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Online Interventions for Cannabis Use Among Adolescents and Young Adults: Systematic Review and Meta-analysis

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Abstract

Background. Young people present high rates of cannabis use, abuse, and dependence. The United Nations estimates that roughly 3.8% of the global population aged 15–64 years used cannabis at least once in 2017. Cannabis use in young people may impair cognitive skills, interfere with learning, impact relationships, and lead to long term behavioural and psychological consequences. Online cannabis interventions (OCI) are increasingly popular, but their dissemination is not often supported by empirical evidence.

Aim. To systematically compile and analyse the effectiveness of OCI for the reduction of cannabis use among adolescents and young adults (AYA).

Methods. Pooled effect sizes of cannabis use between treatment and control groups were estimated. For each comparison, Hedge's *g* was calculated using a random effects model.

Results. The search strategy yielded 4,531 articles. Of those, a total of 411 articles were retrieved for detailed evaluation resulting in 17 eligible studies (*n*=3,525). Analyses revealed that online interventions did not significantly reduce cannabis consumption (Hedge's *g*=-0.061, 95% CI [-0.363]-[-0.242], *p*=0.695) and high heterogeneity was noted (*Q*=191.290). More recent studies using structured interventions, daily feedback, AYA centred designs, and peer support, specifically targeting CU seemed to have positive effects to address CU in this population.

Conclusions: The lack of positive outcomes suggests that more specific and targeted interventions may be necessary to promote cannabis-related behavioural change among young people. These targeted interventions may include structured CU modules, daily feedback, peer support for increased adherence, user-centred design procedures, and input from key stakeholders such as families and service providers.

Key words: cannabis use, online intervention, youth, adolescence, meta-analysis

Running title: Online interventions for cannabis use

1. Introduction

Cannabis is the most widely used drug worldwide after tobacco and alcohol (United Nations, 2019), and adolescents and young adults (AYA) are among the highest users of cannabis in North America (Center for Behavioral Health Statistics and Quality, 2016; Wadsworth & Hammond, 2018). Particularly, there has been a clear increase of cannabis consumption in Canada in the last decade, coinciding with a favoured context for cannabis legalization (Bahji & Stephenson, 2019; Lake et al., 2019), positioning the US and Canada as the countries with the highest rates of cannabis use disorder (Degenhardt et al., 2018). In Europe it is estimated that 17.1 million young people (aged 15–34) used cannabis in a twelve-month period (European Monitoring Centre for Drugs and Drug Addiction, 2017). The incidence of substance use disorders (SUD) peaks between adolescence and young adulthood (Palmer, et al. 2009). Cannabis use is particularly prevalent among youth, and age of initiation is usually lower than for other drugs (Polanczyk, Salum, Sugaya, Caye, & Rohde, 2015).

Adolescence is a unique developmental period, marked by rapid development between childhood and adulthood involving complex social, biological, and psychological changes (Squeglia, Jacobus, & Tapert, 2009). Almost 75% of mental disorders first emerge between the ages of 15 and 25. Although the most significant qualitative changes in brain maturation have been found to occur from childhood to adolescence, recent evidence suggests that specialization of brain processes continues

into the 30s, supporting both cognitive and motivational systems (Hickie, Davenport, Pirkis, Blashki, & Groom, 2004; Kessler et al, 2005; Kim-Cohen et al, 2003; Bonnie, Stroud, & Breiner, 2015). Cannabis use (CU) during this critical developmental period may lead to structural, functional, and histological brain alterations which in turn underpin longer-term behavioral and psychological consequences (i.e., impaired cognitive skills, interference with learning, relationships, and driving skills) (Blest-Hopley, Colizzi, Giampietro, & Bhattacharyya, 2020; Brady & Li, 2014; Volkow, Baler, Compton, & Weiss, 2014). Moreover, adolescents who use cannabis daily are at a higher risk for school failure, psychiatric comorbidity, and suicide attempts (Silins et al., 2014).

A relationship between CU and mental disorders has also been demonstrated. Adults with a severe mental illness report double the lifetime prevalence of CU than the general population (Skalisky et al., 2017). More specifically, the evidence associates tetrahydrocannabinol (THC) with an increased risk of psychosis in a dose-response manner, with heavy cannabis users four times and daily cannabis users twice as likely to develop psychosis (Marconi, Di Forti, Lewis, Murray, & Vassos, 2016). Additionally, the average age of onset of psychosis was six years earlier among daily users of high-potency cannabis products compared to those with a first-episode psychosis who never used cannabis (Di Forti et al., 2014). Moreover, CU in young people with psychosis has been associated with poorer functional recovery over time (González-Blanch, et al. 2015). In a recent meta-analysis, Gobbi et al. (2019) demonstrated that CU in adolescence is associated with an increased risk of developing major depression in young adulthood, suicidal ideation, and suicidality. Therefore, adolescence and young

adulthood are critical times for addressing emerging mental health conditions and cannabis use (Reid, Morton, Garcia-Reid, Peterson, & Yu, 2013).

Given that AYA is a critical developmental period in which young people are setting themselves up for the future, it is important to evaluate the effectiveness of interventions aimed to reducing CU in AYA. A recent systematic review showed that the most effective interventions for CU reduction were cognitive-behavioural therapy (CBT), motivational enhancement therapy (MET), and their combination (Gates, Sabioni, Copeland, Le Foll, & Gowing, 2016). Unfortunately, young people are often reluctant to seek professional help (Slade et al., 2009). Consequently, despite several decades of efforts to identify effective interventions to prevent and reduce youth substance use, few AYAs receive treatment (Silvers, Squeglia, Rømer Thomsen, Hudson, & Feldstein Ewing, 2019). Moreover, those who receive treatment show low rates of engagement and retention (i.e., treatment attendance and regular communication with providers (Bagley, Hadland, & Yule, 2021). Factors associated with low rates of treatment access and retention amongst young people include lack of information about treatment resources, reticence to access mental health services, and stigma (Gulliver, Griffiths, & Christensen, 2010).

Communication technologies provide a promising opportunity for improving, and even transforming intervention delivery in SUDs, addressing issues of adherence (Ben-Zeev, 2012). A recent metanalysis demonstrated the effectiveness of online interventions compared to control groups, to fill mental healthcare gaps (Fu, Burger, Arjadi & Bockting, 2020). During the COVID-19 pandemic, digital psychological interventions have been highlighted as increasingly relevant for addressing mental health problems (Torous, Jan Myrick, Rauseo-Ricupero & Firth, 2020). This is

particularly pertinent for mitigating the potential impacts of social isolation, quarantine and socioeconomic consequences (Brooks et al., 2020), including increased initiation and frequency of substance use (Czeisler et al. 2020), in the COVID-19 context.

The use of the Internet is pervasive and most young people have ready access to mobile phones (Pew Research Center, 2014; Lenhart et al., 2015). Therefore, technology is well integrated in the day-to-day life of AYA (Hauk, 2011; O'Keeffe & Clarke-Pearson, 2011). Moreover, interventions delivered via the Internet have been posited as a means of overcoming many of the traditional barriers to accessing health services such as accessibility, wait lists, lack of trained staff, lack of time and time-limited support (Tait, Spijkerman, & Riper, 2013; Alvarez-Jimenez et al., 2020; Alvarez-Jimenez et al., 2021). In particular, Internet interventions can be especially relevant for SUDs because they are often anonymous, low-cost or free, available whenever required, and may have the key advantage of balancing flexibility with fidelity (Tait et al., 2013; Schueller, Stiles-Shields, & Yarosh, 2017; Becker, Hernandez, Spirito, & Conrad, 2017).

Accordingly, there have been efforts to adapt effective face-to-face CU interventions to a web- or computer-based format, in order to provide a low cost and easily disseminated treatment (Elliott, Carey, & Vanable, 2014). In recent years, several studies have been published focusing on the efficacy of online interventions for cannabis reduction (Shrier et al. 2018; Copeland, Rooke, Rodriquez, Norberg, & Gibson 2017; Mason, Zaharakis, Russell, & Childress, 2018; Sugarman, Campbell, Iles, & Greenfield, 2017). Three previous meta-analyses have reported on the efficacy of online interventions in reducing cannabis consumption (Boumparis, Schulte, & Riper, 2019; Hoch, Preuss, Ferri, & Simon, 2016; Olmos, Tirado-Muñoz, Farré, & Torrens, 2018;

Tait et al., 2013). Most of these online interventions have been based on cognitive behavioral therapy (CBT) programs and motivational interviewing (MI). Tait et al. (2013) found a small but significant overall effect size (g=0.16) in favor of computer-based interventions in reducing the use of cannabis in the adult population. Nevertheless, they included programs for non-addicted populations, recruited through online platforms, and focused mostly on prevention. In addition, they included both randomized controlled trials (RCTs) and non-RCTs, without age exclusion criteria. Some of these characteristics could have limited the generalisability of their conclusions and results. Hoch et al. (2016) found a small effect size in favour of online interventions, with the largest treatment effects reported for interventions both supported by trained therapists and including diary feedback. This meta-analysis included four studies, with older adolescents and adults in non-clinical settings. Olmos et al. (2018) reported that computerized interventions reduced the frequency of CU and other substances. However, while all included studies were RCTs, only two reported significant results from the nine analysed in the meta-analysis. Finally, Boumparis et al. (2019) included both prevention and intervention programs. Results showed that prevention interventions produced a larger pooled effect size for CU reduction compared with treatment interventions.

