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Clinical Exercise Interventions in Alcohol Use Disorders: A Systematic Review

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ABSTRACT

The therapeutic impact of exercise interventions in psychiatric diseases such as depression, anxiety and schizophrenia has already been proven through several reviews whereas substance use disorders such as alcohol use disorders (AUD) have so far less frequently been a matter of investigation. Although several publications have summarized studies focusing on physical activities in substance use disorders, no systematic review exists summarizing the evidence of exercise interventions in AUD. A total of 14 studies using the Medline Database, CCMed, Cochrane Library and PsychINFO were identified and met the inclusion criteria. In order to evaluate the evidence, we used the evaluation system of the Oxford Centre for Evidence-Based Medicine (2011). Due to methodological flaws the overall evidence of the studies is rated level "3" but primarily findings confirm that exercise interventions as a complementary treatment component in AUD are feasible and safe. No adverse events were reported. This systematic review indicates that exercise may have beneficial effects on certain domains of physical functioning including VO_2max, basal heart rate, physical activity level and strength. Inconsistent effects with a slight trend towards a positive effect on anxiety, mood management, craving, and drinking behavior have been shown and need to be verified. Results must be interpreted cautiously due to the numerous methodological flaws and the heterogeneity of the interventions and measures. However, according to preclinical studies several mechanisms of action are conceivable, especially as to alcohol-related outcomes and additionally seem to be promising. RCTs with high methodological quality are urgently needed in future research to establish evidence-based exercise recommendations for the treatment of AUD.

1. Introduction

Alcohol use disorders (AUDs) are worldwide a central public health problem. Among the mental and neurological disorders, AUDs rank after depression and dementia with 3.4% on place 3 of the overall burden of disease (DALYs) in Europe and, as related to men, AUD turns out to be even the most important contributor of all the DALYs in the EU (Wittchen et al., 2011). Thus, the harmful intake of alcohol can lead to serious diseases accompanied by sequelae on physical, psychological and social levels. Despite advanced psychotherapeutic, socio-therapeutic and pharmacotherapeutic approaches in recent years, relapse rates are still high (Bottlender, Köhler, & Soyka, 2006; Dawson, Goldstein, & Grant, 2007; Hunt, Siegfried, Morley, Sitharthan, & Cleary, 2013; Mann et al., 2013; Project MATCH Research Group, 1998) requiring more successful and optimized methods of specialized alcohol treatment.

At present the potential of exercise interventions is at the center of attention in the context of different somatic and psychiatric diseases. With regard to mental disorders such as affective, anxiety and schizophrenic disorders, regular exercise and physical activity have been proved to be effective not only in improving physical functioning but also in reducing negative emotional states such as depressiveness, anxiety, tension of stress, sleep disturbances and other psychological outcomes (Biddle & Mutrie, 2008; Cooney et al., 2013; Gorczynski & Faulkner, 2010; Wipfli, Rethorst, & Landers, 2008). These emotional states are also associated with patients suffering from AUD and seem to play an important role in the initiation of alcohol relapse (Cummings, Gordon, & Marlatt, 1980). Furthermore according to several preclinical studies addressing substance use disorders (Smith & Lynch, 2012) and in the context to the treatment of nicotine use disorders (Ussher, Taylor, & Faulkner, 2012), exercise interventions revealed to be effective in the regulation of substance-specific outcomes such as craving or consumer behavior.

Additionally, AUD is dependent on the grade of severity accompanied by a wide range of somatic symptoms which can affect nearly every organ or organ system of the body. Due to the systemic effect of alcohol, chronic abuse is associated with more than 200 diseases (WHO, 2014). The most frequent diseases attributable to alcohol are gastrointestinal diseases (mainly liver cirrhosis and pancreatitis), cancers, tuberculosis, epilepsy, hemorrhagic stroke, and hypertensive

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Table 1
Inclusion and exclusion criteria.

	Inclusion criteria	Exclusion criteria
Participants	Clinically indicated AUD, alcohol dependence, alcohol abuse, alcoholism or participants labeled as "problem/harmful drinkers"	Subclinical populations referred to as "heavy/hazardous drinkers" or "social drinkers" Youths <20 years of age Persistence of AUD < 5 years
Intervention	Exercise Interventions Supervised or non-supervised, home based interventions	Studies in which exercise constitutes not a separate part of combined interventions such as life style modification programs or nutritional counseling interventions
Outcome	Physical functioning (e.g. strength, endurance, flexibility, coordination),physical activity level, health-related quality of life Psychological outcomes (e.g. body-concept, self-concept, locus of control, self-esteem, self-efficacy), psychological symptoms (e.g. depressiveness, anxiety, sleep disturbances) Alcohol-related outcomes (e.g. craving, abstinence rate, drinking behavior)	
Study design	Randomized controlled trials Nonrandomized controlled trials, Number of patients >20, Published in English or German	

heart diseases (WHO, 2014). Exercise as medicine has already been indicated to be effective in the treatment of certain somatic diseases such as coronary heart diseases, cancers, and musculoskeletal diseases (Fransen, McConnell, Hernandez-Molina, & Reichenbach, 2014; Heran et al., 2011; Mishra et al., 2012).

As a result, the question is imposing if exercise as an adjunct therapeutic intervention may also be beneficial in alcohol treatment. Several authors made exercise or physical activity already a subject of discussion (Brown et al., 2009; Deimel, 2011; Donaghy & Mutrie, 1999; Meyer & Broocks, 2000; Murphy, Pagano, & Marlatt, 1986; Read & Brown, 2003; Zschucke, Heinz, & Ströhle, 2012) but disunity seems to exist about the definition of exercise interventions. Consequently, there is a need to distinguish between exercise or physical activity by itself and indication-specific, clinical exercise as a part of treatment.

