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Sticking with it? Factors associated with exercise adherence in people with alcohol use disorder

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ABSTRACT

Background: Emerging evidence suggests that exercise may be an efficacious treatment for alcohol use disorder (AUD), but adherence is suboptimal. We examined factors associated with adherence to an exercise intervention for non-treatment seeking adults with AUD.

Methods: This secondary analysis of a randomized controlled trial included 95 physically inactive adults aged 18–75 years with clinician-diagnosed AUD. Study participants were randomly assigned to 12-weeks fitness centre-based, supervised aerobic exercise or yoga classes and asked to attend at least three times/week. Adherence was assessed both objectively (based on use of a keycard at entry) and subjectively using an activity calendar. The association between AUD and other predictor variables with adherence was assessed using logistic and Poisson regression models.

Results: Just under half of participants (47/95, 49%) completed ≥ 12 supervised exercise sessions. When both supervised classes and self-reported sessions were included, 32/95 (34%) participants completed ≤ 11 sessions, 28/95 (29%) did 12–23 sessions and 35/95 (37%) completed ≥ 24 sessions. In univariate logistic regression analyses, lower education was associated with non-adherence (<12 sessions) (OR = 3.02, 95%CI = 1.19–7.61). In models adjusted for demographic and clinical variables, moderate AUD (OR = 0.11, 95%CI = 0.02–0.49) and severe AUD (OR = 0.12, 95%CI = 0.02–0.69) were associated with non-adherence, when compared to low severity AUD. Higher body mass index (OR = 0.80, 95%CI = 0.68–0.93) was also associated with non-adherence. Results were materially the same when objective and subjective adherence data were combined.

Conclusion: Adults with AUD can be supported to engage in yoga and aerobic exercise. Additional support may be required for those with moderate or severe AUD, higher BMI, and lower education.

1. Introduction

Alcohol use disorder (AUD) is highly prevalent, affecting around 100 million people globally (Degenhardt et al., 2018). Core features of AUD include impaired control of alcohol consumption, cravings, and physiological dependence. Despite the adverse consequences of AUD, which include an increased risk of acute injury, infections and chronic disease, the majority of those affected do not seek care (Andréasson et al., 2013). Evidence suggests that perceived stigma and feelings of shame are among the drivers of this reluctance to seek help (Probst et al., 2015). Accessible and effective treatment options are needed to help those with AUD to reduce their alcohol consumption, and to address the somatic and psychiatric health problems associated with AUD (Preuss et al., 2018).

Exercise is non-stigmatising, available to those who do not seek healthcare and has established benefits for mental and physical health (Ashdown-Franks et al., 2020). Emerging evidence also suggests that exercise-based interventions are effective as standalone treatments for AUD (Giesen et al., 2015; Hallgren et al., 2017; Thompson, Horrell, Taylor, Wanner, Husk, & Wei, 2020). We recently compared the effects of yoga and aerobic with those of usual care (telephone-based counselling) among 140 non-treatment seeking adults with AUD

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(Gunillasdotter et al., 2022). Participation in supervised, group yoga or aerobic exercise was associated with clinically meaningful reductions in alcohol consumption (5–7 standard drinks/week) – comparable to those associated with usual care (Gunillasdotter et al., 2022). Results further indicated that yoga practice was associated with a clinically-important improvement in symptoms of anxiety and depression – superior to improvements seen with usual care (g = 1.06, 95%CI = 0.69–1.43) (Welford et al., 2022). Allocation to yoga or aerobic exercise was also associated with significant improvements in body mass index (BMI), physical wellbeing, and sleep quality, when compared to usual care. Overall, our study findings suggested that supervised exercise is safe and effective for adults with AUD.

Adherence is defined by the World Health Organization (WHO) as the extent to which a person's behaviour corresponds with agreed recommendations from a healthcare provider and is a key factor in establishing the real-world effectiveness of exercise (Sabaté, 2003). Previous studies suggest that psychiatric disorders are associated with sub-optimal adherence (Helgadottir et al., 2018). For example, a *meta*-analysis of RCTs investigating exercise for depression indicated that adherence was poorer among those with more severe depressive symptoms (Stubbs et al., 2016). Comorbidities may further compromise adherence among those with psychiatric disorders; a secondary analysis of the largest (n = 945) RCT of exercise for depression to date revealed that hazardous alcohol use and tobacco use were associated with lower adherence (Helgadottir et al., 2018). In contrast, interventions delivered by physiotherapists or exercise physiologists were associated with greater adherence and lower drop-out rates (Stubbs et al., 2016). There is also evidence that higher educational level and greater self-efficacy are associated with adherence to exercise programmes (Collado-Mateo et al., 2021). Depression and anxiety, fatigue, poor cardiorespiratory fitness, and obesity may also be relevant to exercise adherence(Collado-Mateo et al., 2021; Herring et al., 2014; Miller et al., 2019), and frequently co-exist with AUD (Castillo-Carniglia et al., 2019; Traversy & Chaput, 2015). Given that individuals with alcohol dependence tend to prioritise drinking over other activities, it is plausible that greater severity of AUD may be associated with lower adherence to exercise interventions.

