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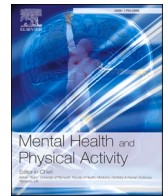
Physical activity interventions for young people with increased risk of problematic substance use: a systematic review including different intervention formats

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Physical activity interventions for young people with increased risk of problematic substance use: A systematic review including different intervention formats

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ABSTRACT

Objective: This systematic review investigates physical activity (PA) interventions for (1) reducing substance use and associated outcomes, (2) increasing physical activity, and (3) improving mental health in young people aged 12–25 years at increased risk for problematic substance use.

Method: Four databases (PsycINFO, CINAHL, SPORTDiscus, and Medline) and grey literature, including hand searches, were searched (2021–2022). Non-randomized controlled or randomized controlled trials of a) multi-modal or unimodal, short or long-term physical activity interventions in young people at increased risk of problematic substance use that b) investigated substance use outcomes were included. PA and mental health outcomes were explored where possible.

Results: Sixty-one percent of the studies ($k = 17/28$) reported a significant improvement in outcomes related to tobacco (e.g., abstinence, cravings, withdrawal symptoms, smoking pattern), alcohol (e.g., quantity, frequency), or other substance use (e.g., frequency, quantity, recent use). Eight studies reported an increase in PA participation; two reported a beneficial effect on depression symptoms. The certainty of the evidence, i.e., the confidence in the reported effect estimates, was downgraded based on the risk of bias assessment. Findings should therefore be interpreted cautiously.

Conclusions: A range of physical activity intervention formats and modalities may decrease substance use and associated outcomes and increase physical activity participation among people at risk for problematic substance use. Future research is warranted to better establish efficacy and investigate the effectiveness of implementing physical activity as part of treatment for substance use in young people.

1. Introduction

The use of substances including alcohol, tobacco, cannabis, cocaine, and amphetamine peaks during adolescence and young adulthood (Degenhardt et al., 2016). Globally, 16% of men and 15.3% of women between the ages of 15 and 24 years report lifetime substance use (United Nations Department of Economic and Social Affairs (UN DESA), 2019; United Nations Office on Drugs and Crime (UNODC), 2021).

Problematic substance use – defined as use that causes health, social, legal, or other problems (Schlag, 2020; Seddon, 2010)– is associated

with comorbid mental illness, cognitive impairment (Guerra & Pascual, 2019; Morin et al., 2019; Thorpe et al., 2020), high-risk behaviors such as intentional self-harm (Bousoño et al., 2017) and sexual risk-taking (Green et al., 2017).

Substance use initiation commonly occurs during adolescence (ages 12–18) (Chaplin et al., 2018; Helzer et al., 1991), with the frequency and amount of use, and the associated harms, reaching their peak in young adulthood (ages 18–25) (Degenhardt et al., 2016; McGorry et al., 2007). During adolescence and young adulthood, important trajectories for later life are established. Substance use may disrupt important

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developmental transitions in social, physiological, neurobiological, and cognitive domains (McGorry et al., 2007), leading to poor social and health outcomes throughout the life course (Degenhardt et al., 2016; Hall et al., 2016). Consequently, problematic substance use in youth should be prioritized within the global health agenda (Castelpietra et al., 2022; Degenhardt et al., 2016), with a focus on early intervention (Chaplin et al., 2018; Stockings et al., 2016). Early intervention aims to reduce substance use before it escalates in young people who may be at-risk or show signs of problematic substance use (Stockings et al., 2016). Many “at-risk” populations for problematic substance use, some identified by Degenhardt et al. (2016) as young people from racial minorities, those with mental illnesses, and from low socioeconomic position or history of early adolescent use, remain understudied (Stockings et al., 2016) despite a plethora of research highlighting their risk status (Rhodes et al., 2003; Sussman & Sinclair, 2022).

There are several treatment approaches targeting problematic substance use in young people, including family-based treatments, motivational enhancement therapy (MET), pharmacological treatments, cognitive behavioral therapy (CBT), and 12-step programs (Austin et al., 2016; Fadus et al., 2019; Hammond, 2016; Hogue et al., 2018; Winters et al., 2018). Yet, these models have limited efficacy (Chung & Maisto, 2006; Ciesla, 2010; Cornelius et al., 2003; Hogue et al., 2018; Winters et al., 2018), may not be appropriate for early intervention, and commonly require young people to identify their substance use as problematic (Hofmann, 2012). With limited effective early interventions for this population (Stockings et al., 2016), there is a clear need for accessible intervention options that may engage young people in alternative ways.

Physical activity, defined as “any bodily movement produced by skeletal muscles that requires energy expenditure” (World Health Organization, 2020), appears to improve substance use-related outcomes such as substance withdrawal symptoms in young people (Lynch et al., 2013; Parker et al., 2016; Smith & Lynch, 2012; Werch et al., 2005), while also increasing physical and mental health more broadly (Babic et al., 2014; Bailey et al., 2018; Carter et al., 2021; Lubans et al., 2012; Parker et al., 2016). Biopsychosocial mechanisms used to explain this effect include a PA-induced activation of dopaminergic brain reward systems, using physical activity as a coping strategy, or the beneficial effect of exercise on cognitive functioning (Abrantes & Blevins, 2019).

Physical activity interventions comprise a range of different approaches targeting the perception, consciousness, behavioral, and cognitive constructs relating to physical activity (Woods et al., 2002), with the latter being of particular relevance for promoting physical activity among those who are considering increasing their physical activity (Marcus et al., 1997). Particularly, the provision of psycho-education and physical activity messages are commonly recommended (Heath et al., 2012).

Although a recent systematic review (Simonton et al., 2018) examined the effect of physical activity interventions on substance use in adolescents, details in several key domains were not reported according to the AMSTAR 2 review appraisal tool (Shea et al., 2017).

Another comprehensive quantitative review (Thompson et al., 2020), and qualitative companion piece (Horrell et al., 2020), investigated different prevention approaches in adolescents and intervention approaches in adults, however, they did not address the particular at-risk period of young adulthood, and the focus in adolescents was on prevention (i.e., before onset of substance use), which can be differentiated from early intervention (see Stockings et al., 2016). The current review focused on early intervention in young people, comparing different intervention formats.

While young people (including adolescents and young adults) record the highest rates of substance use compared to any other age group (United Nations Office on Drugs and Crime, 2022), young adulthood particularly is the peak age range of problematic use and thus needs to

be included in reviews. This review further aimed to encompass all relevant approaches to early (physical activity) intervention. These include but are not limited to behavioral and cognitive strategies as well as informational approaches as suggested by the Lancet Physical Activity Working Group (Heath et al., 2012). The interventions can take different formats, i.e., long-term or short-term (single-session/single-bout) interventions; they can be multimodal interventions (i.e., two or more combined intervention approaches targeting physical activity and/or another health behavior such as eating behaviors), or single-modal “unimodal” (i.e., a single intervention targeting PA). By encompassing this range of formats and modalities, this review establishes a more comprehensive synthesis of physical activity interventions than previously undertaken (e.g., Simonton et al. (2018)) and critically discusses the potential of different intervention formats or modalities that could be integrated into substance use treatment practice. The age range (12–25 years) was based on previous research indicating a particularly high prevalence of substance use and mental ill-health in this age group (McGorry et al., 2007; United Nations Office on Drugs and Crime, 2020); it is also consistent with current evidence about neurobiological development suggesting increased susceptibility to stimulation of the brain reward cycle in this age group, which results in increased impulsive and risky behavior compared to other age groups (Kim-Spoon et al., 2017; Nock et al., 2017).

1.1. Objectives and aims

This review investigated the effects of different formats of physical activity interventions on substance use outcomes, physical activity, and mental health in young people at increased risk for problematic substance use.

By “at-risk” we refer to young people with regular substance use (e.g. regular smokers, regular cannabis users), as well as young sub-populations known to be at risk of problematic substance use e.g., indigenous minorities, young people with mental illness, and/or of low socioeconomic position (see also Degenhardt et al., 2016; Rhodes et al., 2003; Stockings et al., 2016; Sussman & Sinclair, 2022). The review focused on early intervention in the critical risk period between the age of onset of substance use in adolescence to the development of problematic substance use in young adulthood, with the population of interest being young people aged 12–25 years.

Physical activity interventions that were unimodal or multimodal, including behavioral, cognitive, and informational approaches, comprised the independent variable. Substance use outcomes (i.e., frequency and amount of use, intent to use, withdrawal symptoms, craving), and if reported physical activity participation, and mental health (including stress and depression symptoms) were the dependent variables.

2. Method

2.1. Protocol

A review protocol was registered with PROSPERO (registration number CRD42021225252). The background and aims, population of interest, anticipated data extraction, and proposed synthesis methods were described *a priori*. No deviations from the protocol were recorded.

2.2. Information sources

The search was conducted between November 2020 and January 2021 and updated in November 2022 according to the original search criteria. Four databases (PsycINFO, CINAHL, SPORTDiscus, and Medline) were searched for articles reporting on physical activity interventions focusing on any construct relating to physical activity and

applying various approaches (i.e., cognitive, behavioral, informational) including physical activity-promoting educational programs for young people at risk for problematic substance use. All findings were cross-referenced with the Evidence Finder Tool open online database (<https://orygen.org.au/Training/Evidence-List>). Grey literature and manual hand searches were conducted to identify additional eligible studies, including previously published reviews (Linke & Ussher, 2015; Simon-ton et al., 2018), seminal publications on substance use and physical activity in young people (e.g., Kwan et al., 2012), and reference lists.