Exercise is defined as "a type of physical activity consisting of planned, structured, and repetitive bodily movement done to improve and/maintain one or more components of physical fitness" (American College of Sports Medicine, 2013). Clinical exercise interventions in the treatment of AUD pursue therapeutic targets after the bio-psycho-social model (World Health Organization, 2001). Thus the aim is not only the improvement or maintenance of physical functioning such as cardiorespiratory endurance, muscular strength, muscular endurance, flexibility, coordination, physical activity level and body composition but also the improvement of psychological and alcohol-related symptoms such as the reduction of depressiveness, anxiety, states of stress, sleep disturbances, pain and especially craving plays an important role in the treatment of AUD. Furthermore long-term targets such as improvements of body-concept, self-concept, self-efficacy, health-related quality of life and participation in the sense of improved psychophysical resilience are part of the therapeutic exercise goal setting.

According to the 5th edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5) alcohol dependence and alcohol abuse are condensed into one clinical picture with severity based on the number of symptoms criteria endorsed. Thus, depending on the severity AUD occurs from mild (2–3 symptoms) to severe (6 or more symptoms) (American Psychiatric Association, 2013).

In the last decades several studies focusing on exercise interventions as complementary part of standard AUD treatment have been published, beginning with the first study of Gary & Guthrie, 1972. In order to summarize publications which address exercise interventions in AUD or substance use disorders, some reviews have already been published (Daley, 2002; Donaghy & Mutrie, 1999; Meyer & Broocks, 2000; Read & Brown, 2003; Siñol et al., 2013; Wolff et al., 2011; Zschucke, Gaudlitz, & Ströhle, 2013; Zschucke et al., 2012) but to our knowledge no systematic review has been conducted so far. The following paper aims to present a systematic review addressing exercise interventions as an additional component in the standard treatment of AUD including a comprehensive and systematic search with defined inclusion and exclusion criteria and appraisal procedure according to the Oxford Centre of Evidence-based Medicine evaluation system (Oxford Centre for Evidence-Based Medicine, 2011) which is recommended for application in clinical trials. In the focus of interest are the following outcomes: feasibility and safety, physical functioning, psychological outcomes, physical, psychological and alcohol-related symptom reduction and health-related quality of life.

2. Methods

The review focuses on clinical exercise interventions in AUD. In the period of time between January and March 2014, added to the updating search made in October 2014, a comprehensive search of Medline, CCMed, Cochrane Library and PsychINFO according to the guidelines of the Centre of Reviews and Dissemination (Centre for Reviews and Dissemination, 2009) by two independent researchers was conducted. Search terms were entered both as subject headings (e.g. MeSHs) and keywords involving *physical activity, physical fitness, exercise, moving therapy, sport* therapy, aerobic training, endurance training and resistance training* in different combinations with *alcoholism, alcohol use disorder*, alcohol-related disorder*, alcohol dependence and alcohol abuse*. In addition to the search in international databases a hand search of reference lists, conference abstracts and key authors was carried out. According to the defined inclusion and exclusion criteria (see Table 1) only Randomized Controlled Trials (RCTs) and Non-Randomized controlled/follow-up studies investigating exercise interventions as a treatment of AUD published in English or German language were included. Studies with sample sizes under 20 (i.e. at least n = 10 per group), without a clinically defined diagnosis of any alcohol-related disorder (e.g. social drinkers were excluded), participants under 20 years of age and studies without control group were excluded (n = 19[1]). In order to evaluate the evidence of the identified studies, the evaluation system of the Oxford Centre for Evidence-Based Medicine (2011) was used. This system is primarily based on the study design which contains 5 different levels of evidence ranked from the highest level 1 (systematic review of RCTs) to the lowest level 5 (mechanism based reasoning). (See Table 2.)

[1] Russel & Bennett, 1972; Vivian, Goldstein, & Shelly, 1973; Frankel & Murphy, 1974; Kavacas & Richardson, 1976; Schürch, Lagerström, & Hollmann, 1978; Service, 1982; Tsukue & Shohoji, 1981; Bowerman, 1985; Murphy et al., 1986; Klein, 1986; Anstiss, 1991; Burling, Seidner, Robbins-Sisco, Krinsky, & Hanser, 1992; Deimel & Rickert, 1993; Peterson & Johnstone, 1995; Palmer, Palmer, Michiels, & Thigpen, 1995; Patten, Vickers, Martin, & Williams, 2003; Ussher, Mc Cusker, Morrow, & Donaghy, 2000; Matsui et al., 2010; Hallgren, Romberg, Bakshi, & Andréasson, 2014.

As shown in Fig. 1, titles, abstracts and full-text articles were viewed considering the inclusion and exclusion criteria. Finally, 14 studies focusing on exercise interventions in AUD as an additional component of standard treatment were included. All included studies examined some of the following parameters: feasibility and safety, physical functioning, psychological outcomes, symptom reduction or alcohol-related outcomes.