Exercise adherence rates have been reported sporadically in trials involving adults with AUD but range from 50% to 70% depending on the definition of adherence used (Giesen et al., 2015; Thompson et al., 2020). To date, however, no study has examined which factors are associated with exercise adherence in AUD. Increasingly, clinicians seek to tailor treatment regimens to the individual to improve adherence and maximise the positive effects of interventions – an approach often referred to as 'precision medicine'. There is a need to understand how individual patient characteristics are associated with exercise adherence in the context of AUD to facilitate the implementation of precision, evidence-based exercise interventions.

We examined the profile of demographic and clinical factors (e.g., AUD severity, physical and mental health) associated with adherence to exercise (yoga and aerobic exercise) among physically inactive non-treatment seeking adults with AUD.

2. Methods

2.1. Study design

This is a secondary analysis of a parallel, three-arm, single-blind RCT, the primary and secondary outcomes of which have been reported previously (Gunillasdotter et al., 2022; Welford et al., 2022). The focus of the current study is on adherence in the two exercise-based intervention groups (yoga and aerobic exercise). The trial was conducted at Karolinska Institutet (KI) in Stockholm, Sweden and co-ordinated from the Stockholm Centre for Dependency Disorders. Approval was granted by the Regional Ethics Committee in Stockholm (DNR: 2017/1380-31) and the trial was prospectively registered with German Clinical Trials (https://www.drks.de) on 14 July 2017 (DRKS00012311). The trial protocol is publicly available (Osth et al., 2019).

2.2. Participants

In total, 140 participants were recruited between January 2018 and August 2019, via advertisements in a free local newspaper ('Mitt-I') distributed throughout Stockholm. Those eligible were allocated either to exercise-based interventions (yoga n = 46; aerobic exercise n = 49), or to treatment as usual (n = 45). This secondary analysis focuses exclusively on participants allocated to exercise-based interventions (n = 95). Eligibility criteria were as follows: (Degenhardt et al., 2018) Clinician-diagnosed AUD (DSM-5, ≥2 criteria) *and* hazardous drinking during the past month, as defined by the Swedish National Institute for Public Health; (Andréasson et al., 2013) resident in Stockholm County; (Probst et al., 2015) aged 18–75 years. We excluded those who: (a) had uncontrolled hypertension or unstable blood glucose resulting in medical advice to avoid exercise; (b) reported somatic disease or musculoskeletal injuries preventing exercise (c) were receiving specialist psychiatric care; (d) reported thoughts of self-harm; (e) reported exercising twice weekly or more during the past month; (f) were currently receiving treatment for AUD; (g) reported withdrawal symptoms during the past 12 months; (h) were pregnant or (i) reported concurrent use of illicit drugs. Informed, written consent was obtained prior to study enrolment.

2.3. Randomization and masking

Trial participants were assigned to either aerobic exercise, yoga, or treatment-as-usual (1:1:1 group allocation) using a simple randomization list generated by an independent statistician using SAS version 9.4. Allocation was via sealed, opaque envelopes that were opened immediately after participants' baseline assessments.

2.4. Exercise interventions

Participants randomized to exercise-based interventions received a 12-week membership to SATS, a chain of fitness centres at 70 locations across Stockholm. Those allocated to aerobic exercise were asked to attend supervised exercise classes at least three times/week for the 12-week intervention period. Yoga participants were also asked to attend yoga classes at least three times/week during the intervention period. Sessions were supervised by qualified fitness instructors. Participants were allowed to choose from a variety of group classes as a measure to improve adherence. In addition, participants were offered three 30-minute support sessions with a personal trainer (at weeks 1, 3 and 9) to monitor progress and optimize adherence.

2.4.1. Aerobic exercise

Aerobic exercise classes consisted of supervised group training sessions with 10–20 participants and of 60 minutes duration. Options available included cycling/spinning, aerobic training (whole body movements, including running and jumping), boxing-based exercise and dance-based aerobic exercise. Participants could pick and choose from classes according to their individual preferences and could also opt for individual aerobic exercise sessions using a cross-trainer, treadmill, or stationary cycle.

