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Physical Activity Interventions in Suicide Prevention: A Systematic Review.

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ABSTRACT

Background: Regular physical activity helps manage several chronic or recurring conditions; however, a previous review found insufficient studies to evaluate the effect of physical activity interventions on suicidal ideation. This review considers new evidence and expands the scope of inquiry to include any type of self-harm or suicide-related behaviour, such as self-poisoning, self-injury, including “non-suicidal self-injury”, and attempted suicide.

Method: This review followed a systematic approach; I searched the relevant databases for randomised controlled trials of physical activity interventions that reported self-harm or suicide-related outcomes. After initial screening, study inclusion was determined by consensus. The Physiotherapy Evidence Database (PEDro) rating scale informed the quality appraisal. We double-checked the extracted outcome data and used Review Manager (RevMan) statistical software to calculate risk ratio and standardised mean difference.

Results: There were ten eligible studies of a broad geographical spread. There were 681 participants in total, recruited from clinical and non-clinical settings and representing most age groups. Most studies used a parallel design. The most common trial duration was 6 weeks but settings, type and “dosage” varied widely. The reported outcomes were of suicidal ideation only, usually assessed by self-report. Quality varied but there were several indicators of acceptable trial conduct. Meta-analysis showed a probable favourable effect of physical activity interventions, measured dichotomously (RR 0.43, 95% CI 0.23, 0.79). The effect was in the same direction when measured continuously, although highly heterogeneous. Unfortunately, follow-up data is scarce and several potentially relevant studies did not report crucial outcomes.

Conclusion: There is uncertain evidence that physical activity interventions may have a positive impact on suicidal ideation. Its base is small and inherently heterogeneous. High-quality trials that report suicide prevention specific outcomes are urgently required.

Dedication

He hōnore, he korōria

Maungārongo ki te whenua.

Whakaaro pai e

Ki ngā tāngata katoa

Āke ake, ake ake.

Āmine

Te Atua, te piringa,

Tōku oranga.

Honour and glory to God

Peace throughout the land

And goodwill

To all people

Forever, Forever

Amen

For it is God who is my companion

My source of life.

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I'm also grateful to Honorary Associate Professor Elsie Ho for having introduced me (as a Postgraduate Diploma student) to lifestyle change project design.

I'm also grateful to each of the study authors who generously provided additional trial data, without which this review would have been much less informative. They are: Dr Ida Sibylle Haußleiter (Germany), Professor Kate Jolly (United Kingdom), Dr Yasmina Nasstasia (Australia), Dr Martin Plöderl (Austria) and Dr Jennifer Taylor (Australia).

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CHAPTER 1: BACKGROUND

Suicide Prevention is Important and Complex

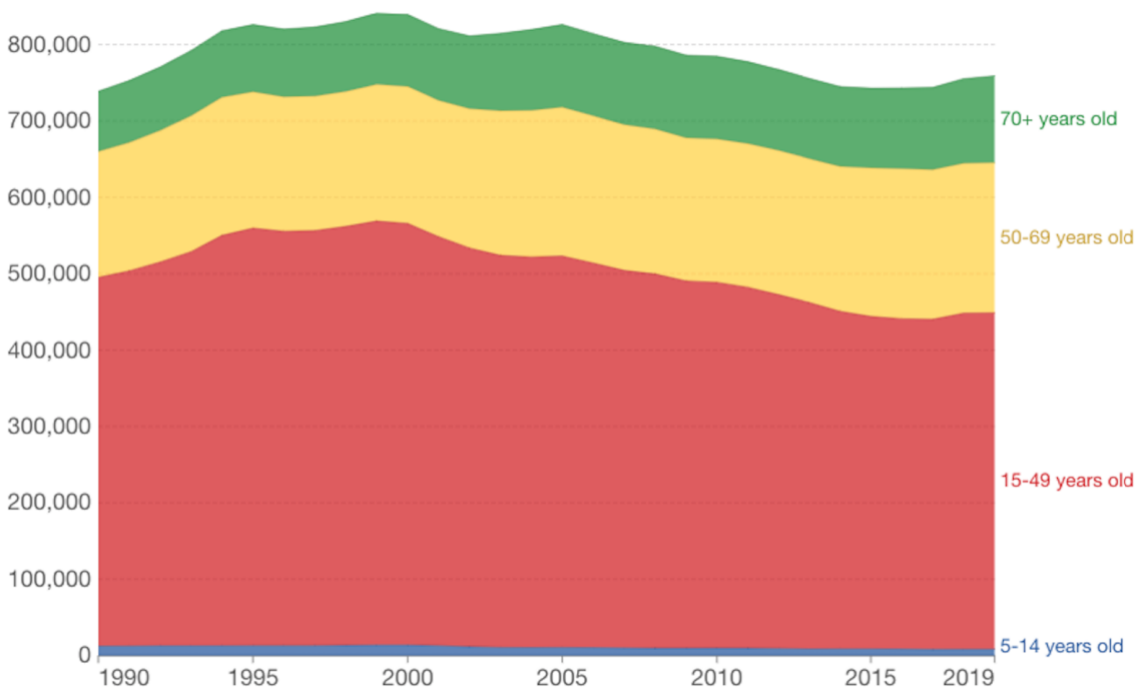
The Impact of Death by Suicide

Deaths by suicide are tragic and devastating. They cause untold grief (Berman, 2011) and the bereaved survivors may report compounding difficulties such as shock, shame and the “‘why’ questions” (Andriessen et al., 2019, p. 2). Stigma nowadays may be less overt than in the past but its effects still cause considerable distress; these include the silencing of appropriate expression of grief (Cerel et al., 2008; Evans & Abrahamson, 2020).

In 2019, death caused by suicide ranked 15th globally for years of life lost (Institute for Health Metrics and Evaluation (IHME), 2020). Most of the global burden of death by suicide falls on the young (as shown in Figure 1), which results in so many years of lost contribution to their families, communities, and societies (Fortune et al., 2007).

Figure 1.

Deaths From Suicide, by Age, World, 1990 to 2019: Annual Number of Deaths From Suicide/Self-Harm by Age Group.



From Our World in Data (n.d.) *Deaths from suicide, by age, World, 1990 to 2019: Annual number of deaths from suicide/self-harm by age group*. Retrieved June 30, 2022 from <https://ourworldindata.org/grapher/suicide-deaths-by-age>

Definitions of Suicidal Behaviour

The thoughts and behaviours that relate to suicide, including self-harm (SH), encompass a range of phenomena, both subjective (e.g., wish to die) and objective (e.g., suicide notes, SH events). There are many different terms to describe these phenomena; furthermore, researchers and practitioners worldwide apply the related terms inconsistently (De Leo et al., 2021).

