and ameliorate persistent symptoms that increase vulnerability to relapse (Dolan et al., 2013). However, challenges still remain in providing efficacious, individualized treatment plans and outcomes vary according to the severity of the AUD and the patient's motivation to change (Bottlender et al., 2006). Given the complexities and shortcomings of current treatment strategies, further work is required to strengthen AUD treatment and seek out novel treatment options that increase engagement in substance-free behaviors (Wackernah et al., 2014; Correia et al., 2005).

Exercise training, primarily in the form of structured aerobic exercise, has been employed in the treatment of a number of addictive disorders including gambling, marijuana and stimulant drug use, and smoking (Marcus et al., 1999; Trivedi et al., 2011a,b; Angelo et al., 2013). Several studies have shown that engaging individuals in exercise training programs prior to, or as a part of, their smoking cessation efforts positively impacts their short-term abstinence rates (Marcus et al., 1999; Bock et al., 2012). Those who exercised more frequently and/or intensely (Marcus et al., 2005), and were better able to maintain a stable body weight (Kawachi et al., 1996; Marcus et al., 1999; Farley et al., 2012) were more successful in their cessation efforts. Similarly, participation in a supervised 2-week exercise-training program reduced marijuana cravings and use in an adult population (Buchowski et al., 2011). Finally, exercise training in substance abuse treatment has been gaining greater levels of attention (Lynch et al., 2013). Pilot investigations involving substance users in outpatient treatment settings have demonstrated that exercise training leads to a significant increase in percent days abstinent (Brown et al., 2010) and decreased urges to use drugs (Roessler, 2010). Additionally, a large, multi-site randomized control trial investigating the impact of exercise training as an augmentation to stimulant abuse treatment in residential treatment centers is currently in progress (Trivedi et al., 2011a,b; Stoutenberg et al., 2012).

Despite the need for more efficacious treatment strategies for individuals with AUDs, and the growing body of evidence of exercise training in other populations with mental health or substance use disorders, relatively little evidence exists regarding the direct impact of exercise training in the treatment of AUDs. While a recent meta-analysis by Wang et al. (2014) demonstrated that exercise training is an effective strategy in enhancing substance abuse outcomes in general, only three studies were included in their analyses that specifically examined exercise training as a part of for AUDs, two of which involved low-intensity yoga programs. This highlights the need for more high quality research investigations. With increasing knowledge regarding the impact of exercise training on mental health and several pathways related to AUDs, there is a need to summarize these benefits and demonstrate the potential utility of exercise training as a part of a comprehensive AUD treatment program. The purpose of this narrative review is to provide insight into the role of exercise training on several pathways related to AUDs including stress, anxiety, impulsivity, and depression, as well as their common neurobiological pathways. We will conclude with a description of completed investigations involving exercise training and alcohol use and provide suggestions for next steps in this innovative field of study.

2. Role of stress and anxiety in alcohol use disorders

Anxiety is a diverse and common comorbidity among individuals with AUDs (Wolitzky-Taylor et al., 2011). Data suggest that there is a significant, bi-directional relationship between anxiety disorders and excessive alcohol use (Kushner et al., 2000). Individuals with an anxiety disorder were 2.6 times more likely to have alcohol dependence, and more than a third of adults with alcohol dependence had at least one form of an anxiety or mood disorder (Grant et al., 2004; Teesson et al., 2009). Individuals may use alcohol as a coping mechanism (i.e., self-medication theory) for emotional events or social situations where anxiety levels are likely to increase to numb their emotions, improve overall mood, and assist in social situations (Bolton et al., 2006; Robinson et al., 2009). Withdrawal symptoms related to chronic alcohol dependence may increase anxiety symptoms and trigger panic attacks, presenting a significant risk for relapse (Driessen et al., 2001; Willinger et al., 2002). Such changes may persist for months or years after abstinence; thus, individuals may continue to suffer from anxiety episodes related to social events involving alcohol consumption long-term (Kushner et al., 2000).

