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**Physical Activity for Adolescents with Severe Mental Illness: A Systematic Scoping
Review**

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Abstract

Adolescents with severe mental illness (SMI) engage in lower levels of physical activity (PA), a modifiable risk factor for poor physical health. Although PA is associated with physical and psychological benefits in adult SMI populations, few studies focus exclusively on adolescents. This systematic scoping review aimed to identify the characteristics, outcomes, and feasibility of studies which have attempted to engage or increase PA in adolescents with SMI. Web of Science, PsycINFO, PubMed and psycARTICLES were used to identify articles published between 2007-2019. PRISMA guidelines were followed in reporting the results. Ten studies, with a total of 281 participants (mean age: 16.1 ± 0.72) met the inclusion criteria. Seven studies aimed to yield improvements in the primary diagnosis in addition to other clinical outcome measures. Five studies adopted a 3x weekly schedule, though exercise modality, duration and intensity varied. Seven found improvements in the primary diagnosis, with five reporting sustained improvement at follow-up. Participant completion of the intervention ranged between 73-90%. Adolescents with SMI will adhere to and experience a range of positive outcomes from a range of exercise modalities and intervention lengths. However, significant heterogeneity between studies limits conclusions with that can be drawn regarding beneficial outcomes and feasibility.

ABBREVIATIONS

SMI: Severe Mental Illness MDD: Major Depressive Disorder

PA: Physical Activity PTSD: Post-Traumatic Stress Disorder

Keywords: Adolescent; Severe Mental Illness; Serious Mental Illness; Physical Activity; Scoping Review

Introduction

Adolescence is a high-risk period for the development of serious mental illness (SMI). SMI is defined as a “mental, behavioural or emotional disorder resulting in serious functional impairment” (NIMH, 2019). Six percent of adolescents will be diagnosed with a SMI at any one time (Avenevoli, Swendsen, He, Burstein, & Merikangas, 2015) with prevalence increasing throughout the adolescent years (Lipari, Hedden, & Hughes, 2013). SMI in adolescence has a poor prognosis, typically proceeding into adulthood, with fifty percent of adult SMI thought to emerge in adolescence (Fairchild, 2011).

Evidence of poor physical health is observed in adolescents with SMI. SMI in adolescence is associated with obesity rates of 30%, triple that of the general population (Gracious et al., 2010). Adolescents treated with second generation antipsychotics report significant weight gain (Dayabandara et al., 2017). The obesogenic effects of antipsychotic medications (Verhaegen & Van Gaal, 2017) appear to exert a greater effect in adolescence than adults (Stafford et al., 2015). Excess weight gain contributes to poor medication adherence within adolescent SMI (Stafford et al., 2015), resulting in lower remission rates, and causing the continuation of SMI into adulthood (Lewandowski et al., 2013).

Physical health conditions associated with obesity are increasingly prevalent in this population. Rates of metabolic syndrome are estimated at 13% in adolescents with SMI (Grover et al., 2015). Again, antipsychotic medication is likely to contribute, one study identified a prevalence increase of 15% after three months of clozapine treatment (Grover, Hazari, Chakrabarti, & Avasthi, 2016). Such treatment is also associated with increased risk of type two diabetes (Pramyothin & Khaodhiar, 2015). SMI is also associated with impaired cognitive function, meaning that appropriate management of diabetes can be problematic (Royal College of Psychiatrists, 2017).

In addition to the impact of medication, negative health behaviours are identified as

detrimental to physical health in SMI (Yarborough, 2019). One of these is low levels of physical activity (PA) observed in adolescents with SMI (Biddle, Ciacconi, Thomas, & Vergeer, 2019; Jewell et al., 2015). NHS guidelines recommend that adolescents engage in sixty minutes of moderate to vigorous PA daily (NHS, 2018). Adolescents treated with antidepressants and antipsychotics self-report lower PA and objectively demonstrate lower fitness levels relative to their healthy peers (Vancampfort & Probst, et al., 2016), who also fail to meet government recommendations (Collings et al., 2014).

Insufficient PA in adolescent SMI is likely influenced by several factors. Pharmacological treatments are associated with extrapyramidal side effects which appear greater in adolescent populations (Dayabandara et al., 2017). Physical side effects include fatigue and sedation (Stroup & Gray, 2018), in addition to sleep disturbances including both insomnia and hypersomnia (Elbe, Black, McGrane, & Procyshyn, 2018). Consequently, motivation and volitional capacity to engage in PA may be diminished. Additionally, 70% of adolescents with SMI report chronic pain; over a third of whom experience pain in three or more places (Mangerud, Bjerkeset, Lydersen, & Indredavik, 2013). Biological factors may also contribute; SMI in adolescents is often preceded by childhood stress and trauma, regularly concurrent with hypothalamic-pituitary-adrenal (HPA) axis overactivity (Faravelli et al., 2012; Guerry & Hastings, 2011). Interestingly, HPA axis overactivity has been associated with increased sedentary behaviour (Roshanaei-Moghaddam, Katon, & Russo, 2009). Consequently, those who develop a SMI in adolescence having experienced prior childhood trauma may be predisposed to sedentary behaviour, partly resultant from HPA axis overactivity.

There is a considerable body of literature exploring the connection between PA and mental health in adolescence. For example, PA has been associated with improved mental health (Biddle et al., 2019; Dale, Vanderloo, Moore, & Faulkner, 2019), with increased PA

1 also protecting against the development of mental illness in adulthood (Rodriguez-Ayllon et
2 al., 2019; Rothon et al., 2010). Specifically, PA has also been shown to improve mild to
3 moderate depressive symptoms (Bailey, Hetrick, Rosenbaum, Purcell, & Parker, 2018; Tim
4 Carter, Callaghan, Khalil, & Morres, 2012), anxiety (McDowell, MacDonncha, & Herring,
5 2017) and cognitive function (Biddle et al., 2019). Whilst this area has been the focus of a
6 number of reviews (Bailey, 2017; Biddle, 2019; Dale, 2019), these mostly include healthy
7 populations or those with mild to moderate mental illness.

8 Whilst informative, these reviews have limited relevance for adolescent SMI.
9 Adolescents with SMI incur more severe psychosocial and functional deficits than those with
10 mild to moderate mental illness and this will likely differentially influence their engagement
11 with PA. SMI treatment is often complex, with high doses of pharmacological therapy
12 common. These give host to a range of extrapyramidal symptoms which not only exacerbate
13 barriers to PA, but also have implications for the type and intensity of activities that are
14 achievable (Vancampfort et al., 2017). Therefore, ability (Vancampfort et al., 2017),
15 motivation (Farholm & Sørensen, 2016) and capacity (Firth et al., 2016) to exercise may be
16 considerably different to those with mild to moderate symptoms. There is a need to build
17 upon previous research to understand the role of PA for adolescents with SMI.

18 The benefits of PA for SMI are demonstrated in adult populations, where there is
19 growing evidence for PA to act a transdiagnostic adjunctive treatment for SMI through its
20 ability to improve multiple health outcomes (Ashdown-Franks, Sabiston, & Stubbs, 2019).
21 However, it is problematic to extrapolate findings from adult to adolescent populations.
22 Whilst diagnostic criteria is age-independent, symptom expression (American Psychiatric
23 Association, 2013), causes (Herpertz-Dahlmann, Bühren, & Remschmidt, 2013), response to
24 treatment (Veru, Jordan, Joober, Malla, & Iyer, 2016) and symptom profiles differ (Rice et
25 al., 2019), perhaps resultant from the different psychosocial, hormonal and environmental

influences this population faces. When considering the role of PA in this population, age needs to be accounted for to the extent that age-appropriate adaptations are made for psychological and pharmacological treatment modalities (Mojtabai, Olfson, Han, & Jimerson, 2015).

Determining whether PA is clinically beneficial in controlled settings (efficacy) and its performance in real-world settings (effectiveness) as a treatment adjunct for adolescent SMI is important given concerns over pharmacological treatments (Stafford et al., 2015). For example, poor outcomes are associated with commonly prescribed medications for clinical depression (Cipriani et al., 2016), bipolar disorder (Liu et al., 2011), and schizophrenia (Stafford et al., 2015). Additionally, increased reports of suicidal ideation and behaviour in antidepressant-treated adolescents remain a cause for concern (Spielmans, Spence-Sing, & Parry, 2020). In addition to improving clinical outcomes, PA potentially represents an accessible adjunct due to no unwanted side effects, nor adverse interactions with other treatment modalities (Stubbs et al., 2018).

Whilst there is growing evidence for the role of PA in improving mental health outcomes in adolescence, little is known about the role of PA as a treatment adjunct for adolescent SMI. The parameters surrounding PA engagement differ for this age group and population, warranting a separate review. As this literature is yet to be synthesised, it is important that an approach is taken which can explore the nature and extent of the research evidence. Consequently, a systematic scoping review was deemed appropriate to explore this research area.

A scoping review differs to a systematic review. Systematic reviews focus on answering a particular question whilst scoping reviews map the available literature on a particular topic. Scoping reviews offer a systematic and structured approach to reviewing

and synthesising the available evidence (Tricco et al., 2018), whilst including a variety of study designs and methodologies to ensure that the wider scope, and multiple research questions within an area can be met. As PA research is relatively heterogenous (incorporating many modalities, measurements and outcomes), and SMI incorporates a range of diagnoses, a methodology which can account for this is necessary. It is anticipated that summarising and collating the research will identify the types of evidence collected in this field, how research is conducted and to explore and identify gaps in the knowledge base. Therefore, the primary aim of this systematic scoping review was to provide a systematic overview and summary of the literature of PA for adolescents with SMI.

Methodology

A framework designed for conducting scoping reviews (Arksey & O'Malley, 2005; Levac, Danielle, Colquhoun, Heather, O'Brien, 2010) informed the structure and process of conducting this review. The PRISMA extension for scoping reviews (Tricco et al., 2018) provided a structured approach for reporting outcomes and all points on the checklist were covered. A study protocol is available on request from the corresponding author.