Suicidal Ideation. Suicidal ideation (SI) has to do with “*thoughts with the wish to die*” and as a concept it may include “*planning, motivation, and intent*” (Silverman, 2016, pp. 14, 20). SI has been succinctly defined as “*thinking about, considering or planning suicide*” (National Institute of Mental Health, 2022, Definitions) but, in reality, it has so far eluded a simple, agreed definition. Silverman (2016) has described the complexities and the unanswered questions about defining SI. He pointed out, for example (p. 20), that in one sample of patients, most endorsed SI when it was measured by any one of the three assessments in that study, yet less than one third of these same patients endorsed SI in all three ways. Further, a recent systematic review (McHugh et al., 2019) handled multiple different definitions for suicidal ideation reported in the included primary studies, including no reported definition at all. In the absence of an agreed definition, it is helpful to turn to descriptions of SI. Although Reeves et al. (2022) discuss the problems with treating SI as binary (i.e. either present or absent), the following sample of items (taken from some of the available measurement tools) illustrate the concept:

- “*Have you wished you were dead or wished you could go to sleep and not wake up?*” (Columbia-Suicide Severity Rating Scale (The Columbia Lighthouse Project, 2016))
- “*I want to kill myself*” (Children’s Depression Inventory (Kovacs, 1992, as cited in Williams, et al., 2019))
- “*I have thoughts of killing myself, but I would not carry them out*” (Beck Depression Inventory-II (Beck et al., 1996)).

Self-Harm. Self-harm (SH) has been described as “*a multifaceted and complex behaviour that varies in both severity and intent*” (Windfuhr et al., 2016, p. 47) and it is accompanied by a variety of possible motivations (Hawton et al., 1982; Hawton et al., 2003; James & Hawton, 1985). SH methods are usually divided into self-injury or self-poisoning. SH might be singular, recurrent, or habitual.

Notwithstanding the diversity, this study and review required workable definitions and the following were adopted:

1. SI is *“To think of suicide with or without suicidal intent, or hope for death by killing oneself, or state suicidal intention without engaging in behaviour”* (De Leo et al., 2021, p. 8).
2. SH is *“all intentional acts of self-poisoning (such as intentional drug overdoses) or self-injury (such as self-cutting), regardless of the degree of suicidal intent or other types of motivation. This definition includes acts intended to result in death ('attempted suicide'), those without suicidal intent (e.g., to communicate distress, to temporarily reduce unpleasant feelings; sometimes termed 'non-suicidal self-injury'), and those with mixed motivation. We did not distinguish between attempted suicide and non-suicidal self-injury in this review, because there is a high level of co-occurrence between them, and the two cannot be distinguished in any reliable way, including on levels of suicidal intent. Lastly, the motivations for SH are complex and can change, even within a single episode.* (Witt, Hetrick, et al., 2021b, p. 24)

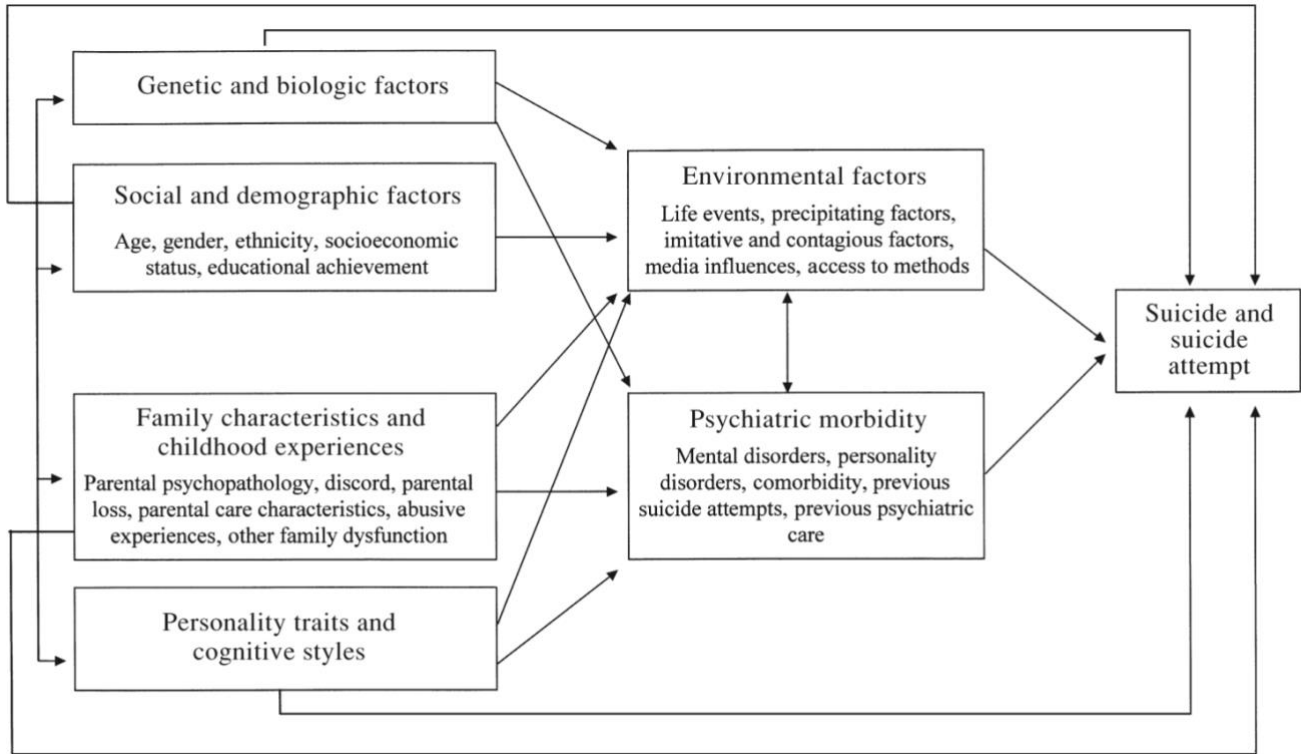
In summary, no matter whether the SH is described as non-suicidal or suicide-related and no matter whether the SI is endorsed or interpreted as serious or not serious, all of these phenomena are associated with increased risk of death by suicide. Of themselves, they signal suffering which may respond to intervention, as evidenced by the growing body of research into psychological and pharmacological interventions for SI and SH (Büscher et al., 2020; Kothgassner et al., 2021; Stefanopoulou et al., 2020; Witt, Chitty, et al., 2021; Witt et al., 2020).