Since the most recent meta-analysis (Boumparis, et al. 2019), several new studies have been published and the findings remain inconsistent. Further, no meta-analyses to date have focused on treatment of CU in AYA specifically. Therefore, the objectives of this study are:

1) To systematically review online cannabis interventions (OCI) among AYA.

2) To describe OCI for AYA.

3) To analyse the effectiveness of online CU interventions for AYA (group-control comparisons).

2. Method

This review was carried out in line with the PRISMA statement for reporting systematic reviews (Liberati et al., 2009) (See supplementary Material, eTable 1).

2.1. Data sources

Systematic bibliographic searches were performed to find relevant English and non-English, peer-reviewed, studies with samples reporting a mean age of 15 to 30 years. The vocabulary and syntax of the strategy were tailored to allow for optimal electronic searching of the following databases: Pubmed, The Cochrane Library, Scopus, Web of Science, and Embase, all from inception to February 2021. No restrictions were applied for languages. The abstracts, titles, and keywords of studies were searched using combination of the following terms: (computer OR cyber OR electronic OR email OR e-mail OR internet OR net OR online OR virtual OR web OR www OR "social media" OR "social network" OR blog OR forum OR mobile OR smartphone OR technology based-treatments OR computer based-intervention OR eHealth) AND (adolescen* OR young OR youth* OR teen*) AND (cannabi* OR marijuana OR marihuana OR hashish) AND (substance use OR substance abuse OR dependence OR addiction) AND (treatment OR intervention).

Additional articles were identified by hand searching the references of retrieved articles and previous reviews. When there was not sufficient data available, authors were contacted for the provision of the necessary additional data.

2.2. Study selection and inclusion criteria

Considered for inclusion criteria were: 1) RCTs studies; 2) online interventions examining the efficacy of user-led, web- or mobile-based programs; 3) interventions specifically targeting CU, abuse or dependence or interventions addressing substance usage and reporting on CU as (one of) the outcome measure(s); 4) adolescents and young adults (mean age from 15 to 30 years); 5) quantitative outcomes (frequency and/or quantity). We defined AYA as participants being aged 15-30. While youth is typically considered to include young people aged 15-24, we opted for being more inclusive in our definition of youth given that online interventions for CU in AYA is a nascent field. This is in keeping with the age range used in several early intervention services for psychosis around the world (Albert et al., 2017; MacDonald et al., 2018).

Online interventions were defined as web or mobile-based interventions including one or more of the following components: peer-to-peer contact, patient-to-expert communication, or interactive psychoeducation/therapy to reduce CU. Mobile-based interventions were defined as interventions delivered via mobile phones using SMS (text), or MMS mobile, or native/web applications. Interventions could include either self-directed as well as online interventions incorporating human support. Studies investigating traditional face-to-face- therapy delivered via teleconference of mobile phones and studies recruiting less than 30 participants were excluded (Alvarez-Jimenez

et al., 2014). Therefore, under Online Cannabis Interventions (OCIs), we included the previously described categories: 1) online interventions and 2) mobile-based interventions for reducing cannabis. Moreover, studies describing interventions that were implemented by CD-ROM system, or were not delivered as an online program, as well as prevention programs were excluded. Studies reporting self reported subjective measures of CU (i.e., number of time periods high) were excluded. Finally, book chapters and poster presentations were also excluded.

One reviewer (AB) assessed all potentially relevant articles for inclusion, and retrieved articles were independently assessed by two reviewers (AB and CDB). Any disagreements were resolved through discussion. If necessary, authors were contacted to determine eligibility against inclusion criteria.

2.3 Data extraction and analysis

Two reviewers (AB and OSE) independently extracted relevant data. The following data were extracted from the selected studies: (1) Characteristics of the study (i.e., study aims, year of publication, country of origin, study design, randomization, blinding, therapist qualification, number of participants, type of outcome measures (including pre and post tests used), follow up time in weeks if applicable and research findings in relation to study aims such as clinical outcome); (2) Characteristics, nature, and purpose of the online or mobile-based intervention and comparison groups (if applicable); (3) Intervention setting (i.e., hospital-based/controlled environment, schools, universities, primary health resource, home), (4) Characteristics of the participants: gender, mean age, mean use of cannabis (baseline data); (5) Characteristics

of the comparison group: number of participants, type of control, type and length of treatment.

In addition, data pertaining to the following domains were extracted and reported: (1) user's engagement with, and use of, the OCI; (2) Dropout rates; (3) CU at different assessment timepoints (baseline, follow-up); (4) variables associated with use of the intervention; (5) comorbid diagnosis and substance abuse of other substances.

Interventions were categorized according to delivery format into either web-based (i.e., designed to be accessed mainly via computers) or mobile-based interventions (designed to be accessed through mobile devices). To minimize the risk of reporting bias, efforts were made to extract and report both positive and negative findings from the included studies. Any discrepancies were resolved by consensus.

2.4 Assessment of methodological quality procedures

Three reviewers (AB, HT and CDB) independently assessed methodological quality, by means of the Cochrane Collaboration 'assessed risk of bias' (Higgins & Green, 2011).

3. Data analysis

We calculated the effect size for each comparison between intervention group and control group for CU. Cohen's *d* was calculated for CU using means and standard deviations. As suggested by Morris & DeShon (2002) and Becker (1988), we used the following formulas (Thomas & Zimmer-Gembeck, 2007):

d_i=($M_{i\text{-post}}$–$M_{i\text{-pre}}$) / $SD_{i\text{-pre}}$

d_c=($M_{c\text{-post}}$–$M_{c\text{-pre}}$) / $SD_{c\text{-pre}}$

d_{oci}=d_t–d_c

where, d_t is the intervention group effect size; d_c is the control group effect size; d_{oci} is the OCI final effect size; $M_{t\text{-post}}$ and $M_{c\text{-post}}$ are the mean values for the intervention and control group, respectively; finally, $SD_{t\text{-pre}}$ and $SD_{c\text{-pre}}$ are the pre-test standard deviation for the intervention and control groups, respectively.

Therefore, we calculated Cohen's *d* for the intervention group (d_i) and the control group (d_c). Each effect size (*d*) represents the difference of the number of standard deviations between the means of the pre- and post-intervention of each group. Finally, we calculated the main effect size by estimating the difference between d_i and d_c (d_{oci}). When variances are not similar over time, the use of pre-test standard deviation is a preferred option to using the pooled standard deviation, so the resulting effect size would be unaffected by the intervention (Morris & DeShon, 2002; Morris, 2000). The main effect size can be interpreted as the number of standard deviations the intervention group changed compared to the control group. If d_{oci} is positive, it indicates a larger effect in reducing CU in the control group compared with the intervention group. We used Comprehensive Meta-Analysis Software (CMA) version 2.2 (Borenstein, Hedges, Higgins, & Rothstein, 2006) to pool the standardized difference in means. For each comparison, Hedge's *g*, a corrected Cohen's *d*, was calculated per outcome. The resulting effect size, Hedge's *g* is an effect size that corrects for small sample sizes employing the correction factor *J* [*J* =1–(3/(4**df*-1))]. We followed Lipsey & Wilson's (1993) indications to interpret the data, whereby a small effect size is a Hedge's *g* between 0.00 to 0.32, a moderate effect is between 0.33 to 0.55 and a large effect is between 0.56 to 1.20. Finally, because the studies included differed in treatment

modality, sample, and methodology, we used random-effects models, which account for within-study error and variation in the true effects across studies (Borenstein, Hedges, Higgins, & Rothstein, 2009). To further assess the robustness of our results, sensitivity analyses were performed to examine statistical heterogeneity and effect of different follow-up periods. Finally, due to the wide range of control groups, we performed exploratory sensitivity analyses to examine differences by type of control group, that is, active control, assessment only, assessment and feedback, psychoeducation and wait list.

3.1 Heterogeneity, publication bias, and sensitivity

Heterogeneity was calculated using the *Q* statistic by testing the null hypothesis that the true effect size is the same in all studies (Borenstein et al., 2009). If the *Q* statistic is significant, the heterogeneity assumption is confirmed. We also estimated the I^2 statistic, which indicates the percentage of total variation across studies that are explained due to heterogeneity. Values of 25%, 50%, and 75% can be considered low, moderate, and high, respectively (Higgins, Thompson, Deeks, & Altman, 2003). We also assessed the variance of true effect sizes using T^2 and the standard deviation of true effects using *T*. Finally, we tested publication bias by entering data in a funnel graph (plot of dispersion between study effect and a measure of study size). Publication bias is indicated by an asymmetrical inverted distribution of the studies about the mean effect size represented in the funnel (Borenstein et al., 2009). Therefore, if publication bias exists, it is expected to see the "small study-effect" (Sterne, Gavaghanb, & Eggera, 2000), or a trend for the small studies to show a larger treatment effect. We used the trim-and fill method (Duval & Tweedie, 2000) to test the number of studies missing

from the meta-analysis. Missing studies fall where it is needed in order to make the plot symmetrical.

4. Results

The electronic search yielded 4,531 studies, of which 411 were retrieved for detailed evaluation. Of these, 394 were excluded on the basis of method or sampling characteristics, leaving a total of 17 articles included in the study. Figure 1 illustrates the study retrieval and selection strategy.