All peer-reviewed publications up to December 2023 in the English language were eligible for inclusion. Terms related to either the population (e.g., youth, young people), the intervention of interest (e.g., physical activity, exercise), general intervention-related terms (e.g., program, intervention, treatment), and substance use (e.g., drugs, addiction, substance misuse) were combined using the boolean operators AND/OR. The search strategy used a combination of appropriate index terms (Thesaurus), subject headings (CINAHL), meSH terms (Medline), and free text terms. All populations within the age range that are known to be at risk for problematic substance use were considered. As some studies included broader age ranges than were of interest in this review, studies were deemed eligible if the mean participant age fell between 12 and 25 years. The risk of reduced applicability by including studies that had some ineligible participants was judged as preferable compared with the data loss if these studies were excluded.

2.3. Study inclusion and exclusion criteria

Where multiple publications were derived from the same study, these publications were treated as one study. For a detailed list of inclusion and exclusion criteria see Table 1.

2.4. Study selection

The search strategy, including the original and updated search, identified 5427 records. After removing duplicates, 5049 abstracts were screened and 180 full texts were assessed. All studies were imported into Covidence (www.covidence.org). Study selection was performed independently by different combinations of two reviewers for abstracts and full-texts, with a third researcher for consensus if needed. All researchers had extensive research experience in one or more investigated areas and/or systematic reviews in these areas.

2.5. Data collection and analysis

Data of interest included descriptions of physical activity interventions to reduce substance use outcomes and increase physical activity in young people at risk for problematic substance use. Substance use outcomes of interest were (1) participants' substance use behavior (e.g., frequency, amount, and type of substance use); (2) self-reported intent to use a substance in the future; (3) urges (cravings or strength of desire) to use a substance; (4) withdrawal symptoms when not using

the substance; and (5) self-reported symptoms associated with substance use disorder (e.g., impaired control over substance use). Other outcomes were (6) physical activity participation (e.g., levels or frequency of physical activity), attitudes towards physical activity, physical fitness, and (7) mental health: symptoms of mental illness (e.g., depression and anxiety) (see also registered protocol).

Other data of interest included participant and intervention characteristics. Data collection and extraction were performed in duplicate. The research team piloted the data extraction form to ensure uniformity and consistency. Any discrepancies in data extraction were discussed and resolved by at least two researchers and a third if necessary. If a reviewer was an author on any of the studies, they did not perform either primary or secondary data extraction or risk of bias assessment on that study. In studies where the promotion of physical activity, which is the focus of this review, was the 'control condition', the control condition was treated and assessed as the experimental condition. Due to large heterogeneity in measurement tools, outcomes, and study designs, no meta-analysis was conducted. Missing data were addressed by contacting corresponding authors.

2.6. Risk of bias assessment

Risk of bias assessment was completed for each study using the Cochrane risk of bias assessment tool for randomized studies (RoB 2, Higgins et al., 2021) and Cochrane recommendations for risk of bias assessment for non-randomized studies (ROBINS-I, Sterne et al., 2021). Risk of bias assessment was completed independently by at least two researchers. Any discrepancies in judgment were resolved by consensus or the involvement of a third researcher.

The certainty and confidence in the body of evidence were assessed with the GRADE approach (GRADE Working Group., 2004; Guyatt et al., 2008). No studies were excluded based on their GRADE rating, as the purpose of the review was to provide a comprehensive analysis of the existing evidence.

2.6.1. Openness and transparency

The review authors report how they determined study selection, all data exclusions (if any), all manipulations, and all measures in the study. The review was conducted following the APA Reporting Standards for Studies Using No Experimental Manipulation (JARS) (<https://apastyle.apa.org/jars>) (Appelbaum et al., 2018). All measures and detailed risk of bias data are available upon request.

3. Results

3.1. Study selection

For study selection and flow see Fig. 1.

Table 1
Criteria for study/manuscript inclusion or exclusion in the review.

Inclusion criteria	Exclusion criteria
<ul style="list-style-type: none"> Participant group: Young people (mean age between 12 and 25 years) known to be at increased risk of problematic substance use (i.e., substance use that is associated with health and/or social problems and/or legal problems) Intervention: Physical activity interventions applying cognitive, behavioral, or informational approaches including comprehensive multimodal interventions, single-bout, acute studies and educational/informative interventions Presence of a control group (active or inactive) Outcomes of interest: Substance use outcomes (e.g., frequency of substance use, craving/urges to use, amount of use) Randomized controlled trials (RCT) or non-randomized studies (NRS) Peer-reviewed 	<ul style="list-style-type: none"> Publication language not English Protocols of prospective study reports Unpublished doctoral theses Conference abstracts

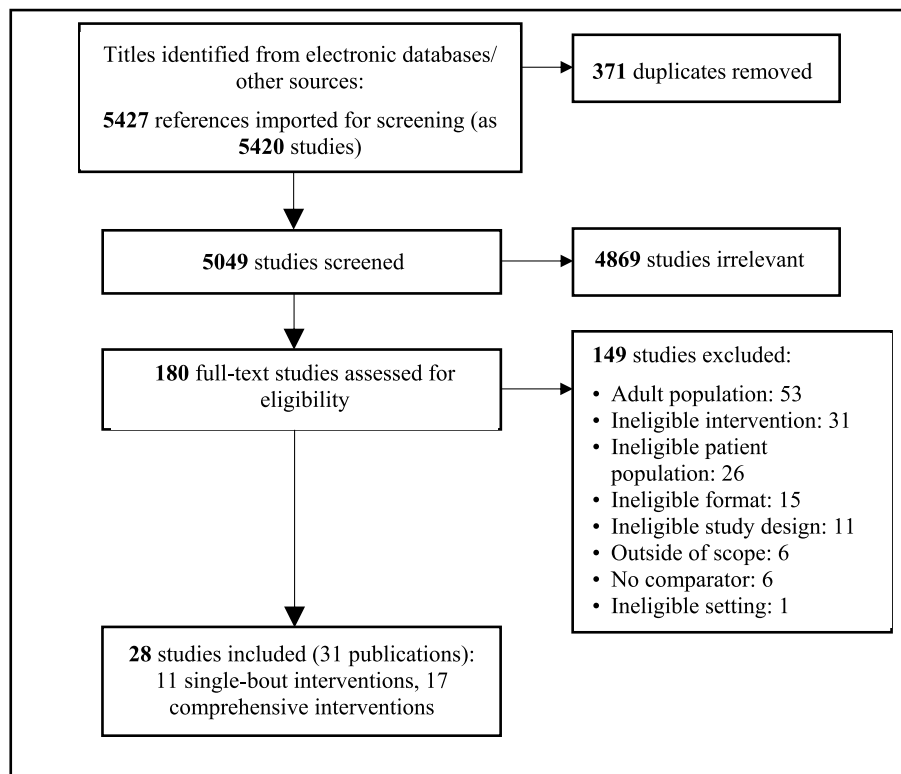


Fig. 1. PRISMA flow diagram of study selection (original and updated).

3.2. Overall study characteristics

A total of 31 publications reporting on 28 studies were included in the systematic review (where one study yielded several publications, only the original is cited). The study designs included 16 randomized controlled trials (An et al., 2013; Correia et al., 2005; Fishbein et al., 2016; Horn et al., 2011; Kerr et al., 2013; Lane et al., 2012; Melamed et al., 2022; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Stanley et al., 2017; Weinstock et al., 2014, 2016; Ybarra et al., 2013), three non-randomized trials (NRS) (Everson et al., 2006; Scott & Myers, 1988; Tesler et al., 2018), four cluster randomized trials (Horn et al., 2011; Lane et al., 2012; Rotheram-Borus et al., 2016; Stanley et al., 2017), and five crossover designs (Faulkner et al., 2010; Janse Van Rensburg & Taylor, 2008; Oh & Taylor, 2014; Taylor et al., 2005; Wilson et al., 2018) (Supplementary Tables 1 and 2).

3.2.1. Differentiation according to intervention format

Interventions included a cluster of short-term, acute interventions predominantly investigating efficacy ($k = 11$, see Supplementary Table 1) (Daniel et al., 2006, 2007; Everson et al., 2006, 2008; Faulkner et al., 2010; Ho et al., 2014; Janse Van Rensburg & Taylor, 2008; Oh & Taylor, 2014; Prapavessis et al., 2014; Taylor et al., 2005; Wilson et al., 2018) and comprehensive, long-term interventions investigating effectiveness ($k = 17$, see Supplementary Table 2) (An et al., 2013; Correia et al., 2005; Fishbein et al., 2016; Horn et al., 2011; Kerr et al., 2013; Lane et al., 2012; Melamed et al., 2022; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Stanley et al., 2017; Tesler et al., 2018; Weinstock et al., 2014, 2016; Ybarra et al., 2013). Efficacy hereby referred to controlled trial environments; effectiveness trials in turn tested the intervention outcomes in 'real-life' environments (Revicki & Frank, 1990; Singal et al., 2014). Studies included both unimodal approaches, i.e., applying one interventional approach, and multimodal approaches targeting health behavior via two or more combined therapeutic approaches. The

combined mean age of participants was 20.7 years across the 28 studies; the overall sample ($N = 5523$) identified as predominantly female (59.1%); 40.9% identified as male.