2.4.2. Yoga

Yoga classes were also delivered in groups and were 60-minutes in duration. Sessions were suitable for beginner-to-intermediate level and involved physical postures that emphasised balance and flexibility, combined with breathing exercises. Participants could choose from Ashtanga and Hatha yoga (gentle physical postures), Les Mills Body Balance (a combination of yoga, Pilates and Tai-chi), Yin Yoga and Yin release (calm postures and breathing exercises).

2.5. Adherence

The primary outcome of interest for this secondary analysis was adherence, a binary (yes/no) variable operationalized as attending 12 or more sessions of supervised yoga or aerobic exercise, respectively, and objectively verified based on participants' use of their keycard at entry to SATS. This was consistent with completing one or more exercise sessions per week during the intervention period. The adherence threshold of ≥ 12 sessions was selected as a pragmatic and realistic indicator of exercise participation to guide clinical practice and inform policy decisions (Sabaté, 2003). Participants who attended fewer than 12 sessions were considered to be non-adherers.

In addition, participants were provided with an activity calendar and asked to record all exercise sessions (≥20 min) that they completed outside of SATS, including brisk walking. These self-reported, unsupervised sessions were then added to the number of keycard entries to SATS in order to estimate the total number of exercise sessions completed by each participant. This secondary outcome of interest, **total adherence,** was categorised as: ≤11 sessions; 12–23 sessions or ≥ 24 sessions. Individuals who did not return or complete an activity calendar were assumed not to have exercised outside of SATS. Finally, to account for the non-binary nature of adherence in real world settings, **adherence extent** was assessed as an additional secondary outcome. This continuous variable consisted of the total number of supervised, objectively verified sessions of yoga or aerobic exercise performed at SATS.

2.6. Predictor variables

Potential predictors of exercise adherence included **intervention group**, sociodemographic characteristics, physical and mental health factors, and measures related to alcohol use. These were collected during a baseline assessment, which occurred prior to group allocation and consisted of a clinical assessment for AUD, physical measurements, a cardiorespiratory fitness test (Ekblom-Bak et al., 2014), and questionnaires.

Sociodemographic characteristics included **age**, **sex**, **income source** (categorised as employed, pension or other) and **education** (high school or lower, or university/college). Physical health factors included self-reported **smoking status** (non–, ex- or current smoker) and habitual moderate-vigorous physical activity (**MVPA**) and **sedentary time** (minutes/week). Participants were asked the first question from the SF-12 Health Survey (Ware et al., 1996), "in general, would you say your health is (poor—excellent)", assessed on a five-point Likert scale, to assess overall **physical wellbeing**. **Waist circumference** was measured, and body mass index (**BMI**) was calculated from objective measurements of weight and height. **Cardiorespiratory fitness** (predicted VO2max) was assessed by a qualified exercise physiologist. The latter six were included as continuous variables. Participants were instructed to avoid alcohol consumption for 24 hours prior to each test.

Anxiety and depressive symptoms were self-reported using the Hospital Anxiety and Depression Scale (**HADS**) (Zigmond & Snaith, 1983) – a widely-used screening and symptom assessment tool with established validity and reliability, including in alcohol-dependent populations (McPherson & Martin, 2011). The HADS includes 14 items with each scored between 0 and 3 according to how the participant felt during the past week. A score ≥ 7 on the depression subscale (**HADS-D**) and ≥ 8 on the anxiety subscale (**HADS-A**) indicates an increased risk of the respective disorder (Brennan et al., 2010; Wu et al., 2021). We focused on changes in symptoms. Fatigue was assessed as a subscale of the short-form Profile Of Mood States (**POMS**) questionnaire (Hassmen & Blomstrand, 1991; McNair et al., 1971).

Alcohol use disorder severity was assessed via clinical interview (with a specialist nurse) according to the Diagnostic and Statistical manual of Mental disorders (DSM-5) (mild = 2–3, moderate = 4–5, severe ≥ 6 criteria) and hazardous alcohol use via the 10-item Alcohol Use Disorders Identification Test (**AUDIT**) (Babor, 2001). Alcohol consumption was assessed as **weekly standard drinks** (one drink = 12 g of pure ethanol), using the 30-day TimeLine Follow-Back method (TLFB) (Sobell, 1992). The TLFB was also used to assess heavy drinking days (HDD) i.e., the number of days male participants consumed ≥ five standard drinks/day, or females ≥ four drinks/day during the preceding 30-day period. Finally, the Alcohol Abstinence Self-Efficacy Scale (**AASE**) assessed how "tempted" or "confident" participants felt about drinking in certain situations.

