

Acute Effects of Brief Exercise on Alcohol Craving Among Young Adults With Problematic Alcohol Use: A Systematic Review

P. Sampedro-Piquero¹  | A. Cordellat-Marzal²  | M. Dragotti³  | L. Mandolesi⁴  | O. Gigliotta^{3,5}  | R. D. Moreno-Fernández⁶ 

¹Department of Biological and Health Psychology, Faculty of Psychology, Autonomous University of Madrid, Madrid, Spain | ²Faculty of Physical Activity and Sport Sciences, University of Valencia, Valencia, Spain | ³Department of Humanities, University of Naples Federico II, Naples, Italy | ⁴Department of Human, Social and Health Sciences, University of Cassino and Southern Lazio, European University of Technology, Badia Fiesolana, Italy | ⁵Institute of Cognitive Sciences and Technologies, National Research Council (CNR), Roma, Italia | ⁶Instituto de Neurociencias y Psicología Social Aplicada (SINAPSICO), Faculty of Education and Psychology, University Francisco de Vitoria, Madrid, Spain

Correspondence: P. Sampedro-Piquero (patricia.sampedro@uam.es) | R. D. Moreno-Fernández (romandario.moreno@ufv.es)

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ABSTRACT

Alcohol craving is a key process in alcohol abuse, especially during young adulthood, a period of heightened vulnerability and continued brain development. Although acute physical exercise has been proposed as a potential strategy to reduce craving and modulate affective and cognitive processes, current evidence remains limited regarding its effectiveness and underlying mechanisms. This systematic review examined the effects of brief exercise interventions on alcohol craving in young adults with problematic alcohol use or alcohol use disorder (AUD) and explored available evidence on associated neurobiological responses. Four electronic databases were searched for studies published between 2016 and 2026 following PRISMA guidelines. The review protocol was registered in PROSPERO (CRD420261371036). Eligible studies included participants aged 18–29 years and assessed alcohol craving following a single bout of exercise. Random-effects meta-analyses using Hedges' g were conducted when sufficient data were available, while additional outcomes were synthesized narratively. Six studies met the inclusion criteria. Meta-analysis showed a moderate and statistically significant reduction in alcohol craving following acute exercise compared with baseline or control conditions ($g \approx 0.55$), with moderate between-study heterogeneity. Narrative findings indicated that acute exercise was often accompanied by reductions in anxiety and negative affective state, modulation of stress-related physiological markers, improvements in executive functioning, and changes in indices of brain and autonomic activity, although findings varied across studies. Overall, available evidence suggests that a single session of physical exercise may be associated with short-term reductions in alcohol craving in young adults, highlighting the need for further clinically focused and methodologically robust research.

1 | Introduction

1.1 | Alcohol Use and Vulnerability During Young Adulthood

Young adulthood is a transitional developmental period characterized by major educational, occupational, and social

changes, extending beyond ages 18–25 into the early 30s (Hanimoğlu 2025; Stroud et al. 2015; Arnett et al. 2014). This stage is associated with elevated engagement in alcohol use and other health-risk behaviors, including smoking, poor sleep, and reduced physical activity (Rod et al. 2025; Lawrence et al. 2017). Despite modest global declines in alcohol use disorder (AUD),

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Highlights

- Acute exercise is associated with short-term reductions in alcohol craving in young adults.
- Brief exercise sessions may modulate affective, cognitive, and stress-related processes linked to craving.
- More research is needed on exercise-related clinical effectiveness and its neurobiological underlying effects.

alcohol consumption remains highly prevalent in young adults, particularly in high-income countries, and represents a significant public health concern (OEDA 2025; WHO 2024).

Alcohol use during this period is associated with adverse outcomes including injury, academic impairment, and increased mortality (White and Hingson 2013). In addition, neurocognitive alterations affecting attention, inhibitory control, memory, and executive functioning have been reported in young alcohol users (Antón-Toro et al. 2026; Avdija 2022; Flores-Bonilla and Richardson 2020; Meda et al. 2017, 2018; Sher 2006). These impairments may contribute to reduced behavioral regulation and increased vulnerability to persistent alcohol use trajectories.

1.2 | Alcohol Craving and Withdrawal: Core Mechanisms of Relapse Vulnerability

Among the mechanisms underlying problematic alcohol use, craving is one of the most robust predictors of severity, relapses, and treatment outcome (Ingesson-Hammarberg et al. 2024; Martins et al. 2022; Wiers and Heinz 2015). Craving refers to a strong urge or desire to consume alcohol and reflects motivational processes underlying substance use behavior (Anton 1999; Mezinis et al. 2001). Importantly, craving is not restricted to clinical populations and is also present in young non-dependent drinkers, where it is associated with patterns of alcohol consumption (Connor et al. 2010; McEvoy et al. 2004; Meisel et al. 2023).

A particularly critical context for craving is alcohol withdrawal; the literature consistently indicates that acute alcohol withdrawal is characterized by a constellation of physiological and psychological symptoms, including craving, sleep disturbance, anxiety, and depressed mood, which are most pronounced during the early abstinence period and generally diminish within approximately 3–6 weeks (Heilig et al. 2010). Recent evidence from inpatient treatment settings further demonstrates that withdrawal symptoms, negative mood, and autonomic disturbances typically resolve by the third week of abstinence, although individuals with greater cumulative lifetime adversity experience significantly more severe withdrawal manifestations and may have poorer treatment outcomes (Fox et al. 2025). Sleep impairment appears to be a particularly salient feature of acute withdrawal, with AUD patients exhibiting markedly poorer sleep quality than healthy controls; moreover, depressive symptoms, anxiety, and craving are strongly associated with worse sleep during detoxification (X. Liu et al. 2025). The role of

negative affect is reinforced by genetic and contextual findings showing that withdrawal-related depression and anxiety increase with greater alcohol dependence severity and may be modulated by oxytocin-related genetic polymorphisms and social environment factors (Xu et al. 2026). Earlier work also highlighted the heterogeneity of withdrawal presentations, reporting generally mild symptoms in many males with AUD, with only a subset displaying clinically significant depressive symptoms or neuroendocrine abnormalities (Sengupta et al. 1992). From a clinical perspective, detoxification involves complex physiological and psychological care needs that require holistic nursing management (Norrish and Jooste 2001). Beyond withdrawal itself, studies in young adults suggest that negative emotional states are closely linked to alcohol-seeking behavior, particularly among individuals with depressive symptoms and coping-motivated drinking patterns (Hogarth et al. 2018), while broader psychosocial research associates alcohol consumption with increased anxiety, depression, and impulsive behaviors in youth populations (Mitincu-Caramfil et al. 2025). Although the direct association between negative affect and alcohol consumption is not always consistent, with some evidence indicating that positive affect may be a stronger predictor of drinking quantity than negative affect (Dali et al. 2023), the overall body of evidence supports a robust interplay between withdrawal severity, negative emotional states, sleep disturbance, psychosocial vulnerability, and relapse-related alcohol-seeking behavior. Consequently, the interplay between negative affect, mood instability, and craving constitutes a critical challenge in the management of alcohol use, as these emotional dimensions significantly amplify the individual's susceptibility to relapse (Khosravani et al. 2017). On the other hand, cue-induced craving also represents a key mechanism of relapses. According to incentive salience theory, repeated alcohol exposure increases the motivational value of alcohol-related cues, enhancing craving responses when individuals are exposed to such stimuli (Robinson and Berridge 1993; de Wit and Phan 2010). This process is associated with greater AUD severity, poorer treatment outcomes, and increased relapse risk (Ramirez and Miranda 2014; Venegas and Ray 2020), and may extend across psychiatric conditions (Yoon et al. 2021).

1.3 | Acute Exercise as a Promising Intervention for Craving

Acute exercise has been proposed as an accessible and potentially effective strategy for reducing anxiety, negative affect, and substance use risk, particularly through brief sessions that are feasible for young adults with time constraints (Broman-Fulks et al. 2004). Systematic reviews suggest that acute exercise may be more effective than long-term interventions for substance-related outcomes (Klamert et al. 2023), with additional benefits observed in emotion regulation, rumination reduction, and neurobiological processes (Bai and Zhang 2026). Nevertheless, the effectiveness of exercise appears to depend on modality, intensity, and individual differences, with different exercise forms potentially engaging distinct cognitive and affective mechanisms.

More broadly, similar patterns of craving modulation through acute exercise have been observed across different addictive behaviors, suggesting partially shared neurobiological and

cognitive mechanisms underlying cue reactivity and craving regulation in substance use disorders. This broader literature on addiction has been extensively examined in nicotine dependence, where experimental paradigms involving abstinence and cue exposure have been used to investigate acute exercise effects on craving. In these studies, brief bouts of physical activity have been shown to reduce cigarette craving and attentional bias toward smoking-related cues, with additional evidence from neuroimaging work indicating modulation of reward- and control-related brain regions during cue exposure (Van Rensburg, Taylor, Hodgson, and Benattayallah 2009; Zhou et al. 2023). Thus, acute exercise has been consistently shown to reduce craving in nicotine dependence, particularly in experimental paradigms where craving is induced through abstinence or exposure to smoking-related cues. Across studies, short bouts of exercise (ranging from 5 to 30 minutes) are effective in decreasing self-reported cigarette craving and withdrawal-related symptoms (H. Kim et al. 2022; Williams et al. 2011; Harper et al. 2012). These effects have been observed following periods of overnight or short-term abstinence (approximately 12–15 hours) as well as after exposure to smoking cues, which normally increase craving intensity but are attenuated following acute physical activity (Sui et al. 2019; Haasova et al. 2013; Van Rensburg, Taylor, and Hodgson 2009). In line with this, a recent meta-analysis by Zhou et al. (2023) further supports the role of acute exercise in reducing cigarette craving (MD = -1.84 , 95% CI $(-2.92, -0.76)$, $p < 0.001$; SMD = -1.64 , 95% CI $(-2.22, -1.05)$, $p < 0.001$), highlighting its potential as a complementary strategy in smoking cessation interventions. In addition to subjective craving reduction, exercise has been associated with decreased attentional bias toward smoking-related stimuli, suggesting a reduction in cue salience and automatic motivational processing related to tobacco use (Van Rensburg, Taylor, and Hodgson 2009; Fong et al. 2014).

Regarding exercise dose, moderate-intensity aerobic exercise (approximately 60%–80% of heart rate reserve) is the most frequently studied protocol and appears to produce the most robust effects, although low-intensity activity has also demonstrated beneficial outcomes in some cases (Haasova et al. 2013; Van Rensburg and Taylor 2008). Typical interventions involve 15–30 minutes of cycling, walking, or structured aerobic activity, with even brief sessions of 5–10 minutes showing measurable reductions in craving and negative affect (Williams et al. 2011; Van Rensburg and Taylor 2008; Ledochowski et al. 2013). Physiological and neurocognitive findings further support these effects, with exercise improving mood states, reducing withdrawal-related distress, and modulating activity in brain regions involved in reward processing and inhibitory control, such as the prefrontal cortex (ERP measures in H. Kim et al. 2022; fNIRS in H. Liu et al. 2022; fMRI in Van Rensburg, Taylor, Hodgson, and Benattayallah 2009). Overall, acute exercise appears to be a promising non-pharmacological strategy for reducing craving and withdrawal symptoms in nicotine dependence, particularly when craving is experimentally induced through abstinence or cue exposure paradigms. Some evidence also suggests additive effects when exercise is combined with nicotine replacement therapy or other cessation aids, enhancing reductions in craving and improving affective states (Harper et al. 2012; Tritter et al. 2015; Chen et al. 2022). However, further research is needed to optimize exercise prescription

parameters and clarify the long-term effects and mechanisms underlying these acute responses.