Risk Factors for Suicidal Behaviour

Suicidal behaviours are the outcome of a complex set of interactions and no single risk factor is established as causative, per se. In young people, for example, one qualitative analysis of a range of factors revealed three distinctly different life-course patterns, each of them complex, that contributed to death by suicide (Fortune et al., 2007). Therefore, a summary of the known risk factors must incorporate caution against simplification or reliance on any one factor. So to begin, the risk factors associated with suicidal behaviour are summarised by Annette Beautrais in Figure 2.

Figure 2.

Beautrais' "Conceptual model of domains of risk factors for suicide and suicide attempt"



From "Risk Factors for Suicide and Attempted Suicide among Young People," by A. L. Beautrais, 2000, *Australian & New Zealand Journal of Psychiatry*, 34(3), p. 429 (<https://doi.org/10.1080/j.1440-1614.2000.00691.x>).

The long-established general risk factors for suicide and attempted suicide include: experience of mental illness, a prior history of self-harm, experience of sexual abuse, being single or widowed or divorced, chronic or life-limiting physical illness, socioeconomic deprivation, unemployment, macroeconomic recession, and ease of access to lethal means (Beautrais, 2000; O'Connor & Pirakis, 2016, Part 1). Chronic physical illness is especially risky if it has "*poor prognosis, chronic pain, mobility impairment, limits to autonomy, cognitive impairment, and social stigma*" (Pompili et al., 2016, p. 143). Furthermore, chronic pain, itself (such as in fibromyalgia (Gill et al., 2021)), is an important independent risk factor (Racine, 2018). Twin studies indicate heritability exists (Windfuhr et al., 2016); moreover, heritability is "*largely independent of the inheritance of psychiatric disorder*" (Mann et al., 2009, p. 556). Among youth, additional factors are important, including parental separation, divorce, or marital discord, parental mental disorder, and impaired parent-child relationships (Beautrais, 2000).

The mental disorders most associated with elevated risk of suicidal behaviour appear to be psychotic disorders (RR_{pooled} 13.2, 95% CI 8.6, 20.3), mood disorders (RR_{pooled} = 12.3, 95% CI 8.9, 17.1), personality disorders (RR_{pooled} 8.1, 95% CI 4.6, 14.2), substance use disorders (RR_{pooled} = 4.4, 95% CI 2.9–6.8), and anxiety disorders (RR_{pooled} = 4.1, 95% CI 2.4, 6.9) (Too et al., 2019). However, the risk associated with mental illness is not straightforward. For example, in people with major mood disorders, studies have found that “*Up to 50% of [unipolar and bipolar depressed patients] never attempt suicide*” but, conversely, some patients go through periods of significantly elevated risk, such as during an acute mood episode or soon after the initial diagnosis (Rihmer & Döme, 2016, p. 77). Anxiety increases risk for “*suicidal ideations (OR = 2.89, 95% CI: 2.09, 4.00), attempted suicides (OR = 2.47, 95% CI: 1.96, 3.10), completed suicides (OR = 3.34, 95% CI: 2.13, 5.25), or [having] any suicidal activities (OR = 2.85, 95% CI: 2.35, 3.46)*” (Kanwar et al., 2013, p. 919).

Meanwhile, studies related to suicide and suicide attempts have found abnormalities of “*the serotonergic system, and the stress response systems of the noradrenergic system and hypothalamic-pituitary-adrenal (HPA) axis*” (Mann & Currier, 2016, p. 149). More recently, a systematic review points to significantly diminished levels of 5-hydroxyindoleacetic acid (5-HIAA), which is a serotonin metabolite, and homovanillic acid (HVA), which is a dopamine metabolite, in the cerebrospinal fluid of suicide attempters (compared with non-attempters) (Hoertel et al., 2021).

Studies using MRI and other imaging techniques have found structural and functional abnormalities in multiple regions of the brain. In particular, several studies have identified decreased grey matter volume in the prefrontal and limbic regions of people who have attempted suicide. In some respects, such findings seem to correlate with clinical features that include impaired decision making; however, this field of enquiry is still emerging, and intervention effects are not yet established (Sudol & Oquendo, 2016).

There is increased risk of repeat (non-fatal) SH (17.03% (95% CI 15.24, 18.90)) and of fatal SH (1.34% (95% CI 0.86, 1.91)) within the first year, and these risks are further increased by the third year, at 24.2 % (95% CI 12.20, 38.73) and 2.46% (95% CI 1.13, 4.26), respectively (Liu et al., 2020). Even so, there is much about risk of repeat SH that is still unknown globally (Arensman et al., 2016).

In addition, empirical evidence indicates there are proximal risk factors for suicide or suicide attempt (against the backdrop of other distal factors), including relationship breakup, sudden

financial loss, humiliation, and being bereaved by suicide. Further, there are acute clinical and cognitive characteristics such as hopelessness, the severity of a major depressive episode, and acute alcohol use that confer risk (Beautrais, 2000; Conner & Ilgen, 2016; Rihmer & Döme, 2016). Very recent research in Aotearoa New Zealand further confirms that acute alcohol use is a significant proximal factor (Crossin et al., 2022).

Models of Suicide

There are many theoretical models of suicidal behaviours; they attempt to explain the emergence and development of SI and suicide-related behaviours. In his seminal work more than a century ago, Durkheim (1897/2002) emphasised social factors. Konrad Michel (2021) comments that, later, several models were developed that emphasised medical explanations (i.e. psychiatric illness). After those, multifactorial models emerged: prominent among these are the “Interpersonal-Psychological Theory” (IPT) of suicidal behaviour (Hagan et al., 2016; Joiner, 2005; Van Orden et al., 2010) and the “Integrated Motivational-Volitional” (IMV) model of suicidal behaviour (O'Connor, 2011a, 2011b; O'Connor et al., 2016).

The IPT model considers an intersection of the documented individual and social risk factors for suicidal behaviour and proposes that these influence suicidal outcomes through learned fearlessness (of suicide), “perceived burdensomeness”, and “thwarted belongingness” (Joiner, 2005). The model may have utility for treatment of suicidal behaviour. Proponents suggest it informs a psychotherapeutic approach (“situational analysis”) as well as a public health approach; namely, that “*preventative efforts should be designed to increase public awareness of the importance of social connectedness and social contribution, because bolstering these factors may act as a buffer against suicidal ideation*” (Hagan et al., 2016, p. 214).