2.7. Statistical analysis

2.7.1. Statistical methods

Baseline descriptive data were calculated according to adherence status. Chi^2 and independent samples t-tests were performed to examine possible differences between adherers and non-adherers for categorical and continuous predictor variables, respectively. The study hypothesis was tested using logistic regression models. Initially, univariate logistic regression analyses assessed the associations between all predictor variables and adherence. Next, to determine the effect of predictor variables in the association between AUD severity and adherence, stepwise multiple logistic regression models (Andréasson et al., 2013; Degenhardt et al., 2018; Probst et al., 2015) were conducted: Model 1 adjusted for sociodemographic factors (age, sex, income source and education) and intervention group; model 2 added physical health factors (BMI and physical wellbeing), and model 3 also included mental health (total HADS). Results were reported as odds ratios (ORs) with 95% confidence intervals (CIs). *P*-values of < 0.05 were considered to represent statistical significance. Models were specified according to the following considerations: strength of univariate associations; theoretical importance of predictor variables; association reported with the outcome in previous literature, model fit and predictive power. Assumptions for logistic regression were fulfilled, including independence of errors, linear relationships between predictors and no multicollinearity. Hosmer-Lemeshow test indicated an adequate fit for included models and the area under ROC curve for model 3 was 0.83, suggesting good predictive power.

2.7.2. Sensitivity analyses

Sensitivity analyses were conducted to assess the association between AUD severity and total adherence; a secondary outcome that consisted of objectively verified sessions based on participants' use of their keycard at entry to SATS and additional self-reported sessions. Descriptive data were calculated for three categories: ≤11, 12–23 or ≥ 24 sessions. Categorical and continuous predictor variables were assessed for possible differences according to total adherence using Chi^2 or one-way ANOVA tests, respectively. Poisson regression models were subsequently conducted. Univariate incidence rate ratios (IRRs) were reported with 95% confidence intervals, followed by IRRs for adjusted models 1–3 (described above). Additional assumptions required for Poisson regression were met, including no overdispersion or zero inflation. Poisson regression was chosen as an appropriate method for count-based outcomes and had a better fit for the data than negative binomial regression models, which were also considered. Finally, linear regression models were used to assess the association between AUD severity and adherence extent, a continuous variable that represented the total number of sessions at SATS. Univariate regression coefficients were reported with 95% CIs, followed by regression coefficients for adjusted models 1–3 as described above. Adherence extent was log-transformed and normal distribution was confirmed prior to analysis. All statistical analyses were conducted in Stata 17 SE.

3. Results

3.1. Participants

The mean age among participants was 54.1 ± 12. More women

(67%) than men took part. Approximately 75% of participants were employed and nearly 70% were educated to university level. A minority (12%) were smokers (43% were ex-smokers). On average, participants engaged in 91 ± 177 min per week at baseline; substantially (59 min/week) less than the WHO recommendation of 150 min/week (World Health Organization, 2010). Similarly, mean BMI (27.9 kg/m^2 ± 4.8) and waist circumference (97 ± 15.3 cm) exceeded recommended parameters. Predicted VO2max was 2.55 L/min (±0.63) at baseline. Self-reported physical wellbeing was, on average, "good" (3.0 ± 0.9) among study participants, while the mean POMS fatigue score was 8.7 ± 5.1 (moderately fatigued). The mean HADS anxiety score was 7.9 ± 4.0, suggesting an elevated risk of anxiety disorders among participants. Mean score for the HADS depression subscale was 5.2 ± 3.2. All participants met the DSM-5 diagnostic criteria for AUD (4.9 ± 2.0) and reported hazardous drinking. The severity of AUD varied among study participants: 31% participants had mild AUD; 36% had moderate AUD, while 34% participants had severe AUD. Participants drank on average 20 ± 12) standard drinks/week, mean AUDIT score was 17.9 ± 5.7 and mean AASE was 1.53 ± 0.44. Baseline participant characteristics are reported according to adherence status (Table 1) and according to total adherence (Supplementary Table 1).

Table 1
Baseline demographic and clinical characteristics of participants, by adherence status (N = 95).