Despite promising findings regarding the acute effects of exercise on craving, the current literature shows considerable heterogeneity in study designs, populations, and outcome measures, which limits direct comparison across studies and calls for cautious interpretation of the findings. This is particularly relevant when considering alcohol-related outcomes in relation to the broader literature on acute exercise and craving in substance use disorders. Across studies, variability in participant characteristics, including age, treatment-seeking status, and motivation to reduce or abstain from substance use, contributes to differences in reported effects. In addition, methodological differences and variability in outcome assessment limit the comparability of effect sizes across studies. Finally, the use of diverse neurobiological and psychophysiological measures further constrains synthesis across the literature, highlighting the need for more standardized experimental approaches and consistent reporting of outcomes. Given these gaps, a systematic review is needed. Accordingly, the present review aims to examine the effects of different types of exercise on alcohol craving in young adults, with special attention to modality-specific effects and underlying neurobiological mechanisms. Although preliminary studies suggest that acute moderate-intensity exercise may reduce mood symptoms, anxiety, and craving in individuals with alcohol dependence (Brown et al. 2016; Hallgren et al. 2017), further rigorous research is required.

1.4 | Aims and Hypotheses

The main objective of this review is to systematically evaluate the effectiveness of different brief exercise modalities, including aerobic, strength, and mindbody interventions, in reducing alcohol craving among young adults (18–29 years-old). Specifically, the review aims to analyze the impact of different exercise protocols on craving outcomes and to examine potential sources of variability in their effectiveness. In addition, this review seeks to explore the neural substrates underlying the effectiveness of each type of exercise, with a focus on exercise-specific neurobiological effects and changes in brain function associated with craving regulation.

2 | Methods

The methods used in this systematic review follow the Prepared Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines (Page et al. 2021). This review protocol is registered in Prospero (Registration Number CRD420261371036).

2.1 | Literature Search

We included only peer-reviewed publications written in English and indexed in the Journal Citation Reports (JCR). The search was conducted on the Web of Science, PubMed, Scopus, and APA PsycINFO. Studies published between 2016 and 2026 were considered eligible for inclusion, as research specifically investigating the acute effects of exercise on alcohol craving among young adults with problematic alcohol use has only recently emerged. This timeframe was chosen to capture the available

evidence within this developing field and to ensure that the included studies reflected current approaches to the assessment of alcohol craving and exercise-based interventions. The following keyword combinations were used: (alcohol use disorder OR alcohol dependence OR alcoholism OR AUD) AND (alcohol craving OR craving) AND (exercise OR physical exercise OR aerobic exercise OR strength exercise OR stretching OR acute exercise OR single session OR brief exercise) AND (human OR young adult OR emerging adult) AND (brain OR neuroimaging OR fMRI OR EEG OR dopamine OR neurobiolog*). We considered empirical studies conducted in humans with participants aged 18–29 years presenting problematic alcohol consumption, as defined by DSM criteria, AUDIT scores, or other validated alcohol misuse questionnaires. Eligible studies were required to include a control group without a diagnosis of alcohol use disorder or other substance use disorders and to assess craving using validated questionnaires or Likert-type scales. The use of other substances was considered an exclusion criterion; however, the presence of comorbid conditions such as anxiety or depression was not excluded. Exercise protocols longer than one session were also excluded. Finally, only studies aimed at investigating the neurobiological effects of brief exercise interventions on alcohol craving were included. Based on these inclusion and exclusion criteria, a total of 174 articles were identified.

2.2 | Study Selection, Data Extraction and Methodological Quality Criteria

All the authors of this paper used the Covidence systematic review software (Veritas Health Innovation) for the selection process. After removing 20 duplicate articles, a total of 154 were screened, of which 14 were deemed irrelevant. The remaining 140 articles were independently assessed by three authors of this systematic review, and following discussion and consensus, it was found that 6 of those studies were eligible for the present review. Articles were excluded from the review according to the following criteria: reviews, study protocols, case reports, animal studies; studies involving adolescents (under 18 years old) or adults (over 30 years old); use of other substances; long exercise protocols involving more than one session; and analysis of alcohol-related variables other than craving. This procedure and a summary of the inclusion and exclusion criteria can be seen in Figure 1.

With the aim of assessing the quality of the selected publications, an examination according to the standards of the NHLBI Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies was implemented independently by two of the authors and later discussed and agreed upon (NHLBI 2014). According to the NHLBI criteria, the quality of the studies included in this review was assessed using a structured set of fourteen criteria (Q1–Q14) aligned with established standards for evaluating methodological rigor and risk of bias. These criteria addressed key domains such as the clarity of research objectives, appropriateness of study design, adequacy of sample selection and size, definition and measurement of variables, and the robustness of data collection and analysis procedures. Each study was systematically evaluated against these criteria to ensure consistency with current professional knowledge and to support a reliable classification of methodological quality across the selected articles (Table 1).

2.3 | Meta-Analyses of Alcohol Craving

All analyses were conducted using the RStudio desktop with Metafor package v5.0–1 (Viechtbauer 2010). A meta-analysis was conducted when adequate data were available for a given outcome measure (i.e., at least three studies) (Ramirez-Campillo et al. 2020). Some included studies involved small sample sizes (fewer or equal than 20 participants), and a correction for small-sample bias was applied in the effect size estimation (Yagiz et al. 2022). Accordingly, adjusted Hedges' g effect sizes (standardized mean differences) were computed using the mean change from baseline and the standard deviation of these changes for both the intervention and control groups. Effect sizes were interpreted according to conventional thresholds as small (0.2), moderate (0.5), or large (0.8) (Brydges 2019). Statistical significance was established at $p < 0.05$. Meta-analyses were performed using a random-effects model for continuous outcomes, applying the inverse-variance method and reporting 95% confidence intervals (CI). Between-study heterogeneity was assessed using the I^2 statistic, which quantifies the proportion of total variability attributable to true heterogeneity rather than random error. I^2 values of 25%, 50%, and 75% were interpreted as indicating low, moderate, and high heterogeneity, respectively (Higgins et al. 2003).

2.4 | Narrative Synthesis of Neurobiological and Psychophysiological Outcomes

In addition to alcohol-related craving, the included studies reported neurobiological, psychophysiological, and neurocognitive outcomes assessed alongside acute exercise protocols. These outcomes comprised affective measures (e.g., positive and negative mood, anxiety), physiological and neuroendocrine markers (e.g., heart rate variability, salivary cortisol, alpha amylase), and neurocognitive or neurophysiological indicators (e.g., executive functioning, cerebral oxygenation, electroencephalographic activity). Given the heterogeneity across outcome domains, assessment tools, timing of measurements, and study designs, these variables were not suitable for quantitative synthesis. Consequently, non-craving outcomes were analyzed using a narrative descriptive approach. Neurobiological and psychophysiological findings were summarised according to outcome category (affective, physiological, neurocognitive), exercise characteristics (modality and intensity), and study context (laboratory-based vs. naturalistic designs). This narrative synthesis was undertaken to complement the meta-analytic findings by providing an overview of concurrent biological and psychophysiological responses following acute physical exercise, without formal estimation of pooled effects or causal inference.

3 | Results

3.1 | Study Selection and Characteristics

Six independent articles met the inclusion criteria and were included in the analysis. Collectively, these studies comprised over 400 participants presenting with alcohol use disorder (AUD), risky alcohol use (RAU), or substance use disorder (SUD), with alcohol as the main drug consumed. All included studies examined the association between acute physical activity and alcohol craving, assessed using validated self-report instruments or ecological momentary assessment (EMA). The included studies

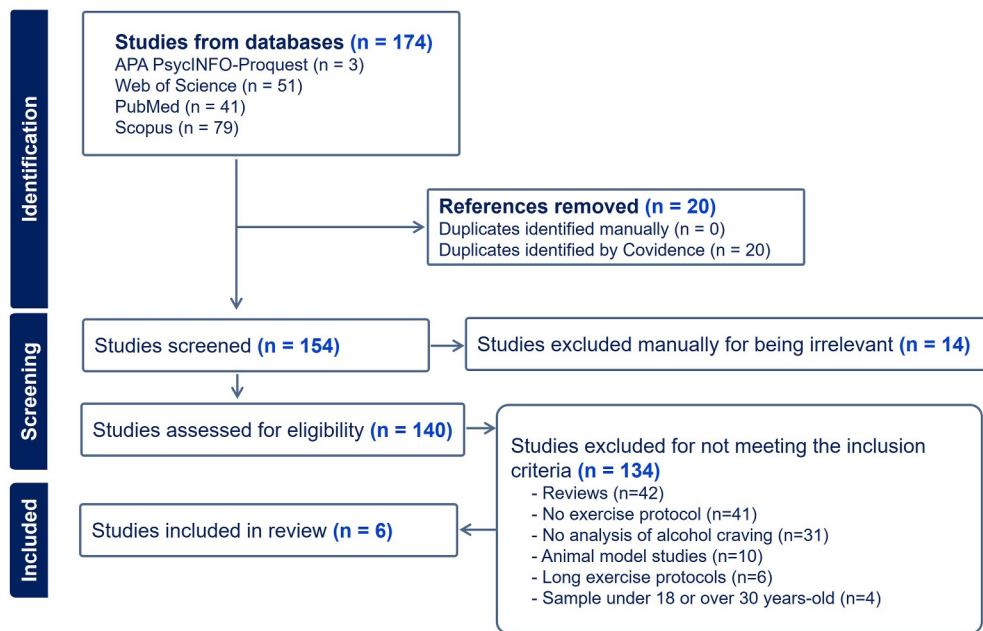


FIGURE 1 | Flowchart of selected studies (PRISMA).

TABLE 1 | Classification of selected articles according to NHLBI criteria.