The IMV model synthesises several previous models and puts forward a complex interplay of psychological, social, and biological factors which exist in three phases: “*intention to engage*” (proximally), “*feelings of entrapment ... triggered by defeat/humiliation appraisals*”, and a collection of background factors that comprise the “*premotivational phase*” (O'Connor et al., 2016, pp. 222-223). The IMV suggests multiple opportunities for intervention. For example:

“we could bolster social problem solving, thereby attenuating the defeat/humiliation–entrapment path, or we could increase positive future thinking in order to reduce the likelihood of developing suicidal ideation/intent following entrapment”. (O'Connor et al., 2016, p. 234)

It is important to understand the underlying processes of SI, suicide attempt, and death by suicide and it might be possible that SI with a plan is importantly different from SI without a plan.

However, the presence or absence of intention is unlikely helpful for predicting future SH (Chan et al., 2016; Fortune & Hetrick, 2022), and “so far, no theoretical model has successfully been translated into a clinical treatment protocol with evidence of effectively reducing suicide” (Michel, 2021, p. 1).

The Epidemiology of Suicide and Self-Harm Globally and in Aotearoa New Zealand

The scale of suicide is very large; there may have been 758,696 cases globally in 2019 (Yip et al., 2022) but the accuracy of estimates such as this is hampered by variable systems for recording deaths by suicide (Windfuhr et al., 2016). The overall estimated rate (age-standardised) is 9.0 per 100,000 but there is a marked difference in the rate for males (12.6) versus females (5.4). There are also marked economic differences, with an estimated 77% of deaths by suicide occurring in low- and middle-income countries. (World Health Organization, 2021).

Estimating the global prevalence of SH is also a difficult task, since systems for identifying and recording these data are unreliable in most countries (Arensman et al., 2016). A recent meta-analysis investigating these events in children and adolescents globally (Lim et al., 2019) found (in part) that aggregate 12-month prevalence of reported non-suicidal self-injury was 19.5%, deliberate self-harm was 14.2%, and suicide attempt was 4.5%. Although rates varied from country to country, the study found gender differences (globally) were insignificant. (These categorisations highlight, once again, the definitional variations that exist. The authors had defined non-suicidal self-injury as “self-inflicted destruction of body tissue without suicidal intent and for purposes not socially sanctioned, such as cutting, burning, and biting”, deliberate SH as “self-injurious behaviors with and without suicidal intent and that have non-fatal outcomes” and suicide attempt as “an act in which an adolescent tries to end his or her life but survives” (Lim et al., 2019, p. 3).) To my knowledge, a similar international review has not been completed for SH in adults; however, a systematic review of “non-suicidal self-injury” found the overall pooled lifetime prevalence was 5.5% among adults (95% CI 1.7, 16.3) (Swannell et al., 2014).

In Aotearoa New Zealand, the Ministry of Health’s Suicide Web Tool (Ministry of Health – Manatū Hauora, 2021) indicated there were 629 suspected deaths by suicide in 2018, which equates to an age-standardised rate of 12.2 per 100,000 population (95% CI: 11.2, 13.2). This overall rate has not significantly changed since 2009. Further, Aotearoa New Zealand has consistently reported one of the highest adolescent suicide rates in the world; a recent meta-analytic review states the rate was

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9.36 per 100,000 in 2013, and this contrasts (for example) with a pooled international estimate of 3.77 per 100,000 (Glenn et al., 2020).

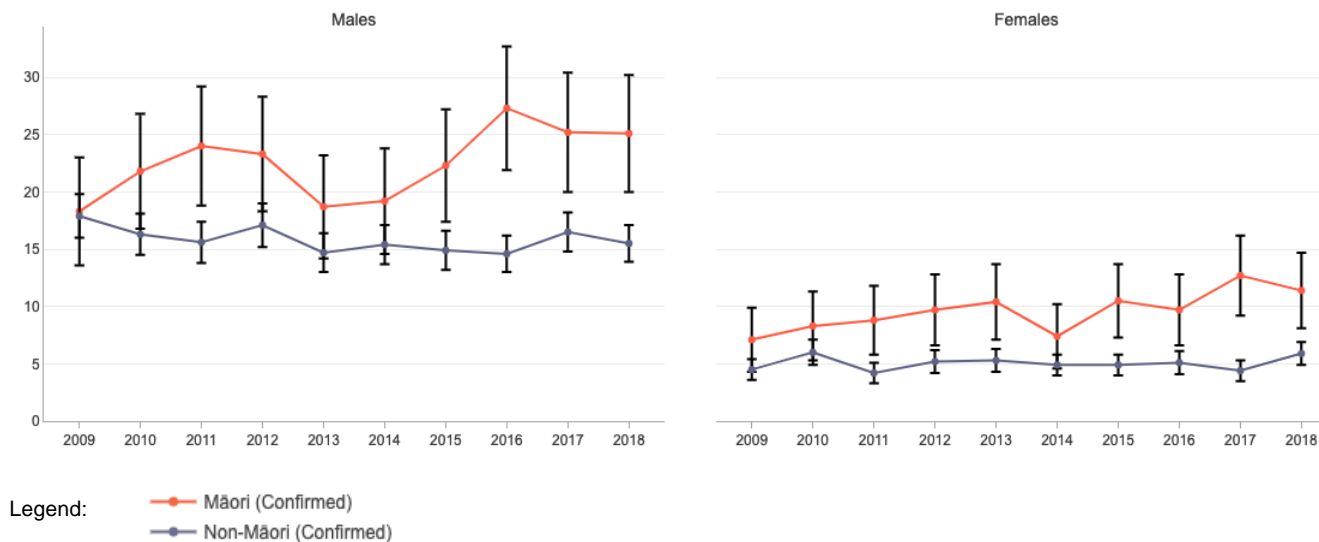
There is striking ethnic disparity: in 2018, Māori had a higher overall suicide rate (18.2 per 100,000) than other ethnic groups. Similarly, there were significantly higher rates for Māori males versus non-Māori males (about 1.6 times), Māori females versus non-Māori females (about 1.9 times) and for Māori versus non-Māori in the 15–24 years age group (about 2.1 times) (Ministry of Health – Manatū Hauora, 2021).

Similar with the global pattern, there is striking gender disparity for death by suicide in Aotearoa New Zealand: in 2018 the rate for males was 17.4 per 100,000, but 6.9 per 100,000 for females (Ministry of Health – Manatū Hauora, 2021).