	Non-Adherers, ≤11 Sessions (n = 48)	Adherers, ≥12 Sessions (n = 47)	*p*
Alcohol use disorder severity (DSM-5)*:			
Mild	8 (27.6)	21 (72.4)	**0.012**
Moderate	20 (58.8)	14 (41.2)	
Severe	20 (62.5)	12 (37.5)	
Intervention group:			
Aerobic exercise (n=49), n (%)*	24 (49.0)	25 (51.0)	0.756
Yoga (n=46), n (%)*	24 (52.2)	22 (47.8)	
Demographic characteristics:			
Age, years	54.1 (13.4)	54.0 (10.5)	0.960
Female sex, n (%)	28 (58.3)	36 (76.6)	0.058
Income source, n (%)*			
Employed	34 (72.4)	37 (80.4)	0.533
Pension	9 (19.2)	5 (10.9)	
Other	4 (8.5)	4 (8.7)	
Education, n (%)*			
High school or lower	20 (41.7)	9 (19.2)	**0.017**
University/college	28 (58.3)	38 (80.8)	
Clinical characteristics:			
Smoking status, n (%)*			
Non-smoker	24 (50.00)	19 (40.5)	
Ex-smoker	18 (37.5)	23 (48.9)	
Current	6 (12.5)	5 (10.6)	0.529
Physical activity:			
Moderate-vigorous physical activity, mins/week*	84.8 (132.1)	97.8 (218.0)	0.727
Sedentary time, mins/day*	455.6 (234.1)	403.7 (206.9)	0.258
Body mass index, kg/m^2	29.3 (4.9)	26.5 (4.3)	**0.003**
Waist circumference (cm)	101.9 (15.3)	92.0 (13.6)	**0.002**
Cardiorespiratory fitness (predicted VO2max), L/min	2.6 (0.7)	2.5 (0.6)	0.301
SF-12 physical wellbeing	3.1 (0.8)	2.9 (1.0)	0.280
POMS fatigue score	9.1 (5.0)	8.3 (5.2)	0.467
Total HADS score	14.1 (6.7)	11.9 (6.7)	0.122
HADS-A score	8.3 (3.9)	7.4 (4.3)	0.298
HADS-D score	5.8 (3.4)	4.5 (2.9)	0.056
Alcohol use:			
Standard drinks/week*	20.1 (10.9)	20.0 (13.3)	0.955
Heavy drinking, days/month*	8.3 (6.7)	9.4 (8.2)	0.480
Diagnostic criteria for AUD (DSM-5)*	5.5 (2.0)	4.3 (1.9)	**0.004**
Alcohol Use Disorders Identification Test (AUDIT)*	18.4 (5.4)	17.3 (6.0)	0.313
AASE	1.51 (0.39)	1.55 (0.49)	0.652

Reported data are means (standard deviations) unless otherwise stated.
Other source of income = sickness benefit, disability support, income support, student, unemployment support, savings.
DSM = Diagnostic and Statistical Manual, POMS = Profile Of Mood States, HADS = Hospital Anxiety and Depression Scale, HADS-A = anxiety subscale, HADS-D = depression subscale, AASE = Alcohol Abstinence Self-Efficacy Scale.
*self-reported/clinical interview data.

4. Insert Table 1 here

4.1. Adherence

Only nine participants (10%) completed 36 or more session at SATS. This was consistent with exercising three times per week, as participants were requested. Just under half of participants (49%) completed 12 or more supervised exercise sessions. Differences between adherers and non-adherers were detected in three areas. Firstly, there were significant differences (p =.012) in AUD severity between adherers and non-adherers, with adherers tending to have lower AUD severity. The mean number of AUD diagnostic criteria among adherers was 4.3 ± 1.9, compared to 5.5 ± 2.0 among non-adherers (p =.004). Secondly, educational differences were observed according to adherence status, with adherers tending to have a higher educational level (p =.017). Thirdly, there was evidence that body composition varied according to adherence status: On average, adherers had a lower BMI (p =.003) and smaller waist circumference than non-adherers (p =.002). No significant differences between adherers and non-adherers were observed according to intervention group, other sociodemographic characteristics, habitual physical activity or baseline cardiorespiratory fitness or other clinical characteristics.

In terms of total adherence (SATS sessions + self-reported additional sessions), 34% of participants completed ≤ 11 sessions, while 29% completed between 12 and 23 sessions and 37% completed ≥ 24 sessions. In keeping with the main findings for adherence, participants who completed a greater total number of exercise sessions tended to have lower BMI (p =.011) and waist circumference (p =.013).

4.2. Association between AUD severity and adherence

The association between AUD severity, other predictor variables and adherence is reported in Table 2 and illustrated in Fig. 1. Overall, participants with moderate or severe AUD were significantly less likely to adhere to 12 or more exercise sessions than participants who had mild AUD. In univariate logistic regression analyses, the estimated OR for adherence was slightly lower for participants with severe AUD (OR = 0.23, 95%CI = 0.08–0.68) than for those with moderate AUD (OR = 0.27, 95%CI = 0.09–0.77), although confidence intervals between the two overlapped. Individuals with university or college level education were significantly more likely to be adherers than those with high school education or lower (OR = 3.02, 95%CI = 1.19–7.61). Significant associations with adherence were also observed in univariate analyses for BMI and waist circumference. Estimated ORs for adherence were broadly consistent with univariate analyses after adjusting for intervention group and sociodemographic factors (model 1) but attenuated when physical health was considered (model 2). In model three, which also adjusted for mental health, ORs for adherence were 0.11 (95%CI = 0.02–0.49) among participants with moderate AUD and 0.12 (95%CI = 0.12–0.69) in individuals with severe AUD, when compared to those who had mild AUD.