3. Results

A total of 14 studies involving 1160 participants with a clinically indicated AUD were included. However, only 3 of the latest studies (Brown et al., 2014; Capodaglio et al., 2003; Vedamurthachar et al., 2006) labeled their participants (n = 164) precisely according to a diagnosis system such as DSM or the International Classification of Diseases (ICD-10) as "alcohol dependent". Thus, inconsistent terminology of alcohol-related disorders was determined, especially in studies that date from the 1970s and 1980s which labeled their examined population either as "patients" of a special alcohol treatment facility or simply as "problematic drinkers", "alcoholics" or "chronic alcoholics" without any reference to a diagnostic system. This is probably due to the fact that the recognition of a defined clinical picture of the alcohol use disorder is historically still young. Instead, there was at least information about chronicity available by indicating the years of problematic drinking which were given in 4 studies and ranked on average between 5.5 and 21.3 years (Gary & Guthrie, 1972; Mc Kelvy, Stein, & Bertini, 1980; Piorkowski & Axtell, 1976; Sinoyer, Brown, Rostant, & Seraganian, 1982). Nine RCTs were identified but only two of them were graded as evidence level "2" (Brown et al., 2014; Donaghy, 1997) according to the CEBM-system while the rest of them had to be downgraded to level "3" due to methodological flaws of the RCTs (Gary & Guthrie, 1972; Lehofer et al., 1995; Mc Kelvy et al., 1980; Piorkowski & Axtell, 1976; Stiensmeier-Pelster, Meyza, & Lenzen, 1989; Vedamurthachar et al., 2006; Weber, 1984). Reasons for downgrades were lack of data and statistical analysis, lack of information about the intervention itself or about the contact times of the control group or because of non-generalizable samples (e.g. veterans), lack of intension-to-treat-analysis, or unequal samples regarding age and/or sample size. Furthermore, 5 non-randomized controlled trials (CTs) met the inclusion criteria; 2 of them were ranked with level "3" (Capodaglio et al., 2003; Ermalinski, Hanson, Lubin, Thornby, & Nahormek, 1997) and 3 had to be downgraded to "4" (Lüdke, 1978; Palmer, Vacc, & Epstein, 1988; Sinoyer et al., 1982) because of not reporting standard alcohol treatment, time-staggered samples, not equal contact times of the controls and not comparable or clear separated control groups.

With the exception of the two RCTs whose settings were outpatient (Brown et al., 2014) or at least mixed in- and outpatient (Donaghy, 1997), all exercise interventions were conducted supervised during an inpatient treatment setting either immediately in the course of detoxification or after completed detoxification. Overall, follow-up data as to alcohol outcomes were collected only from 3 studies and were examined between 1 month and 18 months post treatment (Brown et al., 2014; Donaghy, 1997; Sinoyer et al., 1982). With regard to the form, aerobic exercise programs such as walking, running and cycling were the most conducted interventions (Brown et al., 2014; Capodaglio et al., 2003; Gary & Guthrie, 1972; Lehofer et al., 1995; Lüdke, 1978; Mc Kelvy et al., 1980; Palmer et al., 1988; Stiensmeier-Pelster et al., 1989; Weber, 1984) but also combined exercise regimens including aerobic endurance, strength and coordinative skill training were examined (Donaghy, 1997; Ermalinski et al., 1997; Piorkowski & Axtell, 1976; Sinoyer et al., 1982). One study investigated the effects of a Yoga program (Vedamurthachar et al., 2006). The frequency of the exercise interventions was between 1 and 5 times per week. The duration varied between 14-day interventions and 4-month programs whereas the volume per unit ranged between 15 and 60 min. Only 4 studies stated the intensity of the aerobic exercise intervention which varied between 55% and 85% of the age-predicted HR_{max} (Brown et al., 2014; Donaghy, 1997; Mc Kelvy et al., 1980; Palmer et al., 1988). Seven of all studies were solely conducted with male participants (Ermalinski et al., 1997; Gary & Guthrie, 1972; Mc Kelvy et al., 1980; Piorkowski & Axtell, 1976; Stiensmeier-Pelster et al., 1989; Vedamurthachar et al., 2006; Weber, 1984), partly with not generalizable samples such as male veterans or members of the US army. Comparatively, the percentage of female was only 23.5% (n = 273) of the total of 1160 participants Lehofer et al. (1995).

3.1. Adherence and Safety

All included studies confirm the acceptance and safety of exercise interventions in AUD. No adverse events were reported. Nonetheless, a physical examination in consideration of a chronic disease such as an AUD which is frequently accompanied with physical and psychiatric comorbidities is doubtlessly recommended prior to the intervention. Adherence rates were reported in 3 studies and varied between 66% and 74%. The only follow-up data from Donaghy (1997) showed however that on the one hand only 35% of the participants sustained a home-based, non-supervised exercise program 2 months after treatment. On the other hand the remaining 35% adhered relatively constant to the program with a drop-out rate of 17% after 5 months.

3.2. Physical functioning

With the exception of 3 studies (Stiensmeier-Pelster et al., 1989; Vedamurthachar et al., 2006; Weber, 1984) each of the investigations examined physical functioning outcomes. In 9 out of 11 studies physical functioning was significantly improved although 2 studies did not show significant improvements (Lehofer et al., 1995; Palmer et al., 1988). Heart rate (HR) as a parameter of cardiorespiratory capacity was measured in different situations/positions (resting HR pre/post intervention, during exercise or as recovery heart rate) and was significantly decreased in 4 out of 7 studies in favor of the intervention group in the pre-post comparison (Gary & Guthrie, 1972; Lüdke, 1978; Mc Kelvy et al., 1980; Piorkowski & Axtell, 1976). One study found a decrease in both, intervention and control group after treatment (Sinoyer et al., 1982). In addition, certain physiological outcomes such as the significant reduction of cortisol and adrenocorticotropic hormone (ACTH) values (Vedamurthachar et al., 2006) were proved in favor of the IG whereas the evidences of a reduced blood pressure (BP) were inconsistent and referred only to one of two values, e.g. to the systolic BP but not to the diastolic BP (Ermalinski et al., 1997) or BP did not change at all (Lehofer et al., 1995). In 4 out of 5 Studies, exercise intervention had a significantly positive effect on the estimated maximal oxygen consumption (VO_2max) (Brown et al., 2014; Capodaglio et al., 2003; Donaghy, 1997; Sinoyer et al., 1982). Brown et al. (2014), Capodaglio et al. (2003), and Donaghy (1997) reported about significantly greater physical activity levels in the intervention group which lasted up to 6 months after discharge among the active participants. The two latter authors reported furthermore about significantly increased muscular strength values in their intervention groups.