Insert Figure 1

4.1. Description of studies contributing to data analysis

The 17 studies included involved 3,525 participants at baseline (2,028 in the treatment conditions and 1,497 in the control conditions). Table 1 describes the characteristics of the studies. Studies samples ranged from *n*=30 to *n*=458 participants. Participants' mean age ranged from 16.3 to 29.8, and 47.6% were female. Twelve studies reported CU as the main outcome (Buckner, Zvolensky, Lewis, Buckner, & Lewis, 2020; Elliott, et al. 2014; Jacobus et al. 2018; Lee, Neighbors, Kilmer, & Larimer, 2010; Mason et al., 2018a, 2018b; Schaub et al. 2015; Shrier et al., 2018; Sinadinovic, et al., 2020; Tossman, Jonas, Tensil, Lang, & Strüber, 2011; Walton et al., 2013; Walukevick-Dienst, Neighbors, & Buckner, 2019) while the other five also include use of other drugs as an outcome. Becker, Haug, Sullivan and Schaub (2014)

reported on cannabis and tobacco use; Hernandez, Cancilliere, Graves, & Spirito (2020) on cannabis and alcohol use; Christoff & Boerngen-Lacerda (2015) on cannabis, alcohol, tobacco and other drugs; and finally, Gryczynski et al. (2021) and Thompson, Aivadyan, Stohl, Aharonovich, & Hasin (2020) on cannabis, alcohol and sexual risk behaviours. Five studies reported alcohol as a secondary outcome (Elliott et al. 2014; Jacobus et al. 2018; Schaub et al. 2015; Buckner et al. 2020; and Sinadinovic, et al. 2020), and two studies (Walton et al., 2013 and Shrier et al. 2018) on alcohol and other substance use. All studies reported post-treatment effects and follow-up data.

Insert Table 1

Characteristics of the interventions

Interventions included eleven studies examining motivational interviewing (Becker et al., 2014; Lee et al., 2010; Walton et al., 2013; Christoff & Boerngen-Lacerda, 2015; Mason et al., 2018a, 2018b; Gryczynski et al., 2021; Hernandez et al., 2020; Buckner et al., 2020; Thompson, et al., 2020; Walukevic-Dienst et al., 2019), one study evaluating counselling combined with MI (Shrier et al., 2018), one study evaluating counselling combined with MI and CBT (Schaub et al., 2015), another providing psychoeducation based on MI and CBT (Sinadinovic, et al., 2020), and one study each using counselling (Tossmann et al., 2011), psychoeducation (Elliott et al., 2014), and cognitive training (Jacobus et al., 2018) as shown in Table 2.

Insert Table 2

Becker et al. (2014) evaluated the effectiveness of three web-based interventions to enhance tobacco and cannabis co-smokers' readiness to quit both. These interventions were focused on Personalized Normative Feedback (PNF). In a similar way, the intervention groups in the studies by Lee et al. (2010), Walton et al. (2013), Walukevic-Dienst et al. (2019), and Buckner et al. (2020), received personalized feedback based on MI approach within brief interventions delivered by a computer. Christoff & Boerngen-Lacerda (2015), evaluated the efficacy of Alcohol, Smoking, and Substance Involvement Screening Test (ASSIST), a Motivational Brief Intervention (MBIc) based on MI principles. Similarly, Gryczynsky et al. (2020) and Thompson et al. (2020) analysed and compared computer brief interventions based on MI. Finally, Shrier et al. (2018) evaluated the effectiveness of MOMENT, a mobile app with motivational messages, employing momentary and personal reports.

Three studies combined counselling and MI, (Mason et al., 2018a, 2018b; Schaub et al., 2015). Mason et al. (2018a, 2018b) tested the efficacy of text-message delivered Peer Network Counselling (PNC-txt) with young adults; and Schaub et al. (2015) evaluated a web-based self-help intervention using automated motivational emails, with and without chat counselling. The intervention evaluated by Sinadinovic et al. (2020) combined principles of psychoeducation, CBT, and MI, organized into 13 modules involving text-messages, recommendations, and personal feedback.

Tossman et al. (2011) evaluated a program based on counselling and presented a solution-focused approach based on self-regulation and self-control. Both Elliott et al. (2014) and Hernandez et al. (2020) applied a psychoeducational program called The Marijuana Echeckup to go (e-TOKE) designed to prompt self-reflection and consideration of decrease use. Finally, Jacobus et al. (2018) used a cognitive intervention and tested a computerised cognitive bias modification paradigm.

As depicted in Table 2, recruitment methods consisted of a national drug specialized website (Tossmann et al. 2011; Sinadinovic et al. 2020), local newspapers, radio and TV (Becker et al., 2014), universities (Lee et al., 2010; Christoff & Boerngen-Lacerda, 2015; Walukevic-Dienst et al. 2019; Buckner et al. 2020), community health clinics (Walton et al., 2013; Gryczynski et al. 2021), inner crisis shelters (Thomspon et al. 2020), and family court systems (Hernandez et al. 2020). CU was assessed by means of frequency of use in last 30 days (Tossmann et al., 2011; Elliott et al., 2014), grams consumed in last 30 days (Tossmann, et al., 2011), days of use in the last 90 days (Lee, 2010) or CU-related questions from the ASSIST (Christoff & Boerngen-Lacerda, 2015; Gryczynski et al., 2021), the Marijuana Use Form (MUF) (Walukevich-Dienst et al., 2019), or the Timeline FollowBack (TLFB) (Buckner et al., 2020; Sinadinovic et al., 2020; Gryczynski et al. 2021).

Methodological quality of the studies

Figure 2 illustrates that 94% of the studies were rated at low risk regarding attrition bias (i.e., incomplete outcome data) and 82% of the studies reached a low risk regarding selection bias (i.e., random sequence generation). Low risk in allocation concealment was attained by 76% of the studies, and low risk in selective outcome reporting was attained by 71% of the studies. In the other two domains, the studies attained either an unclear or high risk.

Insert Figure 2

4.2. Meta-analytical results

Usable data for meta-analysis could be retrieved for all but two (Buckner et al., 2020; Shrier et al., 2018) of the 17 studies included. A summary of effect sizes is shown in Figure 3. We found a non-significant effect of OCI on reducing CU (g=-0.061, 95% CI [-0.363]-[-0.242], p=0.695) and important heterogeneity was noted (Q=191.290, df=14, p=0.000, I^2=92.681, T^2=0.317, T=0.563). Becker et al. (2014) reported on two OCI interventions (PNF and MI). Results remained unchanged when pooling PNF vs. MI compared to the control group (web-based psychoeducation) in the overall meta-analysis (See Supplementary Material, eFigure 1). The study reported same mean and standard deviation for CU for both interventions (both at baseline and follow-up measurements). Similarly, Schaub et al. (2015) reported on two OCI interventions (e.g., a web-based self-help intervention with chat – Can Reduce, and the same intervention without chat). Overall results remained unchanged when pooling the Can Reduce without chat vs. Can Reduce compared to the control group (wait list). The authors found small but significant differences between Can Reduce and the control group and between Can Reduce vs the Can Reduce without chat. As is shown in Schaub (2015), they observed one trend level difference in the weekly quantity of standard joints in the comparison to the self-help with chat group versus wait list. However, there were no differences between the non-chat intervention and the control group.

Insert Figure 3

Visual analysis of the plot showed three clear outliers, one reporting a significant negative effect (g=-1.995, 95% CI [-2.329]-[-1.662], p=0.000) and two providing a significant positive effect (g=0.5468, 95% CI [-0.106]-[1.198], p=0.101; g=1.258, 95% CI [0.886]-[1.630], p=0.000). Exclusion of these studies (Christoff &

Boerngen-Lacerda, 2015; Hernandez et al., 2019; Tossmann et al., 2011) eliminated statistical heterogeneity (Q=10.115, df=11, p=0.520, I^2=0.000, T^2=0.000, T=0.000) but did not change the overall effect size (g=-0.032, 95% CI [-0.116]-[0.052], p=0.462) (see Supplementary Material, eFigure 2a and eFigure 2b). Tossman et al. (2011) reported a strong intervention effect. Interestingly, this study was the only one that used qualified psychotherapists within the online intervention, involved a highly structured, 50-day intervention, recruited subjects from a European website already focused on drug-problems (highly motivated subjects), focussed exclusively on CU reduction, and the comparison group was wait list group. Conversely, Christoff & Boerngen-Lacerda (2015) reported a statistically significant negative effect. This study tested the shortest and most unstructured intervention (one session of 20) which focussed on multiple substance use behaviours (i.e., reduction of CU, tobacco use, alcohol use and others), recruited college students in Brazil, and provided participants feedback following assessment as a control condition. Hernandez et al. (2019) also reported a statistically significant negative effect. This study recruited participants from a family court facility, and the comparison group was a therapist-delivered MI (active control group).

