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# Effectiveness of Emotion-Regulation Interventions on Substance Misuse and Emotion Regulation Outcomes in Individuals with Substance Dependence: A Systematic Review and Meta-Analysis

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## Abstract

**Purpose of Review** Substance dependence across multiple substances is consistently associated with emotion dysregulation. In the last two decades, emotion regulation interventions have been developed and applied from cognitive behavioral therapy, dialectical behavior therapy, and mindfulness-based interventions for substance dependence.

**Recent Findings** While previous reviews have focused solely on cognitive behavioral therapy or mindfulness interventions and have found positive outcomes regarding reductions in substance use, aggregate results of clinical outcomes across different emotion-regulation interventions have not been identified to this date.

**Summary** Through our systematic review of 26 studies, our meta-analysis of 10 studies on reduction in substance use, and 11 studies on improvement in emotion regulation outcomes, we found that improved outcomes have been demonstrated across diverse measures from self-report questionnaires to respiratory sinus arrhythmia. Although most emotion-regulation interventions have demonstrated a significant moderate effect size regarding the reduction in substance use and improvement in emotion regulation, mindfulness-based interventions have significantly driven the improvements in emotion regulation. No demographic variables (e.g., age, sex) nor study-design variables (e.g., intervention frequency, intervention length) significantly influenced the reduction in substance use from ER interventions. Our findings demonstrate the importance of cost-effective methods like mindfulness-based interventions towards addressing maladaptive substance use and the broad appeal of emotion regulation interventions to improve the outcomes of individuals afflicted with substance dependence.

**Keywords** Substance Dependence · Emotion Regulation · Mindfulness · Cognitive Behavioral Therapy · Dialectical Behavior Therapy

## Introduction

Substance use is a public health issue that has been attributed to 31.8 million disability-adjusted life-years across the globe and 7% of all global burden of disease [1, 2]. SUDs arise from a complex interplay between various individual and environmental factors, with risk factors that include comorbid mental health diseases, socioeconomic and occupational conditions, and adverse childhood experiences [3, 4, 5••, 6]. According to a report by the National Institute of Drug Abuse, SUDs exacerbate other mental health ailments like anxiety or depression.

Emotion regulation (ER), an internal state strongly implicated in SUD, involves the intensity, form, and duration of outward behavior from managing emotional experiences [7••]. Recent meta-analyses have shown that individuals with SUDs experience greater challenges in ER than those

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without SUDs [8••]. Healthy adolescent development involves a strengthening of top-down connections from the prefrontal cortex to subcortical regions that support affective processes like ER, allowing for impulse control and voluntary emotion regulation [9]. The involvement of the prefrontal cortex in top-down regulation of arousal, motivational, and reward/aversion processes [10•], further suggests a neurobiological link between ER and goal-directed behavior, where adversity, stress, and/or genetics can contribute to emotion dysregulation and substance misuse [9]. Changes in these connections from 10 to 24 years old as well as validated age-dependent impacts on the relation between SUDs and ER suggest age as an important consideration [11••]. There are also increased comorbidities of substance misuse, emotion dysregulation, and posttraumatic stress disorder in females compared to males by a factor of two to three, suggesting key demographic differences in the comorbidities of emotion dysregulation and SUDs [12•, 13•]. While the differences in emotion dysregulation between specific substances misused is less studied, initial research suggested an inverse relation between heroin dependence and ER indicators like hyperarousal and avoidance while the same could not be established for crack/cocaine, nor alcohol dependence [14].

Given these findings, it is understandable why ER therapies are becoming mainstays in SUD treatment. For instance, cognitive behavioral therapy (CBT) is a multisession intervention that teaches individuals skills to cope with environmental, cognitive, and affective risk factors for substance use to achieve and maintain abstinence [15], and often encompasses various strategies, including cue exposure, motivational interviewing, and in-session rehearsal of socially acceptable behaviors [16]. Additionally, CBT has been effective in reducing alcohol usage compared to treatment as usual (TAU) [17••, 18]. Dialectical behavior therapy (DBT), an extension of CBT, is also increasingly employed and incorporates mindfulness- and acceptance-based strategies [19]. Several studies have found that DBT can assist in treatment retention and reduce drug use among individuals with borderline personality disorder and other serious comorbidities [20]. Mindfulness-based interventions (MBI) for treating SUDs have also been examined in the past few years, which help individuals attend to "moment-to-moment experiences" to improve awareness during the reactions that follow a substance-related cue [21]. Multiple studies employing MBI in SUD treatment have found associated decreases in impulsivity, craving, and drug severity and improvements in positive affect compared to treatment-as-usual [22, 23••, 24••].

While meta-analyses have traditionally involved a single primary research question with one effect size per study [25], the diversity of interventions and measures in the field of psychiatry has spawned more exploratory approaches involving the inclusion of multiple measures and effect sizes per study in fields like attention-deficit/hyperactivity disorder [26], autism spectrum disorder [27], impacts of CBT [28•], impacts of DBT [29, 30], and etc. With the emerging diversity of ER interventions and vast literature on the links between SUDs and emotion dysregulation, this divergent integrative approach towards a meta-analysis is needed to understand the impact of ER interventions on substance misuse. In this systematic review and meta-analysis, we will curate studies that have employed ER interventions for individuals with SUD and investigate whether there were significant differences is substance use and ER outcomes between these ER and control interventions across multiple different ER interventions, ER outcomes, and substance use measures. In addition, we are interested in finding any significant contributors of study conditions (e.g., number of sessions per week, intervention duration, proportion of participants dependent on a certain substance) to substance use and ER outcomes.

## Methods

We followed the updated 2020 Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines used to standardize the presentation of our findings [31•].

### Eligibility Criteria

Our eligibility criteria are based on the population, intervention, comparison, and outcome (PICO) framework, which is useful for reviews on clinical intervention effectiveness [32]. For this review, the population (P) is individuals with substance misuse or substance use disorders. The intervention (I) encompasses ER interventions (e.g., CBT, DBT, MBI, and music therapy). The comparison (C) is a longitudinal analysis of the participant outcomes after and before the intervention. The outcome (O) involves measures related to substance misuse (e.g., craving, amount and/or frequency of use, and abstinence duration) and ER, and we curated these measures explicitly reported in the included studies.

Our inclusion and exclusion criteria are presented in Table 1. We included music therapy in our included criteria because music therapy has been demonstrated to improve ER outcomes and has been demonstrated to improve depressive and post-traumatic symptoms [33•, 34•, 35]. We did not employ a year-based cutoff to exclude studies that were published before a particular year.

**Table 1** Inclusion and exclusion criteria for systematic review

| Inclusion Criteria | Rationale |
|---|---|
| Study's population of interest was individuals with substance usage/dependence/misuse | Part of the inquiry for the systematic review and meta-analyses |
| Study involved an emotion regulation or music therapy intervention | Part of the inquiry for the systematic review and meta-analyses |
| Study measured (but did not need to explicitly report) substance use/craving/abstinence measures over two or more timepoints | We were interested in longitudinal changes to substance use habits from the intervention |
| Study measured (but did not need to explicitly report) emotion regulation measures over one or more time point | We were interested in either the resistance initial emotion regulation difficulties had on treatment outcome or longitudinal changes in emotion regulation from the intervention |
| Exclusion Criteria | |
| Non-English papers | |
| Reviews | |
| Systematic reviews | |
| Case reports | |
| Meta-analyses | |
| Commentaries | |
| Editorials | |
| Observational studies | |
| Historical articles | |
| Book chapters | |
| Introductory journal articles | |
| Retracted publications | |
| Studies not involving human subjects (e.g., rats, mice, porcine, in vitro) | |
| Twin studies | |

## Screening and Implemented Inclusion/Exclusion Process

Our search strategy involving substance use, ER concepts, and ER intervention terms yielded 373 results (Online Resource 1). We utilized Rayyan for its high labeling performance for excluding studies resulting in 313 articles to manually review [36, 37•].

After screening titles and abstracts, S.P. and G.N. found 21 relevant articles. Three articles were added after S.P. and G.N. deliberated on each other's assignments. R.B.S independently reviewed 190 articles from the total PUBMED search results (based on a 95% confidence level and 5% margin of error). Cohen's kappa inter-rater reliability was 0.43, requiring deliberation with M.A.P. as an arbitrator for extended disputes, which resulted in two additional articles. R.B.S subsequently reviewed 183 articles that yielded Cohen's kappa of 0.46. Another deliberation session did not add any more articles to the systematic review, yielding 26 articles (Fig. 1).

## Assessing Risk of Bias for Relevant Records

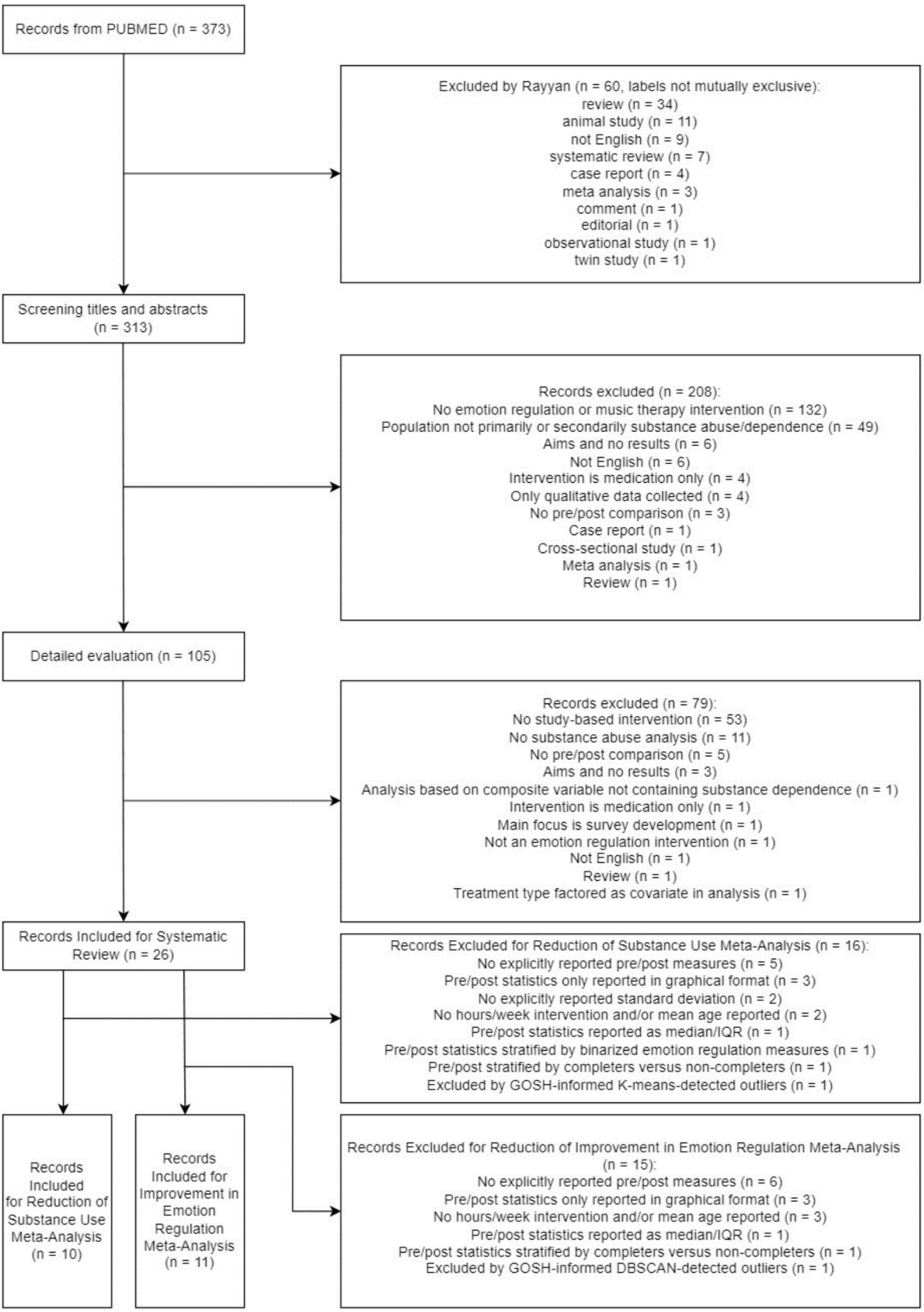
To assess the quality of each study, we employed the National Heart, Lung, and Blood Institute's (NHLBI) Quality Assessment of Controlled Intervention Studies or the NHLBI's Quality Assessment Tool for Before-After (Pre-Post) Studies With No Control Group, depending on the nature of the given study. We assessed the quality of each study by calculating the proportion of answers that were determined "Yes", excluding questions that were not applicable to the study.

## Data Collected for Systematic Review

We collected the sample size of each treatment group; proportion of individuals dependent on alcohol, nicotine, cannabis, opioids, stimulants, depressants, or other substances (e.g., anxiolytics); hours/week of intervention; total duration of intervention; number of weeks follow-up visit(s) were conducted after the end of the intervention; and the summary results regarding substance use and ER outcomes.

## Substance Misuse and ER Data Collected for Meta-Analysis

With diverse substance use and ER measures, we curated all available pre/post measures for substance use and ER (Online Resource 2) [38].


Records from PUBMED (n = 373)
Excluded by Rayyan (n = 60, labels not mutually exclusive):
review (n = 34)
animal study (n = 11)
not English (n = 9)
systematic review (n = 7)
case report (n = 4)
meta analysis (n = 3)
comment (n = 1)
editorial (n = 1)
observational study (n = 1)
twin study (n = 1)
Screening titles and abstracts (n = 313)
Records excluded (n = 208):
No emotion regulation or music therapy intervention (n = 132)
Population not primarily or secondarily substance abuse/dependence (n = 49)
Aims and no results (n = 6)
Not English (n = 6)
Intervention is medication only (n = 4)
Only qualitative data collected (n = 4)
No pre/post comparison (n = 3)
Case report (n = 1)
Cross-sectional study (n = 1)
Meta analysis (n = 1)
Review (n = 1)
Detailed evaluation (n = 105)
Records excluded (n = 79):
No study-based intervention (n = 53)
No substance abuse analysis (n = 11)
No pre/post comparison (n = 5)
Aims and no results (n = 3)
Analysis based on composite variable not containing substance dependence (n = 1)
Intervention is medication only (n = 1)
Main focus is survey development (n = 1)
Not an emotion regulation intervention (n = 1)
Not English (n = 1)
Review (n = 1)
Treatment type factored as covariate in analysis (n = 1)
Records Included for Systematic Review (n = 26)
Records Excluded for Reduction of Substance Use Meta-Analysis (n = 16):
No explicitly reported pre/post measures (n = 5)
Pre/post statistics only reported in graphical format (n = 3)
No explicitly reported standard deviation (n = 2)
No hours/week intervention and/or mean age reported (n = 2)
Pre/post statistics reported as median/IQR (n = 1)
Pre/post statistics stratified by binarized emotion regulation measures (n = 1)
Pre/post stratified by completers versus non-completers (n = 1)
Excluded by GOSH-informed K-means-detected outliers (n = 1)
Records Included for Reduction of Substance Use Meta-Analysis (n = 10)
Records Included for Improvement in Emotion Regulation Meta-Analysis (n = 11)
Records Excluded for Reduction of Improvement in Emotion Regulation Meta-Analysis (n = 15):
No explicitly reported pre/post measures (n = 6)
Pre/post statistics only reported in graphical format (n = 3)
No hours/week intervention and/or mean age reported (n = 3)
Pre/post statistics reported as median/IQR (n = 1)
Pre/post statistics stratified by completers versus non-completers (n = 1)
Excluded by GOSH-informed DBSCAN-detected outliers (n = 1)

◂**Fig. 1** PRISMA Flowchart for the determination of studies that involve substance-dependence and involve an emotion-regulation intervention for systematic review and meta-analyses. DBSCAN: Density-Based Spatial Clustering of Applications with Noise; GOSH: Graphical Display of Study Heterogeneity; PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-Analyses

## Effect Size Calculations

We used the standardized mean difference calculation, Hedges' *g*, between follow-up and baseline visits for substance-related and ER measures, as this measure is effective at correcting for sample sizes smaller than 50 [39]. We interpreted effect sizes of 0.2, 0.5, and 0.8 as small, medium, and large, respectively [40]. We estimated unreported standard deviations by dividing the range by four [41].

## Categorizations for the Meta-Analysis

We employed four top-level categorizations for our meta-analysis: reduction in substance use outcomes for ER interventions (RSUERI), reduction in substance use outcomes for control interventions (RSUCI), improvement in ER outcomes for ER interventions (IERERI), and improvement in ER outcomes for control interventions (IERCI) (Table 2). Within control interventions, we included treatment as usual (TAU) and health-education interventions (HEI) as two subcategories for RSUCI (RSUTAU and RSUHEI), and for IERCI (IERTAU and IERHEI) (Table 2).

## Reducing Statistical Between-Observation Heterogeneity

We used Graphical display Of Study Heterogeneity (GOSH)-informed outlier detection method for reduction of pre/post observation heterogeneity. We chose Cochran's Q to be the heterogeneity measure, and employed three different GOSH clustering approaches: K-means, Density-Based Spatial Clustering of Applications with Noise (DBSCAN), and Gaussian Mixture Model (GMM) [42]. GOSH analysis estimates the pooled effect size and the I2-heterogeneity value for one million combinations where a random set of effect size observations are removed, and the clustering approach groups the observations and determines outliers that need to be removed.

To determine the optimal number of clusters for the K-means approach, we randomly selected statistically representative samples from one million observations based on 95% confidence and 5% margin of error, 385 samples, and ran 13 different K-means clusterings from two clusters to 14 clusters. The clustering that yielded the highest Silhouette Index was used towards determining the outliers and the associated studies that needed to be removed [43••].