Study	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	%	Quality
Elliott et al. (2026)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	NR	Y	Y	78.6	Good
Gawor et al. (2021)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	78.6	Good
Grandjean da Costa et al. (2017)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	NR	Y	Y	85.7	Good
Hallgren, Herring, et al. (2021)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	78.6	Good
Hallgren, Vancampfort, et al. (2021)	Y	Y	Y	Y	N	Y	Y	N	Y	Y	Y	N	Y	Y	78.6	Good
Stevenson et al. (2022)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	N	N	Y	78.6	Good
Total %	100	100	100	100	0	100	100	33.3	100	100	100	0	83.3	100		

Note: The italicized percentages indicate the proportion of NHLBI criteria fulfilled. Italicized quality ratings indicate the overall methodological quality classification of each study. Values in the "Total %" row represent the percentage of studies meeting each criterion. Abbreviations: N, No, NR, Not reported; Y, Yes.

covered a range of populations and study designs: non-treatment-seeking adults with AUD exposed to brief bouts of aerobic exercise (Hallgren, Herring, et al. 2021), adults with AUD participating in acute exercise within randomized controlled trials (Hallgren, Vancampfort, et al. 2021), university students with hazardous alcohol consumption (Gawor et al. 2021), adults with SUD, being alcohol the main drug, assessed using pre-post exercise paradigms (Grandjean da Costa et al. 2017), individuals with AUD monitored using EMA during free-living physical activity episodes (Stevenson et al. 2022), and young adults with RAU participating in an acute cycling or stretching protocol (Elliott et al. 2026). Exercise modalities were predominantly aerobic and varied in intensity from light to vigorous. Given the heterogeneity in study designs, participant populations, and assessment methods, a random-effects model was used for quantitative synthesis (Table 2). None of the included studies used experimental paradigms that examined craving induced in a state of natural or experimental abstinence. In fact, although the studies by Grandjean da Costa et al. (2017) and Stevenson et al. (2022) included participants enrolled in treatment programs, neither article specifies whether the subjects were experiencing a state of natural or experimentally induced withdrawal. However, it

should be highlighted that the study by Grandjean da Costa et al. 2017 used as exclusion criteria the presence of severe withdrawal-related symptoms, without clarifying whether the subjects included during treatment were in a state of alcohol withdrawal or simply clinically stable. Similarly, Stevenson et al. (2022) recruited participants from a treatment program for alcohol use disorder (AUD) but did not report whether participants were abstinent at the time of assessment. At least, the other included studies did not report whether subjects were in natural abstinence status, making it difficult to determine whether participants were in a state of withdrawal.

3.2 | Meta-Analysis of Alcohol Craving

Sufficient and comparable quantitative data were available only for alcohol craving, which was therefore the only variable included in this meta-analysis. Other outcomes reported (e.g., affective responses, withdrawal-related symptoms, or physiological variables) were not analyzed due to insufficient data or lack of methodological comparability. The random-effects meta-analysis showed a moderate and statistically significant association between acute physical activity and reduced alcohol

TABLE 2 | Summary of the 6 studies included in the systematic review, their methodology, and main findings.

Study	Sample	Age (mean $\pm$ SD)	Drug criteria; inclusion & exclusion criteria (not)	Exercise task	Outcome & analysis values	Conclusions
Elliott et al. (2026)	<i>N</i> = 100; 75 ♀ (47 RAU, 53 CO)	19.54 $\pm$ 0.28	RAU (AUDIT: <i>M</i> $\geq$ 8, <i>F</i> $\geq$ 6); CO ($\leq$ 3). NOT: > 150 min/wk exercise (IPAQ-SF), recreational drugs (CAST $\geq$ 4), prescription drugs or, blood pressure before exercise session ($\geq$ 140/90 mmHg)	12 min submaximal (4 min warm-up+ 8 min high intensity) cycling versus static stretching	sCORT interaction (time $\times$ group $\times$ ex $\times$ sex): <i>F</i> (2,158) = 4.77, <i>p</i> = 0.01; rsEEG delta (RAU men): <i>F</i> (1,90) = 3.73, <i>p</i> = 0.05; HRV RMSSD: <i>F</i> (2,166) = 16.52, <i>p</i> = 0.001	Cycling increases sCORT in RAU men and reduces HRV. Stretching unexpectedly enhances slow- wave rsEEG activity (delta/ theta)
Gawor et al. (2021)	<i>N</i> = 60; 38 ♀	20.90 $\pm$ 1.64	Hazardous drinkers (AUDIT $\geq$ 8). NOT: In treatment, injuries or contraindication for exercise	5 min moderate exercise circuit versus coloring versus passive control	ANCOVA on post- intervention craving (baseline adjusted): <i>F</i> (1, 56) = 30.466, <i>p</i> = 0.000, partial η^2 = 0.352; post-hoc (exercise vs. control): Mean diff = 4.70, <i>p</i> = 0.023	Acute moderate exercise effectively reduces alcohol craving in university students, however there no statistically significant difference groups.
Grandjean da Costa et al. (2017)	<i>N</i> = 29; 14 SUD, 15 controls	SUD: 33 (range 20–49); CG: 25 (18–32)	SUD treatment patients, > 27 in ASSIST. NOT: Severe withdrawal, MMSE < 24, psychoactive substance (CG); cardiovascular risk, high blood pressure	Maximum graded exercise test on cycle ergometer (+25 W every 2 min until exhaustion)	Exercise increased PFC oxygenation O2Hb main group effect: <i>F</i> (1,55) = 16.67, <i>p</i> = 0.0001; tHb interaction significant group $\times$ intensity interaction: <i>F</i> (1.37, 75.83) = 17.01, <i>p</i> = 0.0001	SUD individuals exhibit lower PFC O2Hb/tHb during high-intensity exercise compared to controls, however exercise may improve PFC function in SUD
Hallgren, Herring, et al. (2021)	<i>N</i> = 117; 80 ♀	52.7 $\pm$ 12.3 years	Sedentary AUD (DSM-5 $\geq$ 2), baseline craving DAQ > 8. NOT injuries or contraindications for engaging in exercise	12 min submaximal cycling (RPE 14–16)	Paired <i>t</i> -test on craving: <i>p</i> < 0.001, hedges' <i>g</i> = 0.60; hierarchical logistic regression (OR for $\geq$ 0.5 SD reduction): Pre- exercise craving OR = 1.15, <i>p</i> < 0.001. Estimated VO2 max: 31.2 $\pm$ 6.6; mean HR (last minute): 130.6 $\pm$ 16.5	Moderately intense aerobic exercise reduces craving; those with higher baseline cravings benefit most, estimated VO2max and HR as markers of physiological exertion

(Continues)

TABLE 2 | (Continued)

Study	Sample	Age (mean $\pm$ SD)	Drug criteria; inclusion & exclusion criteria (not)	Exercise task	Outcome & analysis values	Conclusions
Hallgren, Vancampfort, et al. (2021)	$N = 140$; 98 ♀	53.7 $\pm$ 11.8 years	Inactive (< 150 min/wk exercise), non- treatment seeking AUD (DSM-5 ≥ 2). NOT injuries or contraindications for engaging in exercise	12 min submaximal cycling (RPE 14–16)	RM-ANOVA main effect of time on craving: F (3,411) = 27.33, $p < 0.001$; mood disturbance: F (3,411) = 53.44, $p < 0.001$. Estimated VO2max: 31.1 $\pm$ 6.3	Brief aerobic exercise reduces alcohol craving and improves tension- anxiety, depression, anger-hostility, and fatigue in AUD.
Stevenson et al. (2022)	$N = 25$; 14 ♀	40 $\pm$ 11 years	AUD patients discharged from partial hospitalization	Naturalistic PA (steps and 10-min bouts of moderate- intensity exercise 100 steps/minute) recorded by fitbit	Multi-level mixed- effects regression: Within-subjects daily steps associated with lower cravings ($B = -0.02$, $p = 0.036$) and higher positive affect ($B = 0.02$, $p = 0.035$). Heart rate data.	Naturalistic physical activity has small but significant daily associations with reduced craving and improved mood

Abbreviations: ASSIST, Alcohol, Smoking, and Substance Involvement Screening Test; AUD, Alcohol Use Disorder; AUDIT, Alcohol Use Disorders Identification Test; DAQ, Desires for Alcohol Questionnaire; HR, heart rate; HRV, heart rate variability; O2Hb/tHb, oxygenated hemoglobin concentration relative to total hemoglobin; OR, odds ratio; PA, physical activity; PFC, prefrontal cortex; RAU, Risk Alcohol Use; RMSSD, Root Mean Square of Successive Differences; RPE, Rate of Perceived Exertion; rsEEG, resting state electroencephalogram; sCORT, salivary cortisol; SUD, Substance Use Disorder; VO2 max, maximal oxygen uptake/consumption.

craving, favoring exercise over baseline or control conditions. The pooled effect size was $g \approx 0.55$ (95% CI ≈ 0.40 – 0.80 , $p < 0.001$). Between-study heterogeneity was in the moderate range, reflecting differences in participant characteristics (clinical vs. non-clinical populations), physical activity modality and intensity, and context of assessment (laboratory-based protocols vs. free-living conditions). Inspection of the forest plot (Figure 2) indicated that most studies reported effects in the same direction, with no individual study exerting a disproportionate influence on the overall pooled estimate. Overall, the meta-analysis suggests an association with short-term reduction in alcohol craving across diverse populations and study designs.

3.3 | Publication Bias

Visual assessment of funnel plot asymmetry (Figure 3) did not indicate clear evidence of publication bias. However, given the small number of included studies ($k = 6$), the assessment of publication bias should be interpreted with caution, and formal statistical tests for funnel plot asymmetry were not performed (Mavridis and Salanti 2014).

3.4 | Evidence Related to Potential Neurobiological Effects (Narrative Synthesis)

Although quantitative meta-analysis focused exclusively on alcohol craving, several of the included studies assessed

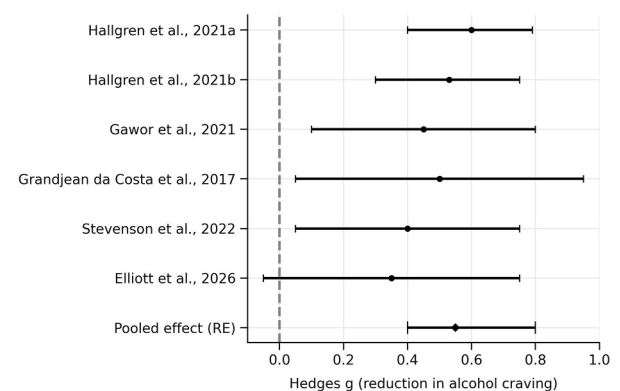


FIGURE 2 | Forest plot of the effects of acute physical activity on alcohol craving. Individual study effects are expressed as hedges' g with 95% confidence intervals. Positive values indicate reductions in alcohol craving following acute physical activity. The diamond represents the pooled random effects estimate.

additional neurobiological, psychophysiological, or neurocognitive variables alongside craving outcomes. Owing to substantial heterogeneity in outcome measures and assessment methods, these variables were synthesized narratively. Across studies conducted in both clinical and non-clinical populations, acute physical exercise was accompanied by changes in affective and stress-related parameters. Reductions in negative affect and anxiety following a single bout of exercise were reported in