Figure 3 depicts the rates for Māori compared with non-Māori deaths by suicide, in both males and females.

Figure 3

Age-Standardised Rate (per 100,000) of Confirmed Suicide Deaths Among Māori and Non-Māori of All Ages, by Sex, 2009–2018 (with Error Bars)



From Ministry of Health – Manatū Hauora. (2021). *Suicide web tool: Numbers and rates of suicide deaths among Māori and non-Māori*. Retrieved May 19, 2022 from <https://minhealthnz.shinyapps.io/suicide-web-tool/>

There is significant uncertainty about rates of SH in Aotearoa New Zealand (Fortune et al., 2022). Research into treated SH, which is now about 15 years old, extrapolated from careful sampling that there would have been 6,200 hospital presentations per year, involving 4,900 people (which was significantly greater than the official figures at the time). Young women and Māori were at greater risk (Hatcher et al., 2009).

Multilevel Approaches to Suicide Prevention

Effective suicide prevention requires concerted, multi-faceted efforts; hence, “*a public health framework towards suicide prevention with participation from a wide range of disciplines, in addition to the health care professionals, should be adopted and actively pursued in the Western Pacific Region and other places around the world*” (World Health Organization. Regional Office for the Western Pacific, 2010, p. 55).

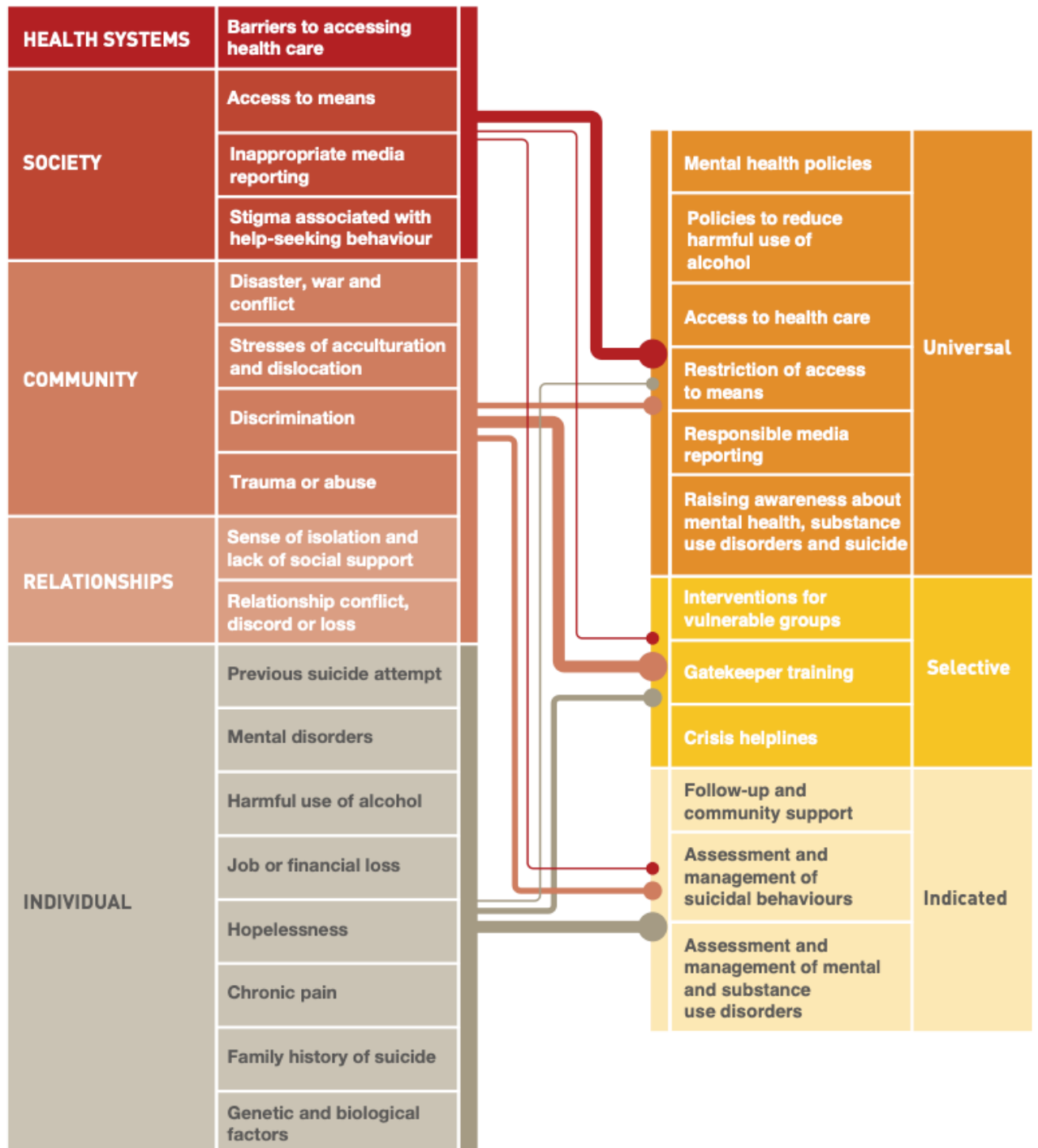
A public health approach typically categorises prevention strategies into three levels: universal, selective, and indicated (which is also called “Health care platform interventions”). Some examples

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for each of these in the field of suicide prevention are (respectively): stigma-reducing campaigns, suicide hotlines, and psychological treatment for individuals who have attempted suicide (Vijayakumar et al., 2016). The recognised risk factors for suicide partially align with these levels, as shown in Figure 4.

Figure 4

“Key Risk Factors for Suicide Aligned With Relevant Interventions”



From “Preventing Suicide A Global Imperative,” by World Health Organization, 2014, p. 31

https://apps.who.int/iris/bitstream/handle/10665/131056/9789241564779_eng.pdf;jsessionid=988764E63442AB4AAB01BCC3E1EE2E4C?sequence=1

Evidence for Indicated Approaches

Self-Harm. A recent Cochrane systematic review of psychological interventions found that cognitive behavioural therapy (CBT), mentalisation-based therapy, and emotion-regulation psychotherapy may reduce SH in adults (Witt, Hetrick, et al., 2021b). Standard dialectical behaviour therapy might be beneficial; however, the evidence for these had limited generalisability (Witt, Hetrick, et al., 2021b). Meanwhile, the evidence about other common psychological approaches for SH in adults, like remote contact interventions or provision of information and support, is inconclusive (Witt, Hetrick, et al., 2021b). A recently updated review of pharmacological treatments for SH in adults was unable to make a general recommendation; in fact, the evidence for each class of drug is “uncertain” (Witt, Hetrick, et al., 2021a). The pharmacological treatment of depression will be relevant to the experience of suicidal behaviour for some people. The effects of new generation antidepressant medications on depression in adolescents and children are also uncertain but, more specifically, they may have increased risk for suicide-related thoughts and behaviours (Hetrick et al., 2021).