3.3. Acute, short-term interventions

Acute, short-term studies ($k = 11$) exclusively used unimodal, behavioral approaches, comprising 15–30 min interventions involving 1–2 sessions on a cycle ergometer or treadmill with immediate measurement of outcomes after the intervention. While these interventions predominantly targeted a single behavior (i.e., substance use), one focused on more than one behavior, i.e. substance use and eating behavior (Oh & Taylor, 2014).

Longer-term maintenance of behavior was not assessed after these short-term interventions. Intervention duration ranged from 10 to 15 min with immediate post-intervention assessments at "Immediate Post" (IP), 5 min, 10 min, and up to 30 min post-intervention. Details on study characteristics of acute, short-term interventions can be found in Supplementary Table 1.

3.3.1. Samples

Samples for short-term interventions were drawn from community and educational settings with a single study recruiting within a partly clinical population (Prapavessis et al., 2014). The overall sample ($N = 339$) had a mean age of 22.8 years and was predominantly male (56.3%); 43.7% identified as female. Short-term studies predominantly focused on regular cigarette smokers, with one study focusing on regular cannabis users (Wilson et al., 2018).

3.3.2. Substance use outcomes

Data on substance use as assessed in short-term studies included a variety of self-reported outcomes for tobacco and cannabis use, including short-term abstinence from cigarette smoking (time to first puff) (Faulkner et al., 2010), tobacco withdrawal symptoms (Daniel et al., 2006, 2007; Everson et al., 2006, 2008; Prapavessis et al., 2014),

desire to smoke cigarettes (Daniel et al., 2006, 2007; Everson et al., 2006, 2008; Janse Van Rensburg & Taylor, 2008; Oh & Taylor, 2014; Taylor et al., 2005), intentions to smoke (Janse Van Rensburg & Taylor, 2008), puff volume and puff duration (tobacco) (Faulkner et al., 2010), attentional bias for smoking cues (tobacco) (Oh & Taylor, 2014), baseline consumption frequency (cannabis) (Wilson et al., 2018), and cravings for tobacco (Prapavessis et al., 2014) and cannabis (Wilson et al., 2018). All included studies reported on use of a single substance. A detailed description of measurement tools used for assessing substance use can be found in [Supplementary Table 1](#).

Almost 73% of the included unimodal, short-term studies (8 out of 11 acute interventions) reported a significant improvement in post-intervention substance use outcomes compared to the control conditions (Daniel et al., 2006, 2007; Everson et al., 2008; Faulkner et al., 2010; Janse Van Rensburg & Taylor, 2008; Oh & Taylor, 2014; Prapavessis et al., 2014; Taylor et al., 2005). For tobacco use, these effects included increased time of smoking abstinence (measured as “time to first puff”) (Faulkner et al., 2010), reduction in intent to smoke (Janse Van Rensburg & Taylor, 2008), reduction in attentional bias for smoking (Oh & Taylor, 2014), and decreased desire to smoke/tobacco cravings and tobacco withdrawal symptoms (Daniel et al., 2006, 2007; Everson et al., 2008; Janse Van Rensburg & Taylor, 2008; Prapavessis et al., 2014; Taylor et al., 2005). No significant effect (i.e., decrease in craving) was found for cannabis use (Wilson et al., 2018).

3.3.3. Physical activity

Overall, all short-term interventions facilitated individual, in-person, and supervised physical activity engagement. The nature of physical activity elements included acute exercise bouts of brisk walking on a treadmill or cycle ergometer and text-based promotion of physical activity prior to exercise bouts. Detailed descriptions of short-term intervention characteristics are in [Supplementary Table 3](#) in line with TIDieR (template for intervention description and replication, Hoffmann et al., 2014). Control conditions included delayed control conditions as comparison groups, low-intensity exercise, or passive controls.

No studies identified as “acute, short term” reported on post-intervention physical activity outcomes.

3.3.4. Mental health

Depression symptoms were assessed in 4 short-term interventions (Daniel et al., 2006, 2007; Everson et al., 2006, 2008), one of which found significant decreases in depression symptoms after participating in a physical activity intervention (Daniel et al., 2007).

3.4. Long-term interventions

Long-term interventions included unimodal approaches ($k = 8$) (Correia et al., 2005; Fishbein et al., 2016; Kerr et al., 2013; Lane et al., 2012; Murphy et al., 1986; Scott & Myers, 1988; Stanley et al., 2017; Ybarra et al., 2013), i.e., applying one interventional approach, and multimodal approaches ($k = 9$) targeting one or more health behaviors via different theoretical channels (An et al., 2013; Horn et al., 2011; Melamed et al., 2022; Parker et al., 2016; Prince et al., 2020; Rotheram-Borus et al., 2016; Tesler et al., 2018; Weinstock et al., 2014, 2016). For instance, Horn et al. (2011) applied two different therapeutic/behavioral approaches to reduce substance use and increase physical activity using an informational/educational approach (i.e., smoking cessation curriculum) paired with a behavioral approach (i.e., step-counting challenge using a pedometer). This approach differs from Fishbein et al. (2016) and Scott and Myers (1988) who each only used a single therapeutic (behavioral) approach (i.e., yoga or fitness training, respectively) to reduce substance use behavior.

Compared to acute interventions, long-term interventions predominantly targeted multiple health behaviors (e.g. substance use, physical activity participation, eating behaviors), with only three studies assessing substance use exclusively (Murphy et al., 1986; Prince et al.,

2020; Ybarra et al., 2013).

Intervention duration in long-term studies ranged from several weeks up to 12 months with immediate post-intervention and some studies included follow-up assessments several weeks after intervention completion to assess the maintenance of behavior. For details see [Supplementary Table 2](#).

3.4.1. Samples

Similar to acute interventions, the combined sample of long-term interventions ($N = 5192$) was predominantly drawn from educational settings; five studies recruited participants from community settings (Kerr et al., 2013; Melamed et al., 2022; Prince et al., 2020; Rotheram-Borus et al., 2016; Tesler et al., 2018), and two studies each recruited within clinical settings (Melamed et al., 2022; Parker et al., 2016) and online settings (An et al., 2013; Ybarra et al., 2013), respectively. The sample was predominantly female (60.1%); 39.9% identified as male. The mean age (19.4 years) was slightly younger than that in acute intervention studies. Sample sizes ranged from eight (Ho et al., 2014) to 1654 participants (Kerr et al., 2013).

The long-term studies focussed on the following populations of young people at increased risk for problematic substance use: regular cigarette smokers or users of another substance (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Prince et al., 2020; Ybarra et al., 2013), hazardous drinkers or at risk for binge drinking (Murphy et al., 1986; Weinstock et al., 2014, 2016), young men affected by alcohol use and violence (Rotheram-Borus et al., 2016), at-risk youth populations with high-risk behavior (Fishbein et al., 2016; Lane et al., 2012; Stanley et al., 2017; Tesler et al., 2018) and/or mental illness (Melamed et al., 2022; Parker et al., 2016) and young members of ethnic minorities and low socioeconomic position at known risk for substance use (Kerr et al., 2013; Scott & Myers, 1988). Drop-out rates varied substantially across studies, ranging from 3.7% (Correia et al., 2005) to 48% (Murphy et al., 1986). Reasons for drop-outs included condition assignment (Murphy et al., 1986), lack of motivation (Rotheram-Borus et al., 2016), severity of comorbid mental illness (Melamed et al., 2022), and mental health symptom improvement (Parker et al., 2016).

3.4.2. Substance use outcomes

Self-reported substance use outcomes (i.e., tobacco, alcohol, and other substances) in long-term interventions included: frequency of use, amount of use, attitudes towards use, and quit rates. More than half of the studies ($k = 9$) investigated polysubstance use (An et al., 2013; Correia et al., 2005; Fishbein et al., 2016; Kerr et al., 2013; Melamed et al., 2022; Parker et al., 2016; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Tesler et al., 2018), i.e., measured more than one substance (including alcohol, tobacco, and other substances). The remaining studies reported exclusively on tobacco ($k = 3$) (Horn et al., 2011; Stanley et al., 2017; Ybarra et al., 2013), alcohol use outcomes ($k = 4$) (Lane et al., 2012; Murphy et al., 1986; Weinstock et al., 2014, 2016), or cannabis use ($k = 1$) (Prince et al., 2020). A detailed description of the measures used to assess substance use can be found in [Supplementary Table 2](#).

Overall, study findings indicated that various long-term physical activity interventions, including multimodal and unimodal approaches, may reduce substance use and/or improve associated outcomes. Assessed substance use outcomes included: abstinence from cigarette smoking or quit rates (An et al., 2013; Horn et al., 2011; Ybarra et al., 2013), consumption frequency (tobacco, cannabis, alcohol, other substances) (An et al., 2013; Correia et al., 2005; Fishbein et al., 2016; Kerr et al., 2013; Lane et al., 2012; Melamed et al., 2022; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020; Scott & Myers, 1988; Tesler et al., 2018; Weinstock et al., 2014, 2016), attitudes towards tobacco use (Stanley et al., 2017), recent substance use (methamphetamine, cocaine, heroin) (Rotheram-Borus et al., 2016), and cravings (cannabis) (Prince et al., 2020).