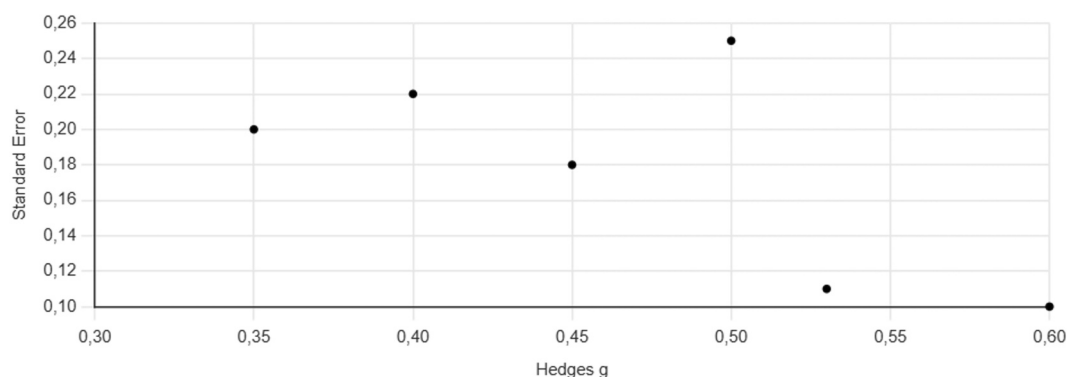


FIGURE 3 | Funnel plot of the effects of acute physical activity on alcohol craving. Each point represents an individual study plotted by effect size (hedges' g) and standard error. The dashed vertical line indicates the pooled random effects estimate. Given the small number of included studies ($k = 6$), the plot should be interpreted with caution.

laboratory-based protocols involving adults and young adults with AUD or RAU (Hallgren, Herring, et al. 2021; Hallgren, Vancampfort, et al. 2021; Gawor et al. 2021; Elliott et al. 2026). In naturalistic settings, daily physical activity was weakly associated with lower same-day alcohol craving and higher affective state, as assessed using EMA (Stevenson et al. 2022). Several studies included physiological indicators related to stress regulation and autonomic function. Acute exercise elicited changes in neuroendocrine markers such as salivary cortisol and alpha amylase, as well as autonomic indices including heart rate variability, with responses varying according to exercise modality and intensity (Elliott et al. 2026). In studies involving clinically diagnosed SUD, exercise was also associated with physiological activation during graded cycling protocols (Grandjean da Costa et al. 2017). Cognitive and neurophysiological measures were examined in a subset of studies. Acute aerobic exercise was associated with short-term improvements in executive functions and attentional performance, including measures of inhibitory control and verbal fluency, particularly in young adults with RAU (Elliott et al. 2026). In parallel, neurophysiological assessments revealed exercise-related changes in brain activity, including alterations in resting-state electroencephalographic oscillations and increases in cerebral oxygenation within prefrontal regions, measured using EEG and near-infrared spectroscopy techniques (Grandjean da Costa et al. 2017; Elliott et al. 2026). Exercise intensity appeared to moderate some of these physiological and neural responses. Thus, moderate to vigorous aerobic exercise was associated with concurrent affective, cognitive, and physiological changes, whereas higher-intensity exercise elicited stronger neuroendocrine and autonomic responses, including greater sympathetic activation (Grandjean da Costa et al. 2017; Elliott et al. 2026). We must consider that variability between individuals in physiological and neurocognitive responses to exercise was observed across both experimental and naturalistic study designs (Hallgren, Herring, et al. 2021; Stevenson et al. 2022).

In summary, beyond reductions in alcohol craving, the included studies reported concurrent changes across affective, physiological, and neurocognitive domains following acute physical exercise. As we mentioned before, due to methodological heterogeneity, these outcomes were reported descriptively rather than quantitatively synthesized (see Table 2). Finally, it should

be noted that, as previously mentioned, the included studies do not address the state of abstinence, a factor that could influence the discussion. Despite this, a study by Xie et al. (2025) showed that abstinence increases both dopamine release and calcium activity in direct-pathway medium spiny neurons (dMSNs). Consequently, it would be interesting to investigate in future research whether the affective, physiological, and neurocognitive changes observed after acute exercise would be the same in subjects assessed during a defined phase of alcohol abstinence.

4 | Discussion

The present review suggests that a single bout of acute physical exercise is associated with a moderate and statistically significant reduction in alcohol craving across diverse populations and study designs. In addition to this main outcome, the included studies reported concurrent changes in affective, physiological and neurocognitive variables following exercise. Specifically, acute exercise was accompanied by increases in positive mood, reductions in negative affect and anxiety, and transient modulation of stress-related physiological markers and prefrontal-related cognitive processes. Although these secondary outcomes could not be quantitatively synthesized due to methodological heterogeneity, their consistent observation across both experimental and naturalistic contexts provides important context for understanding the effects of acute exercise on alcohol craving.

4.1 | Effects of Short Bouts of Exercise on Alcohol Craving: Clinical and Practical Implications

The findings of the present review have relevant implications for the prevention and intervention strategies targeting alcohol use in young adults, a population characterized by high prevalence rates of alcohol consumption and specific patterns of use, including episodic heavy drinking and context-dependent intake (e.g., social and evening drinking) (OEDA 2025; WHO 2024). In this context, the observed reduction in alcohol craving following brief bouts of exercise suggests that acute physical activity may represent a practical and easily implementable strategy to manage momentary urges to drink (Giesen et al. 2015). Given that craving is a key predictor of alcohol consumption and relapse (Kharb et al. 2018; Martins

et al. 2022), interventions that target craving in real time may be particularly valuable in young populations, where drinking behavior is often impulsive and situational. One of the main strengths of the exercise protocols examined in this review lies in their brevity, typically ranging from 5 to 15 minutes. This feature enhances their feasibility in everyday contexts, allowing their integration into daily routines without requiring substantial time or resources. From a practical standpoint, these brief sessions could be recommended as a “just-in-time” strategy to be implemented during high-risk periods when craving and alcohol consumption tend to increase (Gavigan et al. 2026). In this way, exercise may function as a behavioral alternative that temporarily disrupts craving episodes and delays or reduces alcohol intake (Gawor et al. 2021).

These findings are particularly relevant for non-treatment-seeking young adults and individuals with RAU, who are less likely to engage with formal treatment services (Gunillasdotter et al. 2022). In such cases, exercise-based strategies may offer a non-stigmatizing and acceptable entry point for intervention, especially when delivered in settings such as universities, community programs, or digital health platforms. Moreover, given the well-established barriers to sustained behavior change in this age group (e.g., academic demands, irregular schedules), short and flexible interventions may be more easily adopted than traditional structured programs (Cheval and Boisgontier 2021; Klamert et al. 2023). At a clinical level, brief exercise sessions could also be incorporated as complementary tools within existing treatment frameworks for AUD (Ussher et al. 2004). For example, clinicians may encourage patients to use short bouts of moderate-to-vigorous physical activity as a coping strategy in response to craving or negative mood, in line with current behavioral approaches that emphasize the development of adaptive regulation strategies (Colledge et al. 2018; Ray et al. 2019). Importantly, evidence from the studies included suggests that individuals with higher baseline craving may experience greater benefits from acute exercise (Hallgren, Herring, et al. 2021), which may help identify subgroups who could particularly benefit from these interventions. In addition, findings from naturalistic research indicate that even small increases in daily physical activity are associated with lower same-day craving and improved mood (Stevenson et al. 2022), suggesting that promoting general activity levels, not only structured exercise, may have practical relevance in real-world settings. This is consistent with a harm-reduction perspective, where incremental changes in daily behavior may contribute to reducing alcohol-related risk. Despite these promising implications, caution is warranted in translating these findings into clinical recommendations. The effects observed are primarily acute and short-term, and there is currently insufficient evidence regarding their persistence over time. Furthermore, variability in individual responses suggests that exercise prescriptions may need to be adapted to personal characteristics such as fitness level, motivation, and drinking patterns.

Unfortunately, to date, results about alcohol craving modulation through acute exercise are limited and less developed, with relatively few experimental studies and a lack of consistent findings compared to the robust and methodologically mature literature in tobacco use disorders. In contrast, nicotine dependence has been extensively studied using controlled

experimental paradigms such as abstinence-induced craving and cue-reactivity procedures, which have enabled a more detailed characterization of the acute effects of exercise on craving, attentional bias, and associated neurocognitive mechanisms (Van Rensburg and Taylor 2008; Van Rensburg, Taylor, Hodgson, and Benattayallah 2009; Van Rensburg, Taylor, and Hodgson 2009; Haasova et al. 2013; Ledochowski et al. 2013; Sui et al. 2019; Zhou et al. 2023). Within this body of evidence, acute bouts of exercise have consistently been shown to reduce cigarette craving and withdrawal-related symptoms across a range of study designs, including after overnight or short-term abstinence and following exposure to smoking-related cues (Williams et al. 2011; Harper et al. 2012; Fong et al. 2014; Tritter et al. 2015; H. Kim et al. 2022). These effects are further supported by neurocognitive and neuroimaging findings suggesting modulation of reward-related processing and attentional bias toward smoking cues (Van Rensburg, Taylor, Hodgson, and Benattayallah 2009; H. Liu et al. 2022). Systematic reviews and meta-analytic evidence also support the robustness of these acute effects (Haasova et al. 2013; Zhou et al. 2023). By contrast, the literature on alcohol-related craving is still in an early stage of development, and this gap highlights the need for future research to systematically investigate whether the mechanisms observed in nicotine dependence generalize to alcohol use disorders, particularly using standardized experimental designs that assess cue-induced craving and acute exercise responses.

All in all, brief bouts of physical exercise (5–15 minutes) appear to be a time-efficient and potentially feasible strategy for the short-term management of alcohol craving in young adults. Their simplicity and adaptability make them particularly suitable for real-world implementation, especially as part of preventive or early intervention approaches. However, further research is needed to establish optimal implementation strategies and to determine how these acute effects translate into longer-term changes in alcohol use behavior. Further research is needed to inform implementation and effectiveness, given the challenges associated with translating exercise-based interventions into real-world treatment settings (Horrell et al. 2020).

4.2 | Influence of Exercise Type, Intensity, and Duration

Aerobic exercise was the predominant modality across all included studies, likely due to its suitability for achieving vigorous intensity levels in a controlled manner. Exercise intensity was generally aligned with the recommendations of the American College of Sports Medicine, corresponding to approximately 14 on the Borg Rating of Perceived Exertion scale or around 77% of maximal heart rate (Garber et al. 2011). Only one study implemented a circuit-based protocol without reporting objective intensity markers; however, based on the characteristics of the tasks described, it can be reasonably considered submaximal. Submaximal exercise has been associated with beneficial health outcomes, particularly in relation to metabolic regulation (Gibala and Little 2020). Notably, low-intensity exercise was examined in one study, with findings suggesting changes in brain activity (Elliott et al. 2026). This is particularly relevant given that sedentary individuals may exhibit greater adherence to lower-intensity exercise due to

reduced perceived effort, in line with the theory of effort minimization (Cheval and Boisgontier 2021).