Suicidal Ideation. Systematic reviews about interventions for reducing suicidal behaviour sometimes include SI as an outcome of interest, but relatively few have made SI the primary focus. Beneficial effects on SI reported in such systematic reviews (with a broader or different focus) were found with cognitive behavioural therapy for adults who have had recent treatment for SH (Witt, Hetrick, et al., 2021b). Meanwhile, in people with alcohol use disorders, targeted psychological or psychotherapeutic intervention shows “*a non-significant trend to a decrease in suicidal ideation*”(Witt, Chitty, et al., 2021, p. 11). In older people, the effects of pharmacological interventions (antidepressants) on SI are uncertain, since one review in 2009 found an effect but a later one, in 2015, did not find an effect (Laflamme et al., 2022). Ketamine for adults with acute SI probably has a short-lasting benefit (Witt et al., 2020).

Limitations of the Current Literature

The systematic appraisals of evidence gathered from randomised controlled trials (RCTs) of standard (i.e., psychotherapeutic and pharmacological) interventions for SH and SI show that there are some benefits, even if modest, which may be confined to particular sub-groups. Unfortunately, however, the common problems of low quality in trial conduct or reporting,

relatively small participant numbers and the use of multiple different measurement tools hinder the confidence in many of these results.

Another common problem is lack of medium- to long-term follow-up. SI and SH are phenomena that often recur (O'Connor & Pirkis, 2016); therefore, their reduction over an intervention period of weeks or months does not guarantee a benefit afterwards. Furthermore, the psychiatric disorders that may be associated with SI and SH may require long term management. Regardless of the experience of psychiatric disorder, the risk of SI and SH may ebb and flow, even after a significant short- to medium-term improvement.

Of course, RCTs do not report outcomes for individuals who declined consent or were ineligible. A common complaint by review authors is that some trials had excluded individuals who may be most in need of treatment; for example, a trial might exclude people with suicidal thoughts or plans. Only sometimes is the reason for this exclusion discussed; in such cases, there is often reference to ethical concerns.

The practicalities of conducting clinical research trials mean that participation may be limited to urban areas, so some individuals in need of treatment never receive an invitation to participate in an RCT (Fortune & Hetrick, 2021). Clinical research is also financially constrained, which likely explains why review after review highlights the lack of studies in low- to middle-income countries, despite the fact that research reminds us that people in these countries bear the greatest of the burden of suicide worldwide. Another barrier to recruiting participants is the stigma that often accompanies the experience of SH or SI. In fact, internet-based interventions have been developed with this at least partly in mind (Büscher et al., 2020), offering one way around the effects of stigma .

Health System Limitations and Individual Barriers

There is limited access to effective treatments for people with common mental disorders, which would include a proportion experiencing SI and SH. A multi-national study of self-report surveys found large unmet need for mental health treatment (Wang et al., 2007). Defining severe mental disorder by factors that include suicide attempt in conjunction with any mental disorder, the study showed that in high-income countries, only up to 60.9% (in Belgium) of respondents with severe mental disorder had received any mental health service treatment in the previous 12 months. The corresponding rate in Aotearoa New Zealand was 56.6%, and the rates in less-developed nations were especially low. Furthermore, the authors

reported that for people with mental health conditions (of any severity) who received treatment, only 70 to 95% received follow-up care; that is, more than one visit to a service provider.

On the face of it, studies like this suggest resource allocation might largely explain the unmet need for treatment of SI and SH; however, practical barriers are only one part of the picture.

Amongst young people, attitudinal barriers are significant, evidenced by the finding that most young people with SI or SH do not seek help (Michelmore & Hindley, 2012). Aguirre Velasco et al. (2020) systematically investigated help-seeking behaviours amongst adolescents for common mental health problems (and this would include a proportion with SI or SH). They found stigma was the most prominent barrier, followed by “*Negative attitudes and beliefs about mental health services and professionals*” (Aguirre Velasco et al., 2020, p. 16). In Michelmore & Hindley’s (2012) review, focusing specifically on help-seeking for SI and SH, they identified similar themes, as well as fear of being admitted to hospital.

The limited effectiveness of standard treatments, and the frequent practical and attitudinal barriers to receiving treatment, together speak to the need for expanded and improved interventions. Physical activity (PA) interventions might be one additional option.

Definitions of Physical Activity, Inactivity and Physical Activity Interventions

Exercise, physical fitness and PA were defined and distinguished from each other in a seminal report by Caspersen et al. (1985). Working from the foundation of total daily energy expenditure, and explaining that exercise is a subset of PA, they made the memorable statement:

“Physical activity is defined as any bodily movement produced by skeletal muscles that results in energy expenditure” (Caspersen et al., 1985, p. 126).

Their overriding purpose was to offer “*an interpretational framework for comparing studies that relate physical activity, exercise, and physical fitness to health*” (p. 126) and, interestingly, they had both physical and mental health in mind. They discussed relative levels of activity (and of fitness) but did not, in that report, set thresholds for optimum health.

Meanwhile, evidence for PA thresholds for health, particularly cardiovascular health, have been accumulating since the early 1970s (Brannon et al., 2014). The World Health Organization (WHO) gathered the evidence for their first global PA guideline (World Health

Organization, 2010) and has recently updated these recommendations, also covering sedentary behaviour (World Health Organization, 2020). Adults (including older adults) are recommended to do “*at least 150–300 minutes of moderate-intensity aerobic physical activity; or at least 75–150 minutes of vigorous-intensity aerobic physical activity; or an equivalent combination of moderate- and vigorous-intensity activity throughout the week*” and “*muscle-strengthening activities at moderate or greater intensity that involve all major muscle groups on 2 or more days a week*” (p. 32). The thresholds for children and adolescents (5 – 17 years of age) are higher: they should do “*at least an average of 60 minutes per day of moderate- to vigorous-intensity, mostly aerobic, physical activity, across the week*” and should incorporate “*vigorous-intensity aerobic activities, as well as those that strengthen muscle and bone ... at least 3 days a week*” (p. 25). The guideline defines physical inactivity as “*An insufficient physical activity level to meet present physical activity recommendations*” (p. vii).