Slightly more than half (52.9%) of the long-term interventions (9 out

of 17) reported a significant improvement in one or more substance use outcomes post-intervention compared to the control conditions (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Tesler et al., 2018). These effects included increased days of smoking abstinence or quit rates (An et al., 2013; Horn et al., 2011) or reductions in daily cigarettes smoked (Tesler et al., 2018). For other substance use, findings reported a decrease in quantity or frequency of reported alcohol consumption (An et al., 2013; Murphy et al., 1986; Tesler et al., 2018), cannabis use frequency/quantity (Parker et al., 2016; Prince et al., 2020), and other substance use frequency including methamphetamine use (Correia et al., 2005; Rotheram-Borus et al., 2016; Scott & Myers, 1988).

Long-term interventions reporting significant improvements in substance use outcomes were predominantly unsupervised ($k = 6$ of 9) (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020) with in-person contact ($k = 9$ of 9) (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Murphy et al., 1986; Parker et al., 2016; Prince et al., 2020; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Tesler et al., 2018) with group ($k = 5$ of 9) (Horn et al., 2011; Murphy et al., 1986; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Tesler et al., 2018) or individual facilitation ($k = 4$ of 9) (An et al., 2013; Correia et al., 2005; Parker et al., 2016; Prince et al., 2020). Similar to short-term interventions, effect sizes were commonly not reported.

Only four of the long-term interventions reporting a significant reduction in substance use outcomes conducted follow-ups (up to 6 months post-intervention) (An et al., 2013; Horn et al., 2011; Murphy et al., 1986; Prince et al., 2020), thus it was not possible to establish overall maintenance of behavior. For detailed findings see Supplementary 2.

3.4.3. Physical activity

All long-term studies reported on elements of physical activity or physical activity promotion; nonetheless, they differed in the extent, nature, and execution of the described physical activity elements. More than half of identified long-term studies ($k = 17$) delivered physical activity promotion through group sessions ($k = 9$ of 17) (Fishbein et al., 2016; Horn et al., 2013; Kerr et al., 2013; Lane et al., 2012; Murphy et al., 1986; Rotheram-Borus et al., 2016; Scott & Myers, 1988; Stanley et al., 2017; Tesler et al., 2018), with the remaining ($k = 8$) delivered as individual sessions (An et al., 2013; Correia et al., 2005; Melamed et al., 2022; Parker et al., 2016; Prince et al., 2020; Weinstock et al., 2014, 2016; Ybarra et al., 2013). The nature of physical activity elements included various types of physical activity, knowledge building and skills improvement, and avatar or text-based promotion of physical activity. Active and passive conditions were used as control groups, including waitlist controls, treatment as usual, or delayed control conditions as comparison groups; three studies used both active and passive controls (Correia et al., 2005; Fishbein et al., 2016; Murphy et al., 1986). Detailed descriptions of intervention characteristics are in Supplementary Table 4 and in line with TIDieR.

Post-intervention physical activity outcomes (including weekly exercise frequency, physical activity participation, beliefs about physical activity, physical self-efficacy, and exercise behavior) were assessed in 12 long-term interventions (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Kerr et al., 2013; Lane et al., 2012; Melamed et al., 2022; Parker et al., 2016; Scott & Myers, 1988; Stanley et al., 2017; Tesler et al., 2018; Weinstock et al., 2014, 2016), eight of which (66.7%) reported a significant positive effect of the intervention on physical activity or associated outcomes (An et al., 2013; Correia et al., 2005; Horn et al., 2011; Melamed et al., 2022; Scott & Myers, 1988; Tesler et al., 2018; Weinstock et al., 2014, 2016). Of these eight studies, six applied multimodal approaches, while only two studies reporting significant results applied unimodal approaches (Correia et al., 2005; Scott & Myers, 1988).

Finally, a single study reported that the physical activity-promoting information led to a decrease in participants' satisfaction with their usual physical activity levels (Stanley et al., 2017).

3.4.4. Mental health

Depression symptoms were assessed in two long-term interventions (Parker et al., 2016; Rotheram-Borus et al., 2016), one of which found significant decreases in depression symptoms after participating in a physical activity intervention (Parker et al., 2016).

3.5. Assessment of internal validity, publication, and reporting bias

Details of the risk of bias assessment can be found in Supplementary Tables 5 and 6. For RCTs, most ratings across domains were either low risk of bias or raised isolated concerns of risk of bias for the included studies. Notably, several studies had an increased risk of bias due to aspects of their design that did not allow for the blinding of participants or personnel (Faulkner et al., 2010; Fishbein et al., 2016; Janse Van Rensburg & Taylor, 2008; Murphy et al., 1986; Oh & Taylor, 2014; Rotheram-Borus et al., 2016; Wilson et al., 2018), which is common in physical activity intervention studies (El-Kotob & Giangregorio, 2018). Based on the GRADE and risk of bias assessment which assessed most studies as overall low risk, the level of evidence was not downgraded for the included RCTs (An et al., 2013; Correia et al., 2005; Daniel et al., 2006, 2007; Everson et al., 2008; Faulkner et al., 2010; Fishbein et al., 2016; Ho et al., 2014; Horn et al., 2011; Janse Van Rensburg & Taylor, 2008; Kerr et al., 2013; Lane et al., 2012; Melamed et al., 2022; Murphy et al., 1986; Oh & Taylor, 2014; Parker et al., 2016; Prapavessis et al., 2014; Prince et al., 2020; Rotheram-Borus et al., 2016; Stanley et al., 2017; Taylor et al., 2005; Weinstock et al., 2014, 2016; Wilson et al., 2018; Ybarra et al., 2013). By Cochrane recommendations, the level of evidence for the included NRS (Everson et al., 2006; Scott & Myers, 1988; Tesler et al., 2018) was downgraded to low (Schünemann et al., 2021), due to the inherent risk of bias associated with lack of randomization.

3.6. Adverse and harmful effects

Three studies reported on adverse effects of the interventions, two of which were short-term interventions reporting adverse mood effects (Everson et al., 2008) and discomfort (Prapavessis et al., 2014). One long-term intervention reported study-related injury (Weinstock et al., 2016).

4. Discussion

This systematic review examined the effect of various physical activity interventions in the context of early intervention on substance use-related outcomes, physical activity, and mental health outcomes (assessed as depression symptoms) in young people aged 12–25 years, at risk for problematic substance use. The review focused on early intervention in this age group, examining all physical activity intervention types with the potential to affect substance use outcomes. Study formats of interest were acute or short-term studies, and long-term interventions, including multimodal and unimodal interventions. Overall, 61% of the included physical activity interventions improved substance use outcomes in young people, including a reduction in the frequency of use, amount of use, intent to use, and/or cravings for alcohol, tobacco, and other substances. While all types of investigated interventions showed potential benefits for substance use outcomes among young people aged 12–25, more than two-thirds of the short-term or acute studies reported significant effects compared to just over half of the long-term studies.

Short-term, acute studies commonly investigate efficacy rather than effectiveness, and as such are often not considered to be included in the group of "traditional interventions". However, with a significantly

smaller amount of organizational and financial resources associated with the delivery of this type of intervention, the clinical implications of these findings for early intervention, that is the potential of acute physical activity bouts to be integrated into clinical substance use treatment services, needs to be considered.

Additionally, multimodal approaches seemed more likely to reduce substance use and increase physical activity (67%, 6 of 9 multimodal studies) than did unimodal approaches (58%, 11 of 19 unimodal studies). While multimodal physical activity interventions appear promising for the reduction of substance use, it remains unclear which intervention elements contributed to the intervention effect.

Further, the reported effects need to be interpreted in light of the overall low quality of the existing evidence. Moreover, it is currently unclear whether the observed effects persist over time, particularly those in short-term studies, as would be preferable in terms of clinical utility.

Significant effects were reported across short-term and long-term studies with varied individual characteristics such as delivery format and intervention duration (See also [Supplementary Tables 1 and 2](#)). This suggests that even single bouts of physical activity may have the potential to temporarily disrupt substance use in this population. Findings also suggest that physical activity interventions can be delivered in a range of settings and circumstances by different providers (e.g., trained peers, clinicians, and coaches).

The findings of this review are broadly consistent with previous studies and systematic reviews on the effects of physical activity on substance use outcomes in young people ([Linke & Ussher, 2015](#); [Simonton et al., 2018](#); [Zschucke et al., 2012](#)). The current review included 28 studies and a higher mean age of participants of 20.7 years, however, found similar results to the [Simonton et al. \(2018\)](#) review that included fewer studies, did not compare long-term and acute interventions, and had a slightly younger target population. The current review thus captured the peak period of young adulthood associated with the highest risk for problematic substance use ([Degehardt et al., 2016](#)).

The findings further compare to a review by [Thompson et al. \(2020\)](#) who similar to the current review, found a promising trend for short-term effects of physical activity interventions for various substances. However, [Thompson et al. \(2020\)](#) also highlight concerns regarding the inability to quantitatively examine existing physical activity interventions, limits to generalisability of the results, and large heterogeneity of included interventions which were also identified in the current review. In comparison to the current review, which focussed explicitly on young people (referring to at-risk adolescents and young adults aged 12–25 years), the review conducted by Thompson et al. focussed on different age populations, with adolescents being investigated for prevention studies, and adult populations being investigated for approaches focusing on substance use reduction and clinical populations for substance use disorder treatment.