3.3. Psychological outcomes

In 8 out of 14 investigations, psychological parameters were elicited. Concerning the depression outcomes, 7 studies reported results about depression, mental state or mood (Brown et al., 2014; Donaghy, 1997; Ermalinski et al., 1997; Lehofer et al., 1995; Palmer et al., 1988; Stiensmeier-Pelster et al., 1989; Weber, 1984) but only one study showed significant improvements in favor of the intervention group (Palmer et al., 1988). In the remaining investigations, results did not show significant anti-depressive effects associated with exercise interventions unless the participants were surveyed directly after exercise. Acute effects on mental state immediately after the exercise intervention

Table 2
Evidence levels of clinical exercise interventions in alcohol use disorders based on the evidence level of the Oxford Centre for Evidence-Based Medicine.

Reference/type of study	Sample characteristics	Setting	Diagnosis/years of problem drinking	Type of exercise and exercise control/ intensity and volume	Measuring point	Main Outcomes	CEBM levels, (2011)
Gary & Guthrie, 1972, USA, RCT	IG: n = 10 m (38.9 y, range 25–55 y) CG: n = 10 (45.1 y, range 39–56 y)	Inpatient, alcohol treatment ward of a state hospital	IG: 18 y CG: 18 y "alcoholics" (diagnosis not reported)	IG: 4wk; 5×/wk running 1 mile/day until a total of 20 miles have been reached CG: standard care: group therapy, ward clean up, recreation programs	t1: before exercise intervention t2: after the 4th wk	PhysF: BHR in 2 different positions ↓ ($P < 0.05$ and $P < 0.25$) and EHR at stable workload ↓ ($P < .025$) in IG PsychO: self-concept ↑ ($P < .005$); sleep disturbances ↓ (only reported, no data available!) in IG; ACL and body-concept ↔ AlcO: drinking behavior: ↔	3
Piorkowski & Axtell, 1976, USA, RCT	IG: 14 m (42.8 ± 9.7 y) male CG: 12 m (43.0 ± 8.9 y)	Inpatient, alcohol rehabilitation center	IG: 19.6 ± 13.3 y CG: 21.3 ± 7.09 y "chronic alcoholics" (diagnosis not reported)	IG: 4 wk; 5×/wk circuit training: 10 min calisthenics (warm up), 45 min 22 stations (1 min each station): sit-ups, bench press, biceps curls, cycle ergometer CG: 3 wk; 5×/wk table games such as cards or checkers	t1: before exercise intervention t2: after the third wk of treatment	PhysF: aerobic capacity, nr. of cycles of 1 min step-test ↑ ($P < .01$), RHR ↓ ($P < .01$)in IG; BHR ↓in both groups (NS)	3
Lüdke, 1978, Germany, CT	IG1: n = 249 m/52 f IG2: n = 75 m/40 f CG: n = 31 m/21 f (age only in age-groups reported)	Inpatient, alcohol and drug rehabilitation clinic	"alcoholics" (diagnosis not reported)	IG1: 100% participation in the exercise program: 4 wk; 3×/wk cycle ergometer training 2×/wk 15 min moderate endurance training plus 1×/wk 15× interval training, 30 s max. cycling/30 s recreational cycling; IG2: 80% participation in the exercise program of IG 1 CG: no exercise intervention	t1: before exercise intervention t2 after the 4th wk of treatment	PhysF: (statistical analysis of the data not available): HRI↓ (significance levels not reported) In IG1: HRI from 24.4 (t1) to 17.8 (t2) in men and from 25.1 (t1) to 18.5 (t2) in women (vs. no changes in CG); In IG2: HRI from 24.6 (t1) to 20.6 (t2) in men and from 25.3 (t1) to 20.8 (t2) in women (vs. no changes in CG)	4
Mc Kelvy et al., 1980; USA, RCT	IG: n = 31 m (23.7 ± 5.0 y) CG: 17 m (24.0 ± 4.2 y) members of the US Navy	Inpatient, alcohol rehabilitation center	IG: 5.5 y CG: 5.9 y "alcohol-dependents" (diagnosis not reported)	IG: 4wk; 5×/wk running 22 laps i.e. 1.2 miles/day Intensity: 85% of age-predicted HRmax CG: group discussions, other sedentary activities	t1: before exercise intervention t2: after the 4th wk	PhysF: 1 min step-HR ↓ ($P < .05$), 3 min step-HR ↓($P < .001$), BHR↓ ($P < .02$) in IG	3
Sinoyer et al., 1982 Canada, multi-centric CT	IG: n = 38 m/11 f (42.0 y) CG1: n = 8 m/1 f (42.2 y) CG2: n = 8 m/4 f (30 y) abstinence follow-up: IG n = 87 CG n = 80	Inpatient, 3 rehabilitation centers for alcoholics	IG & IG1: 8 y "alcoholics" (diagnosis not reported)	IG1: 6 wk; 5×/wk exercise program: 20 min stretching and calisthenics (warm up), 12 min walking/running, 20 min strengthening, in winter: 45 min. cross-country skiing CG1: no or not sufficient participation in the exercise program CG2: standard care in another treatment facility	t1: before exercise intervention t2 after the 6th wk	PhysF: aerobic capacity, estimated VO_2max ↑ ($P < .001$), BHR ↓ (NS.) in IG AlcO: Rate of abstinence 3 mo follow-up ↑ from 36.9% to 69.3% in IG	4
Weber, 1984, Germany, RCT	IG: n = 23 m (43 y for both groups, SD not reported) CG: n = 13 m (43 y for both groups, SD not reported)	Inpatient, alcohol rehabilitation clinic	"alcoholics" (diagnosis not reported)	IG: 4 mo; 3×/wk progressive running with the aim of 30 min constant running at discharge CG: standard care (not reported)	t1:before treatment t2: after the 8th wk t3:after the 16th wk	PsychO: State anxiety and trait-anxiety ↓ ($P < .05$); perceived Stress ↓ ($P < .05$) in IG; depressiveness, psychosomatics, well-being, coping (NS) Drop out: n = 10 of 23 IG-participants dropped out of IG during the treatment	3
Palmer et al., 1988 USA, time-staggered CT	IG: n = 19 m/7 f (35.6 y, SD not reported) CG: n = 18 m/9 f (38.9 y, SD not reported)	Inpatient, private alcohol treatment hospital	"alcoholics" (diagnosis not reported)	4 wk, 3×/wk 20–30 min walking and/or running, 20 min stretching, Intensity according to ACSM-guidelines: 60%–80% of the age-predicted HRmax CG: standard care without exercise intervention	t1: before treatment t2: after the 4th wk	PhysF: estimated VO_2max ↑ (NS) in IG PsychO: State anxiety and trait anxiety ↓ ($P < .01$), depressiveness ↓ ($P < .05$) self-concept ↑ ($P < 0.6$) in IG	4
Stiensmeier-Pelster et al., 1989 Germany, RCT	IG: 23 m (37 y, 21–56 y) CG:17 m (42 y, 21–56 y)	Inpatient, specialty hospital for alcohol treatment	"alcoholics" (diagnosis not reported)	2 wk; 3×/wk 60 min progressive running combined with walking with the aim of 60 min constant running at discharge, stage-aim after 2 wk: 10 min constant running CG: standard care (not reported)	t1: before treatment t2: after the second wk	PsychO: Mental state ↑ ($P < .01$) in IG Change from patients with state-orientated thinking to action-orientated thinking ↑ ($P < .001$) in IG	3