4.3. Sensitivity analyses

Poisson regression analyses for the association between AUD severity, other predictor variables and total adherence are reported in supplementary table 2. Overall, IRRs suggested that total adherence tended to be lower among participants with moderate AUD when

Table 2
Association between adherence, AUD severity and other baseline characteristics; univariate and multiple logistic regression analyses (N = 95).

	OR (95% CI)			
Alcohol use disorder severity (DSM-5)*:	**Univariate**	**Model 1**	**Model 2**	**Model 3**
Mild	Ref	Ref	Ref	Ref
Moderate	**0.27 (0.09, 0.77)**	**0.18 (0.05, 0.61)**	**0.10 (0.02, 0.45)**	**0.11 (0.02, 0.49)**
Severe	**0.23 (0.08, 0.68)**	**0.25 (0.07, 0.83)**	**0.11 (0.02, 0.57)**	**0.12 (0.02, 0.69)**
Intervention group:				
Aerobic exercise (n=49),	Ref	Ref	Ref	Ref
Yoga (n=46)	0.88 (0.39, 1.97)	1.48 (0.56, 3.89)	0.74 (0.22, 2.42)	0.75 (0.23, 2.49)
Demographic characteristics:				
Age, years	1.00 (0.97, 1.03)	1.03 (0.98, 1.08)	1.03 (0.98, 1.09)	1.03 (0.98, 1.09)
Female sex, n (%)	2.34 (0.96, 5.67)	**3.01 (1.04, 8.69)**	1.57 (0.38, 6.50)	1.88 (0.42, 8.45)
Income source, n (%)*				
Employed	Ref	Ref	Ref	Ref
Pension	0.51 (0.16, 1.67)	0.36 (0.08, 1.63)	0.16 (0.03, 1.03)	**0.15 (0.02, 1.00)**
Other	0.92 (0.21, 3.97)	1.14 (0.21, 6.19)	0.76 (0.11, 5.06)	0.64 (0.09, 4.57)
Education, n (%)*				
High school or lower	Ref	Ref	Ref	Ref
University/college	**3.02 (1.19, 7.61)**	2.30 (0.81, 6.58)	1.79 (0.49, 6.55)	1.83 (0.50, 6.73)
Clinical characteristics:				
Smoking status*				
Non-smoker	Ref			
Ex-smoker	1.61 (0.68, 3.82)			
Current	1.05 (0.28, 3.98)			
Physical activity:				
Moderate-vigorous physical activity, mins/week*	1.00 (1.00, 1.00)			
Sedentary time, mins/day*	1.00 (1.00, 1.00)			
Body mass index, kg/m^2	**0.87 (0.78, 0.96)**		**0.79 (0.68, 0.92)**	**0.80 (0.68, 0.93)**
Waist circumference, cm	**0.95 (0.92, 0.98)**			
Cardiorespiratory fitness (predicted VO2max), L/min	0.70 (0.36, 1.37)			
SF-12 Physical Wellbeing	0.77 (0.48, 1.24)		1.12 (0.60, 2.10)	1.21 (0.62, 2.36)
POMS fatigue score	0.97 (0.90, 1.05)			
Total HADS score	0.95 (0.89, 1.01)			0.97 (0.89, 1.06)
HADS-A	0.95 (0.86, 1.05)			
HADS-D	0.88 (0.77, 1.01)			
Alcohol use:				
Standard drinks/week*	1.00 (0.97, 1.03)			
Heavy drinking, days/month*	1.02 (0.97, 1.08)			
Alcohol Use Disorders Identification Test (AUDIT)*	0.96 (0.90, 1.04)			
AASE	1.24 (0.49, 3.14)			

Other source of income = sickness benefit, disability support, income support, student, unemployment support, savings.
DSM = Diagnostic and Statistical Manual, POMS = Profile Of Mood States, HADS = Hospital Anxiety and Depression Scale, HADS-A = anxiety subscale, HADS-D = depression subscale, AASE = Alcohol Abstinence Self-Efficacy Scale.
*self-reported/clinical interview data.
Results marked in bold are statistically significant at $p < 0.05$.
Model 1 adjusted for: intervention group, sociodemographic factors.
Model 2 adjusted for: intervention group, sociodemographic factors, physical health.
Model 3 adjusted for: intervention group, sociodemographic factors, physical health, mental heal.