Alcohol consumption also reduces the tension associated with the experience of stress (e.g., tension-reduction hypothesis) and alleviates negative effects caused by stressful life events (Sinha, 2001). Additionally, post-traumatic stress disorder (PTSD) and alcohol misuse are often common occurrences (Debell et al., 2014), with as many as 59% of individuals suffering from PTSD also having an AUD (Ralevski et al., 2014). Researchers commonly study the interaction between extreme stress events and increased voluntary, compulsive alcohol consumption in rats and mice (Whitaker et al., 2014). Following a single stressful event, Long-Evans rats increased their voluntary alcohol consumption, regardless of whether they had any prior exposure to alcohol (Meyer et al., 2013). A history of stress exposure also seems to be an important moderating factor for alcohol consumption as it may affect self-administering behaviors (Logrip and Zorrilla, 2012).

Patients receiving treatment for AUDs often benefit from concurrent treatment that target underlying problems for comorbid anxiety and stress disorders that may serve to maintain one another (Lynskey, 1998). Yet, historically patients with comorbid substance use and mental health problems have had to seek addiction treatment first, a practice that may lead to untreated mental health problems (Havassy et al., 2009). Addressing comorbid anxiety disorders concurrently with AUD treatment may prevent alcohol problems from persisting or worsening (Watt et al., 2006; Wolitzky-Taylor et al., 2015). Clearly, there is a need for more integrative approaches to dealing with anxiety and stress disorders as a necessary part of any AUD treatment program (Wolitzky-Taylor et al., 2011; Morley et al., 2013).

2.1. Effect of exercise on anxiety and stress

Individuals participating in exercise training programs have shown greater decreases in anxiety than with other common forms of treatment, such as psychotherapy, and that exercise can be equally, or more, successfully than pharmacotherapy (Wipfli et al., 2008). Exercise has also proven to be effective as an adjunctive treatment therapy in individuals with clinically diagnosed anxiety disorders (Jayakody et al., 2014), as well as in those with chronic illnesses and cancer (Herring et al., 2010). Greater improvements in fitness result in better outcomes (Wipfli et al., 2008), particularly after participating in aerobic training programs lasting as long as 3 months with sessions that are at least 30 min in length (Herring et al., 2010). A growing body of research has also shown that the frequency and intensity of panic symptoms are significantly decreased after low to moderate intensity aerobic activity and strength training (Ströhle et al., 2005; Strickland and Smith, 2014). Preliminary work using resistance training shows reductions in worrying by sedentary women with general anxiety disorders (Herring et al., 2012a,b), in individuals recovering from stroke (Aidar et al., 2012), and can be anxiolytic both acutely (i.e., after a single session) and chronically (i.e., several weeks) (Strickland and Smith, 2014). In individuals with PTSD, structured aerobic (Fetzner and Asmundson, 2015) and strength training (Rosenbaum et al., 2015) programs have significantly reduced the symptoms for anxiety, stress, and PTSD.

3. Role of impulsivity on alcohol use disorders

Impulsivity has been defined as a behavior that tends to be committed without forethought or conscious judgment and is characterized by acting on the spur of the moment with a lack of planning (Evren et al., 2012). Individuals with high impulsivity have a predisposition toward rapid, unplanned actions that are unduly risky, inappropriate, and often result in undesirable consequences (Moeller et al., 2001). Impulsivity is a multi-dimensional construct with individual differences occurring across different constructs, such as impulsive choice, failure to delay gratification, response inhibition, attentional and motor impulsiveness, and novelty seeking (Dawe and Loxton, 2004; Lejuez et al., 2010). Impulsivity is an important determinant of alcohol use and related problems as impulsive choice and inhibitory failure is paramount to the acquisition and escalation of alcohol abuse (Lejuez et al., 2010).

Research has consistently demonstrated an association between impulsivity and the development of alcohol use problems in adolescence and young adulthood (Marshall, 2014).

Dom et al. (2006) found that higher levels of impulsivity and sensation seeking were associated with earlier onset of alcohol drinking and alcohol-related problems. In a sample of 18–25 year olds, those who scored high on impulsivity subscales engaged in higher levels of alcohol use and were more likely to develop AUDs and binge drinking problems (Shin et al., 2012). In a prospective study of heavy drinking adults, Rubio et al. (2008) found that the inability to delay reward was associated with a greater risk of future heavy drinking with individuals choosing smaller immediate rewards over larger delayed rewards. Impulsivity has also been implicated as a fundamental mechanism and predictor of relapse with higher levels of impulsivity traits indicative of poor treatment retention and prognosis (Miller, 1991; Dom et al., 2006). Abstinent patients with high levels of impulsivity may be at high risk of relapse even after prolonged and successful periods of abstinence, suggesting the need to ameliorate impulsivity in order to prevent the risk of relapse (Salgado et al., 2009).