Stage One: Identifying the Research Question

To address the primary review aim, of systematically mapping and summarising the available literature, three secondary objectives were developed. These were formulated to ensure comprehensiveness in addressing the breadth of the research area. The aims of this scoping review are: 1) to identify the characteristics (methodology and design) of studies which have aimed to engage adolescents with SMI in PA, 2) to identify the outcomes of PA engagement in this population, 3) to identify whether PA interventions are feasible in this population.

Stage Two: Identifying Relevant Studies

The PICOS (Population, Intervention, Comparison, Outcome, Study Type)

framework was used to determine study inclusion criteria. This framework was chosen as it allows for the development of clearly defined parameters for study inclusion which align with the research aims (Schardt, Adams, Owens, Keitz, & Fontelo, 2007).

Population: Participants had to be adolescents aged 12-18 years old. Studies with participants outside of this age range were excluded unless participants could be clearly distinguished by age group within the results. Participants had to have a primary diagnosis of a SMI. SMI is defined as a “mental, behavioural, or emotional disorder resulting in serious functional impairment, which substantially interferes with or limits one or more major life activities” (NIMH, 2019). SMI in previous reviews has included major depressive disorder (MDD), schizophrenia and bipolar disorder (BD) (Vancampfort et al., 2017). Post-traumatic stress disorder (PTSD) was also included as it meets this criteria due to resulting in significant functional impairment (Westphal et al., 2011) and severe negative psychosocial outcomes (Dutton, Rojas, Badour, Wanklyn, & Feldner, 2016). Diagnoses had to be established through validated assessment criteria such as the Diagnostic and Statistical Manual of Mental Disorders (DSM) (American Psychiatric Association, 2013) or the International Classification of Diseases (ICD-10) (World Health Organization, 1993). Additionally, diagnoses had to be established by a scale validated for use in adolescent populations. Exceptions were made for studies conducted in secure inpatient settings. This is because legislation regarding patient confidentiality means that diagnoses may not be disclosed. However, such patients would be sectioned under the Mental Health Act (Mental Health Act, 2007). The Mental Health Act details how a person can be detained in a secure setting based on the seriousness of their mental health condition or the risk they pose to themselves or others. Such individuals would have an ICD-10 or DSM-IV certified diagnosis of a SMI and would therefore be included. Any secondary diagnoses were eligible for inclusion. Patients with a primary diagnosis of an eating disorder were excluded. PA is

1 closely intertwined with the pathogenesis of this disorder, therefore, the complexity of the
2 role of PA for this population warrants a separate review.

3 *Intervention:* Studies were included if they engaged participants in any form of PA,
4 sport or exercise. This included aerobic, high-intensity or resistance training, team or
5 individual sports. Any duration, frequency or intensity was included.

6 *Comparator:* Due to the large variation in study types included, comparators were not
7 required. *Studies without a* control group could incorporate a pre-post design. *Other*
8 *comparators could be a* healthy control group, or a comparison group with the same
9 diagnosis receiving another form of treatment or PA modality.

10 *Outcomes:* Outcomes reported were varied and could relate to the primary diagnosis,
11 PA levels, any additional fitness or anthropometric measures and any relevant qualitative or
12 quantitative psychological, social or psychological outcomes.

13 *Study Type:* All sources had to be primary research studies or dissertations written in
14 English. Quantitative, qualitative and mixed-methods research were included. Co-
15 intervention studies were included, as were RCT's. Meta-analyses, systematic reviews and
16 commentaries were excluded as these are secondary research sources. However, primary data
17 could be extracted from these. Cross-sectional and prospective longitudinal studies were
18 excluded.

19 **Stage Three: Study Selection**

20 A comprehensive literature search of three key databases identified relevant literature.
21 Literature searches were conducted between October 2018 and December 2019, with the
22 latest search update conducted in December 2019. Databases searched included Web of
23 Science, PubMed and PsycINFO (ProQuest) and PsycARTICLES. These contained literature
24 most relevant to the research area and have been used in scoping reviews of a similar nature
25 (Machaczek et al., 2018; Rogers, Kinnafock, & Papathomas, 2019). Grey-literature databases

(Opengrey and British Library) were searched in addition to a search with key terms on Google Scholar. Forward and backward citation searching was utilised to identify relevant articles from database and internet searches. Backward citation searching involves searching relevant literature cited in a study. Forward citation searching involves searching the ‘cited by’ list of a particular article.

The search incorporated studies from January 2007 to December 2019. This was in line with the 2007 amendments to the Mental Health Act (Mental Health Act, 2007). The 2007 amendment included changes to diagnoses of certain illnesses, treatment, patient safeguarding and the introduction of age and diagnosis appropriate services. Therefore, studies conducted prior to this were not included. To conduct a meaningful and relevant analysis, it is important to include studies that have treated patients according to current mental health legislature. Studies conducted prior to this may not have used age-appropriate treatments for adolescents, and individuals may have been sectioned under different criteria.

Keywords used in the search included adolescen* or teenage* or youth or student or juvenile AND physical activity or exercise or fitness or running or walking or “aerobic exercise” or “aerobic training” or sport or yoga AND “serious mental illness” or “severe mental illness” or “major depress*” or “bipolar disorder” or schizophreni* or psychosis or “post-traumatic stress disorder or “mania” or “hypomania” AND intervention or treatment or program* or trial. MeSh terms were also used for searching articles in PubMed. The search strategy was reviewed by an experienced librarian.

The primary reviewer (JA) identified eligible studies and screened titles and abstracts for inclusion and exclusion. The primary and secondary reviewer (FK) independently reviewed full-text articles. Any discrepancies were discussed.

The initial database search yielded 762 articles, reduced to 671 after duplicates were removed. Upon title and abstract screening, 616 articles were excluded. Of the 55 full-text

articles assessed for eligibility, 11 included participants outside of the adolescent age range, 16 included participants not diagnosed with a SMI, 6 were not primary research studies and 10 did not engage participants in PA. Two additional studies were identified through citation searching. The remaining 10 studies were eligible for inclusion within the review. Figure 1 details the process of study selection

[Fig. 1 insert here]

Stage Four: Charting the Data

A data charting form was constructed based on several criteria perceived to be relevant to PA intervention research (Carter, Morres, Meade, & Callaghan, 2016; Rogers et al., 2019). The charting form was iterative and updated as the literature search progressed. Data was charted by the primary reviewer (JA) and reviewed and checked for accuracy by two other reviewers (FK, AP). The data charting form included; author information, participant information (gender, diagnosis and age), intervention type and comparator, exercise duration, frequency, intensity, intervention and total study length, primary and secondary measures, use of psychological theory and outcomes relating to primary and secondary measures. Results of any qualitative outcomes were also included within this. The data charting form is shown in Table 1.

[Table 1 insert here]

Stage 5: Collating, Summarising and Reporting Results

A three-step process (Levac, Danielle, Colquhoun, Heather, O'Brien, 2010) recommended for reporting of scoping reviews was followed. Firstly, a descriptive analytical method was used to collate and summarise data in accordance with the goals of the review. Secondly, a content analysis (Hsieh & Shannon, 2005) was used to extract key information related to the research questions. This included study and participant characteristics, methodology, outcomes identified and PA feasibility. Challenges associated with PA

engagement in this population were identified. Results were reported under several key themes within the three outcomes of the research question. Finally, broader implications, limitations, and recommendations for future research and practice were identified.

Quality Assessment

Whilst formal assessment of study quality is not typically required for a scoping review, The mixed methods appraisal tool (MMAT) (Hong et al., 2018) is a useful addition, as it assesses the quality of a range of study types, accounting for qualitative, quantitative and mixed-methods studies. The MMAT uses two screening questions to identify if the research is an empirical study (“Is there a clear research question” and “Do the collected data allow to address the research question”) (Hong et al., 2018). Following this, within each category of study (qualitative, quantitative randomised controlled trials, quantitative non-randomised, quantitative descriptive and mixed methods) there are five criteria for rating the quality of the study, with the option to answer each question with a “yes”, “no” or “not sure”. Summary scores were calculated by dividing the total of “yes” scores by four, then this was expressed as a percentage.

Results

Outcome 1: What are the characteristics of physical activity interventions for adolescents?

Article Characteristics

Studies were conducted in a range of primarily Western countries. Of the 10 studies included, six were conducted in America (Diaz & Motta, 2008; Hughes, 2013; Jelalian et al., 2016; Newman & Motta, 2007). Three studies were conducted in Canada (MacIntosh et al., 2017a; Metcalfe et al., 2016; Subramaniapillai et al., 2016). Other study locations included Australia (Radovic et al., 2017), Germany (Wunram et al., 2018) and Iran (Roshan, Pourasghar, & Mohammadian, 2011). Two studies were conducted in inpatient settings (Diaz

& Motta, 2008; Wunram et al., 2018) whilst eight were conducting in outpatient settings (Hughes, et al., 2013; Jelalian et al., 2016; Metcalfe et al., 2016; Radovic et al., 2018; Roshan et al., 2011; Subramaniapillai et al., 2016). Three studies were randomised control trials (Hughes et al., 2013; Jelalian et al., 2016; Wunram et al., 2018), one study used mixed-methods (Radovic et al., 2017) and six were quantitative non-randomised studies (Diaz & Motta, 2008; MacIntosh et al., 2017; Metcalfe et al., 2016; Newman & Motta, 2007; Roshan et al., 2011; Subramaniapillai et al., 2016).

Scoring from the MMAT revealed that three studies were rated as average (Diaz & Motta, 2008; Jelalian et al., 2016; Roshan et al., 2011) and seven studies were rated as high quality (Hughes et al., 2013; MacIntosh et al., 2017; Metcalfe et al., 2016; Newman & Motta, 2007; Radovic et al., 2017; Subramaniapillai et al., 2016; Wunram et al., 2018). No studies were rated as poor quality. Table 2 details the MMAT scores for each study.