An earlier review by [Linke and Ussher \(2015\)](#) reported a positive impact of physical activity on young people's substance use, finding a superior effect of supervised, group-based interventions. Superiority of supervised interventions has also been found in adult populations ([Abrantes & Blevins, 2019](#)). Conversely, the current review found both supervised and unsupervised, and an overall larger number of individual rather than group-based interventions (including both short-term and long-term interventions) to improve substance use outcomes. This could be due to the inclusion of acute, short-term interventions, which were predominantly facilitated as individual sessions.

Similar to the current review, Linke and Ussher highlighted difficulties in drawing conclusions on the characteristics of effective intervention due to the large methodological diversity among studies, emphasizing the complexity of the effect and covariation with participant characteristics, settings, substance type, and physical activity type.

Last, the studies reviewed here showed mixed findings about the effects of physical activity interventions on depression symptoms. This

differs from two earlier reviews indicating a positive effect of physical activity interventions on depression in young people ([Bailey et al., 2018](#); [Recchia et al., 2023](#)). The difference may be explained by a potential floor effect, i.e., included studies did not recruit participants based on depressive symptoms, and the low number of included studies measuring depression symptoms. Further research focusing on young people with comorbid substance use and depression is needed.

This review has several strengths. The comprehensive search strategy and inclusion criteria, including RCTs and NRS, and different intervention formats (e.g., acute, long-term, multimodal, unimodal) allowed a comprehensive assessment of the evidence base and highlighted the broad scope of different modalities and flexibility of intervention formats with the potential to reduce problematic substance use in young people. Another strength is the focus on early intervention, encompassing both adolescents and young adults at risk for problematic substance use. At-risk populations are of particular relevance to examining interventions in youth mental health, including youth substance use ([Nawi et al., 2021](#); [Stone et al., 2012](#)).

Several limitations to this review exist, including the restriction of study inclusion to studies published in the English language, and consequent lack of knowledge on findings in non-English publications; and the inclusion of studies with a small portion of ineligible sub-populations (i.e. where some individuals in the sample were outside the targeted age range). The risk of limited applicability for these sub-populations was balanced with the critical data loss due to excluding these studies. The conceptual lack of clarity within the academic and clinical literature regarding at-risk definitions and the use of the term "at-risk" needs to be critically considered and this current lack of clarity in definition was another limitation of this review ([Follesø, 2015](#); [Foster & Spencer, 2010](#); [Tait, 1995](#)).

There are several limitations to the available evidence, including the recruitment of participants in predominantly educational settings, with no clear indication of whether participants were treatment-seeking. It is unclear if a comparable effect for the latter can be inferred from data on young people who were not seeking help for their substance use. Further, participant groups were predominantly drawn from Western-centric countries, thus findings may not be generalizable to non-Western societies. The heterogenous nature of existing evidence poses a significant limitation to comparability ([Linke & Ussher, 2015](#); [Simonton et al., 2018](#); [Thompson et al., 2020](#)) and evidence synthesis; no meta-analysis could be conducted to increase explanatory power. Further, the incomplete reporting of relevant data in some studies (e.g., intervention and study characteristics, statistical data, effect size estimates) combined with the methodological diversity, variation in measurement tools and outcomes assessed, and lack of objective measures (previously noted by [Simonton et al., 2018](#); [Thompson et al., 2020](#)) means it remains unclear as to which intervention characteristics are most strongly associated with significant changes in substance use, physical activity, or mental health outcomes. Additionally, while physical activity seems to provide a potential approach to address substance use among young people – possibly increasing engagement of populations that are ambivalent regarding their substance use – it is not clear if physical activity can overcome the limitations of existing interventions and treatments that lead to high attrition and treatment failure rates. Additional research and consistent reporting are needed to explore predictors of intervention adherence ([Abrantes & Blevins, 2019](#)) and to provide clear guidance on whether and how to implement physical activity interventions into youth substance use and mental health services.

One opportunity to enhance cohesion in reporting and reduce methodological heterogeneity is via consensus regarding a set of gold standard measures for assessing young people's substance use within the international research context. This would allow comparability between different studies and synthesis of a seemingly heterogeneous body of research into more precise estimates of treatment effects than is possible via individual studies. Such estimates are crucial for guiding clinical

decision-making and policy development (Haidich, 2010), as it is rarely possible to draw implications for policy and practice from individual research studies (Durlak & Lipsey, 1991).

Last, several studies did not report on post-intervention physical activity outcomes, however, measuring and reporting the levels of engagement in physical activity is essential to be able to determine the mechanisms of action of the PA interventions.

4.1. Recommendations for future research

Further research addressing the following themes is recommended (some of which overlap with Linke & Ussher, 2015): Superior combinations of intervention characteristics (e.g., different exercise intensities, different delivery modes) to optimize efficacy; integration of physical activity as an adjunct to treatment within existing substance use treatment modalities (rather than as a stand-alone treatment, as in the majority of existing studies); differences in effect between treatment-seeking and non-treatment seeking populations; long-term effects on substance use outcomes of single versus multiple short-term bouts versus longer programs of physical activity at different intensities; behavioral maintenance of found effects for acute interventions over a longer period of time; experienced barriers and professional development needs of clinicians regarding the integration of adjunctive physical activity programs for young people at risk for problematic substance use; the effect of physical activity on newly emerging substance use trends (including novel psychoactive substances); covariates, moderators, and mediators influencing the effect of physical activity promotion interventions; and relationships (correlations, interactions) between participant and intervention characteristics and outcomes require consideration. Lastly, the benefits, advantages and disadvantages, and challenges of integrating different intervention formats into treatment practice should be further explored.

4.2. Implications

This review demonstrates that various formats of interventions, such as interventions using one or more modalities including different physical activities (e.g. weight training, tailored running regimens), but particularly acute, short-term physical activity interventions, may have the potential to improve substance use outcomes (alcohol, tobacco and other) such as reducing the frequency or amount of use, intentions to use, and/or craving in young people at risk for problematic substance use recruited in educational and community settings. The broad diversity of potentially beneficial physical activity interventions, but especially the short nature of acute interventions, commonly involving few elements and little personnel, suggest flexibility regarding as to how, when and by whom such interventions could be delivered to young people at risk for problematic substance use. Physical activity interventions may provide an accessible, engaging, and motivating treatment avenue for young people who do not identify their substance use as problematic.

Overall, the promising outcomes identified provide initial evidence to support larger, more rigorous, and more systematic investigations of the efficacy of physical activity in reducing substance use and associated problems in young people. Further research should also focus on assessing the effectiveness of these different formats of physical activity intervention as integrated into treatment to reduce substance use in young people.

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Openness and transparency

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Declaration of competing interest

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

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

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References

- Abrantes, A. M., & Blevins, C. E. (2019). Exercise in the context of substance use treatment: Key issues and future directions. *Current Opinion in Psychology*, 30, 103–108. <https://doi.org/10.1016/j.copsyc.2019.04.001>
- An, L. C., Demers, M. R., Kirch, M. A., Considine-Dunn, S., Nair, V., Dasgupta, K., Narisetty, N., Resnicow, K., & Ahluwalia, J. (2013). A randomized trial of an avatar-hosted multiple behavior change intervention for young adult smokers. *Journal of the National Cancer Institute Monographs*, (47), 209–215. <https://doi.org/10.1093/jncimonographs/igt021>, 2013.
- Appelbaum, M., Cooper, H., Kline, R. B., Mayo-Wilson, E., Nezu, A. M., & Rao, S. M. (2018). Journal article reporting standards for quantitative research in psychology: The APA Publications and Communications Board task force report. *American Psychologist*, 73(1), 3–25. <https://doi.org/10.1037/amp0000191>
- Austin, A. M., Macgowan, M. J., & Wagner, E. F. (2016). Effective family-based interventions for adolescents with substance use problems: A systematic review. *Research on Social Work Practice*, 15(2), 67–83. <https://doi.org/10.1177/1049731504271606>
- Babic, M. J., Morgan, P. J., Plotnikoff, R. C., Lonsdale, C., White, R. L., & Lubans, D. R. (2014). Physical activity and physical self-concept in youth: Systematic review and meta-analysis. *Sports Medicine*, 44(11), 1589–1601. <https://doi.org/10.1007/s40279-014-0229-z>