3.1. Effect of exercise on impulsivity

There has been relatively little research conducted examining the effect of exercise on impulsivity. A 4-week exercise-training program conducted with C57BL/6N mice resulted in decreased impulsiveness (Binder et al., 2004). In humans, the impact of exercise training on impulsivity has been most commonly investigated in children with attention deficit hyperactivity disorder (ADHD). An exercise intervention, conducted among third grade children with high levels of hyperactivity, showed potential for treating both hyperactivity and impulsivity (Klein and Deffenbacher, 1977). Hyperactive boys who were randomized to group relaxation training and large muscle exercise showed significantly higher attention to task, lower impulsivity, and lower locus of control scores, indicating a more internal orientation (Porter and Omizo, 1984). Finally, male college students with ADHD who engaged in higher levels of physical activity reported significantly less behavioral impulsivity and experienced significantly less worrisome and intrusive thoughts (Abramovitch et al., 2013). Other studies have examined the effect of exercise on different components or aspects of impulsivity that have been associated with binge drinking, alcohol-related problems, and AUDs (Shin et al., 2012). Acute aerobic exercise has been show to increase positively activated, affective states compared to non-exercising individuals (Reed and Ones, 2006). Individuals with low baseline affective state scores, similar to individuals with AUDs (Anestis et al., 2007), had increased scores post-exercise (Reed and Ones, 2006).

In addition to a lack of impulse control, intense, involuntary craving has also been linked to continued alcohol use (Flannery et al., 2001). Impulsivity has been positively correlated with severity of craving and, together, they may lead to a rapid, unplanned action without regard to consequence resulting in relapse, continued use, and/or dependence (Bottlender and Soyka, 2004; Evren et al., 2012). Several studies have established the effect of acute exercise bouts on craving (Joos et al., 2013). Ussher et al. (2004) demonstrated that acute bouts of exercise are successful in decreasing cravings for alcohol immediately post-exercise. Similarly, exercise has been shown to be a strong stimulus for decreasing the craving for smoking (Roberts et al., 2012; Haasova et al., 2013), marijuana use (Buchowski et al., 2011), and excessive eating (Oh and Taylor, 2013).

4. Role of depression in alcohol use disorders

Depression is among the psychiatric disorders most frequently associated with AUDs (Lai et al., 2015). Population-based surveys report that nearly one-third of individuals with an AUD have a history of major depression (Kessler et al., 1997), while estimates in clinical samples are over 40% (Miller et al., 1996; Schuckit et al., 1997). Similar to other disorders previously discussed, prospective analyses indicate a bi-directional relationship between AUDs and depressive disorders; those with an AUD are more likely to develop a future depressive disorder and individuals with a history of depressive disorders are more likely to develop an AUD (Dixit and Crum, 2000; Peirce et al., 2000). Comorbid depressive disorders are associated with greater disability and heavier use among those seeking treatment for AUDs and, even though improvements are observed following treatment, those with a comorbid depressive disorder remain more disabled and drink more than those without a comorbid depressive disorder (Burns and Teesson, 2002; Burns et al., 2005).

The integration of depression treatment in patients with comorbid depression and AUDs results in significant improvements in both depression and AUD outcomes compared to those receiving only AUD treatment (Pettinati, 2004). Treatment of patients with comorbid Major Depressive Disorder (MDD) and alcohol dependence with fluoxetine, a selective serotonin reuptake inhibitor (SSRI), resulted in improvement in depressive symptoms and reduced alcohol consumption (Cornelius et al., 1997). An open-label trial found similar effects in adolescents receiving concurrent treatment for depression (Cornelius et al., 2001). Similarly, in a study of relapse prevention psychotherapy, improved mood was correlated with reduced alcohol consumption (McGrath et al., 1996). SSRI treatment, administered concurrently with naltrexone, resulted in greater alcohol abstinence, a delay in relapse, and decreased depression severity (Pettinati et al., 2010). This approach to targeting both MDD and AUDs concurrently is also effective using psychotherapy. Combined psychotherapy, targeting both depression and alcohol consumption, resulted in greater reductions in both alcohol consumption and depression severity compared to intervention arms with only one focus (Baker et al., 2010).