Furthermore, we performed sensitivity analysis including those studies reporting a 6-month follow-up measurement of outcome (Gryczynski et al., 2021; Hernandez et al., 2019; Lee et al., 2010; Walton et al., 2013). A summary of effect sizes is shown in Figure 4. Similar results were obtained; we also found a non-significant effect of OCI on reducing CU (g=-0.500, 95% CI [-0.359]-[0.259], p=0.751) and important heterogeneity was noted (Q=195.314, df=14, p=0.000, I^2=92.832, T^2=0.332, T=0.576). Visual analysis of the plot showed three clear outliers. Exclusion of three studies (Christoff & Boerngen-Lacerda, 2015; Hernandez et al., 2019; Tossmann et al., 2011) eliminated heterogeneity (Q=12.686, df=11, p=0.323, I^2=12.452, T^2=0.003, T=0.058)

due to study characteristics previously described, while results remained unchanged (g=-0.026, 95% CI [-0.119]-[0.067], p=0.586) (see Supplementary Material, eFigure 3a and eFigure 3b).

Insert Figure 4

Finally, we performed exploratory subgroup analysis to examine differences between studies by type of control group: active control (Gryczynski et al., 2021; Hernandez et al., 2019; Jacobus et al., 2018; Thompson et al., 2020), assessment only (Elliott et al., 2014; Lee et al., 2010), assessment + feedback (Christoff & Boerngen-Lacerda, 2015; Walukevich-Dienst et al., 2019), psychoeducation (Becker et al., 2014; Tossmann et al., 2011), or wait list (Mason et al., 2018a, 2018b; Schaub et al., 2015; Sinadinovic et al., 2020; Walton et al., 2013). There were no significant differences when pooling the studies by type of control group for the active control group (g=-0.002, 95% CI [-0.256]-[0.259], p=0.990; Q=4.342, df=3, p=0.227; I^2=30.903; T^2=0.022, T=0.149), assessment only (g=-0.025, 95% CI [-0.199]-[0.150], p=0.783; Q=0.172, df=1, p=0.679; I^2=0.000; T^2=0.000, T=0.000), assessment + feedback (g=0.676, 95% CI [-0.454]-[1.806], p=0.241; Q=22.735, df=1, p=0.000; I^2=95.601; T^2=0.635, T=0.797), psychoeducation (g=-0.995, 95% CI [-2.951]-[0.960], p=0.319; Q=83.305, df=1, p=0.000; I^2=98.800; T^2=1.967, T=1.402) or wait list (g=-0.056, 95% CI [-0.249]-[0.137], p=0.572; Q=7.226, df=4, p=0.124; I^2=44.647; T^2=0.021, T=0.143) (See Supplementary Material, eFigure 4a and eFigure 4b). All exploratory subgroup analysis should be interpreted with caution because having ≤5 studies per group is likely to provide an imprecise estimation (Borenstein et al., 2009).

4.4. Publication bias

The funnel plot indicated that there was an asymmetry for the studies included (see Figure 5). After using the trim-and-fill method (Duval and Tweedie, 2000), some missing studies were shown, meaning that some negative studies were under-represented.

Insert Figure 5

Discussion

The aim of this study was to systematically review and perform a meta-analysis on the effectiveness of OCIs developed for reducing CU among AYA. Mental health disorders have typically their onset in adolescence and early adulthood. For this reason, the need for effective mental health services for the youth population is widely recognised (Schueller et al., 2017; Golberstein, Wen, & Miller, 2020). CU is especially prevalent among AYA, and is associated with important biological, psychological, and functional consequences, including poorer mental health (Squeglia, Jacobus, & Tapert, 2009; Bonnie, Stroud, & Breiner, 2015). The ever-increasing role of new technologies in adolescents' and emerging adults' lives provides an unprecedented opportunity to increase access to evidence-based mental health resources in this cohort (Clarke, Kuosmanen, & Barry, 2014). Additionally, there has been a world-wide effort to develop youth mental health services, as intervening at this critical developmental stage could prevent the negative long-term consequences and disability related to mental-ill health as well as CU (Mei et al. 2020). To the authors' knowledge, this is the first meta-analysis of online interventions targeting cannabis use focused on youth. Seventeen

published RCTs were included, comprising 3,525 participants. Overall, we found a non-significant effect of OCIs on reducing CU both after treatment and at 6-months follow-up. These results remained unchanged after we accounted for statistical heterogeneity.

Our results contrast with the findings from previous meta-analyses on the effect of online interventions on CU. A meta-analysis by Tait et al. (2013) and Boumparis et al. (2019) found a small but significant positive overall effect size for Internet and computer-based prevention and intervention programs for CU. Hoch et al. (2016) found small effects at 3-month follow-up in favour of digital interventions. Similarly, Olmos et al. (2018) found a positive effect for online interventions, reducing use of cannabis and other substances significantly. There are several plausible explanations for the inconsistency between our and previous findings. First, previous meta-analyses included both adolescent and adult populations, combined prevention programs and intervention studies (Newton, Teesson, Vogl, & Andrews, 2010), and comprised heterogeneous samples, such as school populations, adolescent girls and their mothers (Schinke, Fang, & Cole, 2009a, 2009b), post-partum women (Ondersma, Svikis, & Schuster, 2007), and adolescents' girls (Schwinn, Schinke, & Di Noia, 2010; Fang, Schinke, & Cole, 2010). Conversely, we only included studies recruiting AYA. Second, prior studies included both RCTs and uncontrolled studies, whereas we only included RCTs. In addition, we meta-analysed ten recent trials not included in previous meta-analyses (Mason et al. 2018a, 2018b; Jacobus et al. 2018; Shrier et al. 2018; Gryczynski et al., 2021; Hernandez et al., 2019; Thompson et al., 2020; Walukevich-Dienst et al., 2019; Sinadinovic et al., 2020; Buckner et al., 2020).

From the narrative review of the studies, eight studies (Becker et al. 2014; Lee et al. 2010; Walton et al. 2013; Elliott et al. 2014; Christoff & Boerngen-Lacerda 2015;

Sinadinovic et al., 2020; Hernandez et al., 2019; Gryczynski et al., 2021) reported non-significant results for the interventions being tested, and nine reported positive effects (Tossman et al., 2011; Mason et al., 2018a, 2018b; Jacobus et al., 2018; Schaub et al., 2015; Shrier et al., 2018; Walukevich-Dienst et al., 2019; Thompson et al., 2020; Buckner et al., 2020). Interestingly, seven of the studies reporting positive results were recently published (Jacobus et al., 2018; Mason et al., 2018a, 2018b; Shrier et al., 2018; Walukevich-Dienst et al., 2019; Thompson et al., 2020; Buckner et al., 2020), some of them using a different approach compared with previous interventions. Specifically, the interventions included in these studies were more structured, with a relatively consistent mean duration of treatment (from 2 to 4 weeks) and high intensity of contact (i.e., daily text messages by the clinician) (Jacobus et al., 2018; Mason et al., 2018a, 2018b; Shrier et al., 2018; Sinadinovic et al., 2020; Thompson et al., 2020), compared with the more heterogeneous approach of previous interventions (length of treatment ranging from 1 day to 13 weeks and a variable frequency of support) (Becker et al. 2014; Christoff & Boerngen-Lacerda 2015; Elliott et al. 2014; Lee et al. 2010; Schaub et al. 2015; Tossman et al., 2011; Walton et al. 2013). However, when studies were imputed into CMA, only three studies yielded a statistically significant difference between condition, with two (Sinadinovic et al., 2020; Tossman et al., 2011) favouring the treatment condition, and one (Christoff & Boerngen-Lacerda., 2015) favouring the control condition. These differences can be explained in what Walukevich-Dienst et al., (2019) only found significant differences for women. Schaub et al., (2015) compared three groups (self-help + chat, self-help without chat, and wait list) finding significant differences for the self-help + chat group compared to the other two groups but not between self-help without chat and the wait list. We found the same results when we performed sensitivity analyses. Mason et al., (2018b) found significant results for

negative cannabis in urine but not for the self-reported past 30-day CU outcome. Mason et al., (2018a) found significant results in the reduction of the past 30 days use moderated by symptom severity (i.e., benefiting those with fewer symptoms). Thompsom et al., (2020) found a significant (p=0.46) reduction of the times used marijuana for the On Track+BMI condition and did not find such reduction in the treatment as usual (TAU) condition; however, they did not perform case-control analyses, and when change from baseline to post-treatment controlling for baseline symptoms, results were non-significant. Finally, two studies that reported significant results (Shrier et al., 2018; Buckner et al., 2020) were not imputed into CMA due to the lack of usable data for meta-analysis. Taken together, these results suggest that online interventions for CU in AYA may require a more structured approach and more intensive feedback with clinician support to bring about positive outcomes. However, these results cannot be generalized to other age-groups. This is consistent with the findings of a number of meta-analytic and systematic reviews suggest that digital mental health interventions with human support which show greater effect sizes than those without human support (Baumeister, Reichler, Munzinger, & Lin, 2014; Cowpertwait & Clarke, 2013; Palmqvist, Carlbring, & Andersson, 2007; Richards & Richardson, 2012; Saddichha, Al-Desouki, Lamia, Linden, & Krausz, 2014; Spek et al., 2007) for outcomes including depression and anxiety symptoms, and general wellbeing. Further, meta-analyses have shown that human support moderates the effectiveness of digital interventions (Cowpertwait & Clarke, 2013; Gellatly et al., 2007).