[Table 2 insert here]

Participant Characteristics

The total number of participants was 282, with 69.8% of these being female. Three studies used only female participants (Diaz & Motta, 2008; Newman & Motta, 2007; Roshan et al., 2011). The average age was 16.1 ± 0.72 years old.

For studies conducted in outpatient settings, the most common primary diagnosis was MDD (n=5) (Hughes et al., 2013; Jelalian et al., 2016; Radovic et al., 2017; Roshan et al., 2011; Wunram et al., 2018). Other primary diagnoses included bipolar disorder (n=3) (MacIntosh et al., 2017a; Metcalfe et al., 2016; Subramaniapillai et al., 2016) and PTSD (n=2) (Diaz & Motta, 2008; Newman & Motta, 2007). In total, 161 participants had MDD, 94 had BD and 27 had PTSD.

Regarding comorbid diagnoses, one study did not exclude participants based on comorbid diagnoses (Wunram et al., 2018). Four studies excluded participants with comorbid

disorders (Hughes et al., 2013; Jelalian et al., 2016; Mittleman et al., 2018; Radovic et al., 2017; Roshan et al., 2011). Most commonly, studies excluded participants with psychosis or eating disorders. The remaining studies did not specify whether comorbid diagnoses acted as exclusion criteria.

In all studies, PA was an adjunct to participants current treatment regimen. For both inpatient and outpatient studies, these typically included pharmacological and/or psychological therapies. One study reported that participants were taking antipsychotic medication only (MacIntosh et al., 2017). Two reported that the majority of participants were taking antipsychotics, but some within the sample were also taking antidepressants and psychostimulants (Metcalf et al., 2016; Subramaniapillai et al., 2016). One reported that participants were receiving group and individual therapy, but were medication naïve (Wunram et al., 2018). Two reported that participants were taking antidepressants and receiving psychotherapy (Hughes et al., 2013; Radovic et al., 2017). One reported that all participants were receiving psychological therapy, with six out of eleven participants taking antipsychotic and/or antidepressant medication (Newman & Motta, 2007). One study reported that participants were only taking antidepressants (Jelalian et al., 2016) One study did not specify which other treatments participants were receiving (Roshan et al., 2011).

Study Objectives

The primary objective in most studies (n=7) (Diaz & Motta, 2008; Hughes et al., 2013; Jelalian et al., 2016; Newman & Motta, 2007; Radovic et al., 2017; Roshan et al., 2011; Wunram et al., 2018) was to yield improvements in symptom scores relating to the primary diagnosis. Two studies focused on acute changes in mood (MacIntosh et al., 2017; Subramaniapillai et al., 2016) and one on acute changes in cognitive function (Metcalf et al., 2016).

Study Objectives: Secondary Outcomes

There were a variety of secondary outcomes measured. Five studies employed measures of mental health status other than the primary diagnosis (Diaz & Motta, 2008; Hughes et al., 2013; Newman & Motta, 2007; Radovic et al., 2017; Wunram et al., 2018). These included measures of psychosocial functioning, depressive status (when diagnosis was not MDD), anxiety, self-efficacy and general mood. Four studies measured participants' enjoyment of the PA (Hughes, et al., 2013; Mittleman et al., 2018; Subramaniapillai et al., 2016; Wunram et al., 2018). Two of these measured participants' motivation to exercise during the intervention (Radovic et al., 2017; Wunram et al., 2018). Two studies measured objective changes in fitness through VO^2 max (Roshan et al., 2011; Wunram et al., 2018). Three measured anthropometric changes, typically relating to weight, BMI or body fat (Hughes et al., 2013; Jelalian et al., 2016; Wunram et al., 2018).

Data Collection and Study Design

All studies used quantitative measurement of the primary and secondary outcome measures using validated scales. One of these also incorporated a qualitative interview component post-intervention (Radovic et al., 2017). Seven studies used a form of comparison group. In two, the comparison group engaged in a different PA modality for the duration of the intervention (Hughes et al., 2013; Wunram et al., 2018). One comparison group received cognitive behavioural therapy (Jelalian et al., 2016). One study included a comparison group not receiving any treatment (Roshan et al., 2011). Three studies utilised healthy controls as a comparison (MacIntosh et al., 2017; Metcalfe et al., 2016; Subramaniapillai et al., 2016). These three studies measured the acute effects of exercise, thus healthy controls were deemed to be appropriate. Three studies used no control group (Diaz & Motta, 2008; Newman & Motta, 2007; Radovic et al., 2017). These incorporated multiple baseline measurements meaning that participants acted as their own control. The length of the baseline measurement period differed, with one of two weeks, (Radovic et al., 2017) one of either two and four

weeks, (Newman & Motta, 2007) and one of five weeks (Diaz & Motta, 2008).

Study Length

Of the studies which were classified as interventions (n=7), intervention length differed between studies. Intervention lengths ranged from four to twenty-four weeks (median = 6 weeks). Five studies incorporated follow-up measurements (Diaz & Motta, 2008; Hughes et al., 2013; Jelalian et al., 2016; Newman & Motta, 2007; Wunram et al., 2018). These ranged from four weeks, to one-year post-intervention. Median follow-up length was 8 weeks.

Exercise Protocol

The type of exercise modality differed between studies. Exercise modalities included whole body vibration (Wunram et al., 2018), pool walking (Roshan et al., 2011), stationary bike (MacIntosh et al., 2017a; Metcalfe et al., 2016; Subramaniapillai et al., 2016), walking (Diaz & Motta, 2008), aerobics (Newman & Motta, 2007), non-specified aerobic exercise (Jelalian et al., 2016) or self-selected (Hughes et al., 2013; Radovic et al., 2017).

Five studies engaged participants in PA as a group (Diaz & Motta, 2008; Jelalian et al., 2016; Newman & Motta, 2007; Roshan et al., 2011). Three studies had participants engage in supervised exercise alone (MacIntosh et al., 2017; Metcalfe et al., 2016; Subramaniapillai et al., 2016). One study had participants engage in non-supervised home-based sessions alone (Radovic et al., 2017). One study had participants engage in one weekly group session, and two self-led home sessions (Hughes et al., 2013).

Five studies adopted a 3x weekly schedule (Diaz & Motta, 2008; Hughes et al., 2013; Newman & Motta, 2007; Radovic et al., 2017; Roshan et al., 2011). Two of these allowed some patient autonomy in selecting session frequency (Radovic et al., 2017; Wunram et al., 2018). One allowed participants to select session frequency if they completed 18 sessions over a six-week period (Wunram et al., 2018). Another did not monitor but advised a 3x

weekly schedule (Radovic et al., 2017). One study had a single weekly session (Jelalian et al., 2016).

Seven studies included high-intensity exercise quantified by heart rate (Hughes et al., 2013; MacIntosh et al., 2017; Metcalfe et al., 2016; Newman & Motta, 2007; Subramaniapillai et al., 2016; Wunram et al., 2018). Two compared high- to low-intensity exercise (Hughes, et al., 2013; Wunram et al., 2018). Three included moderate-intensity exercise (Diaz & Motta, 2008; Newman & Motta, 2007; Radovic et al., 2017). One study did not measure intensity (Jelalian et al., 2016).

The duration of most exercise sessions (n=8) were between 20-40 minutes (Diaz & Motta, 2008; Hughes et al., 2013; MacIntosh et al., 2017; Metcalfe et al., 2016; Newman & Motta, 2007; Radovic et al., 2017; Subramaniapillai et al., 2016; Wunram et al., 2018). Two studies adopted 60-minute sessions (Jelalian et al., 2016; Roshan et al., 2011).

Physical Activity Supervision

Due to the severity of patients' mental health, staff presence was a key component of interventions. Six studies included sessions that were supervised by the researcher (Diaz & Motta, 2008; MacIntosh et al., 2017; Metcalfe et al., 2016; Newman & Motta, 2007; Subramaniapillai et al., 2016; Wunram et al., 2018). One used an exercise trainer (Hughes et al., 2013). One used individuals with fitness qualifications from local sports centres to design, but not supervise the exercise intervention (Radovic et al., 2017). One used a physical therapist (Jelalian et al., 2016). One did not specify who supervised the intervention (Roshan et al., 2011).

Incentives

Two studies incorporated monetary incentives to promote study adherence, at each session (Hughes et al., 2013) and at study completion (Radovic et al., 2017). One used stickers which could be exchanged for a non-specified reward (Newman & Motta, 2007).

Outcome 2: What are the outcomes of physical activity interventions for adolescents with SMI?

Where possible, data was extracted from each study to determine whether there was a statistically significant difference in the primary outcome measure following PA delivery.

Where sufficient data was available, hedges G effect sizes were computed. These were deemed appropriate to account for the small sample size in some studies (Hedges & Vevea, 1998). Calculated outcomes relate to the between group outcomes for studies with a comparison group and the within group outcomes for those with no comparison group.

Of the studies who measured changes in the primary diagnoses following an intervention (n=7), all reported significant improvements (Diaz & Motta, 2008; Hughes et al., 2013; Jelalian et al., 2016; Newman & Motta, 2007; Radovic et al., 2017; Roshan et al., 2011; Wunram et al., 2018) at intervention end-point. Effect sizes ranged from 1.44-1.89 for those without a comparator (comparing beginning baseline to intervention end) and from 0.14-1.06 for studies using a comparison or control group. Table 3 details the statistical outcomes for the primary outcome measures in intervention studies.

[Table 3 insert here]

Studies comparing high to low-intensity exercise noted similar reductions in depression severity for both modalities (Hughes et al., 2013; Wunram et al., 2018). However, there were quicker reductions in depression severity by intervention mid-point with high-intensity exercise. One study comparing CBT only, to CBT plus exercise found similar reductions in depression severity in both groups (Jelalian et al., 2016). One study using a comparison group receiving no treatment found a significantly greater reduction in depression severity for the exercise group (Roshan et al., 2011). Of studies focusing on the effects of acute exercise, one found that cognitive deficits associated with bipolar disorder

were diminished immediately following exercise (Metcalf et al., 2016), one reported a non-significant increase in positive affect (Subramaniapillai et al., 2016); one found neurobiological indications of improved mood following exercise (MacIntosh et al., 2017).