We used previous literature to inform what hyperparameters to use for DBSCAN clustering [44]. To determine the minimum number of points for each cluster, we did twice the number of input dimensions, entailing four minimum points. For the epsilon distance parameter, the recommendation is to find the four closest points by Euclidean distance to each observation; calculate the average distance from those four points; graph the average distances from all observations in ascending order; and determine the y-value where the graph starts to sharply increase. Since the observation space is one million meaning exhausting all combinations would mean one trillion computations, we chose 385 samples and assessed the closest four points from another random sample of 385 observations. Our epsilon parameters for RSUERI, RSUCI, IERERI, and IERCI were 1.56, 1.04, 0.20, and 0.64 respectively. Lastly, GMM does not have any input parameters.

From each of these three algorithms, we removed outlier observations from our downstream meta-analyses. Our results for heterogeneity before and after GOSH-informed outlier removal can be found in Online Resource 3.

Final data for our meta-analysis included 50 pre/post effect size observations across 10 studies for RSUERI, 22 observations across 4 studies for RSUCI, 79 observations across 11 studies for IERERI, and 120 observations across 6 studies for IERCI.

## Assessing Publication Bias

We determined any small-study effects in our surviving pre/post effect sizes for RSUERI and IERERI by 1) visually observing funnel plots for asymmetry [45], 2) employing Duval and Tweedie's Trim and Fill method to analytically assess asymmetry [46], 3) conducting Egger's regression test for another analytical assessment of asymmetry [47], 4) conducting Rücker's Limit Meta-Analysis Method to address small study effects [48], and 5) conducting p-curve analysis to determine the right-skewness and flatness of the reported pre/post measurement p-values [49].

## Meta-Analysis Approach

Because the data we have collected yields multiple effect size measures per study and involves a diversity of validated measures to explore different facets of change in substance use and ER outcomes, we found a divergent integrative approach to be most appropriate for our meta-analysis as we are interested in an exploratory analysis to address multiple research questions [25]. We asked 38 questions regarding our pre/post effect size data, and employed three-level meta-analyses and meta-regressions to answer these questions (Table 3).

**Table 2** Glossary of the categories we created for our meta-analyses

| Category | Subcategories |
|---|---|
| RSUERI: observations involving reduction in substance use (e.g., inverse cigarettes per day, inverse of Penn Alcohol Craving Scale) from emotion-regulation interventions (e.g. cognitive behavioral therapy, dialectical behavior therapy, mindfulness-based interventions) | NA |
| RSUCI: observations involving reduction in substance use from control interventions (e.g., inpatient/outpatient substance abuse rehabilitation, Women's Health Education intervention) | **RSUTAU:** observations involving reduction in substance use from treatment as usual control groups (e.g., inpatient/outpatient substance abuse rehabilitation) |
| | **RSUHEI:** observations involving reduction in substance use from health-education intervention control groups (e.g., Women's Health Education, neurobiology of addiction psychoeducation control) |
| IERERI: observations involving improvement in emotion regulations (e.g., inverse of Difficulties of Emotion Regulation Scale, Five Facet Mindfulness) from emotion-regulation interventions | NA |
| IERCI: observations involving improvement in emotion regulation from control interventions | **IERTAU:** observations involving improvement in emotion regulation from treatment as usual control groups |
| | **IERHEI:** observations involving improvement in emotion regulation from health-education intervention control groups |

*IERCI* Improvement in Emotion Regulation from Control Interventions, *IERERI* Improvement in Emotion Regulation from Emotion-Regulation Interventions, *IERHEI* Improvement in Emotion Regulation from Health-Education Interventions, *IERTAU* Improvement in Emotion Regulation from Treatment as Usual interventions, *RSUCI* Reduction in Substance Use from Control Interventions, *RSUERI* Reduction in Substance Use from Emotion-Regulation Interventions, *RSUHEI* Reduction in Substance Use from Health-Education Interventions, *RSUTAU* Reduction in Substance Use from Treatment as Usual interventions

Since a given intervention in a study can have multiple reported effect sizes for substance use or emotion regulation, effect sizes across study and intervention are aggregated to ensure interpretability of resulting forest plots, yielding 13 pooled effect sizes for RSUERI study/intervention combinations, 8 pooled effect sizes for RSUCI study/intervention combinations, 14 pooled effect sizes for IERERI, and 10 pooled effect sizes for IERCI [50]. Such aggregation resulted in non-significant differences between pooled effect sizes when aggregating the effect sizes versus not aggregating the effect sizes (RSUERI: $p = 0.99$; RSUCI: $p = 0.99$; IERERI: $p = 0.93$; IERCI: $p = 0.97$) (Online Resource 4).

For our exploratory meta-regressions, we employed independent variables of age due to developmental effects and previously validated findings on the impact of age on ER and SUDs [9, 11••], sex based on unique comorbidities with PTSD [12•, 13•], substance type to investigate potentially unique substance-related effects to ER and substance use [14], intervention length and frequency as previous literature has demonstrated the significant impact of these variables on a broad range of psychiatric outcomes [51••, 52••, 53•, 54], ER intervention type if there was little imbalance in observations from that interventions versus not (e.g., CBT-related effect sizes constituted half the observations), and study design and quality to account for methodological contributions.

Our technical methods involved the inverse variance method with a restricted maximum-likelihood estimator (ReML) and Hartung-Knapp adjustment, and we did not apply robust variance estimation as previous simulation studies have demonstrated that three-level and four-level meta-analyses can address potentially dependent effect sizes measured within the same study [50, 55, 56•, 57, 58]. Our analysis also involved linear and quadratic regressions to assess the influence of time after post-intervention on effect sizes, and included quadratic regression as previous literature has demonstrated that substance use measures follow an inverted U-curve quadratic equation from the start to the end of treatment [59, 60]. The better performing regression (linear or quadratic) was subsequently employed as an interaction variable in the subgroup and meta-regression analyses. We used the R packages *meta*, *metafor*, and *dmetar* throughout our meta-analyses.

## Results

### Summary Information of Relevant Studies

We identified 26 relevant records for our review [61–69, 70••, 71–73, 74••, 75–78, 79••, 80, 81••, 82, 83, 84••, 85, 86••]. Of them, five studies conducted CBT intervention [61, 69, 72, 83, 84••]; eight involved DBT intervention [62, 64, 65, 77, 78, 81••, 82, 86••]; five involved mindfulness-based interventions [70••, 73, 75, 80, 85]; two examined the effects of moment-based interventions [63, 68]; two involved cognitive reappraisal intervention [71, 74••]; and one each involving interpersonal therapy [66], concurrent treatment

**Table 3** The hypothesis-driven and exploratory meta-analysis questions pursued in this review. The aim is to assess the effectiveness of emotion-regulation interventions and control interventions on substance use and emotion regulation measures, compare these groups, and investigate demographic, substance-specific, and study design effects on these effect sizes

| Meta-analysis Question | Analytic Approach and Algorithms Employed | Dependent Variable | Independent Variables | Hypothesis Driven or Exploratory? |
|---|---|---|---|---|
| Do emotion-regulation interventions reduce substance use? | Three-level meta-analysis | RSUERI effect size | NA | Hypothesis |
| Do control interventions reduce substance use? | Three-level meta-analysis | RSUCI effect size | NA | Hypothesis |
| Do emotion-regulation interventions improve emotion regulation? | Three-level meta-analysis | IERERI effect size | NA | Hypothesis |
| Do control interventions improve emotion regulation? | Three-level meta-analysis | IERCI effect size | NA | Hypothesis |
| Is there a difference in emotion-regulation versus control interventions in reducing substance use? | Four-level meta-regression | RSUERI and RSUCI effect sizes | Observation from control intervention? | Hypothesis |
| Is there a difference in treatment as usual versus health-education interventions (control interventions) in reducing substance use measures? | Four-level meta-regression | RSUTAU and RSUHEI effect sizes | Observation from health-education intervention? | Hypothesis |
| Is there a difference in emotion-regulation versus treatment as usual interventions in reducing substance use measures? | Four-level meta-regression | RSUERI and RSUTAU effect sizes | Observation from treatment as usual intervention? | Hypothesis |
| Is there a difference in emotion regulation versus control interventions in improvement in emotion regulation? | Four-level meta-regression | IERERI and IERCI effect sizes | Observation from control intervention? | Hypothesis |
| Is there a difference in treatment as usual versus health education interventions (control interventions) in improvement in emotion regulation? | Four-level meta-regression | IERTAU and IERHEI effect sizes | Observation from health-education intervention? | Hypothesis |
| Is there a difference in emotion-regulation versus treatment as usual interventions in improvement in emotion regulation? | Four-level meta-regression | IERERI and IERTAU effect sizes | Observation from treatment as usual intervention? | Hypothesis |
| Does hours/week of intervention influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Hours/week of intervention | Exploratory |
| Does total duration of intervention influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Total duration of intervention | Exploratory |
| Does proportion of alcohol-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of alcohol-dependent participants in study | Exploratory |
| Does proportion of nicotine-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of nicotine-dependent participants in study | Exploratory |
| Does proportion of cannabis-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of cannabis-dependent participants in study | Exploratory |
| Does proportion of opioid-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of opioid-dependent participants in study | Exploratory |
| Does proportion of stimulant-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of stimulant-dependent participants in study | Exploratory |

**Table 3** (continued)

| Meta-analysis Question | Analytic Approach and Algorithms Employed | Dependent Variable | Independent Variables | Hypothesis Driven or Exploratory? |
|---|---|---|---|---|
| Does proportion of depressant-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of depressant-dependent participants in study | Exploratory |
| Does proportion of other-substance-dependent participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of substance-dependent participants in study | Exploratory |
| Does mean age of participants in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Mean age of participants in study | Exploratory |
| Does proportion of males in a study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of males in a study | Exploratory |
| Does CBT intervention influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Was intervention CBT? | Exploratory |
| Does DBT intervention influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Was intervention DBT? | Exploratory |
| Does the study being an RCT study versus a control study influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Was intervention RCT? | Exploratory |
| Does the proportion of NHLBI quality checklist items met influence the reduction in substance use? | Four-level meta-regression | RSUERI effect sizes | Proportion of NHLBI quality checklist items met | Exploratory |
| Does hours/week of intervention influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Hours/week of intervention | Exploratory |
| Does total duration of intervention influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Total duration of intervention | Exploratory |
| Does proportion of alcohol-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of alcohol-dependent participants in study | Exploratory |
| Does proportion of cannabis-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of cannabis-dependent participants in study | Exploratory |
| Does proportion of opioid-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of opioid-dependent participants in study | Exploratory |
| Does proportion of stimulant-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of stimulant-dependent participants in study | Exploratory |
| Does proportion of depressant-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of depressant-dependent participants in study | Exploratory |

**Table 3** (continued)

| Meta-analysis Question | Analytic Approach and Algorithms Employed | Dependent Variable | Independent Variables | Hypothesis Driven or Exploratory? |
|---|---|---|---|---|
| Does proportion of other-substance-dependent participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of substance-dependent participants in study | Exploratory |
| Does mean age of participants in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Mean age of participants in study | Exploratory |
| Does proportion of males in a study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of males in a study | Exploratory |
| Does DBT intervention influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Was intervention DBT? | Exploratory |
| Do mindfulness based-based interventions influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Was intervention mindfulness-based? | Exploratory |
| Does the study being an RCT study versus a control study influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Was intervention RCT? | Exploratory |
| Does the proportion of NHLBI quality checklist items met influence the improvement in emotion regulation? | Four-level meta-regression | IERERI effect sizes | Proportion of NHLBI quality checklist items met | Exploratory |

*CBT* cognitive behavioral therapy, *DBT* dialectical behavior therapy, *IERCI* improvement in emotion regulation from control interventions, *IERERI* improvement in emotion regulation from emotion-regulation interventions, *IERHEI* improvement in emotion regulation from health-education interventions, *IERTAU* improvement in emotion regulation from treatment as usual interventions, *NHLBI* National Heart, Lung, and Blood Institute, *RCT* randomized controlled trial, *RSUCI* reduction in substance use from control interventions, *RSUERI* reduction in substance use from emotion-regulation interventions, *RSUHEI* reduction in substance use from health education interventions, *RSUTAU* reduction in substance use from treatment as usual interventions

with prolonged exposure [67], integrated intervention program for alcoholism [76], and affect management therapy [79••]. While music therapy is an ER intervention that has been demonstrated to improve patients with depression and PTSD [33•, 34•, 35], we found no studies involving SUD or substance-dependent patients. Alcohol, nicotine, cannabis, opioid, stimulant, depressant, other, and unspecified substance dependence comprised 73.1% (19/26) [62–64, 66, 69, 70••, 72, 73, 74••, 75–78, 80, 81••, 82, 84••, 85, 86••], 19.2% (5/26) [61, 65, 68, 71, 83], 30.8% (8/26) [62, 63, 73, 75, 77, 79, 80, 86••], 38.5% (10/26) [62, 63, 65, 73, 75, 77, 80, 81••, 85, 86••], 38.5% (10/26) [62, 63, 73, 75, 77, 80, 81••, 82, 85, 86••], 26.9% (7/26) [62, 63, 73, 75, 80, 82, 85], 11.5% (3/26) [63, 75, 86], and 3.8% (1/26) [67] of the included studies, respectively. Further details regarding each study can be found in Table 4.

According to the NHLBI Quality Assessment of Controlled Intervention Studies, 14 randomized controlled trials studies showed a mean proportion of checklist met of 0.76 (SD = 0.18), and 12 pre-post studies demonstrated a mean proportion of checklist met of 0.55 (SD = 0.08) through the NHLBI Quality Assessment for Before-After Studies with No Control Group (Online Resources 5 and 6).

## Cognitive Behavioral Therapy (CBT)

Three CBT studies involved alcohol-dependent participants and two studies involved nicotine-dependent participants, where four studies demonstrated reductions in substance use [61, 69, 72, 83], and one study demonstrated improvements in ER [69].

One study reported reduced daily ethanol consumption and increased abstinence days. While cue-induced craving decreased generally, relapsers demonstrated higher cue-induced craving than abstainers from pre- to post-treatment (3 weeks) [72]. However, this effect was not observed with skin conductance response [72], a reliable measure of emotion reactivity [87–89]. Another study that employed CBT in alcohol users showed that the affective startle response (measured by startle eyeblink electromyography in the right orbicularis oculi region and used as a measure of emotional processing of salient stimuli [90–95]) demonstrated a significantly higher startle response to aversive stimuli in the abstinent compared to the relapse group and that unlike relapsers who showed no change, there was a significant decrease in the startle response to aversive cues throughout treatment in abstainers [69]. Lastly, a study comparing CBT with sleep hygiene did not report differences in daily ethanol consumption [84••].

The first study involving nicotine-dependent participants employed a cognitive-behavioral smoking cessation program and a panic-smoking program. The results showed that compared to individuals with lower baseline score on Difficulties in Emotion Regulation Scale (DERS), those with higher DERS scores exhibited greater early withdrawal symptoms (measured via the Minnesota Nicotine Withdrawal Scale), a steeper quadratic-curve slope in withdrawal symptoms, and higher withdrawal symptoms at eight weeks post-treatment [61]. The second study in nicotine-dependent participants compared the effects of CBT combined with either Emotion Regulation Treatment (ERT) or Health and Lifestyle Intervention (HLS). At two months post-intervention, there were less cigarettes per day (CPD) and higher scores on the Smoking Self-efficacy Questionnaire (SSEQ) in the CBT and ERT group, but these findings did not persist at four months. There was no significant difference in relapse rates between those that received CBT and ERT versus those who received CBT and HLS. Moreover, there were no differences in CPD, Fagerstrom Test for Nicotine Dependence (FTND), SSEQ, 7-day Point Prevalence Abstinence, and relapse rates between treatment completers and non-completers [83].

## Dialectical Behavior Therapy (DBT)

Across eight DBT intervention studies, seven studies showed reductions in substance use [62, 64, 65, 77, 78, 81, 82], and six studies showed improvements in ER [62, 64, 65, 77, 82, 86••].

In studies involving DBT for alcohol-dependent participants, one study found a significant increase in consecutive days of abstinence and improvement in the Shorter Promis Questionnaire (SPQ) alcohol subscale [64]. While there were improvements in DBT skills use and reduction in DERS, there was no significant reduction in the dysfunction coping subscale for the DBT Ways of Coping Checklist [64]. Another study in alcohol-dependent participants found significant improvements in the Addiction Severity Index (ASI) alcohol subscale scores in DBT treatment completers versus treatment non-completers, and a significant increase in DERS for treatment non-completers [78].

In participants with nicotine and opioid dependence, there was a significant reduction in CPD smoked, carbon monoxide levels, and nicotine withdrawal measured by the FTND [65]. However, there were no significant improvements in the Kentucky Inventory of Mindfulness Scale (KIMS), Distress Tolerance Scale (DTS), and DERS [65].