Lehofer et al., 1995, Austria, RCT	IG: n = 14 (sex not reported) (37.5 y, SD not reported) CG: n = 14 (sex not reported) (34 y, SD not reported)	Inpatient, psychiatric hospital, dept. alcohol treatment (detoxification and rehabilitation)	"alcoholics" (diagnosis not reported)	IG: 4 wk, 6–7×/wk 60 min running and/or walking, stretching, coordinative training CG: standard care (not reported)	t1: 2nd–6th day after admission t2: after the 4th wk Acute after exercise in IG: (t1–t6) state-anxiety and mental state	PhysF: BP ↔ (NS) PsychO: Long-term effect after 4 wk intervention: Trait-anxiety ↓ (P < .03), state-anxiety (NS), health problems and mental state (NS) in IG PsychO: Acute effects immediately after intervention: State-anxiety ↓ (P < .01), mental state ↑ (P < .01) in IG	3
Ermalinski et al., 1997 USA, CT	IG1: n = 48 m (39.4 y, SD not reported) CG: 42 m (41.6 y, SD not reported) Veterans	Inpatient, alcohol rehabilitation center for veterans	number of hospitalization due to alcoholism: IG: 1.2 CG: 0.9 "alcoholics" (diagnosis not reported)	IG: 6 wk, 5×/wk 90 min instead of group therapy body mind components (BMC)plus 5 days of orientation workshop: 1) breathing and stretching exercise plus 20 min of progressive aerobics, 2) responsibility for health component (verbal) 3) motivational component (verbal) CG: 6 wk, 5×/wk 150 min standard care, group psychotherapy	t1: before exercise intervention t2: after 6th wk of treatment	PhysF: SBP ↓ (P < .01), double product ↑ (P < .01) in IG; FAI ↑ (P < .001) in both groups PsychO: LoC i.e. internal locus ↑ (P < .01), powerful others ↓ (P < .01), change ↔ (NS) in IG; body-concept i.e. breathing ↑(P < .07), energy level ↑ (P < .05), body building ↑ (P < .05); self-concept ↔ in IG but ↑in CG; negative mood ↓ (P < .01) in both groups, group-related outcomes ↑in both groups (NS), satisfaction with sleep ↔ AlcO: craving ↓ (P < .01) in IG in comparison to baseline	3
Donaghy, 1997 GB, RCT, multi-centric	IG: n = 63 m/20 f (42.3 ± 8.0 y) CG: 63 m/19 f (41.7 ± 8.9 y)	Mixed treatment settings: 2 inpatient, 2 outpatient alcohol rehabilitation wards plus outpatient aftercare	"Problem drinkers" SAAD-Score: IG: 29 CG: 27 (diagnosis not reported)	IG: 3wk; 2×/wk 30 min supervised combined endurance, strength and flexibility program, plus 1×/wk non-supervised exercise 12 wk home-based non-supervised exercise after discharge Intensity: according to the ACSM guidelines 70%–75% of the age-estimated HRmax CG: 3wk; 2×/wk placebo-exercise program consisting of gentle stretching and breathing exercises, plus 1×/wk non-supervised placebo-exercise 12 wk home-based placebo-exercise after discharge	t1: before exercise intervention t2: 1 mo after supervised treatment t3: 2 mo follow-up t4: 5-mo follow-up	PhysF: VO_2max ↑ (P < .001 after 1 mo, P < .001 after 2 mo, <.01 after 5 mo), strength ↑ (P < .001 after 1 mo, P < .001 after 2 mo, NS. after 5 mo), flexibility ↔, BHR ↔, PAL ↑ (NS after 1 mo, P < .02 after 2 mo but not after 5 mo) in IG PsychO: physical self-worth ↑ (P < .02 after 1 mo, NS after 2 and 5 mo), perceived condition ↑ (P < .01 after 1 mo, P < .001 after 2 mo, NS after 5 mo) perceived strength ↑ (P < .01 after 1 mo, P < .01 after 2 mo, NS after 5 mo), depressiveness ↔, anxiety ↔ in IG AlcO: alcohol use ↓ after 1 mo (P < .07), after 2 and 5 mo ↔ in IG Feasibility: drop-out rate after 1 mo 26%; after 2 mo 65%; after 5 mo 17%	2
Capodaglio et al., 2003, Italy, CT	IG: n = 28 m/5 f (41.6 ± 7.9 y) CG: n = 15 m/8 f (45.2 ± 8.0 y) HG: n = 13 m/5 f (39.3 ± 7.7 y)	Inpatient, alcohol rehabilitation center	DSM IV diagnosis: alcohol-dependents	IG: 2 wk; 5×/wk 50 min exercise program: 10 min stretching, 30 min combined endurance training (walking, cycling, cranking) Intensity in the tests: Borg scale 4; cancel at 85% of HRmax or if Borg scale of 7 should be overreached CG: standard socio-therapeutic care (CBT)	t1: 3 days after medication during the detoxification t2: after the second wk	PhysF: walking ↑ km/h (P < .01), work capacity ↑ (P < .01), HRmax ↓ (P < .06) in IG vs. HG at t1, ↔ (NS) in IG vs. HG at t2 i.e. IG improved. weight lifting and arm cranking: work capacity ↑ in the IG at t2 so that there was no difference vs. HG, BHR and BP ↔ (NS)	3
Vedamurthachar et al., 2006, India, RCT	IG: n = 30 m (35.6 ± 8.1 y) CG: n = 30 m (37.7 ± 7.3 y)	Inpatient national de-addiction center	DSM IV diagnosis: alcohol-dependents IG: SADQ = 33.2 ± 5.5 CG: SADQ = 31.7 ± 6.3	IG: 2 wk; daily 60 min Yoga (breathing and meditation exercises) CG: standard care (not reported)	t1: after detoxification (7 days), medication for those with sleep disturbances t2: after the second wk	Cortisol values ↓ (P < .001); depressiveness ↓ in both groups but more in IG (P < .001); ACTH decreased in both groups but more in IG (P < .001); prolactin values ↑ (NS)	3
Brown et al., 2014, USA, RCT	IG1: n = 26 (43.5 ± 11.5 y) IG2: n = 23 (45.4 ± 10.0 y)	outpatient and day hospital care setting	DSM-IV-TR diagnosis: alcohol-dependents	IG1: 12 wk; 1×/wk 20–40 min group aerobic exercise (treadmill elliptical machine and recumbent bicycle) at 55%–69% of age-predicted HRmax plus advise to 2–3×/wk non-supervised aerobic exercise plus group behavioral treatment weekly plus incentives for attendance IG2: 12 wk standard treatment plus	t1: before exercise intervention t2: after 12 wk intervention t3: 6-mo follow-up	PhysF: level of exercise and VO2max ↑ from t2 to t3 (baseline data not reported) but no differences between IG1 and IG2 at t2 and t3. Among adherent IG1-participants greater min of exercise ↑ (p = .008) and increased VO2max ↑(p = .025) than in IG2 at t3 PsychO: no sign. changes in depression, anxiety and self-efficacy	2