Furthermore, lower-intensity protocols have been linked to improvements in psychological well-being, including reductions in anxiety (Huang and Wong 2025). In contrast, higher-intensity exercise appears to elicit more pronounced neurocognitive benefits, particularly through acute increases in brain-derived neurotrophic factor (BDNF), a biomarker closely associated with neuroplasticity and cognitive functioning (Fernández-Rodríguez et al. 2022). Additionally, the duration of exercise bouts influences physiological responses, particularly in high-intensity interval exercise, where variations in bout length can significantly modify metabolic and hematological outcomes (Bogdanis et al. 2022). Across the included studies, exercise interventions were generally of short duration, most commonly ranging between 12 and 15 minutes, although one study implemented a protocol lasting 5 minutes. This likely reflects the difficulty of sustaining high intensities in sedentary populations. Importantly, no study incorporated resistance training; however, emerging evidence suggests that acute high-intensity strength exercise may also increase neurocognitive biomarkers such as BDNF, Klotho, and GPLD1, albeit to a lesser extent than aerobic exercise (Bekkos et al. 2025). These findings indicate that short-duration, moderate-to-high intensity aerobic exercise may represent an efficient strategy for eliciting both physiological and neurocognitive benefits, with potential implications for populations at risk of comorbid conditions associated with alcohol use.

Along with this evidence, we must also consider that previous research examining substances other than alcohol, particularly nicotine dependence, has also shown that brief acute exercise interventions may effectively reduce craving and improve affective responses. Several studies have demonstrated that a single session of moderate-intensity aerobic exercise can acutely decrease smoking craving, especially cue-induced craving (Elibero et al. 2011), while also enhancing mood and inhibitory control (H. Kim et al. 2022). Likewise, mind-body modalities such as Hatha yoga have shown comparable or even greater reductions in subjective craving and negative affect following only one session (Elibero et al. 2011; Y. Kim et al. 2021). These effects have been observed after interventions lasting approximately 10–45 minutes and across different exercise modalities, including aerobic exercise, yoga, and combined exercise protocols. In individuals with SUD, acute exercise interventions have also produced immediate reductions in craving that persisted for several hours post-exercise (Ellingsen et al. 2021). Although evidence regarding resistance exercise alone remains more limited and less consistent, combined aerobic and resistance-based interventions appear promising according to recent meta-analytic evidence (Wang et al. 2025). By contrast, fewer studies have examined acute exercise effects on alcohol craving, despite preliminary evidence showing that even short bouts of moderate exercise can reduce alcohol urges and attentional bias toward alcohol-related cues in both high alcohol consumers and university students (Brown et al. 2009; Taylor et al. 2013), as well as in adults with alcohol use disorder (Hallgren, Herring, et al. 2021). One possible explanation proposed in the literature is that alcohol use may involve more complex social, contextual, and reward-related mechanisms

than nicotine, potentially making craving responses less immediately sensitive to acute exercise interventions (Cabé et al. 2021; Taylor et al. 2013). Overall, the available literature suggests that even a single bout of exercise may transiently attenuate craving-related responses across several substances of abuse, with the strongest and most consistent evidence currently reported in nicotine-dependent populations.

4.3 | Neurobiological Processes Associated With Alcohol Use and Acute Exercise

AUD and risky alcohol use are associated with alterations in brain functioning that can be broadly described across three related domains: emotional and stress regulation, cognitive control, and reward systems. Within this framework, alcohol use is closely associated with altered HPA axis functioning, increased stress sensitivity, and impaired autonomic regulation, typically reflected in elevated cortisol reactivity and reduced heart rate variability. These alterations have been associated with higher vulnerability to anxiety states and increased relapse risk (Seo et al. 2024; Georgakouli et al. 2022). In parallel, alcohol consumption is characterized by impairments in prefrontal cortex functionality, leading to deficits in inhibitory control, decision-making, and executive functioning (Sampedro-Piquero et al. 2024; Wilcox et al. 2014). At the neurochemical level, alcohol has been linked to persistent adaptations in mesolimbic dopaminergic circuits involved in incentive salience and craving (Banerjee 2014; Tan et al. 2024), while alcohol-related cues elicit robust dopaminergic responses in the ventral striatum and associated limbic structures, which may be related to compulsive consumption patterns (Gilman et al. 2008). In addition, NMDA receptor-mediated glutamatergic transmission contributes to synaptic adaptations underlying dependence and relapse vulnerability.

In the affective-stress domain, several studies have shown that different exercise protocols have been associated with reductions in stress reactivity, alongside changes in neuroendocrine and autonomic markers, reflected in more adaptive cortisol dynamics, reduced sympathetic activation, and increased heart rate variability. These effects may reflect a transient shift in HPA-axis regulation and autonomic flexibility. Importantly, exercise also promotes adaptive stress responses that reduce amygdala-driven emotional reactivity through top-down inhibitory mechanisms involving medial prefrontal cortical regions (Sedhom et al. 2024; Stoutenberg et al. 2016). In the included studies, these effects are supported by acute modulations in cortisol and autonomic markers following exercise bouts, suggesting a short-term recalibration of stress-system hyperreactivity (Elliott et al. 2026). In the domain of cognitive control, exercise has been associated with neuroplastic and functional changes that may be relevant to alcohol-related prefrontal dysfunction. Acute and chronic physical activity have been linked to improved integrity of hippocampal and cortical regions, greater efficiency of synaptic transmission, and upregulation of BDNF, all of which support enhanced cognitive functioning and more effective engagement of fronto-executive networks (Mandolesi et al. 2018). These changes may be related to improvements in behavioral regulation and impulsivity in alcohol-related contexts (West et al. 2019). Consistently, the included studies reported acute exercise-related changes in

neurophysiological indices of prefrontal activity, including increased cortical oxygenation measured via NIRS and alterations in EEG oscillatory activity, suggesting transient enhancements in cortical efficiency and executive control capacity (Grandjean da Costa et al. 2017; Elliott et al. 2026). Regarding the reward and neurochemical modulation pathway, alcohol involves persistent dysregulation of dopaminergic signaling within mesolimbic circuits, particularly those governing incentive salience and craving (Banerjee 2014; Tan et al. 2024). Alcohol-related cues elicit strong dopaminergic responses within the ventral striatum, reinforcing compulsive consumption patterns and craving intensity (Gilman et al. 2008). NMDA receptor-mediated glutamatergic transmission has been also implicated in synaptic adaptations associated with dependence and relapse vulnerability. Within this context, acute physical exercise has been proposed as a potential modulator of reward-related processes, possibly involving changes in dopamine-related signaling and cue-related processing and influencing glutamatergic plasticity and NMDA-related functions. Additionally, exercise has been associated with the activation of endogenous opioid and endocannabinoid systems, which may contribute to hedonic regulation, anxiolytic effects, and reward substitution processes (Lynch et al. 2013; Sedhom et al. 2024).

Collectively, neurobiological evidence from the included studies converges with this tripartite model, indicating that acute physical exercise may be associated with short-term changes in stress-system regulation, prefrontal functioning, and reward-related processes. Across the review, exercise was associated with acute changes in neuroendocrine (cortisol), autonomic (heart rate variability, sympathetic–parasympathetic balance), and neurophysiological markers (EEG activity and prefrontal oxygenation), supporting its role as a transient multi-system regulator (Grandjean da Costa et al. 2017; Elliott et al. 2026).

5 | Conclusions

Despite these promising findings, several limitations should be acknowledged. The limited number of included studies and the predominance of small samples raise the possibility of publication bias and small-study effects, which may have inflated the observed effect sizes. In addition, craving was typically assessed immediately post-exercise, and little is known about the duration or stability of these effects beyond the acute time window. Although heterogeneity across study designs, populations, and exercise protocols was recognized, it also limits confidence in the precision and generalizability of the pooled estimates. A further limitation is the reliance on self-reported craving measures, which are susceptible to reporting bias and may not fully capture dynamic motivational processes. Importantly, the present synthesis is also limited by the relatively narrow focus on acute exercise effects in isolation from broader psychosocial determinants of alcohol use. Social and individual decision-making processes, including personality traits such as impulsivity, are likely to play a significant role in craving regulation and alcohol consumption behavior (Rømer Thomsen et al. 2018). For instance, in many cultural contexts, particularly within certain team sports environments (e.g., rugby or football), alcohol use is embedded in post-competition social rituals, where anticipation of drinking may contribute to a build-up of

craving in the lead-up to social interaction (Denault and Poulin 2018; Lisha et al. 2014; Murray et al. 2021). Conversely, some individuals may intentionally adopt abstinence decisions at key life transitions and simultaneously engage in sport or exercise as a structured alternative activity and as a means of social affiliation with peers who also avoid alcohol (Advocat and Lindsay 2015; Supski and Lindsay 2017). These contextual and motivational factors suggest that exercise-related effects on craving should be understood within a broader behavioral and cultural framework, where social reinforcement, identity, and self-regulation processes may interact with neurobiological mechanisms.

Future research should therefore prioritize adequately powered studies using standardised craving and neurobiological measures, as well as designs that allow for the assessment of temporal dynamics and real-world relevance of exercise-induced effects on alcohol craving. Hence, integrative approaches that incorporate psychosocial variables such as impulsivity, social drinking norms, and decision-making processes may help clarify for whom and under what circumstances exercise is most effective as an adjunctive strategy for craving regulation.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

- Advocat, J., and J. Lindsay. 2015. "To Drink or Not to Drink? Young Australians Negotiating the Social Imperative to Drink to Intoxication." *Journal of Sociology* 51, no. 2: 139–153. <https://doi.org/10.1177/1440783313482367>.
- Antón-Toro, L. F., D. Shpakivska-Bilan, L. López-Abad, et al. 2026. "Adolescent Predisposition to Binge Drinking Is Associated With Differences in Inhibitory Control MEG Event-Related Fields." *Frontiers in Psychiatry* 16: 1696748. <https://doi.org/10.3389/fpsy.2025.1696748>.
- Anton, R. F. 1999. "What Is Craving? Models and Implications for Treatment." *Alcohol Research & Health* 23, no. 3: 165–173. PMID: 10890811; PMCID: PMC6760371.
- Arnett, J. J., R. Žukauskienė, and K. Sugimura. 2014. "The New Life Stage of Emerging Adulthood at Ages 18–29 Years: Implications for Mental Health." *Lancet Psychiatry* 1, no. 7: 569–576. [https://doi.org/10.1016/S2215-0366\(14\)00080-7](https://doi.org/10.1016/S2215-0366(14)00080-7).
- Avdija, A. 2022. "Substance Use and Stress-Induced Cognitive Impairment: The Causes of Anxiety and Depression Among College Students." *Journal of Drug Education* 51, no. 3–4: 70–81. <https://doi.org/10.1177/00472379221148384>.