- Bailey, A. P., Hetrick, S. E., Rosenbaum, S., Purcell, R., & Parker, A. G. (2018). Treating depression with physical activity in adolescents and young adults: A systematic review and meta-analysis of randomised controlled trials. *Psychological Medicine*, 48(7), 1068–1083. <https://doi.org/10.1017/S0033291717002653>
- Bousoño, S. M., Al-Halabi, S., Burón, P., Garrido, M., Díaz-Mesa, E., Galván, G., García-Alvarez, L., Carli, V., Hoven, C., Sarchiapone, M., Wasserman, D., Bousoño, M., García-Portilla, P., Iglesias, C., Alejandra Sáiz, P., & Bobes, J. (2017). Substance use or abuse, internet use, psychopathology and suicidal ideation in adolescents. *Adicciones*, 29(2), 97–104. <https://doi.org/10.20882/adicciones.811>
- Carter, T., Pascoe, M., Bastounis, A., Morres, I. D., Callaghan, P., & Parker, A. G. (2021). The effect of physical activity on anxiety in children and young people: A systematic review and meta-analysis. *Journal of Affective Disorders*, 285, 10–21. <https://doi.org/10.1016/j.jad.2021.02.026>
- Castelpietra, G., Knudsen, A. K. S., Agardh, E. E., Armocida, B., Beghi, M., Iburg, K. M., Logroscino, G., Ma, R., Starace, F., Steel, N., Addolorato, G., Andrei, C. L., Andrei, T., Ayuso-Mateos, J. L., Banach, M., Barnighausen, T. W., Barone-Adesi, F., Bhagavathula, A. S., Carvalho, F., ... Monasta, L. (2022). The burden of mental disorders, substance use disorders and self-harm among young people in Europe, 1990-2019: Findings from the Global Burden of Disease Study 2019. *The Lancet Regional Health Europe*, 16. <https://doi.org/10.1016/j.lanepe.2022.100341>. article 100341.
- Chaplin, T. M., Niehaus, C., & Goncalves, S. F. (2018). Stress reactivity and the developmental psychopathology of adolescent substance use. *Neurobiology of Stress*, 9, 133–139. <https://doi.org/10.1016/j.ynstr.2018.09.002>
- Chung, T., & Maisto, S. A. (2006). Relapse to alcohol and other drug use in treated adolescents: Review and reconsideration of relapse as a change point in clinical course. *Clinical Psychology Review*, 26(2), 149–161. <https://doi.org/10.1016/j.cpr.2005.11.004>
- Ciesla, J. R. (2010). Evaluating the risk of relapse for adolescents treated for substance abuse. *Addictive Disorders & Their Treatment*, 9(2), 87–92.
- Cornelius, J. R., Maisto, S. A., Pollock, N. K., Martin, C. S., Salloum, I. M., Lynch, K. G., & Clark, D. B. (2003). Rapid relapse generally follows treatment for substance use disorders among adolescents. *Addictive Behaviors*, 28(2), 381–386.
- Correia, C. J., Benson, T. A., & Carey, K. B. (2005). Decreased substance use following increases in alternative behaviors: A preliminary investigation. *Addictive Behaviors*, 30(1), 19–27. <https://doi.org/10.1016/j.addbeh.2004.04.006>
- Daniel, J. Z., Cropley, M., & Fife-Schaw, C. (2006). The effect of exercise in reducing desire to smoke and cigarette withdrawal symptoms is not caused by distraction. *Addiction*, 101(8), 1187–1192. <https://doi.org/10.1111/j.1360-0443.2006.01457.x>
- Daniel, J. Z., Cropley, M., & Fife-Schaw, C. (2007). Acute exercise effects on smoking withdrawal symptoms and desire to smoke are not related to expectation. *Psychopharmacology*, 195(1), 125–129. <https://doi.org/10.1007/s00213-007-0889-6>
- Degenhardt, L., Stockings, E., Patton, G., Hall, W. D., & Lynskey, M. (2016). The increasing global health priority of substance use in young people. *The Lancet Psychiatry*, 3(3), 251–264. [https://doi.org/10.1016/s2215-0366\(15\)00508-8](https://doi.org/10.1016/s2215-0366(15)00508-8)
- Durlak, J. A., & Lipsey, M. W. (1991). A practitioner's guide to meta-analysis. *American Journal of Community Psychology*, 19(3), 291–332. <https://doi.org/10.1007/BF00938026>
- El-Kotob, R., & Giangregorio, L. M. (2018). Pilot and feasibility studies in exercise, physical activity, or rehabilitation research. *Pilot and Feasibility Studies*, 4. <https://doi.org/10.1186/s40814-018-0326-0>. article 137.
- Everson, E. S., Daley, A. J., & Ussher, M. (2006). Does exercise have an acute effect on desire to smoke, mood and withdrawal symptoms in abstaining adolescent smokers? *Addictive Behaviors*, 31(9), 1547–1558. <https://doi.org/10.1016/j.addbeh.2005.11.007>
- Everson, E. S., Daley, A. J., & Ussher, M. (2008). The effects of moderate and vigorous exercise on desire to smoke, withdrawal symptoms and mood in abstaining young adult smokers. *Mental Health and Physical Activity*, 1(1), 26–31. <https://doi.org/10.1016/j.mhpa.2008.06.001>
- Fadus, M. C., Squeglia, L. M., Valdez, E. A., Tomko, R. L., Bryant, B. E., & Gray, K. M. (2019). Adolescent substance use disorder treatment: An update on evidence-based strategies. *Current Psychiatry Reports*, 21(10). <https://doi.org/10.1007/s11920-019-1086-0>. article 96.
- Faulkner, G. E., Arbour-Nicitopoulos, K. P., & Hsin, A. (2010). Cutting down one puff at a time: The acute effects of exercise on smoking behaviour. *Journal of Smoking Cessation*, 5(2), 130–135. <https://doi.org/10.1375/jsc.5.2.130>
- Fishbein, D., Miller, S., Herman-Stahl, M., Williams, J., Lavery, B., Markovitz, L., Kluckman, M., Mosoriak, G., & Johnson, M. (2016). Behavioral and psychophysiological effects of a yoga intervention on high-risk adolescents: A randomized control trial. *Journal of Child and Family Studies*, 25(2), 518–529. <https://doi.org/10.1007/s10826-015-0231-6>
- Follesø, R. (2015). Youth at risk or terms at risk. *Young*, 23(3), 240–253.
- Foster, K. R., & Spencer, D. (2010). At risk of what? Possibilities over probabilities in the study of young lives. *Journal of Youth Studies*, 14(1), 125–143. <https://doi.org/10.1080/13676261.2010.506527>
- GRADE Working Group. (2004). Grading quality of evidence and strength of recommendations. *BMJ*, 328(7454), 1–8.
- Green, K. M., Musci, R. J., Matson, P. A., Johnson, R. M., Reboussin, B. A., & Jalongo, N. S. (2017). Developmental patterns of adolescent marijuana and alcohol use and their joint association with sexual risk behavior and outcomes in young adulthood. *Journal of Urban Health*, 94(1), 115–124. <https://doi.org/10.1007/s11524-016-0108-z>
- Guerrí, C., & Pascual, M. (2019). Impact of neuroimmune activation induced by alcohol or drug abuse on adolescent brain development. *International Journal of Developmental Neuroscience*, 77, 89–98. <https://doi.org/10.1016/j.ijdevneu.2018.11.006>