Of the studies which reported follow-up measurements beyond the intervention length (n=5), all reported sustained improvements in the primary diagnosis (Diaz & Motta, 2008; Hughes et al., 2013; Jelalian et al., 2016; Newman & Motta, 2007; Wunram et al., 2018).

Remission rates, where reported, varied. One reported 86% remission rate for high-intensity group, and 50% remission from the low-intensity group (Hughes et al., 2013). Another (Wunram et al., 2018a) reported 71% remission rate for high-intensity group, 61% remission for low intensity group, and 25% remission for a control group engaging in no PA. One found that 81% of participants no longer met PTSD criteria (Newman & Motta, 2007).

In addition to the primary outcomes, a number of secondary outcomes were reported. Of the studies which measured changes in physical fitness; two reported improvement in aerobic fitness, quantified by VO₂ max (Roshan et al., 2011; Wunram et al., 2018). Of the studies which measured anthropometric variables (n=3), only one reported a bodyfat reduction for both males and females (Hughes et al., 2013). This was reported as an adjunct to improvements in bone-density status. One study reported no change in anthropometric measures (Wunram et al., 2018).

One study measuring psychosocial functioning reported significant improvements for both low and high intensity groups (Hughes et al., 2013). Three studies quantitatively reported that participants were 'satisfied' with the PA that they engaged in (Hughes et al., 2013; Newman & Motta, 2007; Radovic et al., 2017). Two studies reported reductions in negative and increases in positive mood states non-specific to the primary diagnosis (Hughes et al., 2013; Wunram et al., 2018).

Outcome 3: Are physical activity interventions feasible for adolescents with SMI?

Evaluating feasibility explores factors relating specifically to the intervention or implementation process. This can include evaluating factors such as recruitment, retention, data-collection, study procedures and the ability to conduct the study or intervention as planned.

Acceptability of Physical Activity

A focus within feasibility is acceptability. Within healthcare research, acceptability is defined as “a multifaceted construct reflecting the extent to which people receiving a healthcare intervention consider it to be appropriate” (Sekhon, Cartwright, & Francis, 2017, p.4). Acceptability is assessed in a variety of ways, including and not limited to participant satisfaction, perceptions, adherence, compliance alongside attrition and drop-out rates (Sekhon et al., 2017).

One study found through post-intervention interviews that participants enjoyed PA (Radovic et al., 2017). One reported that high and low intensity PA were equally well-liked (Hughes et al., 2013). Another reported increased enjoyment of low, versus high intensity PA, which corresponded with increased motivation to continue low intensity PA (Wunram et al., 2018). Another found that the intervention was ‘well liked’ by 70% of its participants (Newman & Motta, 2007). One study found that participants were motivated to continue exercise due to improved mood, improved fitness and social support as a result of engaging in the intervention (Radovic et al., 2017).

Whilst most studies did not directly explore barriers and facilitators to PA engagement. One study interviewed participants about perceived barriers and motivators to engaging in exercise (Radovic et al., 2017). Barriers included: low motivation, illness, fatigue, pain, poor weather and feeling self-conscious. Motivating factors included the fact that exercise provided routine, perceived fitness improvements and social support from family and staff (Radovic et al., 2017). Studies identified challenges to PA implementation.

Two studies highlighted that institutional settings presented constraints to PA engagement (Diaz & Motta, 2008; Wunram et al., 2018). One found that institutional settings offered little means for continued engagement beyond the completion of the intervention (Diaz & Motta, 2008). However, the nature of this was not specified. Alternatively, one study highlighted that outpatient settings represented a challenge to maintaining adherence. As participation was voluntary, it was difficult to make sessions compulsory (Wunram et al., 2018).

Intervention Attendance and Adherence

Feasibility incorporated participant attendance and adherence to the intervention. One reported 77% attendance for a high intensity exercise group, and 81% attendance for a low-intensity group (Hughes, et al., 2013). Three recorded average number of sessions attended. One reported an average of 3.29 weekly sessions (Radovic et al., 2017), another reported a median of 4 weekly sessions (Wunram et al., 2018). One reported an average of 9 exercise sessions over a 24-week period (Jelalian et al., 2016). Five studies measured participant completion of the intervention. These ranged between 73% and 90%. Attrition rates from intervention-end, to follow-up measurement varied. One had 25% of participants at follow-up (Diaz & Motta, 2008). One had 61% (Wunram et al., 2018), one had 72% (Newman & Motta, 2007) one 73% (Hughes et al., 2013) and another 70% (Jelalian et al., 2016).

Discussion

This systematic scoping review was conducted to determine the characteristics, outcomes and feasibility of PA interventions for adolescents with SMI. The research question had three components: 1) to identify the characteristics (methodology and design) of studies which have aimed to engage adolescents with SMI in PA 2) to identify the outcomes of PA engagement in this population, 3) to identify whether PA interventions are feasible for this population.

Study and Participant Characteristics

1 There were a range of different diagnoses, the most common being MDD. No studies
2 attempted to account for diagnosis-specific variables in the design and implementation of the
3 intervention. Whilst research suggests that symptom manifestation and treatment protocol
4 may differ between diagnoses and individuals, adult literature supports that the value of
5 exercise is that its effects are transdiagnostic in nature, meaning there is less of a need to
6 consider diagnostic specific variables. Similarly, adolescents with SMI may face similar
7 barriers to exercise. Commonly prescribed pharmacological treatments are associated with
8 similar extrapyramidal symptoms. For example, antipsychotic treated adolescents report
9 slower limb movement, poor abdominal muscle strength and poor muscle endurance
10 (Vancampfort et al., 2016). Alternatively, antidepressant medication may induce side-effects
11 including nausea, headaches and postural hypotension (Reekie et al., 2015). These may
12 impact engagement, adherence and motivation to exercise similarly across diagnoses.

13 There were also a range of intervention lengths, which may have influenced
14 participant outcomes. A study reporting no participants achieving remission only had a four-
15 week intervention (Radovic et al., 2017). On the other hand, the two studies reporting
16 the highest remission rates, had intervention lengths of twelve (Hughes et al., 2013) and eight
17 weeks (Newman & Motta, 2007). Previous reviews have associated intervention lengths in
18 excess of 8-weeks yield therapeutic outcomes in mild to severe adolescent depression
19 (Bailey, Hetrick, Rosenbaum, Purcell, & Parker, 2017). In adult SMI, benefits have been
20 found in interventions ranging from six to twenty-four weeks (Stubbs et al., 2018). Longer
21 intervention lengths may be conducive to improved therapeutic outcomes. It could be
22 speculated that ongoing PA is likely to have cumulative and sustained effects. However,
23 research which attempts to maintain engagement long term has not yet been conducted.

24 Prescribed exercise intensity also varied between studies. Two studies compared high-
25 to low-intensity exercise (Hughes et al., 2013; Wunram et al., 2018). Higher self-reported

1 enjoyment and motivation to continue PA was associated with low-intensity exercise. A
2 study which allowed participants to self-select exercise intensity consequently found that
3 participants selected a moderate-intensity exercise (Radovic et al., 2017). Due to the physical
4 and psychological barriers to PA in this population (Kumra & Krill, 2014; Mangerud,
5 Bjerkeset, Lydersen, & Indredavik, 2013), moderate-intensity exercise may be perceived as
6 more acceptable (Stubbs et al., 2018). However, perceptions of a preferred intensity may
7 differ between individuals. In healthy adolescent populations, ‘affect regulated exercise’,
8 (exercising at an intensity which ‘feels best’) is associated with higher levels of PA
9 engagement (Schneider & Schmalbach, 2014) . Additionally, clinically depressed adolescents
10 have been shown to value autonomy in selecting PA intensity (Carter, Morres, Repper, &
11 Callaghan, 2016).

12 Studies included within this review incorporated a range of exercise modalities. It is
13 not possible to ascertain whether any were superior in terms of therapeutic outcomes or
14 intervention acceptability. Two studies allowed participants to select exercise modality
15 (Hughes et al., 2013; Radovic et al., 2017). Both reported high attendance and improvements
16 in depressive symptoms. Allowing patients to select a preferred modality may be beneficial;
17 engaging adolescents in the design of their treatment plan improves treatment effectiveness
18 (Hetrick, Simmons, & Merry, 2008).

19 Similarly, differentiating PA benefits from that of other treatment
20 modalities is challenging as there was significant heterogeneity in the type and nature of
21 comparator used. From the evidence presented within this review it can be assumed that
22 exercise exerts additional therapeutic benefits relative to standard treatment, no treatment and
23 to a lesser extent, low-intensity exercise. However, it is important to note that when PA plus
24 CBT was compared to CBT alone (Jelalian et al., 2016), therapeutic outcomes were similar
25 for both groups. One argument for this effect is that adding additional modalities may ‘dilute’

1 the dose of an established treatment such as CBT (Hollon, Garber, & Shelton, 2005).
 2 However, more research is required to ascertain the impact of additional treatment modalities
 3 on adolescent SMI.

4 *Outcomes*

5 The most common aim (n=7) was to reduce symptomology relating to the primary
 6 diagnosis. All seven reported statistically significant reduction in symptoms relative to
 7 baseline. Of the five studies which reported follow-up measurement, all reported sustained
 8 reduction in symptomology, with four of these being statistically significant.

9 Effect sizes reported ranged from moderate to large, comparable to that of adolescent
 10 trials using CBT plus fluoxetine (March, 2004), superior to those using pharmacological
 11 treatment alone (Cipriani et al., 2016) and similar to those reported in PA interventions in
 12 adults with SMI (Stubbs et al., 2018). However, studies in this review incorporated
 13 significant variation in design and methodology so, in some instances, large effect sizes may
 14 need to be interpreted with caution. For example, large effect sizes were reported in the two
 15 studies without an active control group (Newman & Motta, 2007; Radovic et al., 2017).
 16 Comparing PA interventions to an active control yields lower effect sizes than those
 17 compared to a non-active control (Stikkelbroek, Boddien, Deković, & van Baar, 2013).
 18 Regardless, as this remains a relatively under researched area, identifying preliminary effect
 19 sizes gives an insight into the clinical significance of a relatively heterogenous set of studies,
 20 whilst also providing future research guidance, specifically in power calculation and sample
 21 size justification (Wilkinson, 1999).