Online guided self-help interventions are an innovative way to reach and treat populations with limited access to mental health care (Ince, Gökçay, Riper, & Cuijpers, 2019). Technology evolves tremendously within short periods and thus, the quality of

the technology employed in the most recent studies included in our review may have concurred with their reported significant results. These studies (Mason et al., 2018a, 2018b; Shrier et al., 2018) reached high rates of engagement, with dropout rates below 13%. Daily message interventions were a common feature (Mason et al., 2018a, 2018b; Shrier et al., 2018), as was focus on peer relations, which may be key for adherence to treatment with youth (Mason et al., 2018a, 2018b), while another notable feature was developing interventions with input from key informants; young cannabis users and treatment providers (Shrier et al., 2018).

Twelve of the studies were interventions specifically targeting CU, abuse, or dependence; while others addressed substance usage through general interventions not specific for CU and reported results on CU. Thus, these interventions were not specific for CU (Becker et al., 2014). Importantly, most of the studies with CU as the main outcome obtained significant results to reduce consumption (Tossman et al. 2011; Mason et al. 2018a, 2018b; Schaub et al. 2015; Shrier et al. 2018). An important future direction is therefore to examine which intervention techniques are most effective, to improve CU treatments. Karno et al. (2020) found positive effects of the Screening, Brief Intervention, and Referral to Treatment upon reduction of alcohol and other substance use, but not for CU. These findings suggest that CU treatment may need to be more targeted, and specifically that a focus on CU and the inclusion of MI, CBT and MET strategies is likely to be of benefit (Gates et al., 2016). As within the meta-analyses by Tait et al. (2013), Olmos et al. (2018), and Boumparis et al. (2019), our subgroup analysis found no differences between types of control group. The small number of studies included in the present study precluded subgroup analyses to ascertain whether specific intervention types resulted in larger effects than others.

The literature offers several potential improvements to enhance OCIs. Creating accessible, attractive and innovative platforms for youth, developed following user-centred design procedures, applying motivational theories, and incorporating new technologies such as artificial intelligence can increase engagement to treatment (Alvarez-Jimenez et al., 2018; Rice et al., 2018; D'Alfonso et al., 2017). Moreover, it is important to develop and test interventions that have a strong theoretical base addressing the key therapeutic mechanisms of change (Alvarez-Jimenez et al., 2018). A further potential improvement is using video-based testimonials explaining why quitting cannabis is worthwhile (Tatar, Bastien, Abdel-Baki, Huỳnh, & Jutras-Aswad, 2020). Given that OCIs can be accessed wherever internet-based services are available, geographic barriers to high-quality treatment could be minimized with such improvements (Ritvo et al., 2019).

Our target population, young people, are digital natives and therefore ideally suited for online interventions. The current study focused on a narrower age group than previous investigations, and specifically upon online interventions designed to reduce CU, excluding universal prevention programs. Young cannabis consumers may benefit from specific types of interventions, and the identification of effective elements is key to enhancing the treatment in this population. Factors that can influence intervention effectiveness for reducing CU are motivation to quit, adherence to treatment (Copeland et al. 2017; Squeglia, Fadus, McClure, Tomko, & Gray, 2019), and awareness (Leos-Toro, Fong, Meyer, & Hammond, 2019), which may be particularly problematic in youth. Lambert (2013) found that in face-to-face treatments, 50% of patients achieve clinically significant change after about 20 sessions of standard psychotherapy.

Moreover, it seems that 50% of patients improved by session eight, while 75% needed 14 sessions. Another important factor may therefore be sufficient intervention duration.

Another critical issue impacting the uptake of these tools by youth is ensuring their appropriateness for these populations (Schueller et al., 2017). As Kenny, Dooley, & Fitzgerald (2015) explain, tele-mental health apps have potential as a feasible medium for promoting positive youth mental health, with the majority of youth identifying such technologies as at least somewhat useful and displaying a moderate level of engagement with them. This indicates that such tools are appropriate and acceptable for this population.

Strengths and Limitations

Among the strengths of this study are that only RCTs were included, ensuring all interventions had a control group. In contrast to prior research (e.g., Olmos et al., 2018), within our analyses, we included only analysed patients (i.e., intention-to-treat analyses). Finally, we focused on the population of young people, to examine the specific impact of these interventions for this specific age group.

Nevertheless, some limitations apply. Interventions being tested and control groups varied significantly. This increased statistical heterogeneity and limited our ability to conduct subgroup analyses and determine the relative effectiveness of different intervention approaches. To guarantee methodological quality, strict inclusion criteria were predefined and accordingly, some studies were excluded for not meeting these. Despite the breadth of this literature, few works met inclusion criteria. Due to the heterogeneity across studies and described limitations, conducting a scoping review may be another relevant method of increasing our understanding of online interventions for CU among AYA. That said, we believe that conducting a rigorous meta-analysis that

carefully considers and attempts to address heterogeneity across studies provides a useful initial snapshot as well as important future directions in this emerging field. Rigorously designed evaluations often require the investment of significant resources, and therefore not all interventions can be tested for efficacy and effectiveness (Kenny et al., 2015).

In conclusion, although OCIs offer a promising way to treat CU among young cannabis users, more research is needed to bring about positive outcomes. Our findings show that, to date, there is not enough evidence to suggest that OCIs, taken as a whole, are effective in reducing CU amongst young people. That said, more recent studies including structured interventions, daily feedback, AYA centred designs, peer support, and specifically targeting cannabis use (as opposed to generic interventions), showed promise as potentially effective approaches to address CU in this population. Future research should establish the effectiveness of the newer generation of interventions as well as the key ingredients of effective online interventions addressing cannabis in youth. Moreover, future studies should develop and evaluate culturally adapted programs, explore the caregiver's role in AYA interventions, and determine the impact of these interventions in mental health symptoms associated to CU.

Supplementary Material

Supplementary material can be consulted online in XXX.

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Conflicts of interest statement

JARQ was on the speakers' bureau and/or acted as consultant for Eli-Lilly, Janssen-Cilag, Novartis, Shire, Takeda, Bial, Shionogui, Lundbeck, Almirall, Braingaze, Sincrolab, Medice and Rubió in the last 5 years. He also received travel awards (air tickets + hotel) for taking part in psychiatric meetings from Janssen-Cilag, Rubió, Shire, Takeda, Shionogui, Bial, Medice and Eli- Lilly. The Department of Psychiatry chaired by him received unrestricted educational and research support from the following companies in the last 5 years: Eli-Lilly, Lundbeck, Janssen- Cilag, Actelion, Shire, Ferrer, Oryzon, Roche, Psious, and Rubió.

Contributors

AB performed the literature search**.** AB and CDB independently assessed all potentially relevant articles for inclusion, extracted relevant data and rated each study's methodological quality. Two raters independently, OSE and HT, assessed risk of bias of the studies. OSE performed the statistical analysis and interpreted the results. AB wrote the first draft of the manuscript. MAJ, JARQ, and PM contributed to the design of the

study, participated in the consensus process, and critically revised the manuscript. All authors contributed to and have approved the final manuscript.

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Data Availability Statement

Data available on request from the authors

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Table legends

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Supplementary material legend

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Supplementary Material. eFigure 2a. Sensitivity analyses without outliers (Christoff & Boerngen-Lacerda, 2015; Hernandez et al., 2019; Tossmann et al., 2011) – Pooling Becker (MI) & Schaub (CH)

Supplementary Material. eFigure 2b. Sensitivity analyses without outliers (Christoff & Boerngen-Lacerda, 2015; Schaub et al., 2015 no-CH; Tossmann et al., 2011) – Pooling Becker (NF) & Schaub (no-CH)

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Supplementary Material. eFigure 4a. Subgroup analyses by type of control – Pooling Becker (MI) and Schaub (CH)

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Figure 1.