In participants with alcohol, opioids, and/or stimulant use, a lower proportion of participants reported weekly substance use and demonstrated significant improvement in DERS in the DBT arm compared to those in TAU [77]. Another study with a similar population showed a significant DBT-related reduction in Brief Addiction Monitor-Revised (BAM-R) risk factors, an increase in BAM-R protective factors, and a reduction in DERS [81••]. In the third study with the similar sample characteristic, DBT was found to significantly reduce the ASI substance subscale score, Negative

**Table 4** Summary information of study conditions, emotion-regulation intervention, participant demographics, substance use outcome statistics, and emotion regulation outcome statistics across 26 included studies

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Rogers (2019) | Cognitive-Behavioral Smoking Cessation Program and Panic-Smoking Program | 188 | % Alcohol Dependence: 0<br>% Nicotine Dependence: 100<br>% Cannabis Dependence: 0%<br>Opioids Dependence: 0%<br>Stimulants Dependence: 0%<br>Depressants Dependence: 0%<br>Other Substance Dependence: 0 | 1.5, 4 | -3, -2, 0, 8 | No association between baseline Difficulties in Emotion Regulation Scale (DERS) and withdrawal symptoms (B = 0.01, SE = 0.02, $p < 0.04$).<br>Significant quadratic interaction with DERS and time (B = -0.001, SE = 0.0005, $p = 0.03$). | NA |
| Flynn (2019) | Dialectical Behavior Therapy (DBT) | 64 | % Alcohol Dependence: 73<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 25<br>% Opioids Dependence: 17<br>% Stimulants Dependence: 12.5<br>% Depressants Dependence: 12.5<br>% Other Substance Dependence: 0 | 1, 24 | 0, 24 | Substance use ↓ ($p = 0.002$). | Baseline to midpoint and baseline to final follow-up: dysfunctional coping, DBT skills use, emotion dysregulation, and the Five Facet Mindfulness Questionnaire (FFMQ) ↓ ($p < 0.001$) |
| Black (2019) | Moment-to-Moment in Women's Recovery (MMWR) Neurobiology of Addiction Psychoeducation (NAP) | 100 | % Alcohol Dependence: 50<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 52.5<br>% Opioids Dependence: 6.5<br>% Stimulants Dependence: 76<br>% Depressants Dependence: 8.5<br>% Other Substance Dependence: 1.5 | 2.67, 6 | 0 | Both groups<br>Penn Alcohol Craving Scale (PACS) ↓ ($p < 0.01$) | Both groups<br>FFMQ ↓ ($p < 0.01$)<br>Distress Tolerance Scale (DTS) ↓ ($p < 0.05$)<br>DERS ↓ ($p < 0.01$) |
| Cavicchioli (2019) | Dialectical Behavior Therapy Skills Therapy (DBT-ST) | 108 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 9, 12 | 0 | Continuous days of abstinence (CDA) ↑ ($t_{107} = 21.90$, $p < 0.001$)<br>Shorter Promis Questionnaire (SPQ) alcohol subscale ↓ ($t_{107} = 5.94$, $p < 0.001$) | DERS ↓ ($t_{107} = 8.63$, $p < 0.001$)<br>DBT Ways of Coping Checklist (WCCL) DBT Skills Use (DBT-SU) ↑ ($t_{107} = 4.48$, $p < 0.001$)<br>No improvement in DBT-WCCL dysfunctional coping subscale (DCS) |
| Cooperman (2018) | Dialectical Behavior Therapy Skills Therapy (DBT-ST) | 7 | % Alcohol Dependence: 0<br>% Nicotine Dependence: 100<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 100<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 1.5, 12 | -6, 0 | Cigarettes per day (CPD) ↓ ($p < 0.05$)<br>Carbon monoxide (CO) levels ↓ ($p < 0.05$)<br>Fagerstrom Test for Nicotine Dependence (FTND) ↓ ($p < 0.05$) | No change in DERS, distress tolerance, and Kentucky Inventory of Mindfulness Scale (KIMS) |
| Holzhauer (2017) | Interpersonal Therapy | 48 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 0.75, 16 | 0, 8 | Proportion days abstinent (PDA) ↑ (t = -5.94, $p = 0.000$)<br>No group differences for PDA ($p > 0.05$) | No significant change in DERS<br>No significant group differences between treatment groups ($p > 0.05$). |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Hien (2017) | Concurrent Treatment with Prolonged Exposure (COPE)<br>Relapse Prevention Therapy (RPT)<br>Active Monitoring Control Group (AMCG) | COPE: 39<br>RPT: 43<br>AMCG: 28 | NA | 1.5, 12 | -11, -10, -9, -8, -7, -6, -5, -4, -3, -2, -1, 0 | In low DERS participants:<br>RPT < COPE in substance use days ($\mu = -1.15$, $t_{957} = 2.26$, $p = 0.02$)<br>RPT < AMCG in substance use days ($\mu = -2.35$, $t_{957} = 4.02$, $p < 0.001$)<br>No difference between COPE and AMCG on substance use days<br>In high DERS participants<br>COPE < AMCG in substance use days ($\mu = -1.46$, $t_{957} = 2.30$, $p = 0.02$)<br>RPT < AMCG ($\mu = -1.29$, $t_{957} = 1.99$, $p = 0.047$)<br>No difference between COPE and RPT on substance use days | NA |
| Paz (2017) | Present Moment Attention and Awareness (PMAA) | 104 | % Alcohol Dependence: 0<br>% Nicotine Dependence: 100<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 0.117 - 1.089, 0.117 - 1.089 | 0 | No difference in withdrawal symptoms between PMAA and control group ($t_{90} = 0.52$, $p = 0.60$) | PMAA > control for improvement in state mindfulness ($F_{1, 79} = 95.695$, $p = 0.000$)<br>No significant improvement in physiological regulation during RSA in PMAA versus control ($p = 0.05$) |
| Jurado-Barba (2015) | Cognitive Behavioral Therapy (CBT) | 98 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 1.5, 12 | 0 | Abstainers: Startle response to alcohol pictures ↑ ($p = 0.012$)<br>Relapsers: Startle response to alcohol pictures ↑ ($p = 0.000$) | Abstainers: Startle response from aversive-related cues ↓ ($p = 0.014$) |
| Davis (2023) | Mind Guide mindfulness-training app | 16 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | NA, 2 | 0 | Frequency of alcohol use ↓ (d = -0.54)<br>Alcohol problems ↓ (d = -0.44)<br>Craving ↓ (d = -0.53) | Re-experiencing ↓ (d = -0.74)<br>Avoidance ↓ (d = -0.91)<br>Negative alterations in mood ↓ (d = -1.04)<br>Hyperarousal ↓ (d = -1.09)<br>Expressive suppression ↓ (d = -1.22)<br>No improvement in reappraisal |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Beadman (2015) | Acceptance and Commitment Therapy and Cognitive Behavioral Therapy | 75 | % Alcohol Dependence: 0<br>% Nicotine Dependence: 100<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | NA, 1 | -0.857, 0 | Defusion group: Timeline followback (TLFB)-smoking ↓ ($t_{24} = 4.169$, $p < 0.001$, d = 0.834)<br>Reappraisal group: TLFB-smoking ↓ ($t_{24} = 4.616$, $p < 0.001$, d = 1.246)<br>No change in TLFB-smoking in the suppression group ($t_{22} = 1.644$, $p = 0.105$, d = 0.329)<br>Suppression < Defusion = Reappraisal in time after the experimental session individual began smoking ($U_{47} = 18.849$, p = 0.006)<br>Significant main effect of intervention strategy on cue-induced craving, with reappraisal and suppression driving the reduction ($F_{2, 70} = 3.406$, $p = 0.039$)<br>Significant time x strategy interaction on smoking specific experiential avoidance ($F_{2, 70} = 3.561$, $p = 0.034$)<br>Defusion group: smoking-specific experiential avoidance ↓ ($t_{24} = 2.24$, $p = 0.03$, d = 0.51)<br>No significant change in smoking-specific experiential avoidance in reappraisal ($t_{24} = 1.69$, $p = 0.51$)<br>No significant change in smoking-specific experiential avoidance in suppression ($t_{22} = 0.88$, $p = 0.39$, d = 0.41) | No time x strategy effect on negative affect ($F_{2, 70} = 1.143$, $p = 0.325$) |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Loeber (2007) | Cognitive Behavioral Therapy | 43 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 7.5, 3 | 0, 12, 24 | Daily amount of ethanol consumed ↓ ($F_{1, 55}$ = 72.01, $p < 0.001$)<br>Number of abstinent days ↑ ($F_{2, 82}$ = 134.69, $p < 0.001$)<br>Significant category-relapse interaction ($F_{1, 41}$ = 5.68, $p < 0.05$) with relapsers indicating cue-induced craving at both pre- and post-intervention | Skin conduction response ↓ ($F_{1, 43}$ = 21.51, $p < 0.01$)<br>No significant interaction effect between intervention category ($F_{1, 43}$ = 3.93, $p$ = 0.054) and relapse status ($F_{1, 43}$ = 3.97, $p$ = 0.053) |
| Price (2019) | Mindful Awareness in Body-oriented Therapy (MABT)<br>Women's Health Education (WHE) Treatment As Usual (TAU) | MABT: 74<br>WHE: 46<br>TAU: 67 | % Alcohol Dependence: 39<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 8<br>% Opioids Dependence: 6<br>% Stimulants Dependence: 45<br>% Depressants Dependence: 24<br>% Other Substance Dependence: 0 | MABT: 1.5, 8 – 10<br>WHE: 1.5, 8 – 10<br>TAU: 1.5, 10 - 14 | 2, 14, 38 | Abstinence days<br>6-month follow-up: MABT = WHE > TAU<br>12-month follow-up: MABT > WHE = TAU<br>MABT improvements were maintained for 3 to 12 months.<br>WHE and TAU improvements declined at 12 months<br>Relapse<br>No difference between MABT and TAU<br>Craving<br>Significant reduction in MABT and TAU at three, six, and 12 months ($p$ = 0.03)<br>No differences between MABT and WHE under intent-to-treat (ITT) analysis | Reduction in DERS<br>Baseline to three months: MABT > TAU<br>Baseline to three months: MABT > WHE<br>Increase in RSA<br>Baseline to three months: MABT > TAU<br>Baseline to three months: MABT > WHE<br>Baseline to six months: MABT > TAU<br>Baseline to 12 months: MABT > TAU<br>Baseline to 12 months: MABT > WHE<br>Improvement in mindfulness<br>Baseline to three months: MABT > TAU ($p$ = 0.006)<br>Baseline to three months: MABT > WHE ($p$ = 0.006)<br>Improvement in interoceptive skills<br>Baseline to three months: MABT > TAU ($p < 0.001$)<br>Baseline to three months: MABT > WHE ($p < 0.001$)<br>Baseline to six months: MABT > TAU ($p < 0.001$)<br>Baseline to six months: MABT > WHE ($p < 0.001$)<br>No differences between MABT vs. TAU and MABT vs. WHE |
| Holzhauer (2021) | Cognitive Reappraisal (CR)<br>Pyschoeducation Control (PC) | CR: 25<br>PC: 25 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 0.005, 0.005 | 0 | No main effect of study condition on reported alcohol craving after CR (F = 1.01, $p$ = 0.321).<br>CR group with less severe Alcohol Use Disorders Identification Test (AUDIT) saw decreased craving while the same group with more severe AUDIT reported no change in craving (F = 4.14, p = 0.011). | No demonstrated main effect of study condition on Stop-Signal Reaction Time (SSRT) after CR (F = 1.22, $p$ = 0.274). |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Garland (2016) | Mindfulness-Oriented Recovery Enhancement (MORE)<br>Cognitive Behavioral Therapy<br>Treatment As Usual | MORE: 64<br>CBT: 64<br>TAU: 52 | % Alcohol Dependence: 45<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 26.11<br>% Opioids Dependence: 27.22<br>% Stimulants Dependence: 47.22<br>% Depressants Dependence: 2.78<br>% Other Substance Dependence: 2.22 | MORE: 2, 10<br>CBT: 2, 10<br>TAU: 2, 10 | 0 | All three groups: craving ↓ ($p = 0.01$)<br>MORE > CBT for decrease in craving ($p = 0.03$)<br>No difference between MORE and TAU on changes in craving ($p = 0.18$) | There was a significant increase in dispositional mindfulness in the MORE group compared to both the CBT ($p < 0.001$) and the TAU ($p = 0.004$) groups. There was a significant decrease in negative affect in the MORE group compared to the CBT group ($p = 0.04$).<br>MORE > CBT for increase in dispositional mindfulness ($p < 0.001$)<br>MORE > TAU for increase in dispositional mindfulness ($p = 0.004$)<br>MORE < CBT for decrease in negative affect ($p = 0.04$) |
| Kumar (2019) | Integrated Intervention Program for Alcoholism (IIPA)<br>Treatment As Usual | 25 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 0.39, 2.57 | 0 | Intervention group < control group for relapse rate ($p < 0.01$)<br>Intervention group > control group for period of abstinence ($p < 0.01$) | Intervention group > control group for improvement in affect regulation, task-based impulsivity measure, and Game of Dice Task (GDT) scores ($p < 0.001$) |
| Axelrod (2010) | Dialectical Behavior Therapy | 24 | % Alcohol Dependence: 88<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 6<br>% Opioids Dependence: 25<br>% Stimulants Dependence: 44<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 2.5, 20 | 0 | Proportion of participants reporting weekly substance use ↓ ($\chi^2 = 8.944$, $p = 0.003$) | DERS ↓ ($F_{2, 32} = 16.44$, $p < 0.001$) |
| Maffei (2018) | Dialectical Behavior Therapy | 244 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0% Other Substance Dependence: 0 | 9, 12 | 0 | Treatment non-completers > treatment completers in early relapse rates ($p < 0.001$)<br>Treatment completers: carbohydrate-deficient transferase (CDT) ↓ ($t_{155} = -6.75$, $p < 0.001$), CDA ↑ ($t_{155} = 36.90$, $p < 0.001$) | Treatment non-completers: DERS ↑ ($t_{211} = 2.14$, $p < 0.05$) |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Wolitzky-Taylor (2022) | Affect Management Therapy (AMT)<br>Cognitive Behavioral Therapy | AMT: 25<br>CBT: 24 | % Alcohol Dependence: 0%<br>Nicotine Dependence: 0%<br>Cannabis Dependence: 100%<br>Opioids Dependence: 0%<br>Stimulants Dependence: 0%<br>Depressants Dependence: 0%<br>Other Substance Dependence: 0 | 0.83, 12 | 12 | Cannabis use days<br>AMT ↓ ($t_{74}$ = -4.54, $p$ < 0.001)<br>CBT ↓ ($t_{74}$ = -5.35, $p$ < 0.001)<br>AMT = CBT in decrease ($t_{56}$ = 0.26, p = 0.79)<br>Total number of times cannabis used<br>AMT ↓ ($t_{56}$ = -3.52, $p$ < 0.001)<br>No change in CBT ($t_{50}$ = -1.52, $p$ > 0.13)<br>AMT = CBT in decrease ($t_{56}$ = -1.50, $p$ = 0.14)<br>Average number of times used on cannabis use days<br>AMT ↓ ($t_{56}$ = -2.96, $p$ < 0.01)<br>No change in CBT ($t_{56}$ = -1.93, $p$ = 0.059)<br>AMT = CBT in decrease ($t_{56}$ = -0.81, $p$ > 0.42)<br>Cannabis Abuse Screening Test (CAST)<br>AMT ↓ ($t_{74}$ = -4.54, $p$ < 0.001)<br>CBT ↓ ($t_{74}$ = -5.35, $p$ < 0.001)<br>AMT = CBT in decrease ($t_{74}$ = 0.39, $p$ = 0.70) | Positive and Negative Affect Schedule Negative Affect subscale (PANAS-N)<br>AMT ↓ ($t_{415}$ = -8.70, $p$ < 0.001)<br>CBT ↓ ($t_{415}$ = -4.60, $p$ < 0.001)<br>AMT > CBT in decrease ($t_{415}$ = -2.71, $p$ < 0.01)<br>Peak fear during hyperventilation<br>AMT ↓ ($t_{84}$ = -2.98, $p$ < 0.001)<br>No change in CBT ($t_{84}$ = -0.23, $p$ > 0.81)<br>AMT = CBT in decrease ($t_{84}$ = -1.91, $p$ = 0.06)<br>Distress tolerance<br>AMT ↓ ($t_{415}$ = 3.36, $p$ < 0.001)<br>CBT ↓ ($t_{415}$ = 3.23, p = 0.001)<br>AMT = CBT in decrease ($t_{415}$ = -0.19, $p$ = 0.85)<br>Distress rating during Mirror Tracing Task<br>AMT ↓ ($t_{45}$ = -3.59, $p$ < 0.001)<br>No change in CBT ($t_{45}$ = 0.77, $p$ > 0.44)<br>AMT > CBT in decrease ($t_{45}$ = -3.12, $p$ < 0.01)<br>DERS<br>AMT ↓ ($t_{74}$ = -6.36, $p$ < 0.001)<br>CBT ↓ ($t_{74}$ = -3.73, $p$ < 0.001)<br>AMT > CBT in decrease ($t_{74}$ = -2.06, $p$ < 0.05)<br>Emotion Regulation Questionnaire Reappraisal subscale (ERQ-R)<br>AMT ↑ ($t_{415}$ = 6.71, $p$ < 0.001)<br>CBT ↑ ($t_{415}$ = 3.79, $p$ < 0.001)<br>AMT > CBT in improvement ($t_{415}$ = 2.21, $p$ < 0.05)<br>ERQ Suppression<br>AMT ↑ ($t_{415}$ = 3.86, $p$ < 0.001)<br>CBT ↑ ($t_{415}$ = 2.00, $p$ < 0.05)<br>AMT = CBT (p = 0.33)<br>Brief Experiential Avoidance Questionnaire<br>AMT ↓ ($t_{74}$ = -4.60, $p$ < 0.001)<br>CBT ↓ ($t_{74}$ = -3.05, $p$ < 0.01)<br>AMT = CBT ($t_{74}$ = -1.25, $p$ > 0.21)<br>Negative Urgency<br>AMT ↓ ($t_{74}$ = -5.99, $p$ < 0.001)<br>CBT ↓ ($t_{74}$ = -2.19, $p$ < 0.05)<br>AMT > CBT in decrease ($t_{74}$ = -2.85, $p$ < 0.01) |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Price (2017) | Mindful Awareness in Body-oriented Therapy<br>Women's Health Education Treatment As Usual | MABT: 74<br>WHE: 46<br>TAU: 67 | % Alcohol Dependence: 39<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 8<br>% Opioids Dependence: 6<br>% Stimulants Dependence: 45<br>% Depressants Dependence: 24<br>% Other Substance Dependence: 0 | MABT: 1.5, 8 – 10<br>WHE: 1.5, 8<br>TAU: 0, 0 | MABT: 2<br>WHE: 4<br>TAU: 12 | Improvement in proportion of days abstinent<br>MABT = WHE > TAU (ITT analysis: $\chi^2 = 8.71$, $p = 0.01$)<br>MABT = WHE > TAU (ID analysis: $\chi^2 = 14.20$, $p = 0.0008$)<br>No significant differences between groups (ID analysis: $\chi^2 = 5.88$, $p = 0.053$) | Improvement in mindfulness<br>MABT > WHE = TAU (ID analysis: $\chi^2 = 12.90$, $p = 0.002$)<br>No significant difference in ITT analysis<br>Improvement in interoceptive awareness<br>MABT > WHE = TAU for ITT analysis (Not Worrying from Multidimensional Assessment of Interoceptive Awareness (MAIA): $\chi^2 = 6.55$, $p < 0.04$)<br>MABT > WHE = TAU for ID analysis (Noticing: $\chi^2 = 13.51$; $p = 0.002$, Attention Regulation: $\chi^2 = 16.67$, $p < 0.001$; Emotional Awareness: $\chi^2 = 12.46$, p = 0.002; Self-regulation: $\chi^2 = 14.75$, $p < 0.001$; Body Listening: $\chi^2 = 17.99$, $p < 0.001$; Trust: $\chi^2 = 13.18$, $p = 0.001$)<br>Improvement in DERS<br>MABT > WHE = TAU for ITT analysis ($\chi^2 = 6.38$, $p = 0.04$)<br>Improvement in RSA<br>MABT > TAU = WHE for ITT analysis (Film-reactivity task: $\chi^2 = 13.81$, $p < 0.001$; Body awareness reactivity task: $\chi^2 = 13.51$, $p < 0.001$)<br>MABT > TAU for ID analysis ($\chi^2 = 6.42$, p = 0.04) |
| Byllesby (2023) | Dialectical Behavior Therapy | 138 | % Alcohol Dependence: 54<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 26<br>% Stimulants Dependence: 21<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 2.5, 24 | 48 | Brief Addiction Monitor Revised (BAM-R) risk factors ↓ ($t_{137} = 14.794$, $p < 0.01$)<br>BAM-R protective factors ↑ ($t_{137} = -9.89$, $p < 0.01$) | DERS ↓ ($t_{137} = 5.82$, $p < 0.01$) |
| Courbasson (2011) | Dialectical Behavior Therapy<br>Treatment As Usual | DBT: 15<br>TAU: 15 | % Alcohol Dependence: 58<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 66.4<br>% Depressants Dependence: 50<br>% Other Substance Dependence: 0 | 2, 52 | 0, 12, 24 | ASI-substance composite scores<br>Post-treatment ↓ ($p < 0.02$)<br>3-month follow-up ↓ ($p < 0.02$)<br>6-month follow-up ↓ ($p < 0.03$)<br>DBT > TAU in decrease ($F_{3, 19} = 2.06$, $p < 0.01$) | Negative Mood Regulation Scale (NMRS)<br>Post-treatment ↓ (total score: $p < 0.05$, general score: $p < 0.05$)<br>3-month follow-up ↓ (total score: $p < 0.05$, general score: $p < 0.02$)<br>6-month follow-up ↓ (total score: $p < 0.05$, general score: $p < 0.01$) |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Bradizza (2017) | Emotion Regulation Treatment+Cognitive Behavioral Therapy (ERT+CBT)<br>Health and Lifestyle Intervention+Cognitive Behavioral Therapy (HLI+CBT) | ERT+CBT: 36<br>HLI+CBT: 34 | % Alcohol Dependence: 0<br>% Nicotine Dependence: 100<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | 1, 8 | 0 | No significant differences between treatment completers and treatment non-completers on 7-day Point Prevalence Smoking Abstinence (PPSA), CPD, nicotine dependence, and self-efficacy to quit smoking.<br>No significant differences in abstinence rates between Emotion Regulation Therapy and CBT (ERT+CBT) versus Health and Lifestyle Intervention and CBT (HLI+CBT).<br>Cigarettes per day<br>ERT+CBT at 2 months and 4 months ↑<br>HLI+CBT at 2 months and 4 months ↑<br>ERT+CBT > HLI+CBT for improvement at 2 months ($t_{41} = 2.02$, $p = 0.05$)<br>No differences between ERT+CBT and HLI+CBT at 4 months ($t_{34} = 1.86$, $p = 0.07$)<br>Smoking Self-efficacy Questionnaire (SSEQ) negative affect subscale<br>ERT+CBT > HLI+CBT for improvement at 2 months ($t_{36} = 3.29$, $p = 0.002$)<br>No differences between ERT+CBT and HLI+CBT at 4 months ($t_{37} = 1.87$, $p = 0.07$) | NA |
| Miller (2021) | Cognitive Behavioral Therapy<br>Sleep Hygiene (SH) | 28 | % Alcohol Dependence: 100<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 0<br>% Stimulants Dependence: 0<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 0 | CBT: NA, 5<br>SH: NA, NA | 0, 4 | No significant difference in drinking quantity between CBT and SH participants ($p > 0.12$). | CBT: DERS ↓ from baseline to post intervention ($\mu = -12.87$, SE = 3.01, $p < 0.001$) |