compared to those who had mild AUD, although this association was of a lower magnitude than in the main findings for adherence. After adjusting for intervention group, sociodemographic factors, physical health, and mental health (model 3), the IRR for total adherence was 0.59 (95%CI = 0.35–0.99) in participants with moderate AUD and 0.70 (95%CI = 0.39–1.26) among those with severe AUD. Linear regression analyses for the association between predictor variables and adherence extent are reported in supplementary table 3. Findings were materially the same. Adherence extent tended to be lower among those with moderate AUD (model 3: B = -0.87, 95% CI = -1.41, −0.34) and severe AUD (model 3: B = -0.95, 95% CI = -1.55, −0.34) when compared to those who had mild AUD.

5. Discussion

Exercise adherence can be challenging for those with AUD. In addition to the commonly reported issues of motivation, perceived time, and resources (Mahmood et al., 2022), people with AUD may experience additional obstacles, including co-existing somatic and psychiatric conditions which can impede planning, implementation, or maintenance of new exercise regimes (Giesen et al., 2016). Approximately half of our participants completed ≥ 12 supervised exercise classes during the 12-week intervention. However, when all exercise was considered, including home-based exercise sessions, the adherence rate was higher (66%). These rates are comparable to those reported previously (Giesen et al., 2015) and indicate that, while challenges exist, adults with AUD can be supported to increase their exercise levels. A limitation of previous work is that adherence data has been reported sporadically making interpretation of study findings difficult (Roessler et al., 2017). Our study included both objectively verified and self-reported exercise adherence data in a population that was previously physically inactive. In separate papers, we have shown that these behavior changes were associated with clinically meaningful reductions in alcohol consumption (5–7 standard glasses/week) (Gunillasdotter et al., 2022), and symptoms of depression/anxiety (Welford et al., 2022).

Three factors were associated with non-adherence to exercise: higher BMI (and waist circumference), higher AUD severity (moderate to severe), and lower education level. In the general population, and among those with chronic health conditions, higher BMI is associated with less physical activity and more sedentary behavior (Herring et al., 2014). Those with severe AUD experience worse physical health, including a higher prevalence of the metabolic syndrome, diabetes, and

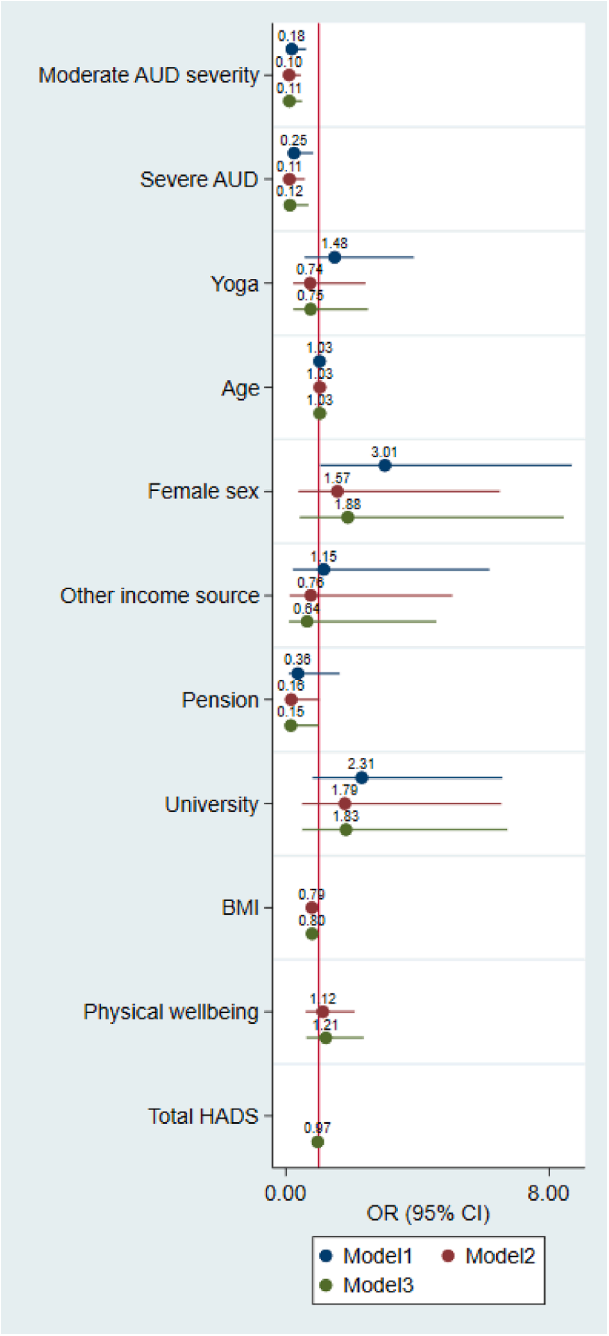

Fig. 1. Adherence odds ratio plots.