Study retrieval and selection strategy

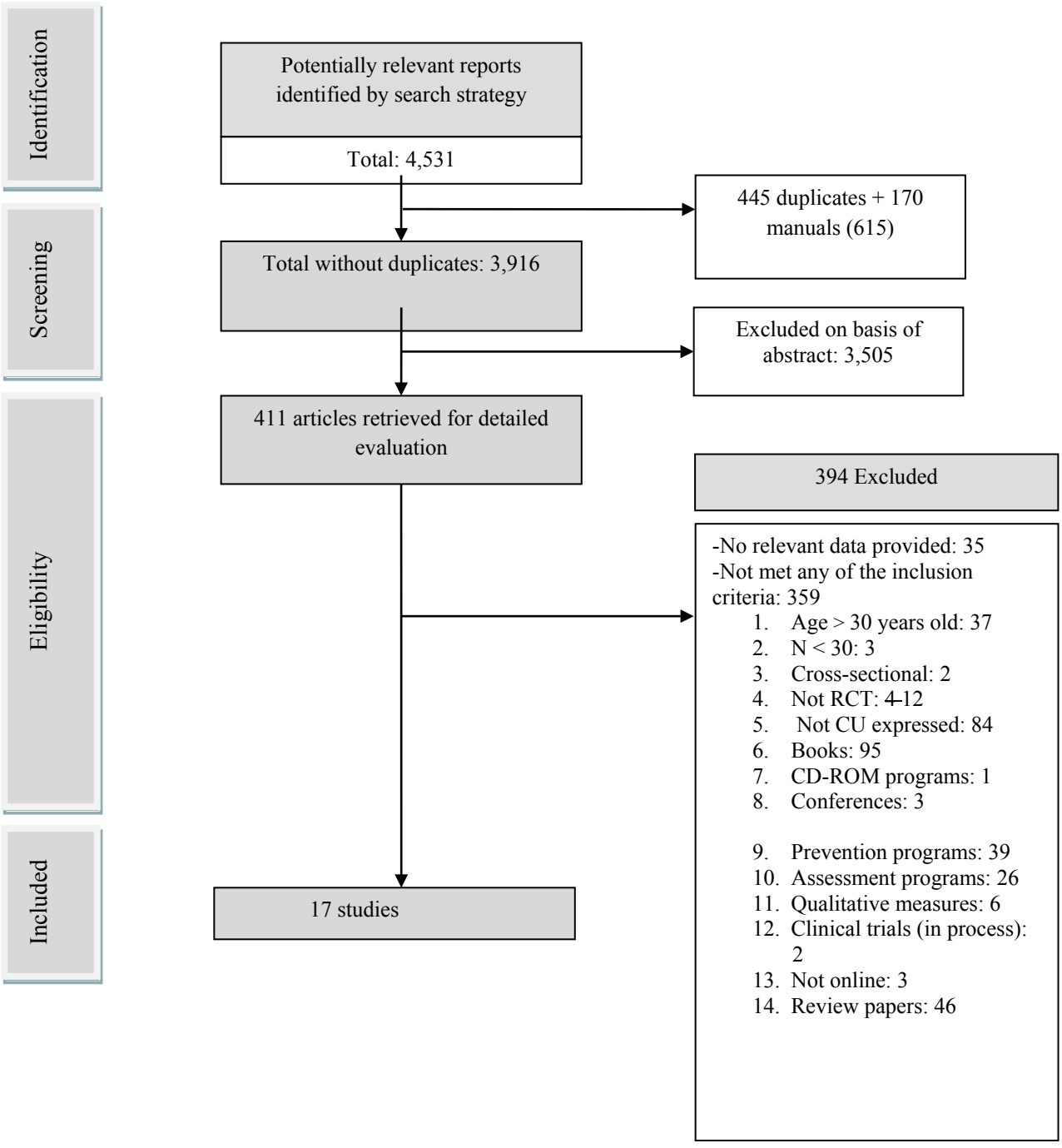


Figure 2.

Risk of bias assessment of the included articles

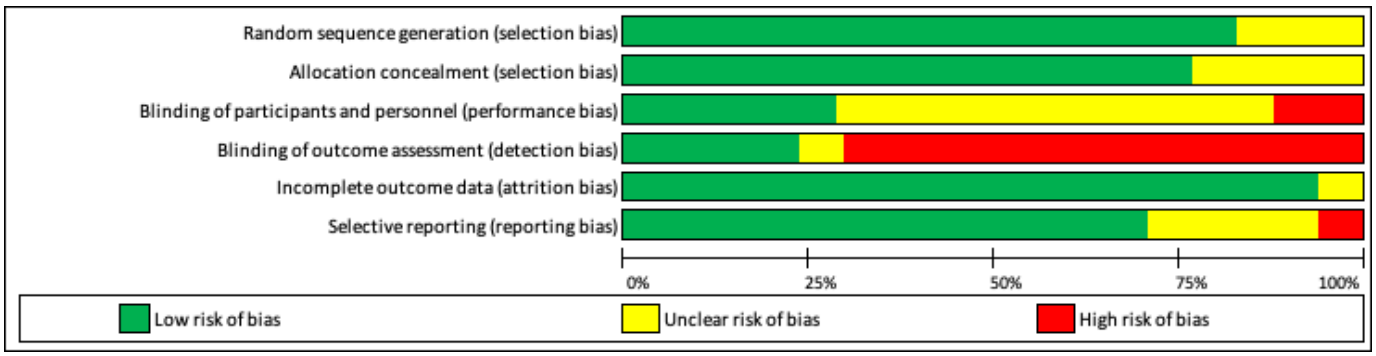


Figure 3.

Online Cannabis Interventions to reduce cannabis use

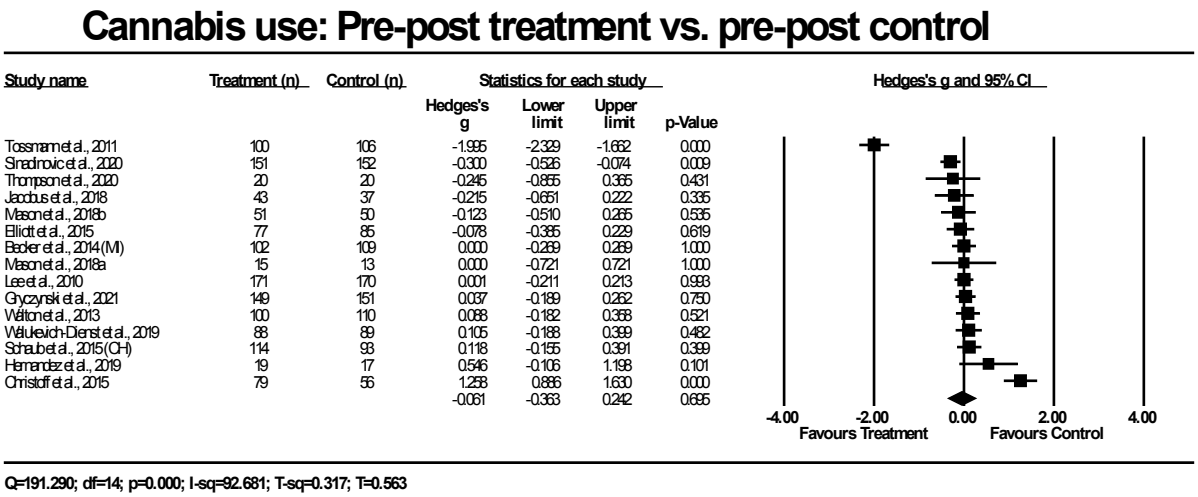
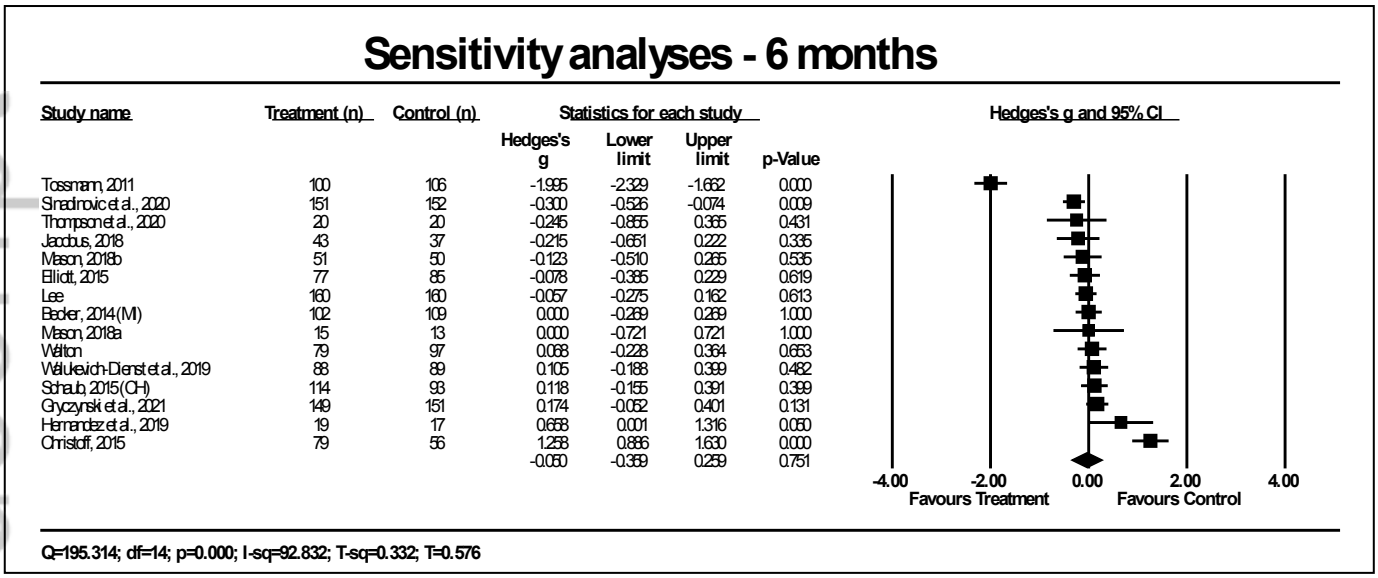


Figure 4.

Online Cannabis Interventions to reduce cannabis use – Sensitivity analyses pooling studies reporting a 6-month follow-up measurement of outcome



Note: Gryczynski et al., 2021; Hernandez et al., 2019; Lee et al., 2010; Walton et al., 2013 reported a 6-month follow-up measurement

Figure 5.

Publication bias plot. Funnel plot of standard error by Hedges's *g*.