**Table 4** (continued)

| Study | Intervention(s) | n | Substance Dependence Makeup | Intervention Hours/Week, Total Weeks Duration | Time Follow-up Visits were Conducted After End of Intervention (Week) | Substance Use Outcomes | Emotion Regulation Outcomes |
|---|---|---|---|---|---|---|---|
| Price (2011) | Mindful Awareness in Body-oriented Therapy<br>Treatment As Usual | MABT: 31<br>TAU: 15 | % Alcohol Dependence: 72<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 0<br>% Opioids Dependence: 15<br>% Stimulants Dependence: 4<br>% Depressants Dependence: 9<br>% Other Substance Dependence: 0 | MABT: 1.5, 8<br>TAU: 0, 0 | 4, 16, 28 | MABT > TAU on percent days of abstinence at 3 months ($p < 0.02$) | Improvement in avoidant coping<br>MABT > TAU at 3 months, 6 months, and 9 months ($p = 0.01$, $p = 0.01$, $p = 0.00$)<br>No significant differences between MABT and TAU for PANAS Positive Affect subscale (PANAS-P) at 3 months, 6 months, and 9 months ($p = 0.58$, $p = 0.36$, $p = 0.26$)<br>No significant differences between MABT and TAU for PANAS-N at 3 months, 6 months, and 9 months ($p = 0.58$, $p = 0.36$, $p = 0.26$)<br>MABT: DERS Control Difficulties ↓ at 6 months ($p = 0.02$)<br>MABT: DERS Limited Strategies ↓ at 6 months ($p = 0.03$) |
| Cavicchioli (2023) | Dialectical Behavior Therapy Skills Therapy<br>Untrested Substance Use Disorder Control (USUDC) | DBT-ST: 29<br>USUDC: 29 | % Alcohol Dependence: 75.9<br>% Nicotine Dependence: 0<br>% Cannabis Dependence: 13.8<br>% Opioids Dependence: 8.6<br>% Stimulants Dependence: 36.2<br>% Depressants Dependence: 0<br>% Other Substance Dependence: 8.6 | 9, 12 | 0 | No relationship between relapse and treatment noncompletion ($\chi^2 = 3.71$, $p > 0.05$) | DBT-ST: Distress tolerance ↑ ($t_{28} = 5.78$, $p < 0.001$)<br>DBT-ST: FFMQ ↑ ($t_{28} = 3.44$, $p < 0.01$)<br>DBT-ST: DERS ↓ ($t_{28} = -2.68$, $p < 0.05$)<br>DBT-ST: Negative urgency ↓ ($t_{28} = -6.10$, $p < 0.001$)<br>DBT-ST: Positive urgency ↓ ($t_{28} = -3.11$, $p < 0.01$)<br>DBT-ST < USUDC for negative urgency ($t_{56} = -3.16$, $p < 0.001$)<br>DBT-ST < USUDC for positive urgency ($t_{56} = -2.44$, $p < 0.05$) |

*AMCG* Active Monitoring Control Group, *AMT* Affect Management Therapy, *ASI* Alcohol Severity Index, *AUDIT* Alcohol Use Disorders Identification Test, *BAM-R* Brief Addiction Monitor Revised, *CAST* Cannabis Abuse Screening Test, *CBT* Cognitive Behavioral Therapy, *CDA* Continuous Days of Abstinence, *CDT* Carbohydrate-deficient transferase, *CO* Carbon Monoxide, *COPE* Concurrent Treatment with Prolonged Exposure, *CPD* Cigarettes per Day, *CR* Cognitive Reappraisal, *DBT* Dialectical Behavior Therapy, *DBT-ST* Dialectical Behavior Therapy Skills Therapy, *DBT-SU* Dialectical Behavior Therapy Skills Use, *DCS* Dysfunctional Coping Subscale, *DERS* Difficulties in Emotion Regulation Scale, *DTS* Distress Tolerance Scale, *ERQ-R* Emotion Regulation Questionnaire Reappraisal subscale, *ERT+CBT* Emotion Regulation Treatment and Cognitive Behavioral Therapy, *FFMQ* Five Facet Mindfulness Questionnaire, *FTND* Fagerstrom Test for Nicotine Dependence, *GDT* Game of Dice Task, *HLI+CBT* Health and Lifestyle Intervention and Cognitive Behavioral Therapy, *ID* Intervention Dose, *IIPA* Integrated Intervention Program for Alcoholism, *ITT* Intent-to-Treat, *KIMS* Kentucky Inventory of Mindfulness Scale, *MABT* Mindful Awareness in Body-oriented Therapy, *MMWR* Moment-to-Moment in Women's Recovery, *MORE* Mindfulness-Oriented Recovery Enhancement, *NAP* Neurobiology of Addiction Psychoeducation, *NMRS* Negative Mood Regulation Scale, *PACS* Penn Alcohol Craving Scale, *PANAS-N* Positive and Negative Affect Schedule Negative subscale, *PANAS-P* Positive and Negative Affect Schedule Positive subscale, PC, Psychoeducation Control, *PDA* Proportion of Days Abstinence, *PMAA* Present Moment Attention and Awareness, *PPSA* Point Prevalence Smoking Abstinence, *RPT* Relapse Prevention Therapy, *RSA* Respiratory Sinus Arrythmia, *SH* Sleep Hygiene, *SPQ* Shorter Promis Questionnaire, *SSEQ* Smoking Self-efficacy Questionnaire, *SSRT* Stop-Signal Reaction Time, *TAU* Treatment As Usual, *TLFB* Timeline Follow-back, *USUDC* Untested Substance Use Disorder Control, *WCCL* Ways of Coping Checklist, *WHE* Women's Health Education

Mood Regulation Scale (NMRS) total score, and NMRS general score, across multiple time points [82].

Similarly, in individuals with polysubstance use, one study showed a significant DBT-related decrease in the proportion of participants who used alcohol and other substances (e.g., cocaine, heroin, ecstasy) across two time points 12 months apart [62]. There were also reductions in DBT dysfunction coping subscale and DERS, and improvements in DBT skills use and the Five Facet Mindfulness Questionnaire (FFMQ) measure [62]. Another study in polysubstance users observed no significant relationship between relapse status and treatment completion. Throughout the DBT skills use intervention, there were significant reductions in DERS and UPPS-P negative and positive urgency subscales, and significant improvements in FFMQ and DTS [86••].

### Mindfulness-Based Interventions (MBI)

Several studies have used the Mindful Awareness in Body-oriented Therapy (MABT) intervention in individuals with substance misuse and use disorders, with four studies showing reductions in substance use and improvements in ER [70, 73, 80, 85]. For example, a study on participants with alcohol, cannabis, opioid, stimulant, and/or depressant-dependent participants compared the effects of MABT, Women's Health Education (WHE), and TAU. The study reported that while both MABT and WHE outperformed TAU in increased number of abstinence days and reduced Penn Alcohol Craving Score (PACS), MABT outperformed both WHE and TAU on decreased respiratory sinus arrhythmia (RSA), a proxy measure of emotion dysregulation [96–98], reduction in DERS, increase in Freiburg Mindfulness Inventory (FMI), and increase in Multidimensional Assessment of Interoceptive Awareness (MAIA) at 3 and 6-months follow-up post-intervention [73]. Improvement in abstinence with MABT and WHE, compared to TAU, was also reported by another study [80]. Similarly, this study also showed greater MABT-related reduction in DERS, film-reactivity RSA, body-awareness RSA, and 3-month post-intervention FMI compared to WHE and TAU in the ID analysis, and in tonic RSA and all MAIA subscales in the ITT analysis [80].

In a sample involving participants with alcohol, cannabis, opioids, stimulants, and/or other substance dependence, similar results were reported such that the MABT group reported a significantly higher percentage of days abstinent at three months, compared to those in TAU, which remained high at nine months [85]. For emotion regulation outcome measures, the study reported a significant improvement in DERS for MABT compared to TAU at 3 and 6-months, a significant reduction in DERS Control Difficulties and DERS Limited Strategies only at six months, and no significant improvement in PANAS scores [85]. One study that used Mindfulness-Oriented Recovery Enhancement found no significant difference in reduction in PACS, compared to TAU in a sample of participants with a diverse set of substance dependence [75].

A study used a mindfulness-training app over two weeks and reported improvements in the frequency of alcohol use, alcohol problems, PACS score, posttraumatic stress disorder (PTSD)-subscale re-experiencing, PTSD-subscale avoidance, PTSD-subscale negative alterations in mood, PTSD-subscale hyperarousal, and PTSD-subscale expressive suppression. However, there was no significant reduction in PTSD-subscale reappraisal [70••].

### Moment-Based Interventions

With two studies employing Moment-Based Interventions, one demonstrated improvement in substance use and ER [63].

Statistically significant improvements in PACS, FFMQ, DTS, and DERS were observed from before to after Moment-to-Moment in Women's Recovery intervention in women with alcohol, cannabis, opioids, stimulants, depressants, and/or other substances misuse or dependence [63]. However, another study found no difference in Minnesota Nicotine Withdrawal Scale score in individuals in the Present Moment Attention and Awareness intervention group compared to those in cope-as-usual group [68].

### Cognitive Reappraisal

Two studies employing cognitive reappraisal strategies saw reductions in substance use [71, 74••], but none saw or measured improvements in ER.

In a study that examined the effects of defusion, reappraisal, and suppression, different components of the Acceptance and Commitment Therapy, on nicotine-dependent participants, a significant reduction in nicotine use and increase in abstinence duration before participants smoked again [assessed via timeline followback (TLFB)] were observed in defusion and reappraisal, but not in suppression. The study also reported that the decrease in cue-induced craving measures was driven by reappraisal and suppression, and the decrease in SSEQ over time was driven by defusion but not reappraisal or suppression. However, none of these strategies showed reductions in negative affect over time [71]. In another study with a cognitive reappraisal intervention in alcohol-dependent participants, an inverse relationship between alcohol use severity [i.e., Alcohol Use Disorders Identification Test (AUDIT) score] and alcohol craving [assessed via the Alcohol Craving Questionnaire short-form revised (ACQ-SF)] was observed, where lower initial alcohol use severity indicated a larger reduction in craving throughout the intervention [74••].

## Other Interventions

For other ER interventions, four studies saw improvements in substance use [66, 67, 76, 79], and three studies saw improvements in ER [67, 76, 79••].

A study that conducted 4-month interpersonal therapy or TAU on alcohol-dependent participants observed higher rates of abstinence across both groups post-treatment compared to pre-treatment initiation [66].

A study that compared groups who underwent Concurrent Treatment with Prolonged Exposure (COPE; an emotion-regulation intervention) [99], Relapse Prevention Therapy (RPT; a cognitive behavioral intervention) [100], and Active Monitoring (AM; control group), showed that participants with higher DERS in COPE and RPT, relative to AM, had lower substance use days, while no difference in substance use days was observed between participants in COPE and RPT groups [67]. However, participants with lower DERS in RPT relative to both COPE and AM had significantly lower substance use days, while there was no difference between COPE and AM [67].

Alcohol-dependent participants demonstrated lower relapse rates and higher abstinence periods in the Integrated Intervention Program for Alcoholism compared to TAU. For emotion regulation outcomes, there was a significant improvement in the Affect Regulation Checklist, Stroop color-word inference test performance (a behavioral measure of inhibitory control which is associated with emotion dysregulation) [101, 102•], and scores on the Game of Dice Task (a behavioral measure of risk-taking, which has also been demonstrated to be influenced by emotion processing) [103•], in the Integrated Intervention Program for Alcoholism group compared to the control group [76].

Cannabis-dependent participants who underwent Affect Management Therapy showed improvements in total number of times cannabis used, average number of times used on cannabis use days, peak fear during hyperventilation, and distress rating from the mirror-tracing task while those who underwent CBT did not see improvements on those measures [79••]. Between-group differences showed significantly greater improvement in PANAS-N, distress rating from the mirror-tracing task, DERS, UPPS negative urgency, and ERQ-R in the Affect Management Therapy compared to the CBT group [79••].

## Publication Bias

Our contour-enhanced funnel plots demonstrated no apparent asymmetry for both RSUERI and IERERI pre/post effect sizes, where the Trim and Fill method imputed 12 and 0 observations for RSUERI and IERERI, respectively (Fig. 2). We saw no significant asymmetry from Egger's regression test for RSUERI (bias = 1.4408, $SE_{bias}$ = 0.8010, $p_{bias}$ = 0.0784) and significant asymmetry for IERERI (bias = 9.2430, $SE_{bias}$ = 2.7766, $p_{bias}$ = 0.0013). Our Rücker's Limit Meta-Analysis Method yielded no significant small-study effects for RSUERI (Q-Q' = 2.62, p = 0.1053) and a significant effect for IERERI (Q-Q' = 8.19, $p = 0.0042$). Although this is the case, the adjusted pooled effect size from Rücker's Limit Meta-Analysis Method lost significance for RSUERI ($g_{adjusted}$ = -0.0615, CI = [-0.8676, 0.7446], $p = 0.8812$) but maintained significance for IERERI but in the opposite direction ($g_{adjusted}$ = 0.5963, CI = [0.4752, 0.7173], $p < 0.0001$).