PA interventions broadly aim to reduce physical inactivity. As in a public health approach, such interventions may be universal, selected, or indicated; as in, a national awareness campaign, a PA promotion programme for office-based workers, or PA counselling in a primary care setting, respectively.

Association of Physical Inactivity with Suicidal Ideation and Risk Factors Associated with Suicidal Behaviours

A recent review of relationships between PA and SI (Vancampfort et al., 2018) suggested that where a person is habitually physically active – the authors adopted a threshold of “*150 min per week of at least moderate or 75 min per week of vigorous intensity physical activity*” (p. 440) – this was associated with a significantly lower risk for SI (OR = 0.91, 95% CI 0.51, 0.99). Similarly, a recent systematic review found reduced risk for SI with team sport participation (Zuckerman et al., 2021). The trend is similar for several mental disorders, which as stated above concur risk for SI and SH: there are lower odds of concurrent depression in physically active people (Gianfredi et al., 2020; Korczak et al., 2017) and a protective effect of PA against onset of depression in all age groups (Dishman et al., 2021; Gianfredi et al., 2020) and against onset of subclinical depressive symptoms (Dishman et al., 2021; Rebar et al., 2015). Regular PA is associated with less anxiety symptoms in older adults (Mochcovitch et al., 2016) and it protects against onset of anxiety disorders and

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clinically significant anxiety symptoms in youth and in adults (McDowell et al., 2019; Schuch et al., 2019).

Physical Activity Interventions for Psychological Symptoms and Mental Disorders

PA interventions are generally beneficial and safe:

There is a plethora of [Cochrane systematic reviews] evaluating the effectiveness of physical activity/exercise. The evidence suggests that physical activity/exercise reduces mortality rates and improves [quality of life] with minimal or no safety concerns. (Posadzki et al., 2020, p. 1)

Putting aside, for a moment, the potential for PA interventions to improve outcomes in people with diagnosed psychological disorders, PA interventions are of proven benefit for psychological symptoms in a range of physical conditions. Here is a brief sampling of findings from systematic reviews looking into the effects of PA interventions on physical conditions, with relevance to risk factors for suicide-related thoughts and behaviours.

In Multiple Sclerosis, exercise therapy improves mood, and “*no evidence of deleterious effects of exercise therapy was described in included studies*” (Rietberg et al., 2005, p. 1). In women treated for breast cancer, PA interventions improved “*emotional function (SMD 0.21, 95% CI 0.10, 0.32, 26 studies, 2102 women, moderate-quality evidence)*” and, overall, there was “*no evidence of negative/ harmful effects*” (Lahart et al., 2018, pp. 2, 41). In adults living with HIV/AIDS, aerobic exercise intervention (compared with non-exercise) clinically improved depression-dejection, measured by the Profile of Mood States subscale (MD -7.68 (95% CI -13.47, -1.90); also, it appears safe (O'Brien et al., 2010). In people with end-stage kidney disease, exercise training (compared with usual care) probably improves depressive symptoms as measured by the Beck Depression Index (MD -7.61, 95% CI -9.59, -5.63), with no reported adverse events (Natale et al., 2019).

That said, in chronically painful conditions the possible benefits from PA interventions on psychological function have not been consistently proven. For example, an overview of Cochrane Reviews (Geneen et al., 2017) reported that one previous review concluded a benefit to depression, another had found a “variable effect” and another had found no effect. Nevertheless, the authors found consistent evidence that “*importantly, exercise [for chronic pain conditions] caused no actual harm, with most adverse events being increased soreness*

or muscle pain, which reportedly subsided after several weeks of the intervention” (Geneen et al., 2017, p. 16).

Turning, now, to the effects of PA interventions on mental illnesses, there are several reviews with positive findings. The disorders in which the effects of PA interventions have been extensively measured are depression-related, then anxiety-related, while the evidence base for psychotic disorders is relatively small.

PA interventions for Depression. Several systematic reviews completed over the past decade have reported promising findings regarding depression. There are beneficial effects of PA interventions on depression in children, adolescents, young adults, adults and older adults (Bailey et al., 2018; Brown et al., 2013; Lee et al., 2021; Miller et al., 2020; Nyström et al., 2015; Oberste et al., 2020; Wegner et al., 2020).

PA interventions for Anxiety. One systematic review on PA interventions and anxiety (and not restricted to any clinical population) found improved state anxiety in children and young people (Carter, 2021). A review considering adults with clinically raised anxiety, raised anxiety sensitivity, or a formal DSM diagnosis of a specific anxiety disorder found moderate effect sizes for exercise (compared with waiting list control group) and for high intensity exercise compared with low intensity (Aylett et al., 2018). Exercise interventions have also been found to reduce anxiety among adults with arthritis and other rheumatic diseases (Kelley et al., 2018).

PA interventions for Schizophrenia. In a systematic review of PA interventions for a range of mental illnesses, the authors were able to use outcome data from eight trials in people with schizophrenia or schizoaffective disorder. They reported an effect size on schizophrenia symptoms of 1.0 (95% CI, 0.37, 1.64) (Rosenbaum et al., 2014). Another systematic review focused on patients with schizophrenia: there were eight RCTs but the data from four were excluded after sensitivity analysis. Meta-analysis of the remaining four RCTs (only one of which was in common with the earlier review) “*showed a strong effect of [moderate-to-vigorous] exercise on total psychiatric symptoms (SMD = -0.72, 95% CI -1.14 to -0.29)*” (Firth et al., 2015, p. 1351).

Altogether, PA interventions seem likely to improve psychological symptoms, not to mention physical health, in a range of conditions that are associated with elevated risk for suicidal behaviours.

In summary, there is extensive evidence for the potential for PA interventions to reduce SI. This provides reason for optimism; nevertheless, a review by Vancampfort et al. (2018), did not find sufficient intervention studies for a meta-analysis, and two subsequent systematic reviews on PA interventions and SI, one regarding older adults (Laflamme et al., 2022) and the other regarding team sport participants (Zuckerman et al., 2021), also concluded there were insufficient studies for meta-analysis.

To my knowledge, the relationships between PA and SH have not been systematically reviewed. Alternatively, a review of PA interventions might discuss SH, suicide attempt or suicide in the context of reported harms or adverse events but, unfortunately, this type of evidence is scant. For example, one review (of PA interventions for chronic pain in adults) found that only 25% of studies actively reported adverse events (Geneen et al., 2017).