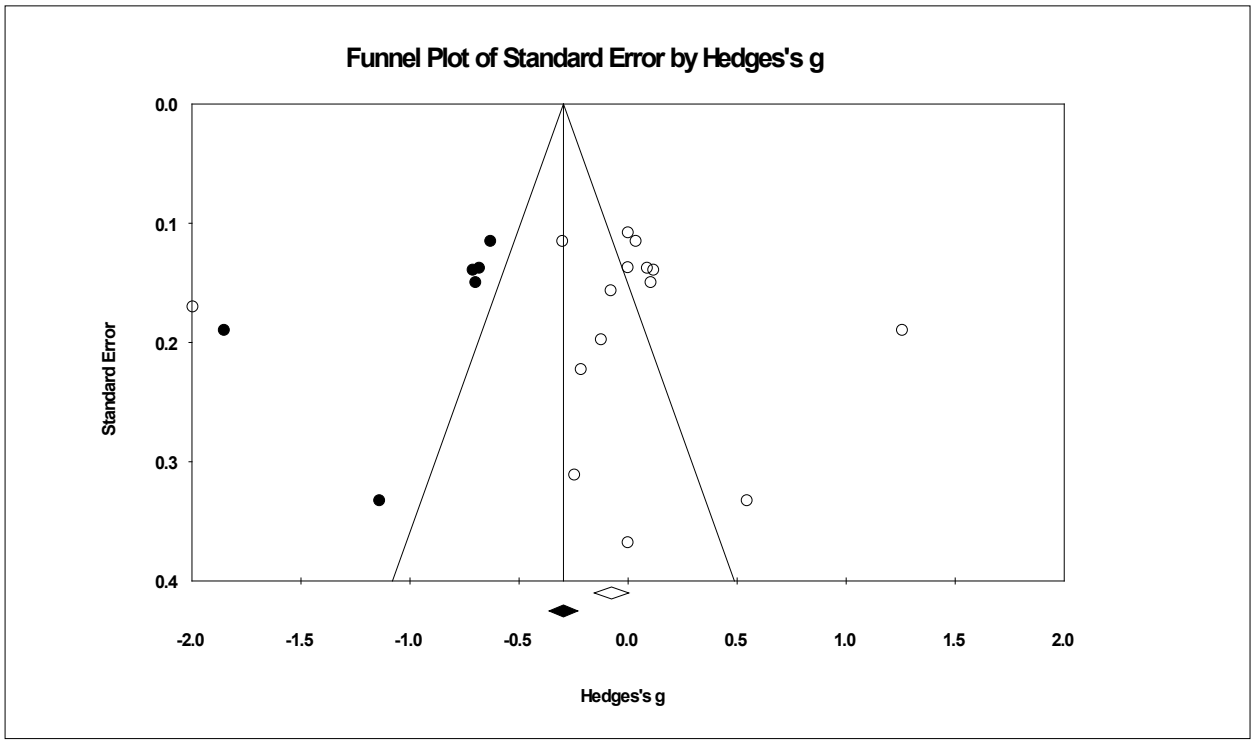


Table 1: Description of the randomized controlled trials included in the meta-analysis

	n	Mean age (*SD*)	Gender (female)	FU (months)	Dropouts (*%*)	Length of treatment	Substances	Treatment group	Control group	Results
Tossman (2011)	206	24.7 (6,8)	30.0%	3	0.0	50 days	CNN	Counselling program QTS	WL	Significant
Becker (2014)	325	29.8 (NR)	20.9%	2	73.84	3 sessions	CNN, tobacco	1. Normative feedback online 2. Principles of MI online	PE	Not significant
Lee (2010)	341	18.0 (0.3)	54.6%	6	6.2 (at 6M)	13 weeks	CNN	PFI based on MI	Assessment only	Not significant
Walton (2013)	328 FU 3m 279 FU 6m 278 FU 12m 275	16.3 (1.6)	66.5%	3-6-12	16.2 (at 12M)	13 weeks	CNN, alcohol, others	1. TBI 2. CBI	Cannabis information	Not significant
Elliott (2014)	317	19.3 (1.2)	52.0%	1	0.0	1 session 20-45’	CNN	e-TOKE + full assessment	Full assessment	Not significant
Christoff (2015)	458 FU 2M 333	23.0 (5.3)	57.7%	3	1.6	1 session 20’	CNN, tobacco, alcohol, others	1. ASSIST/MBIi 2. ASSIST/MBIc	1. Control/ASSISTi 2. Control/ASSISTc	Not Significant
Jacobus (2018)	80 FU 2M 80	19.0 (NR)	CAAT-T (46.5%) CAAT-Sham (40.5%)	0.75	8.8	6 sessions	CNN, alcohol	CAAT-training	CAAT-Sham	Significant
Mason (2018a)	30 FU 1M 29 FU 2M 24 FU 3M 26	20.7 (2.1)	46.7%	1-2-3	13.0	4 weeks	CNN	PNC-txt	WL	Significant (not cannabis use, yes for urine analysis)
Mason (2018b)	96	20.3 (NR)	42.7%	1-2-3	5.0	4 weeks	CNN	PNC-txt	Assessment only	Significant for mild to moderate severity
Schaub (2015)	308 FU 3M 308	29.8 (NR)	24.7%	3	65.7	6 weeks	CNN, alcohol	1.Self-help with chat 2.Self-help without chat	WL	Significant for Self-help with chat
Shrier (2018)	70 FU 3M 54	20.7 (NR)	60.0%	3	0.0	2 weeks	CNN	1.MOMENT 2.No messages (MET)	MET-only	Significant (marijuana use after top-3 exposure, not daily measures)
Thompson (2020)	60	19.1 (0.81)	30%	0.5-1-1.5	33.3%	3 sessions	CNN, alcohol	On Track+BMI	TAU	Significant
Sinadinovic (2020)	303	27.4 (7.2)	32.6%	3	57.75%	6 weeks	CNN, alcohol	Web-based treatment program	WL	Not significant

Hernandez (2020)	36	NR (range between 12-18y)	44.4%	3-6	8.35% (at 3M) 30.5% /at 6M)	1 session	CNN, alcohol	CAI	TDI	Not significant
Buckner (2020)	63	19.06 (NR)	84.13%	0.5	38.24%	1 session	CNN, alcohol	PFI-NAC	Assessment only	Significant (with moderate to high social anxiety)
Gryczynski (2021)	300	16.30 (1.06)	54%	3-6	9.6% (at 3M) 20.67% (at 6M)	1 session	CNN, alcohol	CBI	NBI	No significant.
Walukevich-Dienst (2019)	204 FU 1M 177	19.83 (1.43	77%	1	13.23%	NR	CNN	PFI	PFN	Significant for women. No significant for men.

Note: ASSIST: Alcohol, Smoking, and Substance Involvement Screening Test; CAI: computer-assisted intervention; CAAT: Cannabis Approach-Avoidance Task Training; CBI: Brief Intervention delivered by a Computer; CNN: Cannabis; DTI: therapist-delivered intervention; e-TOKE: The Marijuana eCHECKUP TO GO; FU: Follow-up; M: months; MET/Smartphone-Based Momentary Assessment/Responsive Motivational -Messaging MOMENT: MBI: Motivational Brief Intervention; MI: Motivational Interview; NBI: Nurse Brief Intervention; NR: not reported; PE: Psychoeducation; PFI: Personalized Feedback Intervention; PFI-NAC: Personalized Feedback Intervention with strategies to manage Negative Affect; PNC: Peer Network Counselling; PNF: Personalized Normative Feedback; QTS: Quit the shit; TAU: Treatment As Usual; TBI: Brief Intervention delivered by a Therapist; TDI: Therapist-delivered Intervention; txt: text; and WL: Wait List.

Table 2. Characteristics of interventions

	Recruitment	Payment	Study aim	Online and mobile-based interventions	Type of professional	Primary cannabis outcome	Valid measure (urine analysis vs self-report)	Secondary variables
Tossman et al. (2011) Germany	From website www.drugcom.de	Yes	To assess the effectiveness of a counseling program (QTS) considering cannabis consumption and other clinical variables.	The 50-day program counseling have a solution-focused approach, is based on self-regulation and self-control.	Qualified and trained psychotherapists working for QTS	Frequency days/last 30 days Quantity grams/last 30 days	Self-report	- Use-related self-efficacy (DTCQ-8) - Anxiety (STAI-T) - Depression (ADS) - Satisfaction with life (SWLS)
Becker et al. (2014) Switzerland	Online and offline media.	Yes	To evaluate the effectiveness of three Web-based interventions to enhance co-smokers readiness to quit both tobacco and cannabis simultaneously.	Intervention 1: self-assessment and PNF Intervention 2: MI	NR	Tobacco use frequency, cigarettes per day Cannabis use frequency, times per week	Self-report	NA
Lee et al. (2010) USA	Students at a public university	Yes	To evaluate efficacy of a web-based approach for selective prevention of marijuana during the transition from high school to college	Intervention group received individual PF based on baseline information, according to MI approach. Text messages, pictures and figures/graphs were sent.	NR	Self-reported days of cannabis use in the last 90 days	Self-report	- Marijuana Consequences of marijuana use (RMPI) - Contemplation to change marijuana use (RTCQ) - Family history of drug problems (BDP)
Walton et al. (2013) USA	Adolescents ages 12-18 presenting to community health clinic that reported cannabis use.	Yes	To describe the results of brief interventions delivered by a computer (CBI) among adolescents in urban primary care clinics.	CBIs incorporated MI approach, including goals/values, feedback for cannabis, consequences of consumption, decisional balance exercise, tricky situations and the control brochure.	Research therapists were trained in MI	Frequency of cannabis use during the last month (Add Health)	Urine control and self-report	- Cannabis related consequences (RAPI, SDS) - Driving under cannabis influence - Other drugs use (Add Health) - Perceived risk - Self-efficacy (Likert scale) - Intention to use cannabis in the next three months (Likert scale)
Elliott et al. (2014) USA	Psychology courses at a private university.	NR	To evaluate the program The Marijuana eCHECKUP TO GO (e-TOKE) for Universities & Colleges effectiveness in changing marijuana	e-TOKE is a self-paced, Web-based marijuana educational program designed to prompt self-reflection and consideration of decreased use. The program assesses marijuana use, pros and cons, perceived norms, alcohol and cigarette use, substance-related	NR	Days used in last 30 days	Self-report	- Marijuana Consequences of marijuana use (RMPI) - Percent estimated of college students who use and have used marijuana - Satisfaction