P-curve analysis demonstrated that most three right-skewness tests are significant for RSUERI ($p_{binomial}$ = 0.363, $p_{full}$ = 0.019, $p_{half}$ = 0.004) and IERERI ($p_{binomial}$ = 0.035, $p_{full}$ = 0.004, $p_{half}$ = 0.051). In addition, none of the three flatness tests were significant for RSUERI ($p_{binomial}$ = 0.412, $p_{full}$ = 0.577, $p_{half}$ = 0.999) and IERERI ($p_{binomial}$ = 0.932, $p_{full}$ = 0.753, $p_{half}$ = 0.998). Significant results for all right-skewness tests and no significant results for all flatness tests demonstrate that selective reporting does not dominate our meta-analysis pre/post effect sizes.

RSUERI does not demonstrate heterogeneity, significant small study effects, nor results dominated by selective reporting. While IERERI does have heterogeneity, significant small study effects, its results are not dominated by selective reporting and did not need imputations from the Trim and Fill method. These observations inform our decision not to weight pre/post observations by publication bias for our meta-analysis.

## Time-Dependent Contribution to Effect Sizes

For RSUERI, the linear regression (b = 0.0074, SE = 0.0046, $p = 0.1175$, AICc = 54.5887) performed better than the quadratic regression (b = 0.0001, SE = 0.0001, $p = 0.1814$, AICc = 55.0648). Similarly, for IERERI, the linear regression (b = -0.0048, SE = 0.0097, $p = 0.6254$, AICc = 173.6793) performed better than the quadratic regression (b = -0.0001, SE = 0.0003, $p = 0.6101$, AICc = 173.9122). Even though none of the results were significant, we used the time after follow-up variable in subsequent regressions as a potential interaction effect variable.

## Pooled Effect Size and Subgroup Analyses

While RSUERI demonstrated a significant moderate-to-large effect size ($g_{pooled}$ = 0.6133, SE = 0.1159, $p = 0.0002$), RSUCI displayed a non-significant but large effect size ($g_{pooled}$ = 1.4187, SE = 0.8585, $p = 0.1424$). No significant differences in pooled effect sizes were found between RSUERI and RSUCI (estimate = -0.2225, SE = 0.1556, $p$ = 0.1572), but the variance explained was significant ($F_{3, 68}$ =

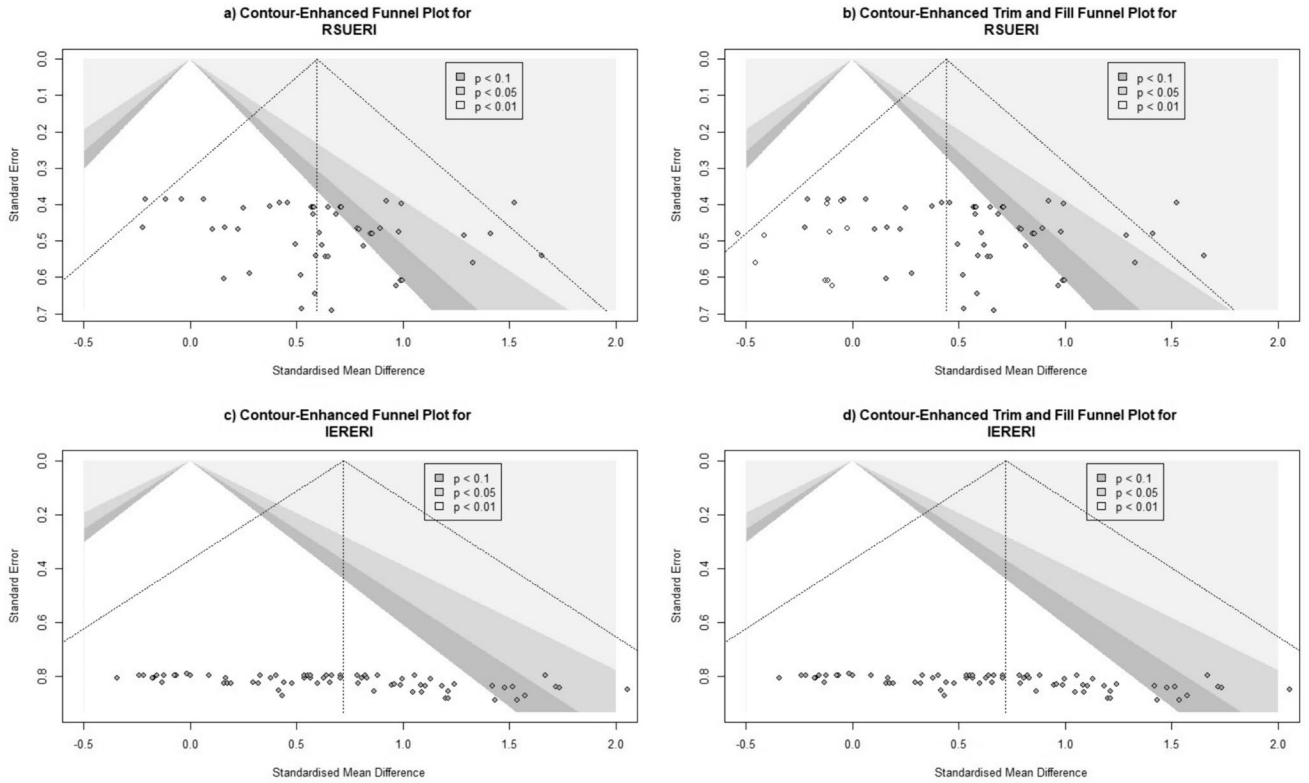



**Fig. 2** Funnel Plots to assess publication bias with and without Duval and Tweedie's Trim and Fill method imputed observations (unfilled circles) for **a**) reduction in substance use in emotion-regulation intervention groups (RSUERI) without trim and fill imputation, **b**) RSUERI observations with trim and fill imputation, **c**) improvement in emotion regulation in emotion-regulation intervention groups (IERERI) without trim and fill imputation, and **d**) IERCI observations with trim-and-fill imputation

6.8726, $p = 0.0004$). RSUHEI, a subgroup within RSUCI, demonstrated a greater pooled effect size than RSUTAU, another subgroup within RSUCI (estimate = 0.5918, SE = 0.1806, $p = 0.0042$), and the binary-variable regression exercised significant explained variance ($F_{3, 18} = 8.9772$, $p = 0.0007$). When RSUERI was compared separately with RSUTAU, the comparison displayed significant variance ($F_{3, 53} = 5.5912$, $p = 0.0021$), but the subgroup regression was not statistically significant (estimate = -0.1164, SE = 0.1916, $p = 0.5461$).

Our three-level meta-analysis demonstrates that there is a moderate-to-large pooled effect size for IERERI ($g_{pooled} = 0.8232$, SE = 0.2472, $p = 0.0054$) and a large but non-significant pooled effect size for IERCI ($g_{pooled} = 0.9532$, SE = 0.5591, $p = 0.1224$). Our subgroup analysis between IERERI and IERCI indicates difference that trended towards significance (estimate = -0.2495, SE = 0.1277, $p = 0.0523$), which was driven by significance between IERERI and IERTAU (estimate = -0.3729, SE = 0.1520, $p = 0.0153$), and not by differences between IERHEI versus IERTAU (estimate = -0.0805, SE = 0.1720, $p = 0.6405$).

The total reporting of pre/post effect sizes can be seen in Figs. 3 and 4.

## Contribution of Study Conditions on Effect Size

Meta-regressions under RSUERI yielded CBT intervention as a significant predictor, which did not survive multiple-comparisons correction (b = -0.3800, SE = 0.1834, $p_{uncorrected} = 0.0439$, $p_{FDR\text{-}corrected} = 0.3758$). The same situation was observed for the time interaction with the proportion of NHLBI quality checklist items met (b = -0.0480, SE = 0.0233, $p_{uncorrected} = 0.0451$, $p_{FDR\text{-}corrected} = 0.3758$). Similarly, meta-regressions under IERERI yielded three significant predictors; however, they also did not survive multiple-comparisons correction: total duration of the intervention (b = -0.0381, SE = 0.0178, $p_{uncorrected} = 0.0354$, $p_{FDR\text{-}corrected} = 0.4405$), proportion of cannabis-dependent participants (b = 0.0277, SE = 0.0106, $p_{uncorrected} = 0.0107$, $p_{FDR\text{-}corrected} = 0.1962$), and proportion of depressant-dependent participants (b = -0.0262, SE = 0.0092, $p_{uncorrected} = 0.0055$, $p_{FDR\text{-}corrected} = 0.1513$) (Table 5).

The only meta-regression that remained statistically significant after multiple-comparisons correction was the positive influence mindfulness-based interventions had on the improvement in ER effect size (b = 2.3981, SE = 0.4381,

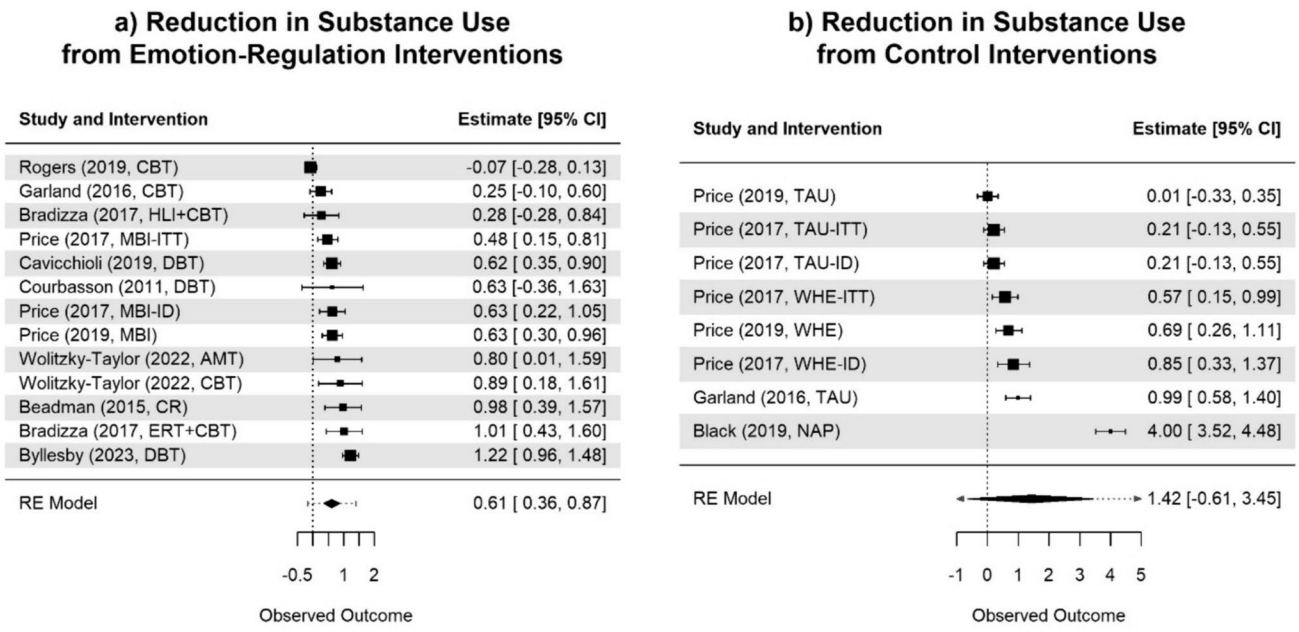



**Fig. 3** Forest plot, stratified by study and intervention, for three-level meta-analyses for reduction in substance use in the a) emotion-regulation intervention (RSUERI) group and b) control intervention (RSUCI) group. AMT: affect management therapy; CBT: cognitive behavioral therapy; CI: confidence interval; CR: cognitive reappraisal; DBT: dialectical behavior therapy; ERT+CBT: Emotion Regulation Treatment and Cognitive Behavioral Therapy; HLI+CBT: Health and Lifestyle Intervention and Cognitive Behavioral Therapy; MBI: Mindfulness-Based Intervention; MBI-ID: Mindfulness-Based Intervention Intervention-Dose analysis; MBI-ITT: Mindfulness-Based Intervention Intent-to-Treat analysis; NAP: Neurobiology of Addiction Psychoeducation; RE: random effects; TAU: Treatment as Usual; TAU-ID: Treatment as Usual Intervention-Dose analysis; TAU-ITT: Treatment as Usual Intent-to-Treat analysis; WHE: Women's Health Education; WHE-ID: Women's Health Education Intervention-Dose analysis; WHE-ITT: Women's Health Education Intent-to-Treat analysis

$p_{FDR\text{-}corrected} < 0.0001$) (Table 5). No other study variable or time interaction variable significantly influenced IERERI or RSUERI before and after multiple comparisons correction (Table 5).

## Discussion

Given the humbling success rate of current SUD rehabilitation services ranging from 40% to 60% [104••, 105, 106], and the recent increase in the implementation of ER intervention for SUD rehabilitation, we investigated the effectiveness of ER interventions on substance use and ER outcomes in this systematic review and meta-analysis. Such an examination is clinically significant as emotion dysregulation is implicated as a key risk factor for SUDs, and ER interventions have broad applicability for anxiety, depression, borderline personality disorder, eating disorders, and SUDs [107–109].

Our meta-analyses demonstrated significant pooled effect sizes in the reduction in substance use and improvement in ER for ER interventions, and nonsignificant pooled effect sizes for control interventions. The control interventions showed increased variability in effect sizes across pre/post observations, perhaps due to substantial heterogeneity in the operationalization of inpatient and outpatient rehabilitation services, which is non-specifically termed as TAU [110••, 111]. The relatively reduced variation in effect sizes as well as significant explained variance in subgroup analyses in ER interventions for reduction in substance use suggests that ER interventions show more consistent outcomes compared to control interventions. The explained variance for reduction in substance use was significant in the ER relative to control intervention subgroup model, but the difference was not statistically significant. In contrast, for ER measures, we found that the ERI versus TAU meta-regression significantly predicted the effect size and significantly explained the variance in effect sizes. Subgroup analyses also suggested that health-education intervention may have a prominent effect on reduction in substance use, similar to health-education interventions helping prevent SUDs when studied in an adolescent population [112•, 113].

We also observed a lack of heterogeneity, small study effects, and selective reporting across reduction in substance use effect sizes, increasing our confidence that our meta-analysis was not corrupted by potential publication bias. Since we observed heterogeneity and small study effects in the ER effect sizes, we recommend ER intervention studies

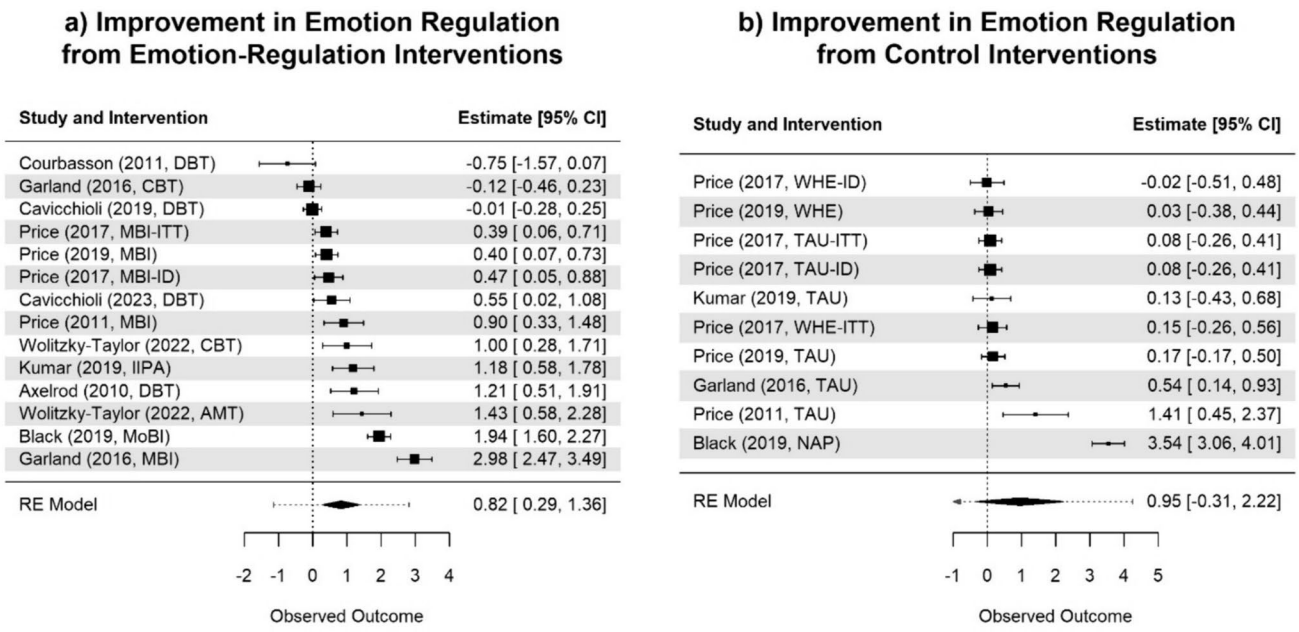



**Fig. 4** Forest plot, stratified by study and intervention, for three-level meta-analysis for improvement in emotion regulation in the **a**) emotion-regulation intervention (IERERI) group and **b**) control intervention (IERCI) group. AMT: affect management therapy; CBT: cognitive behavioral therapy; CI: confidence interval; CR: cognitive reappraisal; DBT: dialectical behavior therapy; ERT+CBT: Emotion Regulation Treatment and Cognitive Behavioral Therapy; HLI+CBT: Health and Lifestyle Intervention and Cognitive Behavioral Therapy; MBI: Mindfulness-Based Intervention; MBI-ID: Mindfulness-Based Intervention Intervention-Dose analysis; MBI-ITT: Mindfulness-Based Intervention Intent-to-Treat Analysis; NAP: Neurobiology of Addiction Psychoeducation; RE: random effects; TAU: Treatment as Usual; TAU-ID: Treatment as Usual Intervention-Dose analysis; TAU-ITT: Treatment as Usual Intent-to-Treat analysis; WHE: Women's Health Education; WHE-ID: Women's Health Education Intervention-Dose analysis; WHE-ITT: Women's Health Education Intent-to-Treat analysis

of larger sample size so that non-significant findings can be reported. With our studies averaging a sample size of 91±63 individuals, we recommend future studies to involve at least 200 participants.