- Guyatt, G. H., Oxman, A. D., Vist, G. E., Kunz, R., Falck-Ytter, Y., Alonso-Coello, P., & Schünemann, H. J. (2008). Grade: An emerging consensus on rating quality of evidence and strength of recommendations. *BMJ*, 336(7650), 924–926.
- Haidich, A. B. (2010). Meta-analysis in medical research. *Hippokratia*, 14, 29–37.
- Hall, W. D., Patton, G., Stockings, E., Weier, M., Lynskey, M., Morley, K. I., & Degenhardt, L. (2016). Why young people's substance use matters for global health. *The Lancet Psychiatry*, 3(3), 265–279. [https://doi.org/10.1016/s2215-0366\(16\)00013-4](https://doi.org/10.1016/s2215-0366(16)00013-4)
- Hammond, C. J. (2016). The role of pharmacotherapy in the treatment of adolescent substance use disorders. *Child and Adolescent Psychiatric Clinics of North America*, 25(4), 685–711. <https://doi.org/10.1016/j.chc.2016.05.004>
- Heath, G. W., Parra, D. C., Sarmiento, O. L., Andersen, L. B., Owen, N., Goenka, S., Montes, F., & Brownson, R. C. (2012). Evidence-based intervention in physical activity: Lessons from around the world. & Lancet Physical Activity Series Working Group *Lancet*, 380(9838), 272–281. [https://doi.org/10.1016/S0140-6736\(12\)60816-2](https://doi.org/10.1016/S0140-6736(12)60816-2)
- Helzer, J. E., Burnam, A., & McEvoy, L. T. (1991). Alcohol abuse and dependence. In L. N. Robins, & D. A. Regier (Eds.), *Psychiatric disorders in America: The epidemiologic catchment area study*. The Free Press.
- Higgins, J. P. T., Savović, J., Page, M. J., Elbers, R. G., & Sterne, J. A. C. (2021). Chapter 8: Assessing risk of bias in a randomized trial. In J. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. Page, & V. Welch (Eds.), *Cochrane Handbook for systematic Reviews of Interventions version 6.2*. Cochrane. www.training.cochrane.org/handbook
- Hoffmann, T., Glasziou, P., Boutron, I., Milne, R., & Perera, R. (2014). Better reporting of interventions: Template for intervention description and replication (TIDieR) checklist and guide. *BMJ*, 348, 1–12. <https://doi.org/10.1136/bmj.g1687>
- Hofmann, S. G. (2012). *An introduction to modern CBT: Psychological solutions to mental health problems*.
- Hogue, A., Henderson, C. E., Becker, S. J., & Knight, D. K. (2018). Evidence base on outpatient behavioral treatments for adolescent substance use, 2014-2017: Outcomes, treatment delivery, and promising horizons. *Journal of Clinical Child and Adolescent Psychology*, 47(4), 499–526. <https://doi.org/10.1080/15374416.2018.1466307>
- Ho, J. Y., Kraemer, W. J., Volek, J. S., Vingren, J. L., Fragala, M. S., Flanagan, S. D., Maladougadock, J., Szivak, T. K., Hatfield, D. L., Comstock, B. A., Dunn-Lewis, C., Ciccolo, J. T., & Maresch, C. M. (2014). Effects of resistance exercise on the HPA axis response to psychological stress during short-term smoking abstinence in men. *Addictive Behaviors*, 39(3), 695–698. <https://doi.org/10.1016/j.addbeh.2013.10.027>
- Horn, K., Branstetter, S., Zhang, J., Jarrett, T., Tompkins, N. O., Anesetti-Rothermel, A., Olfert, M., Richards, T., & Dino, G. (2013). Understanding physical activity outcomes as a function of teen smoking cessation. *Journal of Adolescent Health*, 53(1), 125–131. <https://doi.org/10.1016/j.jadohealth.2013.01.019>
- Horn, K., Dino, G., Branstetter, S. A., Zhang, J., Noerachmanto, N., Jarrett, T., & Taylor, M. (2011). Effects of physical activity on teen smoking cessation. *Pediatrics*, 128(4), 801–811. <https://doi.org/10.1542/peds.2010-2599>
- Horrell, J., Thompson, T. P., Taylor, A. H., Neale, J., Husk, K., Wanner, A., Creanor, S., Wei, Y., Kandiyali, R., Sinclair, J., Nasser, M., & Wallace, G. (2020). Qualitative systematic review of the acceptability, feasibility, barriers, facilitators and perceived utility of using physical activity in the reduction of and abstinence from alcohol and other drug use. *Mental Health and Physical Activity*, 19. <https://doi.org/10.1016/j.mhpa.2020.100355>
- Janse Van Rensburg, K., & Taylor, A. H. (2008). The effects of acute exercise on cognitive functioning and cigarette cravings during temporary abstinence from smoking. *Human Psychopharmacology: Clinical and Experimental*, 23(3), 193–199. <https://doi.org/10.1002/hup.925>
- Kerr, J. C., Valois, R. F., Farber, N. B., Vanable, P. A., Diclemente, R. J., Salazar, L., Brown, L. K., Carey, M. P., Romer, D., Stanton, B., Jemmott, J. B., 3rd, Jemmott, L. S., Spencer, A. M., & Annang, L. (2013). Effects of promoting health among teens on dietary, physical activity and substance use knowledge and behaviors for african american adolescents. *American Journal of Health Education*, 44(4), 191–202. <https://doi.org/10.1080/19325037.2013.798218>
- Kim-Spoon, J., Kahn, R. E., Lauharatanahirun, N., Deater-Deckard, K., Bickel, W. K., Chiu, P. H., & King-Casas, B. (2017). Executive functioning and substance use in adolescence: Neurobiological and behavioral perspectives. *Neuropsychologia*, 100, 79–92. <https://doi.org/10.1016/j.neuropsychologia.2017.04.020>
- Kwan, M. Y., Cairney, J., Faulkner, G. E., & Pullenayegum, E. E. (2012). Physical activity and other health-risk behaviors during the transition into early adulthood: A longitudinal cohort study. *American Journal of Preventive Medicine*, 42(1), 14–20. <https://doi.org/10.1016/j.amepre.2011.08.026>
- Lane, D. J., Lindemann, D. F., & Schmidt, J. A. (2012). A comparison of computer-assisted and self-management programs for reducing alcohol use among students in first year experience courses. *Journal of Drug Education*, 42(2), 119–135. <https://doi.org/10.2190/DE.42.2.a>
- Linke, S. E., & Ussher, M. (2015). Exercise-based treatments for substance use disorders: Evidence, theory, and practicality. *The American Journal of Drug and Alcohol Abuse*, 41(1), 7–15. <https://doi.org/10.3109/00952990.2014.976708>
- Lubans, D. R., Plotnikoff, R. C., & Lubans, N. J. (2012). Review: A systematic review of the impact of physical activity programmes on social and emotional well-being in at-risk youth. *Child and Adolescent Mental Health*, 17(1), 2–13. <https://doi.org/10.1111/j.1475-3588.2011.00623.x>
- Lynch, W. J., Peterson, A. B., Sanchez, V., Abel, J., & Smith, M. A. (2013). Exercise as a novel treatment for drug addiction: A neurobiological and stage-dependent hypothesis. *Neuroscience & Biobehavioral Reviews*, 37(8), 1622–1644. <https://doi.org/10.1016/j.neubiorev.2013.06.011>