22 Some encouraging remission rates were reported, all three studies reporting this
 23 remission rates of over 60% at follow-up, higher than some antidepressant drug trials
 24 (Garland & Ons, 2016) and trials incorporating pharmacological and psychological

1 treatments (March, Silva & Vitiello, 2006). Although such findings lend support for the
2 previously identified role of PA as an adjunctive therapy for SMI (Blumenthal et al., 2007),
3 direct comparisons between exercise and other treatment modalities is necessary. Whilst one
4 study in this review compared CBT to CBT plus exercise (with no reported difference
5 between the two), these comparisons have not been thoroughly researched in adolescent
6 populations.

7 These results indicate that in some cases PA has therapeutic benefit for MDD and
8 PTSD that can be sustained beyond intervention endpoint. However, due to the variety of
9 follow-up lengths, it is challenging to identify whether there is evidence for long-term
10 maintenance beyond intervention length. Only two studies within this review had follow-up
11 lengths beyond 6 months. Whilst both of these showed evidences of clinical effect, more
12 research is required to support these findings.

13 Two studies within the review reported neurobiological indicators of improved mood
14 (MacIntosh et al., 2017) following PA, albeit to a lesser extent than for healthy peers
15 (Subramaniapillai et al., 2016). No other intervention studies within this review attempted to
16 record acute mood changes from PA engagement. However, this has been an intervention
17 component in adult SMI (Long, Rowell, Rigg, Livesey, & McAllister, 2016). Immediate
18 mood improvements may improve negative emotional regulation in adolescent SMI
19 (Stikkelbroek, Bodden, Kleinjan, Reijnders, & Van Baar, 2016), in addition to being a
20 motivating factor for exercise continuation if such information is relayed to, or self-reported
21 by patients. Whether, and how, acute mood benefits correlate with long-term therapeutic
22 effects is yet to be determined.

23 Some studies reported broader benefits to PA engagement such as improvements in
24 psychosocial functioning (Hughes et al., 2013) and cognition (Metcalf et al., 2016). Other
25 studies reported improvements in positive mood states nonspecific to the primary diagnosis

(Diaz & Motta, 2008; Newman & Motta, 2007; Radovic et al., 2017; Wunram et al., 2018). This indicates there may be other benefits to PA engagement which may improve the quality of life (QoL) of adolescents with SMI. QoL is regularly diminished in adolescent SMI and differing pathologies impact QoL outcomes in distinct ways (Sawyer et al., 2002). Incorporating disorder specific measures of QoL may help identify wider benefits to PA engagement within this population.

Physical Health Outcomes

Some studies measured outcomes relating to physical fitness. High-intensity exercise was associated with improvements in fitness in two studies (Roshan, Pourasghar, & Mohammadian, 2011; Wunram et al., 2018a), evidenced by VO2 max increase. Improved physical fitness is unlikely to be the mechanism through which therapeutic outcomes are achieved. For example, one reported similar anti-depressive outcomes for high-, versus low-intensity exercise modalities, despite low-intensity exercise modalities not being associated with improvements in fitness (Wunram et al., 2018). PA is a complex behaviour for individuals with SMI. A conceptual model aiming to explore the mechanisms through which PA exerts its effect has identified that neurological, psychosocial and behavioural factors are all likely to contribute (Lubans et al., 2016). Specific factors such as social interaction (Roberts & Bailey, 2013), perception of self-efficacy (Gyllenstein, Ovesson, Hedlund, Ambrus, & Tornberg, 2019) and distraction (Paluska & Schwenk, 2000) may also contribute to therapeutic outcomes.

Of the three studies which measured anthropometric changes, none reported weight loss. This is unsurprising in a population where weight-loss is challenging due to the obesogenic effects of antipsychotic, and to a lesser extent antidepressant treatment (De Hert et al., 2011; Stafford et al., 2015). Additionally, the increased sedentary time reported in individuals with SMI (Vancampfort et al., 2017) is also likely to have contributed to this.

Physical health incorporates a multitude of variables; it may be beneficial to gain an understanding of health markers which are amenable to improvement through PA in adolescent SMI populations. Research in healthy populations has shown that indicators of physical health such as blood lipids, glucose levels and blood pressure can be improved through exercise in the absence of weight gain (Shaw, Gennat, O'Rourke, & Del Mar, 2006). Relaying such information to participants may increase motivation as improving health is a highly regarded incentive for PA engagement in adults with SMI (Farholm & Sørensen, 2016) who frequently experience poor physical health (Thornicroft, 2011). Whether this also applies to adolescents who may not yet be experiencing poor physical health is uncertain. Due to the lack of longitudinal research, it is yet unclear whether PA engagement in adolescence is a viable mechanism to offset the development of physical comorbidities associated with SMI.

Acceptability and Feasibility

Intervention acceptability is somewhat indicated by adherence (Hommel, Hente, Herzer, Ingerski, & Denson, 2013). Adherence and attrition rates varied between studies. Identifying the characteristics of studies which reported highest adherence levels is important to determine factors pertaining to PA acceptability in this population. Studies incorporating monetary incentives reported the highest adherence rates. Arguably, other factors contribute to attendance; relatively high adherence rates were also reported in the absence of rewards. Regardless, extrinsic rewards may be useful to initially engage individuals with SMI in PA (Vancampfort, Stubbs, Venigalla, & Probst, 2015) due to the motivational deficits associated with engaging in health promoting behaviours in this population (Soundy, Stubbs, Probst, Hemmings, & Vancampfort, 2014). However, if PA engagement is to be sustained, development of autonomous motivation may be necessary (Vancampfort et al., 2013; Vancampfort et al., 2016). In adolescents, intrinsic, self-determined motivation has been

1 positively associated with long-term PA engagement (Owen, Smith, Lubans, Ng, &
2 Lonsdale, 2014). Thus, future research is required to ascertain the most effective ways to
3 promote sustained behaviour change in this population.

4 The use of theoretically informed interventions could be useful here. Theoretically-
5 informed interventions are well-placed to address individual needs in populations with SMI
6 and may contribute to intervention acceptability (Gourlan et al., 2016). For example,
7 motivational deficits pervasive in SMI populations. However, no studies within this review
8 incorporated psychological theory. The use of psychological theory is associated with
9 increased effectiveness of PA interventions (Gourlan et al., 2016). However, developing the
10 self-regulatory skills to become independent exercisers was rarely the study focus. Most
11 clinical exercise interventions explored the efficacy of exercise for improving mental health
12 outcomes not how this exercise might be sustained. Thus, the psychology of long-term
13 exercise promotion was largely absent.

14 The social aspect of exercise is regularly seen as a motivating factor for individuals
15 with SMI. The majority of studies in this review engaged participants in PA in a group
16 setting. Due to few studies exploring participant perceptions of group versus individual
17 exercise, it is hard to ascertain in the scope of this review whether this contributed to
18 intervention effectiveness or acceptability. However, one found through post-intervention
19 interviews that participants valued the social-interaction component of the intervention
20 (Radovic et al., 2017). Additionally, two found that participants valued social support from
21 family and exercise professionals (Radovic et al., 2017; Wunram et al., 2018). This
22 corresponds with literature identifying that depressed adolescents value the ‘shared
23 experience’ of engaging in PA with peers (Carter et al., 2016). Positive peer support and
24 social connectedness is associated with intrinsic motivation and sustained PA engagement in
25 healthy adolescents (Fitzgerald, Fitzgerald, & Aherne, 2012). Whilst social support may

1 contribute to intervention acceptability, it may not underlie anti-depressive effects of
2 exercise. Within this review, one study found that ‘social support within the group’ did not
3 confound therapeutic effects (Wunram et al., 2018). Future research is required to ascertain
4 how different forms of social support influence intervention engagement and effectiveness.

5 Only one study directly explored barriers and facilitators to PA engagement within
6 this population. One identified that motivating factors for exercise included parental and
7 trainer support, perceptions of improved fitness and having a routine. Barriers identified
8 included lack of motivation, poor physical health and low mood (Radovic et al., 2017). These
9 align with barriers to PA in SMI adult populations (Farholm & Sørensen, 2016). PA levels
10 have been shown to decline during adolescence, thus, in addition to the barriers presented by
11 SMI, there may be developmental factors unique to adolescence which need to be addressed
12 in PA interventions (Dumith, Gigante, Domingues, & Kohl, 2011). Incorporating qualitative
13 components to assess PA interventions within this population is imperative to gain an
14 understanding of barriers and facilitators to PA engagement in adolescent populations.

15 Some studies highlighted challenges with conducting PA interventions in this
16 population. Studies specifically identified that the context in which the PA was being carried
17 out presented a significant challenge to engagement. For example, inpatient settings limited
18 the exercise modalities which could be engaged in beyond the intervention length (Diaz &
19 Motta, 2008). Staff members play a key role in PA engagement in secure settings; if they do
20 not value, or are not competent in engaging patients in PA, integrating PA into patient’s
21 routine within standard practice can be difficult (Kinnafock, Papathomas, & Regoczi, 2018).

22 Challenges were also identified when conducting research in outpatient settings.
23 Notably, difficulties maintaining adherence were highlighted due to voluntary participation
24 (Wunram et al., 2018). However, another found that allowing participants to engage in PA at
25 home removed additional burdens associated with the time and travel to the location of PA

sessions (Hughes et al., 2013). Such additional commitments have been identified as barriers to participation in adult research (Dunn, Trivedi, Kampert, Clark, & Chambliss, 2002). Minimising additional burdens in a population which experiences significant motivational deficits may be essential to promote and maintain adherence to PA.