4.1. Effect of exercise on depression

Cross-sectional studies have identified inverse associations between physical activity and depressive symptoms (Farmer et al., 1988; Paffenbarger et al., 1994), while prospective observational studies have demonstrated the protective effects of physical activity and fitness on the incidence of depressive disorders (Farmer et al., 1988; Camacho et al., 1991; Dishman et al., 2012). Similarly, several meta-analyses support the use of exercise as either an augmentation or a stand-alone treatment for patients with MDD (Rimer et al., 2012; Rethorst and Trivedi, 2013). Randomized controlled trials have demonstrated that exercise is more effective than either placebo or attentional control groups, and produces effects equivalent to other depression treatments, such as psychotherapy and antidepressant medications (Klein et al., 1984; Blumenthal et al., 2007). One trial showed that a public health “dose” of aerobic exercise is an effective treatment for those suffering from depression (Trivedi et al., 2006), as well as in individuals who have not responded to treatment with an antidepressant medication (Mather et al., 2002; Trivedi et al., 2011a,b). In

addition to patients with a primary depression diagnosis, exercise is also effective in reducing depressive symptoms in patients with chronic medical conditions (Herring et al., 2012a,b). Finally, not only does exercise provide long-term alleviation of depressive symptoms, but engaging in a bout of exercise results in an acute mood improvement, both in "healthy" individuals (Ekkekakis et al., 2011) and those with MDD (Bartholomew et al., 2005).

5. Role of neurobiology in alcohol use disorders

Substantial research has examined the neurobiological mechanisms responsible for the development of AUDs. The synthesis and metabolism of dopamine (Engel and Jerlhag, 2014), serotonin (LeMarquand et al., 1994a,b) and gluccocorticoids (Stephens and Wand, 2012) have all been implicated in the development and recurrence of AUDs. These mechanisms appear to be responsive to acute consumption of alcohol and also have a role in alcohol craving and relapse. Alcohol consumption stimulates production of dopamine (Boileau et al., 2003), and serotonin (LeMarquand et al., 1994a; McBride et al., 2002). However, these acute effects diminish over repeated administrations in a manner that is indicative of increased alcohol tolerance (Ehrenreich et al., 1997; Lee and Rivier, 1997).

These biomarkers also show alterations during alcohol withdrawal that have been correlated with intensity of alcohol cravings and withdrawal symptoms. Dopamine levels are diminished during withdrawal, as are dopamine receptors and dopamine transporters, and these decreases have been correlated with increased alcohol craving (Laine et al., 1999; Heinz et al., 2004). Similarly, serotonin transporters are decreased in withdrawal and are correlated with increases in anxiety and depression (Heinz et al., 1998), along with seizures and delirium (Schmidt and Sander, 2000). Conversely, cortisol release is increased following alcohol withdrawal and this increase is correlated with severity of withdrawal symptoms (Heinz et al., 1995; Esel et al., 2001; Keedwell et al., 2001) and is predictive of relapse (Adinoff et al., 1998; Kiefer et al., 2002; Junghanns et al., 2003). As alcohol abstinence continues, cortisol levels decrease, often below "normal" levels before eventually returning to normal (Stephens and Wand, 2012). Despite this normalization of basal cortisol levels, dysfunctional hypothalamus–pituitary–adrenal (HPA) axis response to stressors remains (Bernardy et al., 1996; Adinoff et al., 1998, 2005a,b; Anthenelli et al., 2001).