- Bai, J., and J. Zhang. 2026. "Exercise Intervention for Rumination: From Neural Mechanisms to Clinical Applications." *Frontiers in Psychology* 17: 1785621. <https://doi.org/10.3389/fpsyg.2026.1785621>.
- Banerjee, N. 2014. "Neurotransmitters in Alcoholism: A Review of Neurobiological and Genetic Studies." *Indian Journal of Human Genetics* 20, no. 1: 20–31. <https://doi.org/10.4103/0971-6866.132750>.
- Bekkos, C. H., M. A. J. Suján, A. K. Stunes, et al. 2025. "Acute Effects of a Single Bout of High-Intensity Strength and Endurance Exercise on Cognitive Biomarkers in Young Adults and Elderly Men: A Within-Subjects Crossover Study." *Journal of Translational Medicine* 23, no. 1: 685. <https://doi.org/10.1186/s12967-025-06685-y>.
- Bogdanis, G. C., G. Mastorakos, S. Tsirigkakakis, et al. 2022. "Bout Duration in High-Intensity Interval Exercise Modifies Hematologic, Metabolic and Antioxidant Responses." *Journal of Exercise Science & Fitness* 20, no. 3: 216–223. <https://doi.org/10.1016/j.jesf.2022.03.005>.
- Broman-Fulks, J. J., M. E. Berman, B. A. Rabian, and M. J. Webster. 2004. "Effects of Aerobic Exercise on Anxiety Sensitivity." *Behavior Research & Therapy* 42, no. 2: 125–136. [https://doi.org/10.1016/S0005-7967\(03\)00103-7](https://doi.org/10.1016/S0005-7967(03)00103-7).
- Brown, R. A., A. M. Abrantes, J. P. Read, et al. 2009. "Aerobic Exercise for Alcohol Recovery: Rationale, Program Description, and Preliminary Findings." *Behavior Modification* 33, no. 2: 220–249. <https://doi.org/10.1177/0145445508329112>.
- Brown, R. A., M. A. Prince, H. Minami, and A. M. Abrantes. 2016. "An Exploratory Analysis of Changes in Mood, Anxiety and Craving From Pre- to Post-Single Sessions of Exercise, Over 12 Weeks, Among Patients With Alcohol Dependence." *Mental Health and Physical Activity* 11: 1–6. <https://doi.org/10.1016/j.mhpa.2016.04.002>.
- Brydges, C. R. 2019. "Effect Size Guidelines, Sample Size Calculations, and Statistical Power in Gerontology." *Innovation in aging* 3, no. 4: igz036. <https://doi.org/10.1093/geroni/igz036>.
- Cabé, N., A. Laniépce, and A. L. Pitel. 2021. "Physical Activity: A Promising Adjunctive Treatment for Severe Alcohol Use Disorder." *Addictive Behaviors* 113: 106667. <https://doi.org/10.1016/j.addbeh.2020.106667>.
- Chen, H., Y. Yang, H. Miyai, C. Yi, and B. G. Oliver. 2022. "The Effects of Exercise With Nicotine Replacement Therapy for Smoking Cessation in Adults: A Systematic Review." *Frontiers in Psychiatry* 13: 1053937. <https://doi.org/10.3389/fpsyg.2022.1053937>.
- Cheval, B., and M. P. Boisgontier. 2021. "The Theory of Effort Minimization in Physical Activity." *Exercise and Sport Sciences Reviews* 49, no. 3: 168–178. <https://doi.org/10.1249/jes.0000000000000252>.
- Colledge, F., S. Ludyga, M. Mücke, U. Pühse, and M. Gerber. 2018. "The Effects of an Acute Bout of Exercise on Neural Activity in Alcohol and Cocaine Craving: Study Protocol for a Randomised Controlled Trial." *Trials* 19, no. 1: 713. <https://doi.org/10.1186/s13063-018-3062-0>.
- Connor, J. P., G. F. Feeney, A. Jack, and R. M. Young. 2010. "The Obsessive-Compulsive Drinking Scale Is a Valid Measure of Alcohol Craving in Young Adults." *Alcoholism: Clinical and Experimental Research* 34, no. 12: 2155–2161. <https://doi.org/10.1111/j.1530-0277.2010.01312.x>.
- Dali, G., W. Logge, B. Riordan, et al. 2023. "The Role of Impulsivity in the Relationship Between Affect and Alcohol Consumption in Young Adults." *Alcoholism: Clinical and Experimental Research* 47, no. 11: 2161–2168. <https://doi.org/10.1111/acer.15192>.
- Denault, A. S., and F. Poulin. 2018. "A Detailed Examination of the Longitudinal Associations Between Individual and Team Sports and Alcohol Use." *Addictive Behaviors* 78: 15–21. <https://doi.org/10.1016/j.addbeh.2017.10.019>.
- de Wit, H., and L. Phan. 2010. "Positive Reinforcement Theories of Drug Use." In *Substance Abuse and Emotion*, 43–60. American Psychological Association.
- Elibero, A., K. Janse Van Rensburg, and D. J. Drobes. 2011. "Acute Effects of Aerobic Exercise and Hatha Yoga on Craving to Smoke." *Nicotine & Tobacco Research* 13, no. 11: 1140–1148. <https://doi.org/10.1093/ntr/ntr163>.
- Ellingsen, M. M., T. Clausen, S. L. Johannesen, E. W. Martinsen, and M. Hallgren. 2021. "Effects of Acute Exercise on Drug Craving in Adults With Poly-Substance Use Disorder. A Randomized Controlled Trial." *Mental Health and Physical Activity* 21: 100423. <https://doi.org/10.1016/j.mhpa.2021.100423>.
- Elliott, A. S., B. Regodón-Virgos, A. Cordellat-Marzal, et al. 2026. "Differential Cognitive, Neurophysiological, and Stress Responses to Acute Cycling and Stretching in Young Adults With Risky Alcohol Use." *Pharmacology Biochemistry and Behavior* 263: 174190. <https://doi.org/10.1016/j.pbb.2026.174190>.
- Fernández-Rodríguez, R., C. Álvarez-Bueno, I. A. Martínez-Ortega, V. Martínez-Vizcaino, A. E. Mesas, and B. Notario-Pacheco. 2022. "Immediate Effect of High-Intensity Exercise on Brain-Derived Neurotrophic Factor in Healthy Young Adults: A Systematic Review and Meta-Analysis." *Journal of Sport and Health Science* 11, no. 3: 367–375. <https://doi.org/10.1016/j.jshs.2021.08.004>.
- Flores-Bonilla, A., and H. N. Richardson. 2020. "Sex Differences in the Neurobiology of Alcohol Use Disorder." *Alcohol Research* 40, no. 2: 04. <https://doi.org/10.35946/arc.v40.2.04>.
- Fong, A. J., S. De Jesus, S. R. Bray, and H. Prapavessis. 2014. "Effect of Exercise on Cigarette Cravings and Ad Libitum Smoking Following Concurrent Stressors." *Addictive Behaviors* 39, no. 10: 1516–1521. <https://doi.org/10.1016/j.addbeh.2014.05.027>.
- Fox, H. C., J. Alcina, S. M. Hyman, V. Milivojevic, and R. Sinha. 2025. "Early Alcohol Abstinence Symptoms and the Role of Cumulative Adversity." *Alcoholism: Clinical and Experimental Research* 49, no. 10: 2225–2238. <https://doi.org/10.1111/acer.70137>.
- Garber, C. E., B. Blissmer, M. R. Deschenes, et al. 2011. "American College of Sports Medicine Position Stand: Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory, Musculoskeletal, and Neuromotor Fitness in Apparently Healthy Adults: Guidance for Prescribing Exercise." *Medicine & Science in Sports & Exercise* 43, no. 7: 1334–1359. <https://doi.org/10.1249/MSS.0b013e318213fefb>.
- Gavigan, L., H. Prapavessis, and J. Chavarria. 2026. "Walking Away From Alcohol Urges: A Preliminary Test of the Efficacy of Moderate-Intensity Exercise for Reducing Alcohol Craving in Heavy Social Drinkers." *Addictive Behaviors* 179: 108684. <https://doi.org/10.1016/j.addbeh.2026.108684>.
- Gawor, A., E. Hogervorst, and T. Wilcockson. 2021. "Does an Acute Bout of Moderate Exercise Reduce Alcohol Craving in University Students?" *Addictive Behaviors* 123: 107071. <https://doi.org/10.1016/j.addbeh.2021.107071>.
- Georgakouli, K., E. Manthou, I. G. Fatouros, et al. 2022. "HPA-Axis Activity and Nutritional Status Correlation in Individuals With Alcohol Use Disorder." *Nutrients* 14, no. 23: 4978. <https://doi.org/10.3390/nu14234978>.
- Gibala, M. J., and J. P. Little. 2020. "Physiological Basis of Brief Vigorous Exercise to Improve Health." *Journal of Physiology* 598, no. 1: 61–69. <https://doi.org/10.1113/JP276849>.
- Giesen, E. S., H. Deimel, and W. Bloch. 2015. "Clinical Exercise Interventions in Alcohol Use Disorders: A Systematic Review." *Journal of Substance Abuse Treatment* 52: 1–9. <https://doi.org/10.1016/j.jsat.2014.12.001>.
- Gilman, J. M., V. A. Ramchandani, M. B. Davis, J. M. Bjork, and D. W. Hommer. 2008. "Why We like to Drink: A Functional Magnetic Resonance Imaging Study of the Rewarding and Anxiolytic Effects of Alcohol." *Journal of Neuroscience* 28, no. 18: 4583–4591. <https://doi.org/10.1523/JNEUROSCI.0086-08.2008>.