Research Strengths and Limitations

This review is the first to identify the state of the evidence on PA for adolescents with SMI. An established methodology for scoping reviews (Levac, Danielle, Colquhoun, Heather, O'Brien, 2010) was used, ensuring researchers were transparent and rigorous in the design, methods and reporting of findings. This allows searches to be replicated and reviews updated as the literature base continues to grow. However, the process would have benefitted from having more than one reviewer in the title and abstract screening to minimise the chance that any potentially relevant studies were missed.

Although quality of study is not considered a priority in scoping reviews, using the MMAT provides additional depth to the synthesis of data and gave an insight into the quality of the evidence which had been currently conducted in this population. Additionally, this quality assessment indicated that seven of the ten studies were high quality, consequently enhancing confidence in the conclusions of the review. With regards to limitations, literature not in the English language was not included. This potentially means that not all relevant literature was captured. Additionally, only ten studies met the inclusion criteria for this review. As there was significant heterogeneity between study types and designs, we are limited in recommendations that can be made for clinical practice. As scoping reviews are inclusive of many different study types (qualitative, quantitative, mixed methods) it remains challenging to synthesise and collate results coherently.

The cut-off date for study inclusion was 2007, in line with amendments made to the mental health act in 2007. It was recognised that studies conducted close to this date may not

1 have been in line with amended legislature. However, this would not have impacted study
2 inclusion. The amended legislature did not result in absolute changes to the diagnosis, but
3 rather in line with how patients treated for that diagnosis. It would increase the likelihood that
4 individuals are detained under the mental health act, and thus receive treatment in an age
5 appropriate secure setting.

6 Additionally, it is recognised that the Mental Health Act may be less relevant to
7 broader audiences outside of the UK. However, prior to conducting this review, an initial
8 search was conducted allowing for an earlier data range. Whilst two additional eligible
9 studies were included (Cohen-Kahn, 1994; Kanner, 1995) these lacked adequate description
10 of intervention components and variables of interest. Other reviews including these studies
11 have identified challenges in extracting relevant data (Carter, Morres, Meade, & Patrick,
12 2017; Dunn & Weintraub, 2008). Therefore, it was deemed that relevant information for this
13 review was not missed by excluding these two studies.

14 There were also strengths and weaknesses associated with the studies included in the
15 review. Amongst the studies, there was significant variance in the design, implementation
16 and evaluation of studies. Measurement of outcomes occurred at multiple different time
17 points, with little consistency between studies. It would be beneficial for studies at least to
18 incorporate pre-post measurement of outcomes, in addition to follow-up measures at time
19 points beyond the intervention to assess longitudinal effects of PA. This will ensure greater
20 rigor within the studies and inform an understanding of the longitudinal impact of PA for this
21 population.

22 Additionally, as this is a relatively understudied population, to ensure effectiveness of
23 future studies, it is important to explore the characteristics of interventions that are most
24 feasible and acceptable to this population. Qualitative methods are well placed to ascertain
25 intervention acceptability. However, only one study in this review incorporated a post-

intervention interview. Future research would benefit from incorporating qualitative components either in the design or evaluation of interventions.

Whilst all studies engaged participants in PA, quantifying the amount of exercise engaged in was only reported in a few studies. The studies that used objective accelerometer measured PA found good adherence to their use, indicating that these are feasible for use within this population. Whilst increasing PA was not the primary outcome measure, it is still relevant to objectively record and report changes in engagement. This is to not only identify how it impacts other outcome measures, but also to gauge what constitutes an acceptable amount of PA within this population.

Conclusions and Future recommendations

This review highlights that relative to adult populations, the role of PA for adolescent SMI remains under-researched. However, the evidence presented in this synthesis present preliminary findings that PA is multi-beneficial for adolescents with SMI. Specifically, the improvements in primary diagnoses in 7/10 studies, with corresponding moderate to large effect sizes is encouraging.

Few studies measured, or reported changes in physical health outcomes, which may be an important consideration for future interventions. Factors which relate to increased acceptability of PA interventions include extrinsic rewards, autonomy and lower intensity exercise. The complexity and range of variables used has led to differing degrees of therapeutic benefit, adherence and perceived enjoyment. It is therefore challenging to isolate the variables which contribute to the most efficacious interventions. The results are encouraging however, indicating that positive therapeutic outcomes can be achieved through a variety of approaches. Regardless, more high-quality studies that directly compare intervention variables are required. The inclusion of qualitative components within research studies is necessary to identify age- and disorder-specific parameters influencing PA

engagement within this population. The richness obtained from qualitative data is invaluable in a research area where our understanding of effective and acceptable interventions is sparse. It is anticipated that the recommendations identified here can enable research in this area to gain momentum. This consequently can be translated into practice, aiming to improve the notably poor prognosis of SMI in adolescent populations.

Author Contributions

JA designed the study, wrote the manuscript, designed the search strategy and conducted searches, charted and analysed data. FK assisted in study conception and design, reviewed search strategy and data charting process and assisted in review of manuscript and provided feedback on all drafts. AP and KB critically reviewed manuscript and provided feedback on final drafts.

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Conflict of interest statement

The authors can declare there are no conflicts of interest.

Ethical Statement

The manuscript does not contain clinical studies or patient data

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Appendices

Appendix A: PRISMA flow diagram

Figure 1: PRISMA flow diagram depicting the process of study selection

Appendix B: Data Charting Form

Author and Date	Population and diagnosis	Intervention	Control/Baseline	Study and Intervention Length	Measures	Primary Outcomes	Secondary Outcomes	Adherence
Diaz & Motta (2008)	12 inpatient females PTSD Mean age 15.42	Modality: walking Frequency: 3x weekly Duration: 25 minutes Intensity: moderate 60-90% max HR	No control 5-week baseline period	5-week intervention. 4-week follow-up.	CPSS MASC CDI	Between baseline-post-intervention 6/9 participants significantly reduced CPSS scores. 2/3 participants at follow-up reported further reductions in CPSS scores.	3 participants reduced MASC scores. 2 participant s reduced CDI	12 participants completed intervention.3 participants completed follow-up.
Hughes et al., (2013)	30 outpatients Non-psychotic MDD. 67% male	Modality: Treadmill and Stationary Bike + home-based preferred exercise	Comparison low intensity stretch group.	12-week intervention. Follow-up at 26 and 52 weeks.	CDRS-R Anthropometric Measures	Significant CDRS-R reductions for experimental and comparison group	PACES: both groups rated	26 completed intervention.21 attended 6-month follow-up

	Mean age 17	Frequency: 3x weekly Duration 30-40 minutes Intensity: High (12 kilocalories/kilogram/week)			PACES C-GAS	post-intervention EXER group had greater reductions in BDI scores at intervention end-point. 86% remission for experimental group, 50% remission for comparison at follow-up.	exercise with 'neutral' levels of enjoyment. Females lost fat & improved bone-density. Both groups improved C-GAS scores.	15 attended 12 month follow-up. High-intensity group adhered to prescribed intensity 77% of time vs 81% in comparison group.
Jelalian et al., (2016)	33 participants 70% female Mean age: 15.25	Modality: aerobic exercise (not specified).	Cognitive behavioural therapy only	24-week intervention and	Weight and BMI	BDI scores reduced from 22 to 9.3 by intervention end for CBT-HL and from 25	BMI decreased by 0.6. Spent	

	Primary diagnosis of MDD	Frequency: 1x weekly Duration: 60 minutes Intensity: not specified.		48-week follow- up	Accelerometer measured PA BDI	to 6.9 for CBT group only. At 48-week follow-up, scores reduced by an additional 0.9 for CBT group and rose by 1.3 for the CBT- HL group.	3.8% more time in MVPA compared to baseline.	
Metcalfe et al., (2016)	31 outpatients Bipolar disorder (BD) 70% male Mean age 16.9	Modality: Stationary Bike Frequency: Single Session Duration: 27 minutes Intensity: moderate 70% max HR	Healthy Control	n/a	Performance on Attention and Response Inhibition task (SART) immediately	Task-specific cognitive deficits on SART diminished after exercise for BD group.	n/a	n/a

					y after exercise			
Macintosh et al., (2016)	30 outpatients Bipolar disorder 57% female Mean age: 16.54	Modality: Stationary Bike Frequency: Single Session Duration: 27 minutes Intensity: moderate 70% max HR	Healthy Control	n/a	CBF (implicated in mood)	CBF increased at baseline. Post- exercise reduced to similar levels as controls.	n/a	n/a
Newman & Motta (2007)	15 inpatient females PTSD Mean age 15.7	Modality: TV based aerobics Frequency: 3x weekly Duration: 40 minutes Intensity: Moderate 60- 80% HR max	No control 2- or 4-week baseline	8-week intervention 4-week follow-up.	CPTSDI PTSD-RI CDI RCMAS.	Scores on CTPSDI significantly reduced from baseline to intervention end.	Significant reduction in all CDI and RCMAS from baseline start to	11 participants completed intervention (average 2.5 sessions per- week)

							interventio n end	
Radovic, Melvin & Gordon (2017)	10 outpatients MDD 70% female Mean age 15.1	Modality: Aerobic/Strength exercises (participant choice) Frequency: advised 3x weekly Duration: 30 minutes Intensity: Moderate	No control 2-week baseline	4-week intervention. No follow-up.	CDI Exercise Feedback Interview (qualitative)	Significant reduction in CDI scores from baseline start to intervention end. No participants achieved remission (note no follow-up period).	Interview: motivated by exercise benefits, social support. Barriers: mood, motivation, self- efficacy	90% participants completed intervention. Average attendance 3.29 sessions per week.
Roshan, Pourasghar &	24 outpatients with MDD 100% female	Modality: Pool Walking	Control group receiving no treatment	6-week intervention. No follow-up	HAM-D Fitness measured	Significant reduction in HAM-D scores following intervention both pre-	Vo2 max increase (32.32±5.4 5-	Did not report.