Across our exploratory meta-analyses, we found five significant predictors of the improvement in substance use and ER effect size. Of them, only MBIs predicting improvement in ER survived multiple comparisons correction. This finding is consistent with our systematic review, such that across MBI studies conducted on participants dependent on a diverse range of substances [73, 75, 80, 85], we found that three studies that reported a reduction in DERS [73, 80, 85], two showed improvement in mindfulness [73, 80], and two studies demonstrated improvement in emotion dysregulation in the MBI group compared to TAU assessed via the RSA measurements [73, 80]. While our meta-regression did not find MBIs contributing to RSUERI, two studies demonstrated improvements in abstinence and two reported significant improvements in craving. Importantly, MBIs have the advantage of being implementable in clinical settings [114], schools [115], and workplaces [116], are cost-effective, and require less training compared to other techniques, such as CBT [117]. In addition, our included MBI studies involved sound study designs, such that three out of five studies conducted follow-up visits as far as 28 weeks post-intervention [73, 80, 85], and four conducted RCT designs comparing MBI with Women's Health Education, CBT, and/or TAU [73, 75, 80, 85]. Notably, these MBI studies used a mean MBI dosage of 1.63±0.25 hours/week and a mean duration of 7.60±3.21 weeks, which is consistent with the broader literature and clinical practice of 1–3 hours/week and 7-12 weeks [118]. Although these results for MBIs are promising, we encourage future research studies to involve biospecimen and neuroimaging analyses for more objective evidence [119••].

Other predictors, which did not survive multiple comparisons correction, included the significant negative contribution of CBT on substance use outcomes. This result is in contrast with two studies demonstrating that abstainers showed a decline in cue-induced craving over treatment while relapsers did not [69, 72]. Interestingly, one study found that higher baseline emotion dysregulation contributed to steeper changes in withdrawal during treatment [61], suggesting that CBT may be more effective in individuals with less severe emotion dysregulation [120•, 121, 122•, 123•]. In addition, with a recent review of CBT showing positive outcomes for individuals with depression, anxiety, obsessive-compulsive disorders, and panic disorders, CBT could

**Table 5** List of meta-regressions to assess the impact that demographic variables, substance types, emotion-regulation intervention types, and study design and quality has on reduction in substance use and improvement in emotion regulation

| Meta-Regression Results with Improvement in Emotion Regulation Effect Size | | | | | | | |
|---|---|---|---|---|---|---|---|
| Study Condition | Estimate | SE | $p_{FDR\text{-}corrected}$ | Time Interaction Estimate | $SE_{Time\ Interaction}$ | $p_{Time\ Interaction,\ FDR\text{-}corrected}$ | F-test p-value |
| Hours/Week | -0.0857 | 0.1028 | 0.7808 | -0.0714 | 0.0637 | 0.7712 | 0.4467 |
| Weeks Duration | -0.0381 | 0.0178 | **0.4405**** | 0.0002 | 0.0019 | 0.9892 | 0.0881 |
| % Alcohol Dependence | -0.0040 | 0.0078 | 0.8382 | 0.0001 | 0.0006 | 0.9892 | 0.9213 |
| % Nicotine Dependence | NA | NA | NA | NA | NA | NA | NA |
| % Cannabis Dependence | 0.0277 | 0.0106 | **0.1962**** | -0.0017 | 0.0009 | 0.4405 | 0.0461 |
| % Opioid Dependence | 0.0254 | 0.0227 | 0.7712 | 0.0002 | 0.0021 | 0.9892 | 0.6524 |
| % Stimulant Dependence | -0.0002 | 0.0077 | 0.9892 | -0.0004 | 0.0005 | 0.7808 | 0.7689 |
| % Depressant Dependence | -0.0262 | 0.0092 | **0.1513**** | 0.0055 | -0.0006 | 0.7808 | 0.0009 |
| % Other Substance Dependence | 0.0027 | 0.0785 | 0.9892 | NA | NA | NA | 0.8944 |
| Mean Age | -0.0312 | 0.0376 | 0.7808 | 0.0013 | 0.0033 | 0.8539 | 0.8134 |
| % Males | 0.0034 | 0.0050 | 0.7808 | 0.0006 | 0.0009 | 0.8093 | 0.7253 |
| DBT Intervention? | -0.6788 | 0.3835 | 0.4405 | -0.0634 | 0.0714 | 0.7808 | 0.1510 |
| Mindfulness-Based Intervention? | 2.3981 | 0.4381 | **<0.0001*** | -0.0225 | 0.0611 | 0.8539 | <0.0001 |
| RCT Study? | 0.3368 | 0.4757 | 0.7808 | NA | NA | NA | 0.6935 |
| % of NHLBI Quality Checklist Items Met | 2.0597 | 1.3991 | 0.6143 | -0.1490 | 0.1274 | 0.7712 | 0.4094 |
| Meta-Regression Results with Reduction in Substance Use Effect Size | | | | | | | |
| Study Condition | Estimate | SE | $p_{FDR\text{-}corrected}$ | Time Interaction Estimate | $SE_{Time\ Interaction}$ | $p_{Time\ Interaction,\ FDR\text{-}corrected}$ | F-test p-value |
| Hours/Week | 0.0006 | 0.0443 | 0.9886 | 0.0086 | 0.0084 | 0.7386 | 0.4104 |
| Weeks Duration | 0.0036 | 0.0090 | 0.8321 | 0.0001 | 0.0004 | 0.9537 | 0.4735 |
| % Alcohol Dependence | 0.0019 | 0.0034 | 0.7766 | -0.0001 | 0.0003 | 0.9537 | 0.5102 |
| % Nicotine Dependence | -0.0026 | 0.0022 | 0.7326 | 0.0001 | 0.0002 | 0.7470 | 0.2395 |
| % Cannabis Dependence | 0.0101 | 0.0115 | 0.7386 | -0.0007 | 0.0009 | 0.7386 | 0.4240 |
| % Opioid Dependence | -0.0079 | 0.0147 | 0.7773 | 0.0007 | 0.0005 | 0.7312 | 0.2777 |
| % Stimulant Dependence | 0.0025 | 0.0041 | 0.7622 | -0.0005 | 0.0003 | 0.3955 | 0.1171 |
| % Depressant Dependence | 0.0061 | 0.0066 | 0.7386 | -0.0006 | 0.0003 | 0.3758 | 0.1037 |
| % Other Substance Dependence | -0.1390 | 0.1785 | 0.7386 | NA | NA | NA | 0.2513 |
| Mean Age | -0.0183 | 0.0145 | 0.7312 | 0.0011 | 0.0007 | 0.5047 | 0.1845 |
| % Males | -0.0030 | 0.0032 | 0.7386 | 0.0002 | 0.0001 | 0.3758 | 0.1029 |
| CBT Intervention? | -0.3800 | 0.1834 | **0.3758**** | 0.0258 | 0.0159 | 0.5047 | 0.0418 |
| DBT Intervention? | 0.1162 | 0.2709 | 0.8321 | 0.0078 | 0.0101 | 0.7386 | 0.2962 |
| RCT Study? | -0.2561 | 0.2735 | 0.7386 | -0.0071 | 0.0100 | 0.7386 | 0.1627 |
| % of NHLBI Quality Checklist Items Met | 0.5562 | 0.6169 | 0.7386 | -0.0480 | 0.0233 | **0.3758**** | 0.0790 |

*CBT* cognitive behavioral therapy, *DBT* dialectical behavior therapy, *FDR* false-discovery rate, *NHLBI* National Heart, Lung, and Blood Institute, *RCT* randomized controlled trial, *SE* standard error. *FDR-corrected $p$-value < 0.05 **uncorrected $p$-value < 0.05

be more effective for substance dependence with comorbid mood and anxiety disorders [124•]. While our meta-analysis found no contribution of CBT to IERERI, one study demonstrated a decrease in electromyography-based startle response from aversive cues in abstainers [72]. Majority of CBT studies conducted follow-up visits as far as two-years post-intervention, whereas only few studies involved RCT design. The high variability in dosage (3.50±3.46 hours/week) and duration (5.00±4.18 weeks) were also observed in CBT studies. However, such duration was shorter than those reported by previous reviews for other psychopathologies (16-24 weeks for schizophrenia and 12-16 weeks for anxiety and stress-related disorders) [125, 126•]. We encourage future CBT studies to pursue an RCT design, implement at least 12 weeks of intervention, compare the intervention with other ER interventions done in five studies [61, 71, 75, 79••, 83], and investigate the impact of CBT on substances other than alcohol and nicotine.

Another predictor that did not survive multiple comparisons correction was the total duration of intervention on ER

outcomes. We encourage future studies to further investigate the effects of ER treatment length as traditional SUD rehabilitation length has predicted positive outcomes [127, 128].

Interestingly, the proportion of cannabis- and depressant-dependent participants were also observed as predictors of improvement in ER effect size, but neither survived FDR correction. Nevertheless, these results are of high clinical and social consequences. The associated public health risks from increased legalization and potency of cannabis products as well as the sparse literature on emotion dysregulation from cannabis use necessitates further research into the impact of ER interventions on individuals dependent on cannabis [129, 130•, 131•, 132••, 133]. Similarly, with 5.3 million individuals musing benzodiazepines and sparse literature on the effectiveness of ER interventions for benzodiazepine dependence [134, 135•, 136•], more research should be conducted with individuals dependent on benzodiazepines.

Our systematic review showed that seven studies that used DBT reported reduced substance use outcomes [62, 64, 65, 77, 78, 81••, 82], with one reporting no significant relationship between relapse status and treatment completion [86••]. In addition, seven out of the eight DBT studies found significant improvement in emotion dysregulation (reduction in DERS) [62, 64, 65, 77, 78, 81••, 86••], except for one study that did not report on this measure [82]. Such improvement in substance use and ER outcomes across a diverse range of substance dependences suggests that DBT has broad applicability in SUDs. There was high variability in the intervention dosage, with an average of 4.56±3.71 hours/week over 21.00±13.65 weeks. Such distribution, however, is consistent with DBT interventions generally involving 3.5 – 5.5 hours/week and treatment duration lasting six months to 12 months [137]. Only three of the eight studies assessed substance use and ER measures in follow-up visits weeks or months after the end of intervention [62, 81, 82]. Only one study involved an RCT, comparing DBT to TAU, highlighting the need for future studies involving DBT and SUDs to consider the RCT study design approach [82].

The rest of the intervention study classes did not have enough studies to form generalizations regarding the aggregation of their outcomes and the representative dosage and duration compared to the broader clinical and research environment. We also encourage studies to examine the impact of music therapy interventions on substance use outcomes as they have been shown to improve ER skills in several psychopathologies, including depression and PTSD [33•, 34•, 35].

Eleven out of 26 studies examined the stability of the therapeutic effects of these interventions using post-intervention follow-ups [61, 62, 66, 72, 73, 79••, 80, 81••, 82, 84••, 85]. With our subgroup analysis demonstrating explained variance in ER outcomes when comparing ER interventions and control intervention while the same was not demonstrated for substance use outcomes, we speculate that perhaps ER outcomes improve quicker than substance use outcomes, a research question that would be answered by studies employing multiple post-intervention follow-up visits. Highlighting the need for multiple follow-up visits is the finding that time after intervention did not significantly contribute to the effect sizes in substance use and ER outcomes, suggesting persistent longitudinal effects for improvement in emotion regulation and reduction in substance use. These findings align with previous research on the long-lasting behavioral and neurobiological effects of employing ER strategies [138, 139•, 140•].

While we collected 18 substance use and ER measures, we find it worthwhile for future studies interested in ER interventions on SUDs to consistently include certain measures that directly measure substance use, ER, or serve as an important mediator in SUD outcomes. We recommended employing objective measures for substance use such as exhaled carbon monoxide levels for tobacco use and carbohydrate-deficient transferrin assays for alcohol use [141, 142]. Since most emotion-regulation measures were self-report questionnaires, which can risk underreporting or over-reporting due to social desirability bias [143], our systematic review and meta-analysis benefitted from objective measures like RSA, skin conductance response, and startle eyeblink electromyography. We encourage future studies to employ these measures and neuropsychoimaging to present further evidence to their findings [87–95, 97, 98, 119••, 144]. With two studies that assessed negative affect [79••, 85], we encourage researchers to include PANAS in their study as higher emotion dysregulation is linked to greater negative affect, a contributor to greater difficulty in delayed discounting, which is a risk factor for addiction [145•, 146•]. We also encourage researchers to include PTSD, anxiety, and depression measures, as done in 13 of the included studies [63, 64, 66, 68, 74••, 75, 77, 78, 79••, 80, 82, 85, 86••], as these psychiatric symptoms are often comorbid with substance dependence and may interact or mediate effects on intervention outcomes [147, 148, 149•].

In summary, 26 studies included in this systematic review and meta-analysis demonstrated a significant reduction in substance use and improvements in ER from ER interventions, as shown by using a diverse set of outcome measures, tasks, and recordings. Perhaps a major concern in the field is the high variability in types, doses, and duration of these interventions and the heterogeneity in the sample, which prevented effect sizes for control interventions from achieving significance. Further inquiry into the impact of the length of ER intervention, population involving cannabis-dependent individuals, and population involving depressant-dependent individuals on ER outcomes is warranted. This review is the first qualitative and quantitative investigation into the current

landscape of ER interventions on longitudinal SUD and ER outcomes across a variety of measures, intervention types, and substances, and serves as a guide for researchers interested in this area on trends (e.g., MBIs contributing positively to the improvement in ER compared to non-MBIs) as well as study design considerations (e.g., adopt RCT design, employ objective measures like RSA, track outcomes past the end of intervention).

## Conclusion

Our systematic review and meta-analysis have demonstrated moderate to large improvements in emotion regulation and reduction in substance use across emotion-regulation interventions through multiple diverse measures from questionnaires on distress tolerance, cognitive reappraisal, expressive suppression, or mindfulness to physiological readings such as respiratory sinus arrhythmia. We observed that mindfulness-based interventions significantly contributed to the significant pooled improvement in emotion regulation effect size, and that intervention parameters, study design, and population demographics did not significantly influence reductions in substance use. We encourage researchers to continue investigating the impact of mindfulness interventions on substance use outcomes and determine if other psychiatric symptoms like PTSD, anxiety, and depression affect the broad impact of emotion-regulation interventions of substance use and emotion-regulation outcomes.

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**Data Availability** No datasets were generated or analysed during the current study.

## Compliance with Ethical Standards

**Conflict of Interest** The authors declare no competing interests.

**Human and Animal Rights and Informed Consent** Our research did not involve human participants or animal subjects.

**Disclosures** The authors declare no competing financial interests.

## References

Papers of particular interest, published recently, have been highlighted as:
- • Of importance
- •• Of major importance

1. Degenhardt L, Charlson F, Ferrari A, Santomauro D, Erskine H, Mantilla-Herrara A, et al. The global burden of disease attributable to alcohol and drug use in 195 countries and territories, 1990–2016: a systematic analysis for the Global Burden of Disease Study 2016. Lancet Psychiatry. 2018;5:987–1012.
2. Rehm J, Shield KD. Global Burden of Disease and the Impact of Mental and Addictive Disorders. Curr Psychiatry Rep. 2019;21:10.
3. Marel C, Sunderland M, Mills KL, Slade T, Teesson M, Chapman C. Conditional probabilities of substance use disorders and associated risk factors: Progression from first use to use disorder on alcohol, cannabis, stimulants, sedatives and opioids. Drug Alcohol Depend. 2019;194:136–42.
4. Diala CC, Muntaner C, Walrath C. Gender, Occupational, and Socioeconomic Correlates of Alcohol and Drug Abuse Among U.S. Rural, Metropolitan, and Urban Residents. Am J Drug Alcohol Abuse. 2004;30:409–28.
5.• Bryant DJ, Coman EN, Damian AJ. Association of adverse childhood experiences (ACEs) and substance use disorders (SUDs) in a multi-site safety net healthcare setting. Addict Behav Rep. 2020;12:100293. **Assesses the impact of adverse childhood experiences on developing substance use disorders in the future.**
6. Hughes K, Bellis MA, Hardcastle KA, Sethi D, Butchart A, Mikton C, et al. The effect of multiple adverse childhood experiences on health: a systematic review and meta-analysis. Lancet Public Health. 2017;2:e356–66.
7.•• Kok R. Emotion Regulation. In: Zeigler-Hill V, Shackelford TK, editors. Encyclopedia of Personality and Individual Differences. Cham: Springer International Publishing; 2020. **Defines and characterizes emotion regulation, its dysfunctions, and development from childhood to adolescence to adulthood.**
8.•• Stellern J, Xiao KB, Grennell E, Sanches M, Gowin JL, Sloan ME. Emotion regulation in substance use disorders: a systematic review and meta-analysis. Addiction. 2023;118:30–47. **A meta-analysis inspired by twenty-two studies pooled across 1,936 individuals demonstrated that individuals with substance use disorders have increased emotion dysregulation.**
9. Rose EJ, Picci G, Fishbein DH. Neurocognitive Precursors of Substance Misuse Corresponding to Risk, Resistance, and Resilience Pathways: Implications for Prevention Science. Front Psych. 2019;10:399.
10.• Souza R, Bueno D, Lima LB, Muchon MJ, Gonçalves L, Donato J, et al. Top-down projections of the prefrontal cortex to the ventral tegmental area, laterodorsal tegmental nucleus, and median raphe nucleus. Brain Struct Funct. 2022;227:2465–87. **This study discusses the top-down control the prefrontal cortex has on other regions and the importance it has to key behaviors discussed in this study like reward processing.**
11.•• Weiss NH, Kiefer R, Goncharenko S, Raudales AM, Forkus SR, Schick MR, et al. Emotion regulation and substance use: A meta-analysis. Drug Alcohol Depend. 2022;230:109131. **This meta-analysis looks at the links between emotion regulation and substance use with higher emotion dysregulation increasing the risk for substance use.**

12.• Sanchez M, Amaro H. Cumulative exposure to traumatic events and craving among women in residential treatment for substance use disorder: The role of emotion dysregulation and mindfulness disposition. Front Psychol. 2022;13:1048798. **A sex-specific study where the finding was that higher cumulative exposure to traumatic events and emotion dysregulation is linked to higher craving for substances.**

13.• Killeen TK, Brewerton TD. Women with PTSD and Substance Use Disorders in a Research Treatment Study: A Comparison of those with and without the Dissociative Subtype of PTSD. J Trauma Dissociation. 2023;24:229–40. **Among women, PTSD was linked to increased propensity for alcohol use disorder and non-cocaine stimulant use disorder.**

14. Tull MT, Gratz KL, Aklin WM, Lejuez CW. A preliminary examination of the relationships between posttraumatic stress symptoms and crack/cocaine, heroin, and alcohol dependence. J Anxiety Disord. 2010;24:55–62.