(continued on next page)

Table 2 *(continued)*

Reference/type of study	Sample characteristics	Setting	Diagnosis/years of problem drinking	Type of exercise and exercise control/ intensity and volume	Measuring point	Main Outcomes	CEBM levels, (2011)
				15–20 min advise to exercise based on ACSM recommendations plus incentives for engagement		AlcO: alcohol use (days and amount)↓during treatment ($P = .002$) and at t2 ($P < .001$) but no more at t3 Inverse relationship between min of exercise and alcohol use at t3 ($p = .000$) in both conditions Feasibility/Adherence: participants attended in 8.44 ± 4.1 of 12 sessions; 62% completed at least 8 out of 12 sessions after 12 weeks	

were reported by Lehofer et al. (1995) and (Stiensmeier-Pelster et al., 1989). In 3 out of 5 studies at least one anxiety domain of the State-Trait Anxiety Inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 1983) changed significantly in favor of the intervention groups (Lehofer et al., 1995; Palmer et al., 1988; Weber, 1984) but in two studies anxiety parameters did not change at all (Brown et al., 2014; Donaghy, 1997). Psychosomatic outcomes such as satisfaction with sleep was evaluated twice but only Gary and Guthrie (1972) reported about significantly reduced sleep disturbances related to exercises whereas Weber (1984) proved a significant reduction in the domain "perceived stress" among running patients. Furthermore, there were single indices for improved locus of control and certain domains of body-concept but not as to self-concept (Ermalinski et al., 1997). Stiensmeier-Pelster et al. (1989) found a significant shift from state-orientated thinking to a more positive action-orientated thinking in the experimental group and finally Palmer et al. (1988) showed a slightly trend towards an improved self-concept after 4 weeks ($P = .06$) of intervention.