In addition to the direct effect that these neurobiological mechanisms impart on AUDs, the psychological comorbidities discussed above (anxiety, stress, impulsivity, and depression) share common neurobiological underpinnings with AUDs. For example, aspects of reward and impulsivity appear to be greatly influenced by dopaminergic functioning (Spanagel and Weiss, 1999; Buckholtz et al., 2010), targeting serotonin production and reuptake is a primary treatment for anxiety and depression (Baldwin and Rudge, 1995), and stress response is mediated by the functioning of the HPA axis (Sapolsky et al., 2000). Therefore, interventions that can alter these neurobiological mechanisms have the potential to impact treatment through by simultaneously addressing several of co-morbidities associated with AUDs.

5.1. The effect of exercise on neurobiological mechanisms related to alcohol use disorders

Evidence suggests that exercise has both acute and long-term effects on the neurobiological mechanisms previously discussed (Dishman et al., 2006). In animal models, research has indicated that the synthesis of dopamine (Hattori et al., 1994; Meeusen et al., 2001), serotonin (Chaouloff, 1997; Struder et al., 1999), and glucocorticoids (Fediuc et al., 2006; Campbell et al., 2009) increases acutely following exercise. Chronic exercise in animals has shown to increase whole brain dopamine (de Castro and Duncan, 1985; Heyes et al., 1988), downregulate dopamine D_2 receptor density (de Castro and Duncan, 1985; Greenwood et al., 2011), and increase D_2 receptor binding (Gilliam et al., 1984; MacRae et al., 1987). Chronic exercise also attenuates the HPA response to stress (Droste et al., 2003; Fediuc et al., 2006; Zheng et al., 2006) and appears to alter serotonin production and synthesis (Greenwood et al., 2005; Young, 2007; Greenwood and Fleshner, 2011).

Though less extensive, and often measured through changes in the periphery, research has replicated many of these findings in humans. Research suggests that an acute bout of exercise increases serotonin production and metabolism (Jakeman et al., 1994; Struder et al., 1999; Struder and Weicker, 2001), as well as cortisol (Luger et al., 1987; McGuigan et al., 2004; Rojas Vega et al., 2006). However, in trained individuals, decreased serum serotonin levels have been observed after exercise, likely due to increased serotonin release, re-uptake and metabolism (Struder et al., 1999; Weicker and Struder, 2001; Wipfli et al., 2011). HPA axis response to exercise is also blunted following chronic exercise (Luger et al., 1987; Nabkasorn et al., 2006), suggesting that the HPA axis response is altered by exercise. This is supported by the fact that greater physical fitness is associated with lower cortisol response to acute physical or psychosocial stressors (Traustadottir et al., 2005; Rimmele et al., 2007).

6. Exercise, self-efficacy, and alcohol use disorders

Self-efficacy refers to the extent to which someone believes they are capable of successfully managing a challenging circumstance (Bandura, 1986). Applied to addictive behavior, self-efficacy can be understood as the extent to which the addicted individual views themselves as being able to cope with a difficult situation without relying on alcohol or other drugs. The self-efficacy construct is featured prominently in models of addiction as an important etiological mechanism (Maisto et al., 1999; Witkiewitz and Marlatt, 2004). Self-efficacy is also important to successful recovery from addiction with many formal interventions targeting self-efficacy cognitions (Randall et al., 2003; Kelly and Greene, 2014). It has been suggested that one way that exercise may facilitate cessation of problematic substance use is through improvements in global self-efficacy. Indeed, data show that both acute bouts of exercise, as well as longer-term engagement in exercise regimens, are associated with an enhanced sense of self-efficacy (McAuley et al., 1993; McAuley and Blissmer, 2000; Parschau et al., 2013). Though changes in both general and exercise-specific self-efficacy have been linked to exercise, to our knowledge, no studies have examined whether exercise also exerts an influence on the domains of self-efficacy that are especially relevant to alcohol use behaviors, such as drink/drug refusal self-efficacy, and may present an important direction for future research.