15. Magill M, Ray LA. Cognitive-Behavioral Treatment With Adult Alcohol and Illicit Drug Users: A Meta-Analysis of Randomized Controlled Trials. J Stud Alcohol Drugs. 2009;70:516–27.

16. McHugh RK, Hearon BA, Otto MW. Cognitive Behavioral Therapy for Substance Use Disorders. Psychiatr Clin N Am. 2010;33:511–25.

17.•• Magill M, Kiluk BD, Ray LA. Efficacy of Cognitive Behavioral Therapy for Alcohol and Other Drug Use Disorders: Is a One-Size-Fits-All Approach Appropriate? SAR. 2023;14:1–11. **A narrative review demonstrated that while cognitive behavioral therapy is effective, it is not as consistent in its outcomes for alcohol dependence compared to other empirically supported interventions.**

18. Watkins KE, Hunter SB, Hepner KA, Paddock SM, De La Cruz E, Zhou AJ, et al. An Effectiveness Trial of Group Cognitive Behavioral Therapy for Patients With Persistent Depressive Symptoms in Substance Abuse Treatment. Arch Gen Psychiatry. 2011;68:577.

19. Welch SS, Rizvi S, Dimidjian S. Mindfulness in Dialectical Behavior Therapy (DBT) for Borderline Personality Disorder. In: Mindfulness-Based Treatment Approaches. Elsevier; 2016. https://doi.org/10.1016/B978-012088519-0/50007-1.

20. Dimeff L. Dialectical Behavior Therapy for Substance Abusers. ascp. 2008;4:39–47.

21. Rösner S, Willutzki R, Zgierska A. Mindfulness-based interventions for substance use disorders. Cochrane Drugs and Alcohol Group, editor. Cochrane Database of Systematic Reviews. 2015; 10.1002/14651858.CD011723

22. Zemestani M, Ottaviani C. Effectiveness of Mindfulness-Based Relapse Prevention for Co-occurring Substance Use and Depression Disorders. Mindfulness. 2016;7:1347–55.

23.•• Félix-Junior IJ, Donate APG, Noto AR, Galduróz JCF, Simionato NM, Opaleye ES. Mindfulness-based interventions in inpatient treatment for Substance Use Disorders: A systematic review. Addict Behav Rep. 2022;16:100467. **A systematic review of 21 studies found that while mindfulness-based interventions were successful in reducing craving, stress was a significant determiner of treatment outcome.**

24.•• Ramadas E, Lima MPD, Caetano T, Lopes J, Dixe MDA. Effectiveness of Mindfulness-Based Relapse Prevention in Individuals with Substance Use Disorders: A Systematic Review. Behav Sci. 2021;11:133. **Twelve out of thirteen studies reviewed found that mindfulness-based relapse prevention interventions produced positive outcomes on at least one addiction measure.**

25. López-López JA, Page MJ, Lipsey MW, Higgins JPT. Dealing with effect size multiplicity in systematic reviews and meta-analyses. Res Synth Methods. 2018;9:336–51.

26. Daley D, Van Der Oord S, Ferrin M, Danckaerts M, Doepfner M, Cortese S, et al. Behavioral Interventions in Attention-Deficit/Hyperactivity Disorder: A Meta-Analysis of Randomized Controlled Trials Across Multiple Outcome Domains. J Am Acad Child Adolesc Psychiatry. 2014;53:835–847.e5.

27. Virués-Ortega J. Applied behavior analytic intervention for autism in early childhood: Meta-analysis, meta-regression and dose–response meta-analysis of multiple outcomes. Clin Psychol Rev. 2010;30:387–99.

28.• Jang J-S, Oh S, Kim G, Lee N, Song H, Park J, et al. Analysis of the effectiveness of cognitive rehabilitation for patients with chronic mental illness: A meta-analysis. World J Clin Cases. 2023;11:7822–32. **This was a meta-analysis on the impact of cognitive rehabilitation therapy on cognitive states and psychiatric disorders, informing this study on the newer age of meta-analytic techniques.**

29. Panos PT, Jackson JW, Hasan O, Panos A. Meta-Analysis and Systematic Review Assessing the Efficacy of Dialectical Behavior Therapy (DBT). Res Soc Work Pract. 2014;24:213–23.

30. DeCou CR, Comtois KA, Landes SJ. Dialectical Behavior Therapy Is Effective for the Treatment of Suicidal Behavior: A Meta-Analysis. Behav Ther. 2019;50:60–72.

31.• Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021:n71. **The updated set of guidelines for reporting systematic review and meta-analysis strategy and results.**

32. Schardt C, Adams MB, Owens T, Keitz S, Fontelo P. Utilization of the PICO framework to improve searching PubMed for clinical questions. BMC Med Inform Decis Mak. 2007;7:16.

33.• Zhang M, Ding Y, Zhang J, Jiang X, Xu N, Zhang L, et al. Effect of Group Impromptu Music Therapy on Emotional Regulation and Depressive Symptoms of College Students: A Randomized Controlled Study. Front Psychol. 2022;13:851526. **The impact of music therapy on emotion regulation and depressive symptoms.**

34.• Nwokenna EN, Sewagegn AA, Falade TA. Effect of educational music intervention on emotion regulation skills of first-year university music education students. Medicine. 2022;101:e32041. **The impact of music therapy on emotion regulation for undergraduate music education students.**

35. Landis-Shack N, Heinz AJ, Bonn-Miller MO. Music therapy for posttraumatic stress in adults: A theoretical review. Psychomusicol: Music, Mind, Brain. 2017;27:334–42.

36. Ouzzani M, Hammady H, Fedorowicz Z, Elmagarmid A. Rayyan—a web and mobile app for systematic reviews. Syst Rev. 2016;5:210.

37.• Valizadeh A, Moassefi M, Nakhostin-Ansari A, Hosseini Asl SH, Saghab Torbati M, Aghajani R, et al. Abstract screening using the automated tool Rayyan: results of effectiveness in three diagnostic test accuracy systematic reviews. BMC Med Res Methodol. 2022;22:–160. **Accuracy assessment of Rayyan for automatic screening of studies.**

38. Shorter GW, Bray JW, Giles EL, O'Donnell AJ, Berman AH, Holloway A, et al. The Variability of Outcomes Used in Efficacy and Effectiveness Trials of Alcohol Brief Interventions: A Systematic Review. J Stud Alcohol Drugs. 2019;80:286–98.

39. Hedges LV. Distribution Theory for Glass's Estimator of Effect Size and Related Estimators. J Educ Stat. 1981;6:107.

40. Leppink J, O'Sullivan P, Winston K. Effect size – large, medium, and small. Perspect Med Educ. 2016;5:347–9.

41. Hozo SP, Djulbegovic B, Hozo I. Estimating the mean and variance from the median, range, and the size of a sample. BMC Med Res Methodol. 2005;5:13.

42. Olkin I, Dahabreh IJ, Trikalinos TA. GOSH – a graphical display of study heterogeneity. Res Synth Methods. 2012;3:214–23.

43.•• Shutaywi M, Kachouie NN. Silhouette Analysis for Performance Evaluation in Machine Learning with Applications to Clustering.

Entropy. 2021;23:759. **Silhouette analysis is done for unsupervised machine learning algorithms like clustering, and this algorithm was used in this meta-analysis to remove outlier effect size observations.**
44. Ester M, Kriegel HP, Sander J, Xu X. A density-based algorithm for discovering clusters in large spatial databases with noise. Ass Comp Mach. 1996:226–31.
45. Peters JL, Sutton AJ, Jones DR, Abrams KR, Rushton L. Contour-enhanced meta-analysis funnel plots help distinguish publication bias from other causes of asymmetry. J Clin Epidemiol. 2008;61:991–6.
46. Duval S, Tweedie R. Trim and Fill: A Simple Funnel-Plot-Based Method of Testing and Adjusting for Publication Bias in Meta-Analysis. Biometrics. 2000;56:455–63.
47. Egger M, Smith GD, Schneider M, Minder C. Bias in meta-analysis detected by a simple, graphical test. BMJ. 1997;315:629–34.
48. Rucker G, Schwarzer G, Carpenter JR, Binder H, Schumacher M. Treatment-effect estimates adjusted for small-study effects via a limit meta-analysis. Biostatistics. 2011;12:122–42.
49. Simonsohn U, Simmons JP, Nelson LD. Better P-curves: Making P-curve analysis more robust to errors, fraud, and ambitious P-hacking, a Reply to Ulrich and Miller (2015). J Exp Psychol Gen. 2015;144:1146–52.
50. Van Den Noortgate W, López-López JA, Marín-Martínez F, Sánchez-Meca J. Meta-analysis of multiple outcomes: a multilevel approach. Behav Res Ther. 2015;47:1274–94.
51.•• Robinson L, Delgadillo J, Kellett S. The dose-response effect in routinely delivered psychological therapies: A systematic review. Psychother Res. 2020;30:79–96. **This was a review on the effect on the number of sessions of psychiatric outcomes.**
52.•• Dallenbach ML, Moeller K, Givens A. Does Duration of Dialectical Behavioral Therapy for Adolescents (DBT-A) Skills Groups Affect Outcomes: A Rapid Review. Child Adolesc Soc Work J. 2024; https://doi.org/10.1007/s10560-024-00961-4. **A review that assessed the impact that Dialectical Behavioral Therapy length has on various psychiatric symptoms/disorders on adolescents.**
53.• Harned MS, Schmidt SC, Korslund KE, Gallop RJ. Does Adding the Dialectical Behavior Therapy Prolonged Exposure (DBT PE) Protocol for PTSD to DBT Improve Outcomes in Public Mental Health Settings? A Pilot Nonrandomized Effectiveness Trial With Benchmarking. Behav Ther. 2021;52:639–55. **This study assessed the effectiveness of prolonged DBT on PTSD outcomes.**
54. Goldberg SB, Hoyt WT, Nissen-Lie HA, Nielsen SL, Wampold BE. Unpacking the therapist effect: Impact of treatment length differs for high- and low-performing therapists. Psychother Res. 2018;28:532–44.
55. Pastor DA, Lazowski RA. On the Multilevel Nature of Meta-Analysis: A Tutorial, Comparison of Software Programs, and Discussion of Analytic Choices. Multivar Behav Res. 2018;53:74–89.
56.• . Tanriver-Ayder E, Faes C, Van De Casteele T, McCann SK, Macleod MR. Comparison of commonly used methods in random effects meta-analysis: application to preclinical data in drug discovery research. BMJ Open Sci. 2021; https://doi.org/10.1136/bmjos-2020-100074. **A modern guide towards which meta-analysis heterogeneity measure methods are most appropriate for a given research question.**
57. Van Den Noortgate W, López-López JA, Marín-Martínez F, Sánchez-Meca J. Three-level meta-analysis of dependent effect sizes. Behav Res Ther. 2013;45:576–94.
58. Moeyaert M, Ugille M, Natasha Beretvas S, Ferron J, Bunuan R, Van Den Noortgate W. Methods for dealing with multiple outcomes in meta-analysis **:** a comparison between averaging effect sizes, robust variance estimation and multilevel meta-analysis. Int J Soc Res Methodol. 2017;20:559–72.
59. Gu X. Incubation of craving: a Bayesian account. Neuropsychopharmacol. 2018;43:2337–9.
60. Parvaz MA, Moeller SJ, Goldstein RZ. Incubation of Cue-Induced Craving in Adults Addicted to Cocaine Measured by Electroencephalography. JAMA Psychiatry. 2016;73:1127.
61. Rogers AH, Bakhshaie J, Garey L, Piasecki TM, Gallagher MW, Schmidt NB, et al. Individual differences in emotion dysregulation and trajectory of withdrawal symptoms during a quit attempt among treatment-seeking smokers. Behav Res Ther. 2019;115:4–11.
62. Flynn D, Joyce M, Spillane A, Wrigley C, Corcoran P, Hayes A, et al. Does an adapted Dialectical Behaviour Therapy skills training programme result in positive outcomes for participants with a dual diagnosis? A mixed methods study. Addict Sci Clin Pract. 2019;14:28.
63. Black DS, Amaro H. Moment-by-Moment in Women's Recovery (MMWR): Mindfulness-based intervention effects on residential substance use disorder treatment retention in a randomized controlled trial. Behav Res Ther. 2019;120:103437.
64. Cavicchioli M, Movalli M, Vassena G, Ramella P, Prudenziati F, Maffei C. The therapeutic role of emotion regulation and coping strategies during a stand-alone DBT Skills training program for alcohol use disorder and concurrent substance use disorders. Addict Behav. 2019;98:106035.
65. Cooperman NA, Rizvi SL, Hughes CD, Williams JM. Field Test of a Dialectical Behavior Therapy Skills Training–Based Intervention for Smoking Cessation and Opioid Relapse Prevention in Methadone Treatment. J Dual Diagn. 2019;15:67–73.
66. Holzhauer CG, Gamble SA. Depressive symptoms mediate the relationship between changes in emotion regulation during treatment and abstinence among women with alcohol use disorders. Psychol Addict Behav. 2017;31:284–94.
67. Hien DA, Lopez-Castro T, Papini S, Gorman B, Ruglass LM. Emotion dysregulation moderates the effect of cognitive behavior therapy with prolonged exposure for co-occurring PTSD and substance use disorders. J Anxiety Disord. 2017;52:53–61.
68. Paz R, Zvielli A, Goldstein P, Bernstein A. Brief mindfulness training de-couples the anxiogenic effects of distress intolerance on reactivity to and recovery from stress among deprived smokers. Behav Res Ther. 2017;95:117–27.
69. Jurado-Barba R, Rubio Valladolid G, Martínez-Gras I, Alvarez-Alonso MJ, Ponce Alfaro G, Fernández A, et al. Changes on the Modulation of the Startle Reflex in Alcohol-Dependent Patients after 12 Weeks of a Cognitive-Behavioral Intervention. Eur Addict Res. 2015;21:195–203.
70.•• Davis JP, Pedersen ER, Borsari B, Bowen S, Owen J, Sedano A, et al. Development of a mobile mindfulness smartphone app for post-traumatic stress disorder and alcohol use problems for veterans: Beta test results and study protocol for a pilot randomized controlled trial. Contemp Clin Trials. 2023;129:107181. **Assessment of the effectiveness of a mindfulness-based intervention for veterans with alcohol use disorder, a study included in our systematic review.**
71. Beadman M, Das RK, Freeman TP, Scragg P, West R, Kamboj SK. A comparison of emotion regulation strategies in response to craving cognitions: Effects on smoking behaviour, craving and affect in dependent smokers. Behav Res Ther. 2015;69:29–39.
72. Loeber S, Croissant B, Nakovics H, Zimmer A, Georgi A, Klein S, et al. The Startle Reflex in Alcohol-Dependent Patients: Changes after Cognitive-Behavioral Therapy and Predictive Validity for Drinking Behavior. Psychother Psychosom. 2007;76:385–90.
73. Price CJ, Thompson EA, Crowell S, Pike K. Longitudinal effects of interoceptive awareness training through mindful awareness

in body-oriented therapy (MABT) as an adjunct to women's substance use disorder treatment: A randomized controlled trial. Drug Alcohol Depend. 2019;198:140–9.

74.•• Holzhauer CG, Epstein EE, Smelson DA, Mattocks K. Targeting women veteran's stress-induced drinking with cognitive reappraisal: Mechanisms and moderators of change. J Subst Abuse Treat. 2021;130:108408. **Assessment of the effectiveness of cognitive reappraisal for women veterans with alcohol dependence, a study included in our systematic review.**

75. Garland EL, Roberts-Lewis A, Tronnier CD, Graves R, Kelley K. Mindfulness-Oriented Recovery Enhancement versus CBT for co-occurring substance dependence, traumatic stress, and psychiatric disorders: Proximal outcomes from a pragmatic randomized trial. Behav Res Ther. 2016;77:7–16.

76. Kumar R, Kumar KJ, Benegal V, Roopesh BN, Ravi GS. Effectiveness of an Integrated Intervention Program for Alcoholism (IIPA) for enhancing self-regulation: Preliminary evidence. Asian J Psychiatr. 2019;43:37–44.

77. Axelrod SR, Perepletchikova F, Holtzman K, Sinha R. Emotion regulation and substance use frequency in women with substance dependence and borderline personality disorder receiving dialectical behavior therapy. Am J Drug Alcohol Abuse. 2011;37:37–42.

78. Maffei C, Cavicchioli M, Movalli M, Cavallaro R, Fossati A. Dialectical Behavior Therapy Skills Training in Alcohol Dependence Treatment: Findings Based on an Open Trial. Subst Use Misuse. 2018;53:2368–85.

79.•• Wolitzky-Taylor K, Glasner S, Tanner A, Ghahremani DG, London ED. Targeting maladaptive reactivity to negative affect in emerging adults with cannabis use disorder: A preliminary test and proof of concept. Behav Res Ther. 2022;150:104032. **Assessment of the impact of Affect Management Therapy on individuals with cannabis use disorder, a study included in our systematic review.**

80. Price CJ, Thompson EA, Crowell SE, Pike K, Cheng SC, Parent S, et al. Immediate Effects of Interoceptive Awareness Training through Mindful Awareness in Body-Oriented Therapy (MABT) for Women in Substance use Disorder Treatment. Subst Abus. 2019;40:102–15.