3.4. Alcohol outcomes

Only 4 studies evaluated alcohol outcomes. Ermalinski et al. (1997) showed significant changes in craving for the intervention group, Sinoyer et al. (1982) reported significantly improved abstinence rates 3 months after introduction of the exercise program in the facility (from 37% to 69%), and Brown et al. proved a significantly reduced alcohol use (amount and frequency) in adherent patients during and after 12 weeks of intervention but not anymore in the 6 month follow-up. They found furthermore an inverse relationship between alcohol use and minutes of exercise; that is, the more physically active the participants were, the less they drank during that period.

4. Discussion

In the overall view of this systematic review focusing on exercise interventions in AUD, 14 studies met the inclusion criteria. However only 2 RCTs were ranked with level "2" of the CEBM-system, whereas the majority of studies had to be graded down to level "3" due to methodological flaws or because of the design (without randomization). Thus, samples were partly very small and/or were not sufficiently described (e.g. lack of accurate diagnosis, description of the grade of severity and/or treatment context), or control groups were not always comparable (e.g. not comparable settings, time-staggered, availability of other substance use disorders). In some cases data were not sufficiently reported or statistical analyses were missing. Furthermore, only Brown et al. (2014) reported confidence intervals which would reinforce the reliability of the data. Additionally, the majority of exercise interventions were conducted adjunctive to already occurring AUD treatment in an inpatient setting which might bias the results, especially as to outcomes such as alcohol behavior and mental health because patients are in a restricted environment, receiving counseling and pharmacotherapy which may influence outcomes significantly and obscure any effect of exercise. Thus, further studies in outpatient settings are needed to verify the underlying mechanisms of action. Furthermore, AUD treatment has changed crucially during the last decades and with regard to the earlier studies of the review it is not clear which therapeutic targets were used (e.g. abstinence vs. controlled drinking) and what kind of treatment they had and if it is comparable to the settings we have today. Despite weak evidence due to the methodological flaws and the risk of over- or underestimation of the results first hints can cautiously be discussed in the following.

The most examined outcomes in the review were physiological outcomes which were given either as aerobic capacity depicted as estimated VO_2max, as basal heart rate, exercise heart rate, recovery heart rate, systolic and diastolic blood pressure, as physical activity level or as muscular strength value. One single study examining a yoga intervention

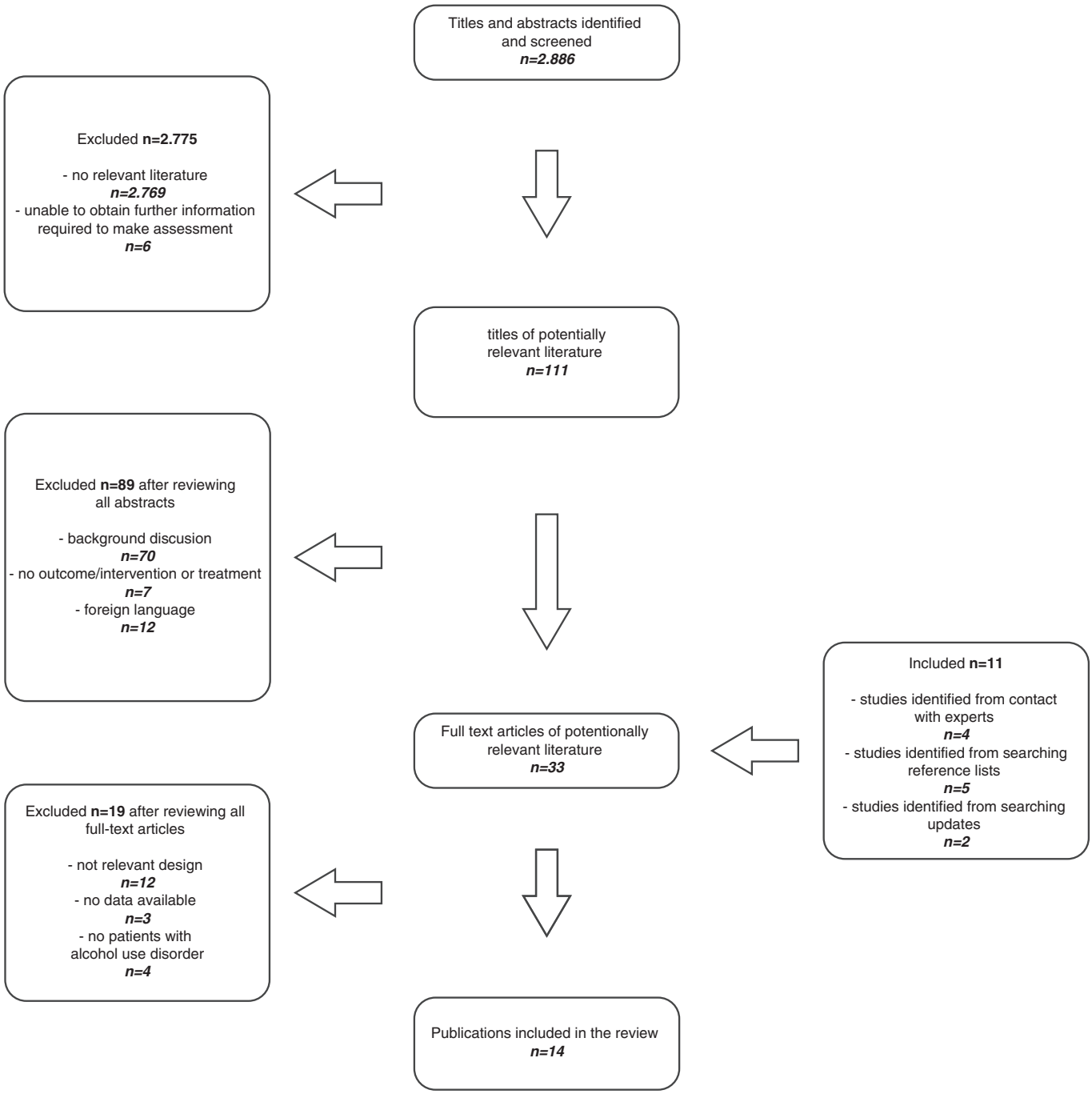

Fig. 1. Flow chart of study selection process.