			involvement and perceived norms in undergraduates.	expenses, other valued activities, and readiness to change.				
Christoff et al. (2015) Brazil	Students at two public and private universities	No	To evaluate the efficacy of a computer-based intervention program called ASSIST Motivational Brief Intervention (ASSIST/MBIc) on substance involvement compared with those receiving only feedback (control group).	The intervention is based on the motivational interview, using Feedback, Responsibility, Advice, Menu of Options, Empathy, and Self-Efficacy (FRAMES)	Interviewers trained by the principal investigator using the WHO manual	ASSIST scores baseline and follow-up 3 months (The Alcohol, Smoking and Substance Involvement Screening Test)	Self-report	- Other substance consumption (ASSIST questions about 10 types of substances)
Jacobus et al. (2018) USA	From fliers at local high school and college campuses and through online media advertising	Yes	To test Approach-Avoidance Training to reduce cannabis use with non-treatment seeking adolescents	Computerized cognitive bias modification paradigms was used. Six sessions of Cannabis Approach-Avoidance Task Training (CAAT-training) designed to reduce automatic approach biases for cannabis cues were included	Researchers	1. Cannabis approach bias 2. % CU days pre- and post-.	Not reported	- Depression symptoms (BDI-II) - Anxiety symptoms (STAI) - Motivation to change – (CWS) - Marijuana Effect Expectancies - Self-Efficacy Questionnaire - Marijuana Craving Questionnaire - Marijuana Problem Scale - Stages of Change Readiness and Treatment (SOCRATES)
Mason et al. (2018a) USA	Using flyers, digital signs, radio advertising and a campus recruitment table	Yes	To test Peer Network Counseling-txt, a 4-week, automated text-delivered cannabis treatment that focuses on close peer relations with treatment seeking young adults	Peer network counseling-txt (PNC-txt) is adapted from an in-person intervention. PNC-txt applies motivational interviewing principles, but focusing on the interpersonal and environmental interactions. Each day's texts took approximately 1–2min to complete	NR	Severity cannabis use disorder: Past 30-day cannabis use/ largest amount Memory problems Craving Relationship problems due to cannabis use	Urine control and self-report	- Past 30-day largest amount CU - Memory problems - Craving - Urine analysis - Peer network health - Satisfaction items assessment
Mason et al. (2018b) USA	Flyers, posting, informational notices posted on media display boards around the VCU campus and VCU Medical Center	Yes	To test the efficacy of text-message delivered Peer Network Counseling (PNC-txt) with young adults meeting DSM-5 criteria for Cannabis Use Disorder	Peer Network Counseling (PNC-txt), which is a substance use intervention that focuses on peer relations.	NR	Past 30-day cannabis use Past 30-day cannabis problems Negative Urine Cannabis related problem Craving	Urine control and self-report	- Number of users in network - Frequency of use in network - Offers to use - Use with friend - Asked to reduce or not use - Support - Prosocial - Encouragement - Satisfaction items assessment
Schaub et al. (2015) Switzerland	Online and offline media for the Web-based trial	Yes	To test the efficacy of a Web-based self-help intervention with and without chat counseling—Can Reduce—in reducing	Patients received weekly-automated motivational emails to remind the user to log in and fill out the consumption diary. Two arms were tested, the first it consisted of the Web-based self-help	Clinical training therapist	Cannabis use days per week Mean weekly quantity of cannabis used in standard joints	Self-report	-Self-reported symptoms of cannabis use disorder (SDS) - Severity of cannabis dependence, risky alcohol use (FDA) - Mental health symptoms (MHI-5)

			the cannabis use of problematic cannabis users as an alternative to outpatient treatment services.	intervention, in combination with up to two individual chat counseling sessions based on MI and CBT. The second study arm consisted of the same intervention but without chat counseling				- Mental Health Inventory (MHI-5) - Fragebogen Substanzanamnese (FDA) - Cannabis Use Disorders Identification Test (CUDIT) - Severity of Dependence Scale (SDS)
Shrier et al. (2018) USA	From clinics providing primary care	Yes	To evaluate study feasibility and explore intervention effects on marijuana desire and use at three months with linear mixed effects modeling	MOMENT arm. App with motivational messages following momentary report of trigger for use, marijuana desire, use, or effort to avoid use. Messages were developed with input from key informants. Participants completed reports and received messages for 2 weeks. No-message arm. 2 weeks of Smartphone reports without motivational messages	Trained counselor	Momentary marijuana desire was assessed by, "At the time of the signal, how strong was your desire to use marijuana?" Recent marijuana use was assessed by, "Since the last signal you answered, have you used marijuana?"	Self-report	Study feasibility (recruitment, retention, and response rates, feedback survey responses)
Thompson et al. (2020) USA	From the inner-city crisis shelter	Yes	To evaluate the feasibility and preliminary effectiveness of a smartphone application to self-monitor substance use and sexual risk behaviors, with the aim to reduce substance use and sexual risk among homeless young adults.	OnTrack+BMI comprises two theory- and evidence-based components: (a) brief daily technology-supported self-monitoring of alcohol, marijuana, and sexual risk behaviors (2–3 min/day) over 28 days and (b) brief motivational sessions at Weeks 0, 2, and 4 to promote use of OnTrack, encourage risk reduction, and provide graphed personalized feedback from the self-monitoring data.	Trained counselor, master's degree in social work	Times used marijuana assessed by TLFB.	Self-report	- Number of drinks - Times unprotected sex - Times drank before sex - Times drugs before sex
Sinadinovic, et al. (2020) Sweden	From a website http://www.cannabishjalpen.se	NR	To investigate the effects of a web-based treatment program for adults and adolescents with regular cannabis use.	The web-based treatment program consisted of psych educative information based on a manual-based treatemtn program for chronic cannabis users, and training and exercises grounded on principles of CBT and MI.	Therapists	Number of days without cannabis use (past week) assessed by TLFB. Gram cannabis (past week)	Self-report	- Number of DSM-5 cannabis use disorder - Cannabis Abuse Screening Test (CAST) - Help seeking - Number of standard glasses of alcohol (past week) - Sense of Coherence Scale (SCS) - Montgomery Asberg Depression Rating Scale – Self Reported (MADRS) - Generalized Anxiety Disorder (GAD-7)

Hernandez et al. (2020) USA	From the family court system in a northeastern U.S. state for an alcohol and other drugs use-related offense.	Yes	To compare the preliminary efficacy of a computer-assisted intervention to a therapist-delivered intervention for adolescent substance use.	The electronic-Check-Up to Go and the e-TOKE were draw from MI principles, self-efficacy, social norms feedback, and peer modeling.	Master-level therapists.	Marijuana Use Days	Self-report	- Alcohol use days - Co-ocurring use days - Alcohol and other drugs related problems - Adolescent Drinking Questionnaire (ADQ) - Drug Use Questionnaire (DUQ) - RAPI and DPI - Brief Situational Confidence Questionnaire (BSCQ)
Buckner et al. (2020) USA	From the psychology participant pool of a university in the southern United States.	Yes	To test the utility of a newly developed PFI-NAC designed to reduce cannabis use, teach quit strategies and to manage negative skills.	PFI-NAC integrates personalized feedback intervention and corrective information with strategies to manage negative affect.	NR	Cannabis frequency (number of joints used per day) using TLFB self-reported measure of cannabis use.	Self-report	- Cannabis related problems - Typical drinking quantity - Heavy drinking quantity - Number of drinking related problems - Anxiety treatment history - Drug treatment history - Social Interaction Anxiety Scale (SIAS-S) - The Positive and Negative Affect Scale (PANAS) - Brief Marijuana Consequences Questionnaire
Gryczynski et al. (2021) USA	From the SBHCs.	NR	To compare two BI delivered approaches to addressing substance use and sex risk behaviors.	CBI is an interactive program delivered via tablet computer using strategies from motivational interviewing.	NR for the intervention group. Nurses trained in BI techniques for the control group.	Days of marijuana use assessed by ASSIST.	Self-report	- CRAFFT abuse screening test - Days of alcohol use - Days of binge drinking - Days of unprotected sex - Days of sex while intoxicated - Marijuana specific problems - Alcohol specific problems
Walukevich-Dienst (2019) USA	From the psychology department's online research pool and via flyers on campus	Yes	To test intervention effects of an online university specific PFI for high-risk cannabis users, moderated by gender.	PFI included PNF and feedback pertaining to cannabis including risk for CUD, risks related to cannabis use and personalized feedback on cannabis-related problems.	NR	Cannabis use frequency measured using the Marijuana Use Form (MUF).	Self-report	- Marijuana Problems Scale (MPS) - DSM-IV symptoms of CUD