81.•• Byllesby BM, Haney AM, Asamsama OH. Emotion Dysregulation and Substance Use Risk and Protective Factors among Veterans in Residential Treatment. Subst Use Misuse. 2023;58:930–8. **Assessment of the impact of Dialectical Behavior Therapy on veterans with substance use disorders, a study included in our systematic review.**

82. Courbasson C, Nishikawa Y, Dixon L. Outcome of Dialectical Behaviour Therapy for Concurrent Eating and Substance Use Disorders: DBT and Concurrent Eating and Substance Use Disorders. Clin Psychol Psychother. 2012;19:434–49.

83. Bradizza CM, Stasiewicz PR, Zhuo Y, Ruszczyk M, Maisto SA, Lucke JF, et al. Smoking Cessation for Pregnant Smokers: Development and Pilot Test of an Emotion Regulation Treatment Supplement to Standard Smoking Cessation for Negative Affect Smokers. Nicotine Tob Res. 2017;19:578–84.

84.•• Miller MB, Freeman L, Park CJ, Hall NA, Deroche C, Sahota PK, et al. Insomnia treatment effects among young adult drinkers: Secondary outcomes of a randomized pilot trial. Alcoholism Clin Exp Res. 2021;45:1136–48. **Assessment on the impact of cognitive behavioral therapy versus sleep hygiene on individuals with alcohol dependence, a study included in our systematic review.**

85. Price CJ, Wells EA, Donovan DM, Rue T. Mindful awareness in body-oriented therapy as an adjunct to women's substance use disorder treatment: A pilot feasibility study. J Subst Abus Treat. 2012;43:94–107.

86.•• Cavicchioli M, Movalli M, Bruni A, Terragni R, Maria Elena G, Borgia E, et al. The Initial Efficacy of Stand-Alone DBT Skills Training for Treating Impulsivity Among Individuals With Alcohol and Other Substance Use Disorders. Behav Ther. 2023;54:809–22. **Assessment of the impact of Dialectical Behavior Therapy on individuals with substance use disorders, a study included in our systematic review.**

87. Egloff B, Schmukle SC, Burns LR, Schwerdtfeger A. Spontaneous emotion regulation during evaluated speaking tasks: Associations with negative affect, anxiety expression, memory, and physiological responding. Emotion. 2006;6:356–66.

88. Driscoll D, Tranel D, Anderson SW. The effects of voluntary regulation of positive and negative emotion on psychophysiological responsiveness. Int J Psychophysiol. 2009;72:61–6.

89. Urry HL, Van Reekum CM, Johnstone T, Davidson RJ. Individual differences in some (but not all) medial prefrontal regions reflect cognitive demand while regulating unpleasant emotion. NeuroImage. 2009;47:852–63.

90. Mucha RF, Geier A, Stuhlinger M, Mundle G. Appetitive effects of drug cues modelled by pictures of the intake ritual: generality of cue-modulated startle examined with inpatient alcoholics. Psychopharmacology. 2000;151:428–32.

91. Rubio G, Borrell J, Jiménez M, Jurado R, Grüsser SM, Heinz A. Variables involved in the cue modulation of the startle reflex in alcohol-dependent patients: Startle reflex and alcoholism. Addict Biol. 2013;18:170–80.

92. Grüsser S-M, Heinz A, Raabe A, Wessa M, Podschus J, Flor H. Stimulus-induced craving and startle potentiation in abstinent alcoholics and controls. Eur Psychiatry. 2002;17:188–93.

93. Wilkins DE, Hallett M, Wess MM. Audiogenic Startle Reflex of Man and its Relationship to Startle Syndromes: A REVIEW. Brain. 1986;109:561–73.

94. Bradley MM, Cuthbert BN, Lang PJ. Pictures as prepulse: Attention and emotion in startle modification. Psychophysiology. 1993;30:541–5.

95. Morgan CA, Southwick SM, Grillon C, Davis M, Krystal JH, Charney DS. Yohimbine — facilitated acoustic startle reflex in humans. Psychopharmacology. 1993;110:342–6.

96. Beauchaine TP. Respiratory sinus arrhythmia: a transdiagnostic biomarker of emotion dysregulation and psychopathology. Curr Opin Psychol. 2015;3:43–7.

97. Butler EA, Wilhelm FH, Gross JJ. Respiratory sinus arrhythmia, emotion, and emotion regulation during social interaction. Psychophysiology. 2006;43:612–22.

98. Gentzler AL, Santucci AK, Kovacs M, Fox NA. Respiratory sinus arrhythmia reactivity predicts emotion regulation and depressive symptoms in at-risk and control children. Biol Psychol. 2009;82:156–63.

99. Back SE. Concurrent treatment of PTSD and substance use disorders using prolonged exposure (COPE): therapist guide. Oxford. New York: Oxford University Press; 2015.

100. Carroll KM. Relapse prevention as a psychosocial treatment: A review of controlled clinical trials. Exp Clin Psychopharmacol. 1996;4:46–54.

101. Cardinale EM, Subar AR, Brotman MA, Leibenluft E, Kircanski K, Pine DS. Inhibitory control and emotion dysregulation: A framework for research on anxiety. Dev Psychopathol. 2019;31:859–69.

102.• Alamos P, Williford AP, Downer JT, Turnbull KLP. How does inhibitory control predict emotion regulation in preschool? The role of individual children's interactions with teachers and peers. Dev Psychol. 2022;58:2049–63. **A study that demonstrates that inhibitory control impacts emotion regulation in the developmental stage, hence is a valid indirect measure of emotion regulation.**

103.• Institute for Cognitive & Brain Sciences, Shahid Beheshti University, Tehran, Iran., Shahrabi Farahani F, Khosrowabadi R, Institute for Cognitive & Brain Sciences, Shahid Beheshti University, Tehran, Iran., Jaafari G, Center for Complex Networks & Social Data Science, Faculty of Physics, Shahid Beheshti University, Tehran, Iran. Risk-taking Behavior Under the Effect of Emotional Stimuli Among Children and Adults. BCN. 2022;13:585–94. **A study that demonstrates that the game of dick task performance is modulated by emotion regulation, hence a valid indirect measure of emotion regulation.**

104.•• Beaulieu M, Tremblay J, Baudry C, Pearson J, Bertrand K. A systematic review and meta-analysis of the efficacy of the long-term treatment and support of substance use disorders. Soc Sci Med. 2021;285:114289. **A systematic review and meta-analysis of twelve articles that assessed the efficacy of substance use disorder treatments and the contribution of intervention length, participant demographics, and treatment parameters on success outcomes.**

105. Brecht M-L, Herbeck D. Time to relapse following treatment for methamphetamine use: A long-term perspective on patterns and predictors. Drug Alcohol Depend. 2014;139:18–25.

106. Schellekens AFA, De Jong CAJ, Buitelaar JK, Verkes RJ. Co-morbid anxiety disorders predict early relapse after inpatient alcohol treatment. Eur Psychiatry. 2015;30:128–36.

107. Shadur JM, Lejuez CW. Adolescent Substance Use and Comorbid Psychopathology: Emotion Regulation Deficits as a Transdiagnostic Risk Factor. Curr Addict Rep. 2015;2:354–63.

108. Siegel JP. Emotional Regulation in Adolescent Substance Use Disorders: Rethinking Risk. J Child Adolesc Subst Abuse. 2015;24:67–79.

109. Sloan E, Hall K, Moulding R, Bryce S, Mildred H, Staiger PK. Emotion regulation as a transdiagnostic treatment construct across anxiety, depression, substance, eating and borderline personality disorders: A systematic review. Clin Psychol Rev. 2017;57:141–63.

110.•• Watson DP, Staton MD, Dennis ML, Grella CE, Scott CK. Variation in brief treatment for substance use disorder: a qualitative investigation of four federally qualified health centers with SBIRT services. Subst Abuse Treat Prev Policy. 2021;16:58. **A study that found considerable variation in the operationalization of treatment for individuals with substance use disorders across four Federally Qualified Health Centers.**

111. McCarty D, Braude L, Lyman DR, Dougherty RH, Daniels AS, Ghose SS, et al. Substance Abuse Intensive Outpatient Programs: Assessing the Evidence. PS. 2014;65:718–26.

112.• Griffin KW, Williams C, Botvin CM, Sousa S, Botvin GJ. Effectiveness of a hybrid digital substance abuse prevention approach combining e-Learning and in-person class sessions. Front Digit Health. 2022;4:931276. **Assessed the impact of health education intervention on prevention of substance abuse among middle schoolers.**

113. Griffin KW, Botvin GJ. Evidence-Based Interventions for Preventing Substance Use Disorders in Adolescents. Child Adolesc Psychiatr Clin N Am. 2010;19:505–26.

114. Demarzo MMP, Montero-Marin J, Cuijpers P, Zabaleta-del-Olmo E, Mahtani KR, Vellinga A, et al. The Efficacy of Mindfulness-Based Interventions in Primary Care: A Meta-Analytic Review. Ann Fam Med. 2015;13:573–82.

115. Sapthiang S, Van Gordon W, Shonin E. Health School-based Mindfulness Interventions for Improving Mental Health: A Systematic Review and Thematic Synthesis of Qualitative Studies. J Child Fam Stud. 2019;28:2650–8.

116. Mesmer-Magnus J, Manapragada A, Viswesvaran C, Allen JW. Trait mindfulness at work: A meta-analysis of the personal and professional correlates of trait mindfulness. Hum Perform. 2017;30:79–98.

117. Singh SK, Gorey KM. Relative effectiveness of mindfulness and cognitive behavioral interventions for anxiety disorders: Meta-analytic review. Soc Work Ment Health. 2018;16:238–51.

118. Sancho M, De Gracia M, Rodríguez RC, Mallorquí-Bagué N, Sánchez-González J, Trujols J, et al. Mindfulness-Based Interventions for the Treatment of Substance and Behavioral Addictions: A Systematic Review. Front Psych. 2018;9:95.

119.•• Goldstein RZ. Neuropsychoimaging Measures as Alternatives to Drug Use Outcomes in Clinical Trials for Addiction. JAMA Psychiatry. 2022;79:843. **Demonstrates the importance of neuropsychoimaging for a more objective assessment of craving, salience attribution, value assignment, and emotion regulation.**

120.• Garke MÅ, Isacsson NH, Sörman K, Bjureberg J, Hellner C, Gratz KL, et al. Emotion dysregulation across levels of substance use. Psychiatry Res. 2021;296:113662. **A study that demonstrated a clear positive association between substance use and frequency and emotion dysregulation.**

121. Wolff S, Holl J, Stopsack M, Arens EA, Höcker A, Staben KA, et al. Does Emotion Dysregulation Mediate the Relationship between Early Maltreatment and Later Substance Dependence? Findings of the CANSAS Study. Eur Addict Res. 2016;22:292–300.

122.• Hitch AE, Brown JL, DiClemente RJ. Interpersonal abuse and alcohol use among African American young women: the mediating role of emotion dysregulation. J Ethn Subst Abuse. 2023;22:433–52. **A study demonstrating that emotion dysregulation was an important mediating factor between history of abuse and substance abuse in African American women.**

123.• Lozano-Madrid M, Clark Bryan D, Granero R, Sánchez I, Riesco N, Mallorquí-Bagué N, et al. Impulsivity, Emotional Dysregulation and Executive Function Deficits Could Be Associated with Alcohol and Drug Abuse in Eating Disorders. JCM. 2020;9:1936. **Higher impulsive behavior demonstrated alcohol and/or drug abuse symptoms.**

124.• . Nakao M, Shirotsuki K, Sugaya N. Cognitive–behavioral therapy for management of mental health and stress-related disorders: Recent advances in techniques and technologies. BioPsychoSocial Med. 2021;15:16. **Based on 345 articles on the impact of cognitive behavioral therapy, the intervention is effective for psychiatric ailments like anxiety, ADHD, and eating disorders.**

125. Naeem F, Farooq S, Kingdon D. Cognitive behavioural therapy (brief versus standard duration) for schizophrenia. Cochrane Schizophrenia Group, editor. Cochrane Database of Systematic Reviews. 2015; https://doi.org/10.1002/14651858.CD010646.pub3

126.• Curtiss JE, Levine DS, Ander I, Baker AW. Cognitive-Behavioral Treatments for Anxiety and Stress-Related Disorders. FOC. 2021;19:184–9. **Assessment of the impact of cognitive behavioral therapy on anxiety disorders and stress-related disorders.**

127. Jason LA, Salina D, Ram D. Oxford Recovery Housing: Length of Stay Correlated with Improved Outcomes for Women Previously Involved with the Criminal Justice System. Subst Abus. 2016;37:248–54.

128. Turner B, Deane FP. Length of stay as a predictor of reliable change in psychological recovery and well being following residential substance abuse treatment. TC. 2016;37:112–20.

129. Bahorik AL, Leibowitz A, Sterling SA, Travis A, Weisner C, Satre DD. Patterns of marijuana use among psychiatry patients with depression and its impact on recovery. J Affect Disord. 2017;213:168–71.

130.• Urits I, Gress K, Charipova K, Li N, Berger AA, Cornett EM, et al. Cannabis Use and its Association with Psychological Disorders. Psychopharmacol Bull. 2020;50:56–67. **There is a**

**demonstrated increased risk for psychosis symptoms and anxiety in individuals with cannabis use disorder.**

131.• Kancherla N, Jeyanthi K, Abbas R, Sathi TCR, Upadhyay A, Garlapati SP. Cannabis associated mental health effects: A review. J Pharm Bioall Sci. 2021;13:943. **A review of studies that demonstrates that cannabis use can increase the risk for anxiety, depression, psychosis, paranoia, hallucinations, disorientation, bipolar disorder, delusions, and et cetera.**

132.•• . Wisener M, Khoury B. Specific emotion-regulation processes explain the relationship between mindfulness and self-compassion with coping-motivated alcohol and marijuana use. Addict Behav. 2021;112:106590. **From data analysis of two separate studies, researchers found mindfulness and self-compassion to be important mediating variables that demonstrated better emotion regulation strategies and lowered the likelihood of coping with substances.**

133. Zimmermann K, Walz C, Derckx RT, Kendrick KM, Weber B, Dore B, et al. Emotion regulation deficits in regular marijuana users. Hum Brain Mapp. 2017;38:4270–9.

134. Maust DT, Lin LA, Blow FC. Benzodiazepine Use and Misuse Among Adults in the United States. PS. 2019;70:97–106.

135.• Colizzi M, Meneghin N, Bertoldi A, Lugoboni F. Further evidence on the interplay between benzodiazepine and Z-drug abuse and emotion dysregulation. J Affect Disord Rep. 2021;6:100234. **This study demonstrates that individuals with higher benzodiazepine dependence exhibit greater emotion dysregulation.**

136.• Greenwald MK, Moses TEH, Lundahl LH, Roehrs TA. Anhedonia modulates benzodiazepine and opioid demand among persons in treatment for opioid use disorder. Front Psychiatry. 2023;14:1103739. **Benzodiazepine misuse is associated with greater self-report affective dysregulation.**

137. Chapman AL. Dialectical behavior therapy: current indications and unique elements. Psychiatry (Edgmont). 2006;3:62–8.

138. Denny BT, Inhoff MC, Zerubavel N, Davachi L, Ochsner KN. Getting Over It: Long-Lasting Effects of Emotion Regulation on Amygdala Response. Psychol Sci. 2015;26:1377–88.

139.• Yang M, Deng X, An S. The Immediate and Lasting Effect of Emotion Regulation in Adolescents: An ERP Study. IJERPH. 2021;18:10242. **An EEG study that demonstrated the long-lasting effect of cognitive reappraisal on adolescents.**

140.• Hermann A, Neudert MK, Schäfer A, Zehtner RI, Fricke S, Seinsche RJ, et al. Lasting effects of cognitive emotion regulation: neural correlates of reinterpretation and distancing. Soc Cogn Affect Neurosci. 2021;16:268–79. **A study that demonstrated the long-lasting effect of cognitive reappraisal when looking at a series of pictures containing aversive stimuli.**

141. Zhang Q, Li L, Smith M, Guo Y, Whitlock G, Bian Z, et al. Exhaled carbon monoxide and its associations with smoking, indoor household air pollution and chronic respiratory diseases among 512 000 Chinese adults. Int J Epidemiol. 2013;42:1464–75.

142. Madhubala V. Serum Carbohydrate Deficient Transferrin as A Sensitive Marker in Diagnosing Alcohol Abuse: A Case – Control Study. JCDR. 2013; https://doi.org/10.7860/JCDR/2013/5137.2726.

143. Brenner PS, DeLamater J. Lies, Damned Lies, and Survey Self-Reports? Identity as a Cause of Measurement Bias. Soc Psychol Q. 2016;79:333–54.

144. Zhang W, Fagan SE, Gao Y. Respiratory Sinus Arrhythmia Activity Predicts Internalizing and Externalizing Behaviors in Non-referred Boys. Front Psychol. 2017;8:1496.

145.• Malesza M. Relationship between emotion regulation, negative affect, gender and delay discounting. Curr Psychol. 2021;40:4031–9. **Demonstration that negative affect is positively correlated with delayed discounting.**

146.• Weinsztok S, Brassard S, Balodis I, Martin LE, Amlung M. Delay Discounting in Established and Proposed Behavioral Addictions: A Systematic Review and Meta-Analysis. Front Behav Neurosci. 2021;15:786358. **78 studies demonstrated that steeper reward discounting is associated with behavioral addiction.**

147. Flanagan JC, Korte KJ, Killeen TK, Back SE. Concurrent Treatment of Substance Use and PTSD. Curr Psychiatry Rep. 2016;18:70.

148. Back SE, Brady KT. Anxiety Disorders with Comorbid Substance Use Disorders: Diagnostic and Treatment Considerations. Psychiatr Ann. 2008;38:00485713-20081101–01.

149.• . Hunt GE, Malhi GS, Lai HMX, Cleary M. Prevalence of comorbid substance use in major depressive disorder in community and clinical settings, 1990–2019: Systematic review and meta-analysis. J Affect Disord. 2020;266:288–304. **48 studies demonstrate that substance use disorders are highly prevalent in individuals with major depressive disorders.**