reported laboratory parameters such as lower cortisol and reduced ACTH values in blood tests (Vedamurthachar et al., 2006).

Physiological outcomes should be interpreted preferably in the context of the conducted exercise regimen including not only information about frequency, intensity, time and type of exercise but also details about testing mode (e.g. maximal or submaximal test), testing protocol and training monitoring. Only 4 studies reported intensity-levels (Brown et al., 2014; Donaghy, 1997; Mc Kelvy et al., 1980; Palmer et al., 1988). Programs of these 4 studies (aerobic endurance-based, 55%–85% of HRmax, 1–5×/week à 20–40 min over 3–12 weeks) were proved as effective related to all examined physiological parameters (VO_2max, HR, physical activity level, and strength) except one VO_2max-outcome from Palmer et al. (1988) indicating that exercise may have beneficial effects on certain domains of physical functioning. Additionally, according to the recent findings from Brown et al. (2014) physical activity level may have a positive impact on drinking behavior of alcohol dependents. Nevertheless, results must be interpreted cautiously because of the heterogeneity of the programs and measures used to assess physical functioning. The determination of threshold ranges is urgently needed and should be an important matter of future investigations

With regard to psychological parameters the most evaluated outcome was depressive symptoms but with exception of one study (Palmer et al., 1988), no significant improvement of depressive symptoms was ascertainable in favor of the exercise condition. Thus, either the symptoms improved in both conditions (Ermalinski et al., 1997) or they did not change at all unless the measures were applied acutely after the exercise, where mental state or well-being was significantly

improved (Lehofer et al., 1995; Stiensmeier-Pelster et al., 1989). Similar inconsistency was found as to anxiety outcomes because in only 3 out of 5 but only partially in one domain of the anxiety outcome were improvements approved. We found additionally single hints addressing psychosomatic symptoms such as improved sleep disturbances and reduced perceived stress as well as positive changes in personal traits such as body-concept, locus of control, and action-orientated thinking but, due to the weak evidence base, interpretation would be too insecure. Furthermore, the multi-professional treatment approaches of the studies state methodological problems with regard to psychological parameters because in most cases it seems nearly impossible to isolate the special psychological effect of an exercise intervention from the rest of treatment components such as psychotherapy, occupational therapy or other psychosocial interventions. Additionally, although the applied questionnaires may be reliable and well validated, answering towards social desirability and especially unrealistic self-assessment among AUDs cannot be excluded and might bias the results. Thus, further investigations should use in addition to questionnaires also biological measures and neuroimaging techniques, which would probably verify the findings.

Although alcohol-related outcomes play a key role in the treatment of AUD they were examined very rarely. Only 4 studies elicited parameters such as craving, rates of abstinence and drinking behavior through questionnaires and/or via laboratory parameters. As to craving, a positive effect of the exercise intervention was reported (Ermalinski et al., 1997) but it is not clear if this effect is directly related to the physically active part of this holistic body–mind program from Ermalinski et al. (1997). Nevertheless there are promising hints towards both the acute effect of exercise on alcohol urges in AUD (Ussher, Sampuran, Doshi, West, & Drummond, 2004) and the role of exercise as an ongoing skill for reducing alcohol behavior (Brown et al., 2014) as well as a better relapse prognosis in the sense of a lifestyle modification (Marlatt & Gordon, 1985).

As to exercise interventions in AUD, several mechanisms of action are conceivable. Exercise might act beneficially not only on psychological levels including mood regulation, improved self-efficacy, social reinforcement, experience of mastery, stress- and self-management and health related quality of life but also on a biological level, exercise seems to be promising concerning possible mechanisms of action respectively metabolic and immune-related effects as well as neurocognitive functioning (Dishman et al., 2006; Knöchel et al., 2012).

5. Conclusion

Taken together, according to the literature available at present, evidence-based recommendations cannot be drawn so far. However, first hints from the results can be cautiously concluded.

First of all, exercise interventions seem to be feasible and safe due to the fact that no adverse events were reported and adherence rates were between 66% and 74% which are acceptable considering that the subjects are well known to be quite ambivalent towards alcohol treatment in general.

Secondly, this systematic review indicates that exercise may have beneficial effects on certain domains of physical functioning including VO_2max, basal heart rate, physical activity level and strength. Results however must be interpreted cautiously due to the numerous methodological flaws and the heterogeneity of the interventions and measures.

Thirdly, potential mechanisms of action on psychological and alcohol-related outcomes are conceivable but either inconsistent or unknown so far.

Considering the fact that AUD is still an important public health problem worldwide, innovative and cost-efficient approaches in the treatment of AUD necessitate investigations in order to reduce the high social costs caused by alcohol misuse on the one hand and to improve the treatment of persons affected and to prevent further harm on the other hand. Thus, further research determining biological, psychosocial and alcohol-related effects of exercise interventions through well-designed RCTs are urgently required in the field of AUD.

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