Mohammadi an (2011)	Mean age 16.8	Frequency: 2x daily in week 1, 3x daily after 3x per week. Duration: 60 minutes Intensity: high (60- 70% max HR).			by Vo2 max.	post and compared to control. No remission rates reported.	38.37±4.85)	
Subramania pillai et al., (2016)	32 outpatients Bipolar Disorder 50% male Mean age 16.9	Modality: Stationary Bike Frequency: Single session Duration 20 minutes Intensity: moderate 60- 80% max HR.	Healthy Control	n/a	EFI Borg RPE	No significant EFI between group differences. Both groups reported slight increase in revitalisation, control: & reduction in tranquillity and control.	Borg RPE scores higher for bipolar patients - indicates greater exercise tolerance among healthy controls.	n/a

Wunram et al., (2018)	64 inpatients MDD 28% male Mean age 15.9	Modality: Whole Body Vibration (WBV) Frequency: choice but had to equal 18 sessions over 3 weeks Duration: 6x2-3-minute exercises Intensity: low	Stationary Bike (high intensity) and Treatment as Usual. Cycling and WBV also received treatment as usual.	6-week intervention 8-week follow-up	DIKJ MSES Body-fat & Weight Vo2 max	DIKJ scores reduced relative to control for ergometer and WBV but not control. 71% remission for ergometer, 61.5% WBV at 26-week follow-up.	MSES: Enjoyment and motivation for WBV ranked higher than ergometer. Weight/body-fat did not change. Vo2 max increase for ergometer only.	48 completed intervention 39 completed follow-up. Similar attendance rates between cycling and WBV (average 4 sessions weekly)
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Table 1:
Table showing study data.
PTSD, Post-

Traumatic Stress Disorder; CPSS, Child PTSD symptom scale; MASC, Multidimensional anxiety scale; CDI, Childrens Depression Inventory; MDD, Major Depressive Disorder; CDRS-R, Childhood Depression Rating Scale; PACES, Physical Activity Enjoyment Scale; C-GAS, Childrens Global Assessment Scale;

BMI, Body Mass Index; PA, Physical Activity; BDI, Beck Depression Inventory; MVPA, Moderate and Vigorous Physical Activity; SART, Sustained Attention to Response Task; CBF, Cerebral Blood Flow; CPTSDSI, Childrens PTSD Inventory; PTSD-RI, PTSD Reaction Index; RCMAS, Revised Childrens Anxiety Manifest Scale; HAM-D, Hamilton Depression Scale; EFI, Exercise Induced Feelings Inventory; RPE, Rating of Perceived Exertion; DIKJ, German Depression Inventory for Children; Magglinger Sports Enjoyment Scale.

Appendix C: Scoring from the MMAT

Study	MMAT section	MMAT Score	Areas where failed to score points
Diaz & Motta (2008)	Quantitative non-randomised	60%	Clear inclusion/exclusion criteria not specified Confounders not accounted for in design and analysis
Hughes et al., (2013)	Quantitative randomised control trial	100%	None
Jelalian et al., (2016)	Quantitative randomised control trial	80%	Potential confounding variables were not accounted for.
Macintosh et al (2017)	Quantitative non-randomised	100%	
Metcalfe et al., (2016)	Quantitative non-randomised	100%	
Newman & Motta (2007)	Quantitative non-randomised	80%	Potential confounding variables were not accounted for.
Radovic, Melvin & Gordon (2017)	Mixed Methods	80%	Divergencies between qualitative and quantitative results were not adequately addressed.

Roshan, Poursaghar & Mohammadian (2011)	Quantitative non- randomised	60%	Participants not representative of target population. Confounders not adequately accounted for.
Subramaniapillai et al., (2016)	Quantitative non- randomised	100%	
Wunram et al., (2018)	Quantitative randomised control trial	100%	

Table 2: Quality Assessment of studies included in review. Low Quality scores = 0-40% are shown in red., medium quality scores = 41-79% are shown in orange, high quality scores = 80-100% are shown in green. Areas where studies failed to score points are shown in column 4. Full scoring criteria for each study type can be found at <http://mixedmethodsappraisaltoolpublic.pbworks.com/>

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Author	Primary Outcome Measure	Comparator	P value	Effect size (Hedges g)
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Table 3 details p-values and effect sizes for the primary outcome measure at intervention end point relative to a comparison or control group, * denotes significance at $p < 0.05$. For studies without a comparison or control group these effect sizes relate to the difference in the primary outcome measure at the start of baseline relative to the intervention end-point. CPSS, Child PTSD symptom scale; CDRS-R, Childhood Depression Rating Scale; BDI, Beck Depression Inventory; CBT, Cognitive Behavioural Therapy; SART, Sustained Attention to Response Task; CBF, Cerebral Blood Flow; CPTSDI, Children's PTSD Inventory; CDI, Children's Depression Inventory; HAM-D, Hamilton Depression Scale; EFI, Exercise Induced Feelings Inventory; DIKJ, German Depression Inventory for

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Appendix E: Reference list of included studies

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Wunram, H. L., Hamacher, S., Hellmich, M., Volk, M., Jänicke, F., Reinhard, F., ... Fricke, O. (2018a). Whole body vibration added to treatment as usual is effective in adolescents with depression: a partly randomized, three-armed clinical trial in inpatients. *European Child and Adolescent Psychiatry*, 27(5), 645–662.

Appendix E: PubMed Search Strategy

Search Conducted 10th November 2019

(((((("serious mental illness"[All Fields] OR "severe mental illness"[All Fields] OR bipolar[All Fields] OR ("psychotic disorders"[MeSH Terms] OR ("psychotic"[All Fields] AND "disorders"[All Fields]) OR "psychotic disorders"[All Fields] OR "psychosis"[All Fields]) OR ("schizophrenia"[MeSH Terms] OR "schizophrenia"[All Fields]) OR "major depression"[All Fields] OR "post-traumatic stress disorder"[All Fields] OR ("stress disorders, post-traumatic"[MeSH Terms] OR ("stress"[All Fields] AND "disorders"[All Fields] AND "post-traumatic"[All Fields]) OR "post-traumatic stress disorders"[All Fields] OR "ptsd"[All Fields] OR ("bipolar disorder"[MeSH Terms] OR ("bipolar"[All Fields] AND "disorder"[All Fields]) OR "bipolar disorder"[All Fields] OR "mania"[All Fields]) OR hypomania[All Fields] OR ("depressive disorder"[MeSH Terms] OR ("depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]))) AND ("physical activity"[All Fields] OR ("exercise"[MeSH Terms] OR "exercise"[All Fields]) OR fitness[All Fields] OR "physical exercise"[All Fields] OR ("running"[MeSH Terms] OR "running"[All Fields]) OR ("walking"[MeSH Terms] OR "walking"[All Fields]) OR ("sports"[MeSH Terms] OR "sports"[All Fields] OR "sport"[All Fields]) OR "aerobic exercise"[All Fields] OR "aerobic training"[All Fields] OR ("yoga"[MeSH Terms] OR "yoga"[All Fields]))) AND (adolescent[Title/Abstract] OR youth[Title/Abstract] OR teen[Title/Abstract] OR teenager[Title/Abstract] OR juvenile[Title/Abstract] OR student[Title/Abstract])) AND (("methods"[MeSH Terms] OR "methods"[All Fields] OR "intervention"[All Fields]) OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR program[All Fields] OR programme[All Fields])) NOT (adult[Title] OR "older people"[Title] OR elderly[Title] OR aging[Title]) AND ("2001/01/01"[PDAT] : "2019/12/31"[PDAT]))

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Appendix F: PRISMA Checklist

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Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

4

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	6
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	9-10

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	9 (and supplementary material)
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	11
Data charting process‡	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	11
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	11
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	12
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	11-12
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	10 (and supplementary material)
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	12-21
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	13
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table 1 (data charting form)
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Table 1 (data charting form)

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	21-30
Limitations	20	Discuss the limitations of the scoping review process.	30-31
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	32
FUNDING			
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	n/a

1 JBI = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-
2 Analyses extension for Scoping Reviews.

3 * Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social
4 media platforms, and Web sites.

5 † A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g.,
6 quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping
7 review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

8 ‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JBI guidance (4, 5) refer to
9 the process of data extraction in a scoping review as data charting.

10 § The process of systematically examining research evidence to assess its validity, results, and relevance before
11 using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more
12 applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence
13 that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy
14 document).

17 *From:* Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews
18 (PRISMA-ScR): Checklist and Explanation.

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Appendices

Appendix A: PRISMA flow diagram

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Figure 1: PRISMA flow diagram depicting the process of study selection

Appendix B: Data Charting Form

Author and Date	Population and diagnosis	Intervention	Control/Baseline	Study and Intervention Length	Measures	Primary Outcomes	Secondary Outcomes	Adherence
Diaz & Motta (2008)	12 inpatient females PTSD Mean age 15.42	Modality: walking Frequency: 3x weekly Duration: 25 minutes Intensity: moderate 60-90% max HR	No control 5-week baseline period	5-week intervention. 4-week follow-up.	CPSS MASC CDI	Between baseline-post-intervention 6/9 participants significantly reduced CPSS scores. 2/3 participants at follow-up reported further reductions in CPSS scores.	3 participants reduced MASC scores. 2 participant s reduced CDI	12 participants completed intervention.3 participants completed follow-up.
Hughes et al., (2013)	30 outpatients Non-psychotic MDD. 67% male	Modality: Treadmill and Stationary Bike + home-based preferred exercise	Comparison low intensity stretch group.	12-week intervention. Follow-up at 26 and 52 weeks.	CDRS-R Anthropometric Measures	Significant CDRS-R reductions for experimental and comparison group	PACES: both groups rated	26 completed intervention.21 attended 6-month follow-up

	Mean age 17	Frequency: 3x weekly Duration 30-40 minutes Intensity: High (12 kilocalories/kilogram/week)			PACES C-GAS	post-intervention EXER group had greater reductions in BDI scores at intervention end-point. 86% remission for experimental group, 50% remission for comparison at follow-up.	exercise with 'neutral' levels of enjoyment. Females lost fat & improved bone-density. Both groups improved C-GAS scores.	15 attended 12 month follow-up. High-intensity group adhered to prescribed intensity 77% of time vs 81% in comparison group.
Jelalian et al., (2016)	33 participants 70% female Mean age: 15.25	Modality: aerobic exercise (not specified).	Cognitive behavioural therapy only	24-week intervention and	Weight and BMI	BDI scores reduced from 22 to 9.3 by intervention end for CBT-HL and from 25	BMI decreased by 0.6. Spent	