- Marcus, B. H., Eaton, C. A., Rossi, J. S., & Harlow, L. L. (1997). Initiation and maintenance of exercise behavior. In D. S. Gochman (Ed.), *Handbook of health behavior research II* (pp. 335–352). Plenum Press.
- McGorry, P. D., Purcell, R., Hickie, I. B., & Jorm, A. F. (2007). Investing in youth mental health is a best buy. *Medical Journal of Australia*, 187(Supplement 7), 5–7. <https://doi.org/10.5694/j.1326-5377.2007.tb01326.x>
- Melamed, O., Voineskos, A., Vojtila, L., Ashfaq, I., Veldhuizen, S., Dragonetti, R., Carriere, R., LaChance, L., Kohut, S. A., Tulloch, T., Argarwal, S. M., Hahn, M., Mulsant, B. H., & Selby, P. (2022). Technology-enabled collaborative care for youth with early psychosis: Results of a feasibility study to improve physical health behaviours. *Early Intervention in Psychiatry*, 16(10), 1143–1151. <https://doi.org/10.1111/eip.13266>
- Morin, J. G., Afzali, M. H., Bourque, J., Stewart, S. H., Seguin, J. R., O'Leary-Barrett, M., & Conrod, P. J. (2019). A population-based analysis of the relationship between substance use and adolescent cognitive development. *American Journal of Psychiatry*, 176(2), 98–106. <https://doi.org/10.1176/appi.ajp.2018.18020202>
- Murphy, T. J., Pagano, R. R., & Marlatt, G. A. (1986). Lifestyle modification with heavy alcohol drinkers: Effects of aerobic exercise and meditation. *Addictive Behaviors*, 11(2), 175–186. [https://doi.org/10.1016/0306-4603\(86\)90043-2](https://doi.org/10.1016/0306-4603(86)90043-2)
- Nawi, A. M., Ismail, R., Ibrahim, F., Hassan, M. R., Manaf, M. R. A., Amit, N., Ibrahim, N., & Shafuridin, N. S. (2021). Risk and protective factors of drug abuse among adolescents: A systematic review. *BMC Public Health*, 21(1), Article 2088. <https://doi.org/10.1186/s12889-021-11906-2>
- Nock, N. L., Minnes, S., & Alberts, J. L. (2017). Neurobiology of substance use in adolescents and potential therapeutic effects of exercise for prevention and treatment of substance use disorders. *Birth Defects Research*, 109(20), 1711–1729. <https://doi.org/10.1002/bdr2.1182>
- Oh, H., & Taylor, A. H. (2014). Self-regulating smoking and snacking through physical activity. *Health Psychology*, 33(4), 349–359. <https://doi.org/10.1037/a0032423>
- Parker, A. G., Hetrick, S. E., Jorm, A. F., Mackinnon, A. J., McGorry, P. D., Yung, A. R., Scanlan, F., Stephens, J., Baird, S., Moller, B., & Purcell, R. (2016). The effectiveness of simple psychological and physical activity interventions for high prevalence mental health problems in young people: A factorial randomised controlled trial. *Journal of Affective Disorders*, 196, 200–209. <https://doi.org/10.1016/j.jad.2016.02.043>
- Prapavessis, H., De Jesus, S., Harper, T., Cramp, A., Fitzgeorge, L., Mottola, M. F., Ussher, M., Faulkner, G., & Selby, P. (2014). The effects of acute exercise on tobacco cravings and withdrawal symptoms in temporary abstinent pregnant smokers. *Addictive Behaviors*, 39(3), 703–708. <https://doi.org/10.1016/j.addbeh.2013.10.034>
- Prince, M. A., Collins, R. L., Wilson, S. D., & Vincent, P. C. (2020). A preliminary test of a brief intervention to lessen young adults' cannabis use: Episode-level smartphone data highlights the role of protective behavioral strategies and exercise. *Experimental and Clinical Psychopharmacology*, 28(2), 150–156. <https://doi.org/10.1037/pha0000301>
- Recchia, F., Bernal, J. D., Fong, D. Y., Wong, S. H., Chung, P. K., Chan, D. K., ... Siu, P. M. (2023). Physical activity interventions to alleviate depressive symptoms in children and adolescents a systematic review and meta-analysis. *JAMA Pediatrics*, 177(2), 132–140.
- Reveck, D. A., & Frank, L. (1990). Pharmacoeconomic evaluation in the real world: Effectiveness versus efficacy studies. *Pharmacoeconomics*, 15, 423–434.
- Rhodes, T., Lilly, R., Fernández, C., Giorgino, E., Kemmesis, U. E., Ossebaard, H. C., Lalam, N., Faasen, I., & Spannow, K. E. (2003). Risk factors associated with drug use: The importance of 'risk environment'. *Drugs: Education, Prevention & Policy*, 10(4), 303–329. <https://doi.org/10.1080/0968763031000077733>
- Rotheram-Borus, M., Tomlinson, M., Durkin, A., Baird, K., DeCelles, J., & Swendeman, D. (2016). Feasibility of using soccer and job training to prevent drug abuse and HIV. *AIDS and Behavior*, 20(9), 1841–1850. <https://doi.org/10.1007/s10461-015-1262-0>
- Schlag, A. K. (2020). Percentages of problem drug use and their implications for policy making: A review of the literature. *Drug Science, Policy and Law*, 6, 1–9. <https://doi.org/10.1177/2050324520904540>
- Schünemann, H. J., Higgins, J. P. T., Vist, G. E., Glasziou, P., Akl, E. A., Skoetz, N., & Guyatt, G. H. (2021). Chapter 14: Completing 'Summary of findings' tables and grading the certainty of the evidence. In J. P. T. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. J. Page, & V. A. Welch (Eds.), *Cochrane handbook for systematic reviews of interventions version 6.2*. Cochrane. <http://www.training.cochrane.org/handbook>.
- Scott, K. A., & Myers, A. M. (1988). Impact of fitness training on native adolescents' self-evaluations and substance use. *Canadian Journal of Public Health*, 79(6), 424–429.
- Seddou, T. (2010). What is a problem drug user? *Addiction Research and Theory*, 19(4), 334–343. <https://doi.org/10.3109/16066359.2010.512109>
- Shea, B. J., Reeves, B. C., Wells, G., Thuku, M., Hamel, C., Moran, J., Moher, D., Tugwell, P., Welch, V., Kristjansson, E., & Henry, D. A. (2017). Amstar 2: A critical appraisal tool for systematic reviews that include randomised or non-randomised studies of healthcare interventions, or both. *BMJ*, 358, 1–9. <https://doi.org/10.1136/bmj.j4008>
- Simonton, A. J., Young, C. C., & Johnson, K. E. (2018). Physical activity interventions to decrease substance use in youth: A review of the literature. *Substance Use & Misuse*, 53(12), 2052–2068. <https://doi.org/10.1080/10826084.2018.1452338>
- Singal, A. G., Higgins, P. D., & Waljee, A. K. (2014). A primer on effectiveness and efficacy trials. *Clinical and Translational Gastroenterology*, 5(1). <https://doi.org/10.1038/ctg.2013.13>. article e45.
- Smith, M. A., & Lynch, W. J. (2012). Exercise as a potential treatment for drug abuse: Evidence from preclinical studies. *Frontiers in Psychiatry*, 2, 1–10. <https://doi.org/10.3389/fpsy.2011.00082>
- Stanley, Z. D., Asfour, L. W., Weitzman, M., & Sherman, S. E. (2017). Implementation of a peer-mediated health education model in the United Arab Emirates: Addressing risky behaviours among expatriate adolescents. *Eastern Mediterranean Health Journal*, 23(7), 480–485.
- Sterne, J. A. C., Hernán, M. A., McAleenan, A., Reeves, B. C., & Higgins, J. P. T. (2021). Chapter 25: Assessing risk of bias in a non-randomized study. In J. Higgins, J. Thomas, J. Chandler, M. Cumpston, T. Li, M. Page, & V. Welch (Eds.), *Cochrane Handbook for systematic Reviews of Interventions version 6.2*. Cochrane. <http://www.training.cochrane.org/handbook>.
- Stockings, E., Hall, W. D., Lynskey, M., Morley, K. I., Reavley, N., Strang, J., Patton, G., & Degenhardt, L. (2016). Prevention, early intervention, harm reduction, and treatment of substance use in young people. *The Lancet Psychiatry*, 3(3), 280–296. [https://doi.org/10.1016/s2215-0366\(16\)00002-x](https://doi.org/10.1016/s2215-0366(16)00002-x)
- Stone, A. L., Becker, L. G., Huber, A. M., & Catalano, R. F. (2012). Review of risk and protective factors of substance use and problem use in emerging adulthood. *Addictive Behaviors*, 37(7), 747–775. <https://doi.org/10.1016/j.addbeh.2012.02.014>
- Sussman, S., & Sinclair, D. L. (2022). Substance and behavioral addictions, and their consequences among vulnerable populations. *International Journal of Environmental Research and Public Health*, 19(10). <https://doi.org/10.3390/ijerph19106163>
- Tait, G. (1995). Shaping the 'at-risk youth': Risk, governmentality and the Finn report. *Discourse: Studies in the Cultural Politics of Education*, 16(1), 123–134. <https://doi.org/10.1080/0159630950160108>
- Taylor, A. H., Katomeri, M., & Ussher, M. (2005). Acute effects of self-paced walking on urges to smoke during temporary smoking abstinence. *Psychopharmacology*, 181(1), 1–7. <https://doi.org/10.1007/s00213-005-2216-4>
- Tesler, R., Plaut, P., & Endvelt, R. (2018). The effects of an urban forest health intervention program on physical activity, substance abuse, psychosomatic symptoms, and life satisfaction among adolescents. *International Journal of Environmental Research and Public Health*, 15(10), 1–12. <https://doi.org/10.3390/ijerph15102134>
- Thompson, T. P., Horrell, J., Taylor, A. H., Wanner, A., Husk, K., Wei, Y., Creanor, S., Kandiyali, R., Neale, J., Sinclair, J., Nasser, M., & Wallace, G. (2020). Physical activity and the prevention, reduction, and treatment of alcohol and other drug use across the lifespan (the phase review): A systematic review. *Mental Health and Physical Activity*, 19. <https://doi.org/10.1016/j.mhpa.2020.100360>. article 100360.
- Thorpe, H. H. A., Hamidullah, S., Jenkins, B. W., & Khokhar, J. Y. (2020). Adolescent neurodevelopment and substance use: Receptor expression and behavioral consequences. *Pharmacology & Therapeutics*, 206. <https://doi.org/10.1016/j.pharmthera.2019.107431>. article 107431.
- United Nations Department of Economics and Social Affairs. (2019). *World population prospects 2019*. United Nations Publications.
- United Nations Office on Drugs and Crime. (2020). *World drug report 2020*. United Nations Publications.
- United Nations Office on Drugs and Crime. (2021). *World drug report 2021*. United Nations Publications.
- United Nations Office on Drugs and Crime. (2022). *World drug report 2022*. United Nations Publications.
- Weinstock, J., Capizzi, J., Weber, S. M., Pescatello, L. S., & Petry, N. M. (2014). Exercise as an intervention for sedentary hazardous drinking college students: A pilot study. *Mental Health and Physical Activity*, 7(1), 55–62. <https://doi.org/10.1016/j.mhpa.2014.02.002>
- Weinstock, J., Petry, N. M., Pescatello, L. S., & Henderson, C. E. (2016). Sedentary college student drinkers can start exercising and reduce drinking after intervention. *Psychology of Addictive Behaviors*, 30(8), 791–801. <https://doi.org/10.1037/adb0000207>
- Werch, C. C., Moore, M. J., DiClemente, C. C., Bledsoe, R., & Jobli, E. (2005). A multihealth behavior intervention integrating physical activity and substance use prevention for adolescents. *Prevention Science*, 6(3), 213–226. <https://doi.org/10.1007/s11121-005-0012-3>
- Wilson, S. D., Collins, R. L., Prince, M. A., & Vincent, P. C. (2018). Effects of exercise on experimentally manipulated craving for cannabis: A preliminary study. *Experimental and Clinical Psychopharmacology*, 26(5), 456–466. <https://doi.org/10.1037/pha000200>
- Winters, K. C., Botzet, A. M., Stinchfield, R., Gonzales-Castaneda, R., Finch, A. J., Piehler, T. F., Ausherbauer, K., Chalmers, K., & Hemze, A. (2018). Adolescent substance abuse treatment: A review of evidence-based research. In C. G. Leukefeld, & T. P. Gullotta (Eds.), *Adolescent substance abuse* (pp. 141–171). Springer. https://doi.org/10.1007/978-3-319-90611-9_5.
- Woods, C., Mutrie, N., & Scott, M. (2002). Physical activity intervention: A transtheoretical mode-based intervention designed to help sedentary young adults become more active. *Health Education Research*, 17(4), 451–460.
- World Health Organization. (2020). *Physical activity*. World Health Organization. <https://www.who.int/news-room/fact-sheets/detail/physical-activity>.
- Ybarra, M. L., Holtrop, J. S., Prescott, T. L., Rahbar, M. H., & Strong, D. (2013). Pilot RCT results of stop my smoking USA: A text messaging-based smoking cessation program for young adults. *Nicotine & Tobacco Research*, 15(8), 1388–1399. <https://doi.org/10.1093/ntr/nts339>
- Zschucke, E., Heinz, A., & Strohle, A. (2012). Exercise and physical activity in the therapy of substance use disorders. *The Scientific World Journal*, 1–19. <https://doi.org/10.1100/2012/901741>