7. Exercise and the social environment for individuals with alcohol use disorders

In addition to the direct effects that exercise may have on factors such as mood or craving, exercise also may act on other, more distal factors that have a positive influence on AUD outcomes. Most notable among these are the effects that exercise may have on an individual's social environment. The social environment is one of the strongest predictors of alcohol and other drug involvement (Laudet et al., 2002; Bischof et al., 2007; Longabaugh et al., 2010) and has been posited to be a critical mechanism of successful recovery from addiction (Galanter, 2007; Litt et al., 2007; Chi et al., 2009; Apodaca et al., 2013). Given this, the potential for group-based exercise interventions to foster interpersonal relationships that may support recovery efforts is evident. Exercise groups or classes provide an occasion to bring people together, thus contributing to a sense of social connectedness and the chance to develop social support (Palmer et al., 1995; Lawson, 2005). Moreover, even exercise that is not group-based may offer opportunities for positive social interaction, as many of those who exercise do so with others (Dunton et al., 2008) and, in these cases, may still serve as a conduit to sociability and support. In addition to strong and supportive relationships, another way in which the social environment may influence AUD outcomes is through the development of social networks that are supportive of sobriety. Specifically, group-based exercise programs allows those in recovery to experience group interactions that do not involve alcohol or other drugs and thus can help to build or strengthen a social network focused on healthy activities rather than substance use (Lawson, 2005; Landale and Roderick, 2014).

Engagement in an exercise regimen can also help to change how an individual spends his or her social-recreational time. Behavioral economic models of addiction highlight the importance of rewarding social and emotional experiences that will compete with if not supplant the rewarding effects of substance use (Bickel et al., 2014). As noted previously in this review, exercise is associated with myriad positive mental health effects, including increases in positive mood and decreases in anxiety and depression. Yet, exercise can also offer a way of spending free time that represents an alternative to drug use (Marlatt and Gordon, 1985; Correia et al., 2010; Meyers et al., 2011). Engagement in exercise may also shift an individual's orientation toward the rewards of physical wellness. As heavy alcohol use is inconsistent with this orientation, the relative value of drug use may decrease as the value of exercise and fitness increases.

8. Animal models of exercise training and alcohol consumption

Animal models are commonly used to examine the impact of exercise training on alcohol use and associated mediating factors. Chronic exercise has been shown to alleviate stress-produced anxiety- and depression-like behavior (Kim and Leem, 2014). Other studies have demonstrated that C57BL/61BG mice (a genetic strain that willingly seeks and consumes higher levels of ethanol) alter their alcohol consumption patterns when given unlimited access to a running wheel over several days as compared to non-alcohol preferring mice or those that did not have access to a running wheel (Ehringer et al., 2009; Pichard et al., 2009;

Darlington et al., 2014). 1n a population of male Syrian hamsters, access to a running wheel reduced ethanol consumption and, conversely, that access to ethanol decreased wheel running (Hammer et al., 2010). Another investigation found that while access to ethanol changed wheel running patterns (running distance increased during abstinence), access to wheel running did not modify total ethanol intake (Ozburn et al., 2008). However, when the wheel was accessible, mice consumed less ethanol per bout (i.e., decreased binge-type drinking patterns). Voluntary exercise also appears to both prevent (Engelmann et al., 2014) and/or diminish (O'dell et al., 2012) methamphetamine-induced forebrain damage. However, the neuroprotective effects of wheel running may be transient and continued activity may be necessary to prevent compulsive methamphetamine intake (Engelmann et al., 2014). These observations highlight the positive aspects of moderate activity on alcohol consumption and provide further support that the rewarding properties of exercise may substitute (hedonic substitution) for the rewarding properties of alcohol intake and drug use and serve as an effective intervention in drug abuse and alcohol treatment programs.

9. Direct effect of exercise training on alcohol consumption and alcohol use disorders

While several investigators have examined integrating exercise as a part of AUD treatment, few have reported its direct impact on alcohol-related outcomes in humans (Frankel and Murphy, 1974; Palmer et al., 1988). One of the first studies to provide evidence of the potential impact of exercise training in alcohol treatment was conducted by Sinyor et al. (1982). Their study, involving 58 individuals attending a 6-week in-patient treatment program, engaged patients in a daily 1 h of physical activity session. At the end of the treatment program, individuals who participated in the exercise training showed significant improvements in physical fitness and abstinence rates compared to individuals at neighboring treatment centers that did not offer a fitness program. Another study enrolled male college students, who reported high volume drinking and no history of physical activity, in group run training three times per week (Murphy et al., 1986). They observed significant gains in fitness accompanied by a reduction in ethanol consumption (60%) in the exercise group as compared to the controls. However, this study had a small sample size and did not quantify the dose of exercise training (e.g., varying intensities, caloric expenditure, and weekly compliance).