	Primary diagnosis of MDD	Frequency: 1x weekly Duration: 60 minutes Intensity: not specified.		48-week follow-up	Accelerometer measured PA BDI	to 6.9 for CBT group only. At 48-week follow-up, scores reduced by an additional 0.9 for CBT group and rose by 1.3 for the CBT-HL group.	3.8% more time in MVPA compared to baseline.	
Metcalfe et al., (2016)	31 outpatients Bipolar disorder (BD) 70% male Mean age 16.9	Modality: Stationary Bike Frequency: Single Session Duration: 27 minutes Intensity: moderate 70% max HR	Healthy Control	n/a	Performance on Attention and Response Inhibition task (SART) immediately	Task-specific cognitive deficits on SART diminished after exercise for BD group.	n/a	n/a

					y after exercise			
Macintosh et al., (2016)	30 outpatients Bipolar disorder 57% female Mean age: 16.54	Modality: Stationary Bike Frequency: Single Session Duration: 27 minutes Intensity: moderate 70% max HR	Healthy Control	n/a	CBF (implicated in mood)	CBF increased at baseline. Post- exercise reduced to similar levels as controls.	n/a	n/a
Newman & Motta (2007)	15 inpatient females PTSD Mean age 15.7	Modality: TV based aerobics Frequency: 3x weekly Duration: 40 minutes Intensity: Moderate 60- 80% HR max	No control 2- or 4-week baseline	8-week intervention 4-week follow-up.	CPTSDI PTSD-RI CDI RCMAS.	Scores on CTPSDI significantly reduced from baseline to intervention end.	Significant reduction in all CDI and RCMAS from baseline start to	11 participants completed intervention (average 2.5 sessions per- week)

							interventio n end	
Radovic, Melvin & Gordon (2017)	10 outpatients MDD 70% female Mean age 15.1	Modality: Aerobic/Strength exercises (participant choice) Frequency: advised 3x weekly Duration: 30 minutes Intensity: Moderate	No control 2-week baseline	4-week intervention. No follow-up.	CDI Exercise Feedback Interview (qualitative)	Significant reduction in CDI scores from baseline start to intervention end. No participants achieved remission (note no follow-up period).	Interview: motivated by exercise benefits, social support. Barriers: mood, motivation, self- efficacy	90% participants completed intervention. Average attendance 3.29 sessions per week.
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Roshan, V. D., Pourasghar, M., & Mohammadian, Z. (2011). The efficacy of intermittent walking in water on the rate of MHPG sulfate and the severity of depression. *Iranian Journal of Psychiatry and Behavioral Sciences*, 5(2), 26–31.

Subramaniapillai M, Goldstein BI, MacIntosh BJ, Korczak DJ, Ou X, Scavone A, Arbour-Nicitopoulos K, Faulkner G. Characterizing exercise-induced feelings after one bout of exercise among adolescents with and without bipolar disorder. *Journal of affective disorders*. 190, 467-73.

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Appendix E: PubMed Search Strategy

Search Conducted 10th November 2019

(((((("serious mental illness"[All Fields] OR "severe mental illness"[All Fields] OR bipolar[All Fields] OR ("psychotic disorders"[MeSH Terms] OR ("psychotic"[All Fields] AND "disorders"[All Fields]) OR "psychotic disorders"[All Fields] OR "psychosis"[All Fields]) OR ("schizophrenia"[MeSH Terms] OR "schizophrenia"[All Fields]) OR "major depression"[All Fields] OR "post-traumatic stress disorder"[All Fields] OR ("stress disorders, post-traumatic"[MeSH Terms] OR ("stress"[All Fields] AND "disorders"[All Fields] AND "post-traumatic"[All Fields]) OR "post-traumatic stress disorders"[All Fields] OR "ptsd"[All Fields] OR ("bipolar disorder"[MeSH Terms] OR ("bipolar"[All Fields] AND "disorder"[All Fields]) OR "bipolar disorder"[All Fields] OR "mania"[All Fields]) OR hypomania[All Fields] OR ("depressive disorder"[MeSH Terms] OR ("depressive"[All Fields] AND "disorder"[All Fields]) OR "depressive disorder"[All Fields] OR "depression"[All Fields] OR "depression"[MeSH Terms]))) AND ("physical activity"[All Fields] OR ("exercise"[MeSH Terms] OR "exercise"[All Fields]) OR fitness[All Fields] OR "physical exercise"[All Fields] OR ("running"[MeSH Terms] OR "running"[All Fields]) OR ("walking"[MeSH Terms] OR "walking"[All Fields]) OR ("sports"[MeSH Terms] OR "sports"[All Fields] OR "sport"[All Fields]) OR "aerobic exercise"[All Fields] OR "aerobic training"[All Fields] OR ("yoga"[MeSH Terms] OR "yoga"[All Fields]))) AND (adolescent[Title/Abstract] OR youth[Title/Abstract] OR teen[Title/Abstract] OR teenager[Title/Abstract] OR juvenile[Title/Abstract] OR student[Title/Abstract])) AND ((("methods"[MeSH Terms] OR "methods"[All Fields] OR "intervention"[All Fields]) OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "treatment"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR ("therapy"[Subheading] OR "therapy"[All Fields] OR "therapeutics"[MeSH Terms] OR "therapeutics"[All Fields]) OR program[All Fields] OR programme[All Fields])) NOT (adult[Title] OR "older people"[Title] OR elderly[Title] OR aging[Title]) AND ("2001/01/01"[PDAT] : "2019/12/31"[PDAT]))

Appendix F: PRISMA Checklist

Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) Checklist

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
TITLE			
Title	1	Identify the report as a scoping review.	1
ABSTRACT			
Structured summary	2	Provide a structured summary that includes (as applicable): background, objectives, eligibility criteria, sources of evidence, charting methods, results, and conclusions that relate to the review questions and objectives.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known. Explain why the review questions/objectives lend themselves to a scoping review approach.	6
Objectives	4	Provide an explicit statement of the questions and objectives being addressed with reference to their key elements (e.g., population or participants, concepts, and context) or other relevant key elements used to conceptualize the review questions and/or objectives.	7
METHODS			
Protocol and registration	5	Indicate whether a review protocol exists; state if and where it can be accessed (e.g., a Web address); and if available, provide registration information, including the registration number.	6
Eligibility criteria	6	Specify characteristics of the sources of evidence used as eligibility criteria (e.g., years considered, language, and publication status), and provide a rationale.	7-9
Information sources*	7	Describe all information sources in the search (e.g., databases with dates of coverage and contact with authors to identify additional sources), as well as the date the most recent search was executed.	9-10
Search	8	Present the full electronic search strategy for at least 1 database, including any limits used, such that it could be repeated.	9 (and supplementary material)
Selection of sources of evidence†	9	State the process for selecting sources of evidence (i.e., screening and eligibility) included in the scoping review.	10

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Data charting process†	10	Describe the methods of charting data from the included sources of evidence (e.g., calibrated forms or forms that have been tested by the team before their use, and whether data charting was done independently or in duplicate) and any processes for obtaining and confirming data from investigators.	10
Data items	11	List and define all variables for which data were sought and any assumptions and simplifications made.	10-11
Critical appraisal of individual sources of evidence§	12	If done, provide a rationale for conducting a critical appraisal of included sources of evidence; describe the methods used and how this information was used in any data synthesis (if appropriate).	11
Synthesis of results	13	Describe the methods of handling and summarizing the data that were charted.	10-11
RESULTS			
Selection of sources of evidence	14	Give numbers of sources of evidence screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally using a flow diagram.	10 (and supplementary material)
Characteristics of sources of evidence	15	For each source of evidence, present characteristics for which data were charted and provide the citations.	11-19
Critical appraisal within sources of evidence	16	If done, present data on critical appraisal of included sources of evidence (see item 12).	12
Results of individual sources of evidence	17	For each included source of evidence, present the relevant data that were charted that relate to the review questions and objectives.	Table 1 (data charting form)
Synthesis of results	18	Summarize and/or present the charting results as they relate to the review questions and objectives.	Table 1 (data charting form)
DISCUSSION			
Summary of evidence	19	Summarize the main results (including an overview of concepts, themes, and types of evidence available), link to the review questions and objectives, and consider the relevance to key groups.	20-27
Limitations	20	Discuss the limitations of the scoping review process.	27-29
Conclusions	21	Provide a general interpretation of the results with respect to the review questions and objectives, as well as potential implications and/or next steps.	29
FUNDING			

SECTION	ITEM	PRISMA-ScR CHECKLIST ITEM	REPORTED ON PAGE #
Funding	22	Describe sources of funding for the included sources of evidence, as well as sources of funding for the scoping review. Describe the role of the funders of the scoping review.	n/a

JB1 = Joanna Briggs Institute; PRISMA-ScR = Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews.

* Where *sources of evidence* (see second footnote) are compiled from, such as bibliographic databases, social media platforms, and Web sites.

† A more inclusive/heterogeneous term used to account for the different types of evidence or data sources (e.g., quantitative and/or qualitative research, expert opinion, and policy documents) that may be eligible in a scoping review as opposed to only studies. This is not to be confused with *information sources* (see first footnote).

‡ The frameworks by Arksey and O'Malley (6) and Levac and colleagues (7) and the JB1 guidance (4, 5) refer to the process of data extraction in a scoping review as data charting.

§ The process of systematically examining research evidence to assess its validity, results, and relevance before using it to inform a decision. This term is used for items 12 and 19 instead of "risk of bias" (which is more applicable to systematic reviews of interventions) to include and acknowledge the various sources of evidence that may be used in a scoping review (e.g., quantitative and/or qualitative research, expert opinion, and policy document).

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