- Grandjean da Costa, K., V. Soares Rachetti, W. Quirino Alves da Silva, et al. 2017. "Drug Abusers Have Impaired Cerebral Oxygenation and Cognition During Exercise." *PLoS One* 12, no. 11: e0188030. <https://doi.org/10.1371/journal.pone.0188030>.
- Gunillasdotter, V., S. Andréasson, M. Jirwe, Ö. Ekblom, and M. Hallgren. 2022. "Effects of Exercise in Non-Treatment Seeking Adults With Alcohol Use Disorder: A Three-Armed Randomized Controlled Trial (FitForChange)." *Drug and Alcohol Dependence* 232: 109266. <https://doi.org/10.1016/j.drugalcdep.2022.109266>.
- Haasova, M., F. C. Warren, M. Ussher, et al. 2013. "The Acute Effects of Physical Activity on Cigarette Cravings: Systematic Review and Meta-Analysis With Individual Participant Data." *Addiction* 108, no. 1: 26–37. <https://doi.org/10.1111/j.1360-0443.2012.04034.x>.
- Hallgren, M., M. P. Herring, D. Vancampfort, et al. 2021. "Changes in Craving Following Acute Aerobic Exercise in Adults With Alcohol Use Disorder." *Journal of Psychiatric Research* 142: 243–249. <https://doi.org/10.1016/j.jpsychires.2021.08.007>.
- Hallgren, M., D. Vancampfort, M. T. Hoang, et al. 2021. "Effects of Acute Exercise on Craving, Mood and Anxiety in Non-treatment Seeking Adults With Alcohol Use Disorder: An Exploratory Study." *Drug and Alcohol Dependence* 1, no. 220: 108506. <https://doi.org/10.1016/j.drugalcdep.2021.108506>.
- Hallgren, M., D. Vancampfort, F. Schuch, A. Lundin, and B. Stubbs. 2017. "More Reasons to Move: Exercise in the Treatment of Alcohol Use Disorders." *Frontiers in Psychiatry* 28, no. 8: 160. <https://doi.org/10.3389/fpsy.2017.00160>.
- Hanimoğlu, E. 2025. "Life Satisfaction in Emerging Adulthood: A Longitudinal Study of Social Support, Resilience, and Gender Differences." *Frontiers in Psychology* 16: 1602140. <https://doi.org/10.3389/fpsy.2025.1602140>.
- Harper, T., L. Fitzgeorge, A. Tritter, and H. Prapavessis. 2012. "Acute Exercise Effects on Craving and Withdrawal Symptoms Among Women Attempting to Quit Smoking Using Nicotine Replacement Therapy." *Journal of Smoking Cessation* 7, no. 2: 72–79. <https://doi.org/10.1017/jsc.2012.15>.
- Heilig, M., M. Egli, J. C. Crabbe, and H. C. Becker. 2010. "Acute Withdrawal, Protracted Abstinence and Negative Affect in Alcoholism: Are They Linked?" *Addiction Biology* 15, no. 2: 169–184. <https://doi.org/10.1111/j.1369-1600.2009.00194.x>.
- Higgins, J. P. T., S. G. Thompson, J. J. Deeks, and D. G. Altman. 2003. "Measuring Inconsistency in Meta-Analyses." *British Medical Journal* 327, no. 7414: 557–560. <https://doi.org/10.1136/bmj.327.7414.557>.
- Hogarth, L., L. Hardy, A. R. Mathew, and B. Hitsman. 2018. "Negative Mood-Induced Alcohol-Seeking Is Greater in Young Adults Who Report Depression Symptoms, Drinking to Cope, and Subjective Reactivity." *Experimental and Clinical Psychopharmacology* 26, no. 2: 138–146. <https://doi.org/10.1037/pha0000177>.
- Horrell, J., T. P. Thompson, A. H. Taylor, et al. 2020. "Qualitative Systematic Review of the Acceptability, Feasibility, Barriers, Facilitators and Perceived Utility of Using Physical Activity in the Reduction of and Abstinence From Alcohol and Other Drug Use." *Mental Health and Physical Activity* 19: 100355. <https://doi.org/10.1016/j.mhpa.2020.100355>.
- Huang, W., and T. L. Wong. 2025. "Exercise Prescriptions for Young People's Emotional Wellbeing: A Systematic Review of Physical Activity Intensity, Duration, and Modality." *Frontiers in Psychology* 16: 1552531. <https://doi.org/10.3389/fpsy.2025.1552531>.
- Ingesson-Hammarberg, S., N. Jayaram-Lindström, and A. Hammarberg. 2024. "Predictors of Treatment Outcome for Individuals With Alcohol Use Disorder With a Goal of Controlled Drinking." *Addiction Science & Clinical Practice* 19, no. 1: 12. <https://doi.org/10.1186/s13722-024-00443-z>.
- Kharb, R., L. S. Shekhawat, R. P. Beniwal, T. Bhatia, and S. N. Deshpande. 2018. "Relationship Between Craving and Early Relapse in Alcohol Dependence: A Short-Term Follow-Up Study." *Indian Journal of Psychological Medicine* 40, no. 4: 315–321. https://doi.org/10.4103/IJP.SYM.IJPSYM_558_17.
- Khosravani, V., F. S. Bastan, F. Ghorbani, and Z. Kamali. 2017. "Difficulties in Emotion Regulation Mediate Negative and Positive Affects and Craving in Alcoholic Patients." *Addictive Behaviors* 71: 75–81. <https://doi.org/10.1016/j.addbeh.2017.02.029>.
- Kim, H., J. Kim, M. Woo, and T. Kim. 2022. "Changes in Inhibitory Control, Craving and Affect After Yoga vs. Aerobic Exercise Among Smokers With Nicotine Dependence." *Frontiers in Psychiatry* 13: 940415. <https://doi.org/10.3389/fpsy.2022.940415>.
- Kim, Y., S. Kwon, M. Kwon, M. Lee, and D. Lim. 2021. "Changes in Smoking Craving, Affect, and Breath Carbon Monoxide in Nicotine Dependents Following Single Bouts of Exercise: A Comparison of Aerobic Exercise and Yoga Effects." *Korean Journal of Sport Studies* 60, no. 6: 309–321. <https://doi.org/10.23949/kjpe.2021.11.60.6.22>.
- Klamert, L., M. Craike, G. Bedi, S. Kidd, M. C. Pascoe, and A. G. Parker. 2023. "Behaviour Change Techniques in Physical activity-focused Interventions for Young People at Risk of Problematic Substance Use: A Systematic Review and Meta-Analysis." *Early Intervention in Psychiatry* 17, no. 12: 1139–1153. <https://doi.org/10.1111/eip.13467>.
- Lawrence, E. M., S. Mollborn, and R. A. Hummer. 2017. "Health Lifestyles Across the Transition to Adulthood: Implications for Health." *Social Science & Medicine* 193: 23–32. <https://doi.org/10.1016/j.socscimed.2017.09.041>.
- Ledochowski, L., A. H. Taylor, M. Haasova, G. E. Faulkner, M. H. Ussher, and M. Kopp. 2013. "Immediate Effects of Single Bouts of Exercise on Cravings to Smoke: A Systematic Review of the Literature." *Zeitschrift für Gesundheitspsychologie* 21, no. 3: 122–137. <https://doi.org/10.1026/0943-8149/a000099>.
- Lisha, N. E., W. D. Crano, and K. L. Delucchi. 2014. "Participation in Team Sports and Alcohol and Marijuana Use Initiation Trajectories." *Journal of Drug Issues* 44, no. 1: 83–93. <https://doi.org/10.1177/0022042613491107>.
- Liu, H., Y. Zhang, S. Zhang, and Z. Xu. 2022. "Effects of Acute Aerobic Exercise on Food-Reward Mechanisms in Smoking-Addicted Individuals: An fNIRS Study." *Physiology & Behavior* 254: 113889. <https://doi.org/10.1016/j.physbeh.2022.113889>.
- Liu, X., X. Kong, and X. Chen. 2025. "Investigation and Analysis of Factors Related to Sleep Conditions During the Acute Withdrawal Period of Alcohol Use Disorder." *Frontiers in Psychiatry* 16: 1469324. <https://doi.org/10.3389/fpsy.2025.1469324>.
- Lynch, W. J., A. B. Peterson, V. Sanchez, J. Abel, and M. A. Smith. 2013. "Exercise as a Novel Treatment for Drug Addiction: A Neurobiological and Stage-Dependent Hypothesis." *Neuroscience & Biobehavioral Reviews* 37, no. 8: 1622–1644. <https://doi.org/10.1016/j.neubiorev.2013.06.011>.
- Mandolesi, L., A. Polverino, S. Montuori, et al. 2018. "Effects of Physical Exercise on Cognitive Functioning and Wellbeing: Biological and Psychological Benefits." *Frontiers in Psychology* 9: 509. <https://doi.org/10.3389/fpsyg.2018.00509>.
- Martins, J. S., N. Fogelman, S. Wemm, S. Hwang, and R. Sinha. 2022. "Alcohol Craving and Withdrawal at Treatment Entry Prospectively Predict Alcohol Use Outcomes During Outpatient Treatment." *Drug and Alcohol Dependence* 231: 109253. <https://doi.org/10.1016/j.drugalcdep.2021.109253>.
- Mavridis, D., and G. Salanti. 2014. "How to Assess Publication Bias: Funnel Plot, Trim-and-Fill Method and Selection Models." *Evidence-Based Mental Health-The BMJ* 17, no. 1: 30. <https://doi.org/10.1136/eb-2013-101699>.