A recent randomized pilot trial demonstrated that group aerobic exercise training was successful in reducing drinking patterns compared to a brief advice control condition (Brown et al., 2014). However, levels of activity did not significantly differ across the two conditions suggesting that the individuals engaged in the exercise training may have been influenced by factors, such as frequent contact with other group members, receiving supervision and support, accountability to others in their group, which those in the control condition did not receive. Additionally, the benefits of the exercise training appeared to be limited primarily to those individuals most adherent to the intervention. Finally, the results of a meta-analysis by Wang et al. (2014) demonstrate, albeit across a small number of studies, that exercise training attenuates withdrawal symptoms and eases anxiety symptoms in individuals with AUDs over an extended follow up period. While these studies are

generally supportive of exercise training as a part of AUD treatment, they highlight the need for more highly controlled trials to determine the isolated effect of the exercise training on patient outcomes.

10. Future directions

The information presented in this review provides a rationale for the potential efficacy of exercise in the treatment of AUDs. However, direct evidence of the efficacy of exercise as an intervention in AUD treatment is limited and randomized controlled trials involving exercise training in individuals with substance use disorders are extremely rare (Zschucke et al., 2012). To our knowledge, no study has investigated the efficacy of exercise training in alcohol treatment in a controlled environment. A recent review by Giesen et al. (2015) determined that only two studies on alcohol and exercise training could be graded as evidence level 2 investigations (level 1 being the highest level of evidence originating from systematic reviews of randomized control trials). Methodological considerations, such as not accounting for exercise intensity, dose, or the use of unsupervised exercise sessions, limit our knowledge of the exact impact of exercise training and how it should be integrated into treatment programs. Given this, we feel that it is essential to establish the efficacy of exercise training in a highly controlled environment prior to determining its effectiveness in a real world setting, such as a part of outpatient treatment programs. The results from this work could then be used to establish the optimal dose, frequency, and intensity of an exercise intervention that would be best tolerated by individuals, particularly as an augmentation to their AUD treatment program.

Due to the many complications and stressors that individuals with AUDs face, in addition to completing their treatment program, residential treatment programs might serve as the ideal location for conducting these well-controlled efficacy trials. Residential treatment programs provide a structured environment, which may be ideal for implementing an exercise-training program to augment a client’s treatment program. Individuals seeking assistance for AUDs and substance disorders are open to participating in exercise training as part of their treatment program (Read et al., 2001; Abrantes et al., 2014; Stoutenberg et al., 2014). In particular, patients in residential treatment programs are receptive to the idea and feel that they are capable of engaging in exercise training as a part of their treatment program (Stoutenberg et al., 2014). A majority of the patients expressed that exercise training be initiated in a face-to-face format during, rather than after, their residential treatment, especially since access to facilities and a lack of resources were mentioned as the primary barriers for being regularly active. One of the greater challenges to conducting exercise-training interventions in alcohol and substance abusing populations is adherence to the program. Using the in-patient treatment period provides clients with the opportunity to gradually adapt to an exercise routine, allows for a greater level of support to enhance exercise adherence, and presents a period of time where positive health behaviors can be established and maintained post-discharge. Findings from these controlled trials could then be translated into less structured outpatient and long-term recovery programs.

11. Conclusion

The behavioral, neurobiological, and psychological disorders discussed in this paper rarely occur in isolation and are often seen in combination, amplifying their overall impact on AUDs. Furthermore, among substance users and individuals with AUDs, quality of life is generally very poor (Smith and Larson, 2003; Donovan et al., 2005). The proven ability of exercise to successfully to impact quality of life is an additional benefit of exercise training and may increase commitment to abstinence (Laudet and Stanick, 2010). Across these multiple disorders, exercise training is the one treatment strategy that has consistently been efficacious, highlighting its potential impact and importance as an important part of any AUD treatment program (Penedo and Dahn, 2005; US Department of Health and Human Services, 2008). The evidence presented in this paper provides a compelling case for further examination of integrating exercise training as a regular part of treatment programs for individuals seeking treatment for AUDs.

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