cardiovascular disease (Day & Rudd, 2019; Vancampfort, Mugisha, Hallgren, De Hert, Probst, & Monsieur, 2016; Vancampfort, Hallgren, Mugisha, De Hert, Probst, & Monsieur, 2016). These conditions may directly or indirectly (e.g., through medication use) impact one's ability to exercise regularly or with sufficient intensity. Mental health problems are shown to negatively affect exercise adherence and are more prevalent in those with severe AUD (Burns & Teesson, 2002). Depression is associated with anhedonia, poor motivation, and physical inertia. Similarly, anxiety may lead to the avoidance of environments involving social interaction, such as fitness centers. Those with severe AUD are also more likely to experience socio-occupational problems (unemployment, less social supports) (Lasserre et al., 2022), which can result in the absence of daily routines that might otherwise support exercise adherence (Sari et al., 2017). Of interest, we found no significant associations between alcohol consumption (i.e., number of drinks/week) and adherence, in contrast to AUD severity (number of DSM5 criteria). This might suggest that, with regards to adherence, the features of addiction could be more important than the actual level of alcohol consumption. Consistent with previous studies, we found that lower levels of education were associated with worse exercise adherence (univariate models only) (Giesen et al., 2015). Our findings suggest that additional support may be needed to assist those with one or more of these attributes to initiate and maintain new exercise regimes in the context of a treatment or intervention.

In a qualitative study, we identified several factors influencing the exercise behaviors of our participants (Gunillasdotter et al., 2022). Exercise needed to be enjoyable, performed at the 'right intensity', and with the 'right group of people' (i.e., those with similar fitness levels). Some participants expressed disappointment at being randomized to a non-preferred exercise group, and not being able to vary their training sufficiently (Gunillasdotter et al., 2022). Previous studies have shown that being able to self-select one's preferred exercise may improve exercise adherence (Callaghan et al., 2011; Meyer et al., 2016). Abrantes and colleague found that tailoring interventions based on exercise preferences, and when exercise is initiated in the recovery process, may partly address adherence issues (Abrantes et al., 2011). These findings point toward the need to tailor interventions to the unique preferences of individuals.

Strengths of the study include our focus on non-treatment seeking adults with AUD, who comprise > 80% of those with AUD (Schmidt, 2016). Previous studies have focused largely on hospitalized inpatients - an important but much smaller group. Objective assessment of exercise adherence is a strength and avoids over-reporting of physical activity levels. We assessed several demographic and clinical factors that are plausibly associated with exercise adherence. Potential limitations are also acknowledged. The primary adherence outcome in the current study was binary, but given that a dose–response phenomenon may underlie the effects of exercise, it can argued that adherence lies on a continuum. The World Health Organization emphasizes, however, that pragmatic and realistic adherence thresholds are needed to guide clinical practice and policy decisions (Sabaté, 2003). We thus considered 12 or more sessions to represent meaningful participation in this study but acknowledge that other thresholds could have been selected. Social support has been linked to exercise adherence but was not assessed in this study (Eynon et al., 2019; Schmidt, 2016). Work related factors (e.g., flexibility) could have practical implications for exercise adherence. We did not ask participants about their preferred type of exercise at baseline, which may have predicted adherence (Abrantes et al., 2011). Lastly, while we report both objective and self-report measures of adherence, we acknowledge that these data remain an estimate of participants' actual physical activity.

In conclusion, we found that almost half of our participants adhered to a 12-week exercise intervention for AUD. Three factors were associated with adherence: AUD severity, BMI, and educational level. Future studies should assess exercise preferences, work-related factors, and social support, and examine their association with adherence over time.

Data sharing

The protocol for this trial is publicly available. Individual participant data is not available and is in secure storage at the Karolinska Institute, Stockholm.

Clinical trial registration

This trial was prospectively registered with German Clinical Trials (https://www.drks.de) on 14 July 2017 (DRKS00012311).

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CRediT authorship contribution statement

Paul Welford: Formal analysis, Writing – original draft. **Victoria Gunillasdotter:** Project administration. **Sven Andreasson:** Funding acquisition, Writing – review & editing. **Matthew Herring:** Conceptualization, Funding acquisition, Methodology, Data curation, Project administration, Supervision, Formal analysis, Writing – original draft. **Davy Vancampfort:** Writing – review & editing. **Mats Hallgren:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The authors do not have permission to share data.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.addbeh.2023.107730.

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