- McEvoy, P. M., W. G. Stritzke, D. J. French, A. R. Lang, and R. Kertman. 2004. "Comparison of Three Models of Alcohol Craving in Young Adults: A Cross-Validation." *Addiction* 99, no. 4: 482–497. <https://doi.org/10.1111/j.1360-0443.2004.00714.x>.
- Meda, S. A., A. D. Dager, K. A. Hawkins, et al. 2017. "Heavy Drinking in College Students Is Associated With Accelerated Gray Matter Volumetric Decline Over a 2-Year Period." *Frontiers in Behavioral Neuroscience* 11: 176. <https://doi.org/10.3389/fnbeh.2017.00176>.
- Meda, S. A., K. A. Hawkins, A. D. Dager, et al. 2018. "Longitudinal Effects of Alcohol Consumption on the Hippocampus and Parahippocampus in College Students." *Biological Psychiatry: Cognitive Neuroscience and Neuroimaging* 3, no. 7: 610–617. <https://doi.org/10.1016/j.bpsc.2018.02.006>.
- Meisel, S. N., H. Treloar Padovano, M. Pielech, K. Goodyear, and R. Miranda Jr. 2023. "Peer-Elicited Alcohol Craving in Adolescents and Emerging Adults: Bridging the Laboratory and Natural Environment." *Alcoholism: Clinical and Experimental Research* 47, no. 5: 975–985. <https://doi.org/10.1111/acer.15057>.
- Mezinskas, J. P., L. Honos-Webb, F. Kropp, and E. Somoza. 2001. "The Measurement of Craving." *Journal of Addictive Diseases* 20, no. 3: 67–85. https://doi.org/10.1300/J069v20n03_07.
- Mitincu-Caramfil, S. D., L. A. Moroianu, A. V. Bradeanu, O. M. Isailă, C. Curis, and E. Drima. 2025. "The Correlation Between Emotionality Changes and Alcohol Consumption in Young Persons: A Pilot Study." *Healthcare* 13, no. 9: 987. <https://doi.org/10.3390/healthcare13090987>.
- Murray, R. M., C. M. Sabiston, I. Doré, M. Bélanger, and J. L. O'Loughlin. 2021. "Longitudinal Associations Between Team Sport Participation and Substance Use in Adolescents and Young Adults." *Addictive Behaviors* 116: 106798. <https://doi.org/10.1016/j.addbeh.2020.106798>.
- National Heart, Lung, and Blood Institute. 2014. *Quality Assessment Tool for Observational Cohort and Cross-Sectional Studies*. National Institutes of Health, U.S. Department of Health and Human Services. <https://www.nhlbi.nih.gov/health-topics/study-quality-assessment-tools>.
- Norrish, M. E., and K. Jooste. 2001. "Nursing Care of the Patient Undergoing Alcohol Detoxification." *Curationis* 24, no. 3: 36–48. <https://doi.org/10.4102/curationis.v24i3.846>.
- Observatorio Español de las Drogas y las Adicciones (OEDA). 2025. Informe 2025. Alcohol, Tabaco y drogas ilegales en España. Madrid: Ministerio de Sanidad. Delegación del Gobierno para el Plan Nacional sobre Drogas: 229
- Page, M. J., J. E. McKenzie, P. M. Bossuyt, et al. 2021. "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews." *British Medical Journal* 372, no. 71: 71. <https://doi.org/10.1136/bmj.n71>.
- Ramirez-Campillo, R., J. Sanchez-Sanchez, B. Romero-Moraleda, J. Yanci, A. Garcia-Hermoso, and F. M. Clemente. 2020. "Effects of Plyometric Jump Training in Female Soccer Player's Vertical Jump Height: A Systematic Review With Meta-Analysis." *Journal of Sports Sciences* 38, no. 13: 1475–1487. <https://doi.org/10.1080/02640414.2020.1745503>.
- Ramirez, J., and R. Miranda. 2014. "Alcohol Craving in Adolescents: Bridging the Laboratory and Natural Environment." *Psychopharmacology* 231, no. 8: 1841–1851. <https://doi.org/10.1007/s00213-013-3372-6>.
- Ray, L. A., S. Bujarski, E. Grodin, et al. 2019. "State-of-the-Art Behavioral and Pharmacological Treatments for Alcohol Use Disorder." *American Journal of Drug and Alcohol Abuse* 45, no. 2: 124–140. <https://doi.org/10.1080/00952990.2018.1528265>.
- Robinson, T. E., and K. C. Berridge. 1993. "The Neural Basis of Drug Craving: An Incentive-Sensitization Theory of Addiction." *Brain Research Reviews* 18, no. 3: 247–291. [https://doi.org/10.1016/0165-0173\(93\)90013-p](https://doi.org/10.1016/0165-0173(93)90013-p).
- Rod, N. H., M. Davies, T. R. de Vries, et al. 2025. "Young Adulthood: A Transitional Period With Lifelong Implications for Health and Well-being." *BMC Global and Public Health* 3, no. 1: 25. <https://doi.org/10.1186/s44263-025-00148-8>.
- Rømer Thomsen, K., M. B. Callesen, M. Hesse, et al. 2018. "Impulsivity Traits and Addiction-Related Behaviors in Youth." *Journal of Behavioral Addictions* 7, no. 2: 317–330. <https://doi.org/10.1556/2006.7.2018.22>.
- Sampedro-Piquero, P., F. Buades-Sitjar, A. Capilla, C. Zancada-Menéndez, A. González-Baeza, and R. D. Moreno-Fernández. 2024. "Risky Alcohol Use During Youth: Impact on Emotion, Cognitive Networks, and Resting-State EEG Activity." *Progress In Neuro-Psychopharmacology & Biological Psychiatry* 132: 110994. <https://doi.org/10.1016/j.pnpbp.2024.110994>.
- Sedhom, S., N. Hammond, K. Z. Thanos, et al. 2024. "Potential Link Between Exercise and n-Methyl-d-Aspartate Glutamate Receptors in Alcohol Use Disorder: Implications for Therapeutic Strategies." *Psychology Research and Behavior Management* 17: 2363–2376. <https://doi.org/10.2147/PRBM.S462403>.
- Sengupta, S. N., R. Roy, K. T. Shetty, and N. G. Desai. 1992. "Pituitary—Adrenal Functioning in Male Alcoholics." *Indian Journal of Psychiatry* 34, no. 2: 102–107.
- Seo, D., J. S. Martins, and R. Sinha. 2024. "Brain Correlates and Functional Connectivity Linking Stress, Autonomic Dysregulation, and Alcohol Motivation." *Neurobiology of Stress* 31: 100645. <https://doi.org/10.1016/j.ynstr.2024.100645>.
- Sher, L. 2006. "Functional Magnetic Resonance Imaging in Studies of Neurocognitive Effects of Alcohol Use on Adolescents and Young Adults." *International Journal of Adolescent Medicine and Health* 18, no. 1: 3–7. <https://doi.org/10.1515/ijamh.2006.18.1.3>.
- Stevenson, B. L., Z. J. Kunicki, L. Brick, C. E. Blevins, M. Stein, and A. M. Abrantes. 2022. "Using Ecological Momentary Assessments and Fitbit Data to Examine Daily Associations Between Physical Activity, Affect and Alcohol Cravings in Patients With Alcohol Use Disorder." *International Journal of Behavioral Medicine* 29, no. 5: 543–552. <https://doi.org/10.1007/s12529-021-10039-5>.
- Stoutenberg, M., C. D. Rethorst, O. Lawson, and J. P. Read. 2016. "Exercise Training—A Beneficial Intervention in the Treatment of Alcohol Use Disorders?" *Drug and Alcohol Dependence* 160: 2–11. <https://doi.org/10.1016/j.drugalcdep.2015.11.019>.
- Stroud, C., L. R. Walker, M. Davis, and C. E. Irwin Jr. 2015. "Investing in the Health and Well-Being of Young Adults." *Journal of Adolescent Health* 56, no. 2: 127–129. <https://doi.org/10.1016/j.jadohealth.2014.1.012>.
- Sui, W., S. Rollo, and H. Prapavessis. 2019. "The Acute Effect of Exercise on Cravings and Withdrawal Symptoms." In *Neuroscience of Nicotine: Mechanisms & Treatment*, 205–212. <https://doi.org/10.1016/B978-0-12-813035-3.00026-5>.
- Supski, S., and J. Lindsay. 2017. "There's Something Wrong With You': How Young People Choose Abstinence in a Heavy Drinking Culture." *Young* 25, no. 4: 323–338. <https://doi.org/10.1177/1103308816654068>.
- Tan, B., C. J. Browne, T. Nöbauer, A. Vaziri, J. M. Friedman, and E. J. Nestler. 2024. "Drugs of Abuse Hijack a Mesolimbic Pathway That Processes Homeostatic Need." *Science* 384, no. 6693. <https://doi.org/10.1126/science.adk6742>.
- Taylor, A. H., H. Oh, and S. Cullen. 2013. "Acute Effect of Exercise on Alcohol Urges and Attentional Bias Towards Alcohol Related Images in High Alcohol Consumers." *Mental Health and Physical Activity* 6, no. 3: 220–226. <https://doi.org/10.1016/j.mhpa.2013.09.004>.
- Tritter, A., L. Fitzgeorge, and H. Prapavessis. 2015. "The Effect of Acute Exercise on Cigarette Cravings While Using a Nicotine Lozenge." *Psychopharmacology* 232, no. 14: 2531–2539. <https://doi.org/10.1007/s00213-015-3887-0>.

- Ussher, M., A. K. Sampuran, R. Doshi, R. West, and D. C. Drummond. 2004. "Acute Effect of a Brief Bout of Exercise on Alcohol Urges." *Addiction* 99, no. 12: 1542–1547. <https://doi.org/10.1111/j.1360-0443.2004.00919.x>.
- Van Rensburg, K. J., A. Taylor, and T. Hodgson. 2009. "The Effects of Acute Exercise on Attentional Bias Towards Smoking-Related Stimuli During Temporary Abstinence From Smoking." *Addiction* 104, no. 11: 1910–1917. <https://doi.org/10.1111/j.1360-0443.2009.02692.x>.
- Van Rensburg, K. J., A. Taylor, T. Hodgson, and A. Benattayallah. 2009. "Acute Exercise Modulates Cigarette Cravings and Brain Activation in Response to Smoking-Related Images: An fMRI Study." *Psychopharmacology* 203, no. 3: 589–598. <https://doi.org/10.1007/s00213-008-1405-3>.
- Van Rensburg, K. J., and A. H. Taylor. 2008. "The Effects of Acute Exercise on Cognitive Functioning and Cigarette Cravings During Temporary Abstinence From Smoking." *Human Psychopharmacology* 23, no. 3: 193–199. <https://doi.org/10.1002/hup.925>.
- Venegas, A., and L. A. Ray. 2020. "Comparing Alcohol Cue-Reactivity in Treatment-Seekers Versus Non-Treatment-Seekers With Alcohol Use Disorder." *American Journal of Drug and Alcohol Abuse* 46, no. 1: 131–138. <https://doi.org/10.1080/00952990.2019.1635138>.
- Viechtbauer, W. 2010. "Conducting Meta-Analyses in R With the Metafor Package." *Journal of Statistical Software* 36, no. 3: 1–48. <https://doi.org/10.18637/jss.v036.i03>.
- Wang, C., Y. Yang, K. Wang, L. Sun, S. Q. Liu, and J. Luo. 2025. "Effects of Different Exercise Types on Craving in Substance Use Disorder Patients With Drug Dependence -Network Meta-Analysis and Dose-Response Relationships Based on Frequentist and Bayesian Models." *Addiction Science & Clinical Practice* 21, no. 1: 12. <https://doi.org/10.1186/s13722-025-00639-x>.
- West, R. K., L. Z. Najjar, and J. L. Leasure. 2019. "Exercise-Driven Restoration of the alcohol-damaged Brain." *International Review of Neurobiology* 147: 219–267. <https://doi.org/10.1016/bs.irn.2019.07.003>.
- White, A., and R. Hingson. 2013. "The Burden of Alcohol Use: Excessive Alcohol Consumption and Related Consequences Among College Students." *Alcohol Research: Current Reviews* 35, no. 2: 201–218. <https://doi.org/10.35946/arcr.v35.2.11>.
- Wiers, C. E., and A. Heinz. 2015. "Neurobiology of Alcohol Craving and Relapse Prediction: Implications for Diagnosis and Treatment." In *The Wiley Handbook on the Cognitive Neuroscience of Addiction*, edited by S. J. Wilson, 219–239. Wiley Blackwell.
- Wilcox, C. E., C. J. Dekonenko, A. R. Mayer, M. P. Bogenschutz, and J. A. Turner. 2014. "Cognitive Control in Alcohol Use Disorder: Deficits and Clinical Relevance." *Reviews in the Neurosciences* 25, no. 1: 1–24. <https://doi.org/10.1515/revneuro-2013-0054>.
- Williams, D. M., S. Dunsiger, J. A. Whiteley, M. H. Ussher, J. T. Ciccolo, and E. G. Jennings. 2011. "Acute Effects of Moderate Intensity Aerobic Exercise on Affective Withdrawal Symptoms and Cravings Among Women Smokers." *Addictive Behaviors* 36, no. 8: 894–897. <https://doi.org/10.1016/j.addbeh.2011.04.001>.
- World Health Organization. 2024. *Global Status Report on Alcohol and Health and Treatment of Substance Use Disorders*. World Health Organization.
- Xie, X., R. Chen, Y. Huang, X. Wang, and J. Wang. 2025. "Abstinence and Extinction Drive Opposing Changes in Striatal Activity and Dopamine Signaling During Alcohol Relapse." *Neuropharmacology* 279: 110646. <https://doi.org/10.1016/j.neuropharm.2025.110646>.
- Xu, Z., X. Ye, G. Shen, et al. 2026. "Context-Dependent Interaction Between Oxytocin Gene Polymorphisms and Alcohol Dependence in Modulating Negative Emotions During Acute Alcohol Withdrawal in Adult Males." *Frontiers in Psychiatry* 17: 1680226. <https://doi.org/10.3389/fpsy.2026.1680226>.
- Yagiz, G., E. Akaras, H. P. Kubis, and J. A. Owen. 2022. "The Effects of Resistance Training on Architecture and Volume of the Upper Extremity Muscles: A Systematic Review of Randomised Controlled Trials and Meta-Analyses." *Applied Sciences* 12, no. 3: 1593. <https://doi.org/10.3390/app12031593>.
- Yoon, G., K. Thompson, J. K. Hakes, J. Westermeyer, I. L. Petrakis, and S. W. Kim. 2021. "Alcohol Craving and Psychiatric Disorders Among Current Drinkers." *American Journal on Addictions* 30, no. 1: 34–42. <https://doi.org/10.1111/ajad.13083>.
- Zhou, Y., W. Feng, Y. Guo, and J. Wu. 2023. "Effect of Exercise Intervention on Smoking Cessation: A Meta-Analysis." *Frontiers in Physiology* 14: 1221898. <https://doi.org/10.3389/fphys.2023.1221898>.