Altogether, then, the effects of PA interventions on any suicide-related phenomenon, whether measured as an intended or unintended outcome, are unclear to-date.

Description of Physical Activity Interventions

PA interventions are very diverse in their characteristics. The amount of direct therapist-client interaction ranges from one or two sessions, as sometimes occurs with motivational interviewing, up to many, as in progressive strength training. Then again, some types have none, as in the case of mobile phone apps. There is variety in the applied skills of therapists; for example, motivational interviewing can be learned with some additional training to a primary health qualification but tailored exercise prescription develops during years of relevant undergraduate training. The number of people involved varies from one client to a group and from one therapist to several. The settings vary: indoors or outdoors, clinical or non-clinical, home-based or facility-based. The choice of setting might be guided by what practically suits the participants or by a theorised mechanism of action, such as the benefits of sunlight. The modes of activity vary; there might be a particular cultural salience, as in traditional dance, or an emphasis on fun, as in active games and sports. There might be flexibility with participant choice or there might be structure and prescription, as in yoga. Nevertheless, walking programmes are common, as are aerobic exercises generally. Some PA interventions have physiological goals, using monitoring devices or adjustable exercise equipment, and others might have a goal set around perceived exertion and minimum duration; either measurement method can be valid. Most programmes aim for relatively large chunks of devoted time, like three 45-minute sessions per week; however, some allow for an

accumulation of small chunks of time. Some PA interventions aim to ensure participant engagement through tailoring the design to the participants (Ma et al., 2021). Finally, the programme duration may be weeks or months, with or without a follow-up assessment, and this choice would be influenced by a range of factors that include expectations for adaptive physical changes and funding.

Common Components and Objectives of Physical Activity Interventions.

The change from physical inactivity to activity happens gradually. Part of the reason is that the physical body, which has adapted to chronically low energy expenditure and habitually low levels of power output, must physically adapt. A sudden change will likely cause intolerable levels of perceived exertion and delayed-onset muscle discomfort or pain. Accordingly, PA guidelines usually recommend that people who have been physically inactive commence moderately. The recommendations for aerobic or resistance exercise intensities are based in a well-developed body of evidence from physiological studies. It seems remarkable that a person's consistent efforts lead to significant improvements in aerobic capacity or muscle strength within weeks after entrenched sedentary behaviours. Physical activity intervention trials typically align with the recommendation for starting moderately and some programmes include progression of intensity or duration, often planning to achieve the minimum recommendation – for aerobic activity, at least – well before the end date.

Across all the variety, most PA interventions assign “homework” to the participants, along with the recording and monitoring of its completion. Perhaps this is a feature imposed by financial limitations, since direct supervision on five days of the week (the minimum recommended frequency) would involve significantly greater resources than three days per week, or less. On the other hand, perhaps it strengthens the participant's confidence in being able to maintain a physically-active lifestyle and in developing a sense of identity as an active person.

By nature, PA interventions are active and contingent upon the participants' persistently effortful involvement. Sometimes this is a barrier to uptake; on the other hand, persistent effort might lead to success, which contributes to mastery and improved self-esteem (Smith & Merwin, 2021).

Many People Are Inactive

Many people do not achieve the PA recommendation that applies to them. Globally in 2016, insufficient PA (measured by questionnaire) was 27.5% (95% uncertainty interval 25.0–32.2) for adults (Guthold et al., 2018) and it was 81.0% (95% uncertainty interval 77.8–87.7) for adolescents (Guthold et al., 2020). Guthold et al. (2018) adopted a PA threshold for adults that was similar to that adopted by Vancampfort et al. (2018); while their threshold for adolescents was defined as “*not reaching the current WHO recommendation (doing less than 60 min of daily physical activity of moderate-to-vigorous intensity) or as being active for less than 60 min on 5 days per week*” (Guthold et al., 2020, p. 24). In Aotearoa New Zealand, they found the rate for adults appears significantly worse, at 42.4% (95% CI 35.3, 49.8), although the rate for adolescents appears similar to their global rate (88.7% (95% uncertainty interval 87.1–90.2)) (Guthold et al., 2018; Guthold et al., 2020).

Theory of Behaviour Change

PA interventions aim by various means to help people habitually replace some of the waking hours they usually spend in activities of lower energy expenditure with activities of higher energy expenditure. In theory, they diminish barriers and capitalise on enablers, with the aim of effecting behavioural change.

The body of research dubbed “the science of behaviour change” includes many theories, developing since the 1950s, that consider the “*individual, social, contextual, and environmental conditions that may magnify or diminish intervention effects*” (Hagger et al., 2020, Section 1.2.2). The various theories are not necessarily in competition with each other, and they may bring complimentary understanding to a particular behavioural challenge.

Meanwhile, empirical research tends to test the results, rather than the processes, of behaviour change interventions. It is thought that the combination of theoretical and empirical research brings understanding of how behaviour change interventions “work”; in other words, their mechanisms of action on the behaviours, per se, rather than on the health benefits (outcomes) of the behaviour change (Hagger et al., 2020, Chapter 1). Published reports of lifestyle-change RCTs typically lay out their reasoning along the lines of why a specific health benefit would be expected by the achievement of a habit change in their population of interest. Rarely; however, do they use theories of behaviour change to justify their intervention design choices; that is, an explicit discussion is usually absent regarding how the intervention’s elements work to create or maintain behavioural change (Hagger et

al., 2020, Section 1.2). Without such discussion, the implication seems to be that the PA intervention will bring about authentic change by means of the opportunity itself and the direct influences of programme staff. These design elements are necessary but they would be insufficient to address some important considerations for behaviour change, especially the pervasive risk of relapse.

How Might PA Interventions Work on Self-Harm and Suicidal Ideation?

Biological and Physical Mechanisms of Action

Exercise training induces multiple and diverse structural, functional, and biochemical adaptations in healthy individuals. As examples, resistance training increases bone density, muscle strength, and shape, while aerobic training increases peak oxygen consumption and glycaemic control, and it decreases fat mass. Useful training-induced adaptations have also been shown in people with physical illnesses including hypertension and asthma (World Health Organization, 2020). These types of adaptations have also been confirmed in some of the populations known to be at increased risk of suicide, including diabetes (Thomas et al., 2006), schizophrenia (Firth et al., 2015) and HIV (Fillipas et al., 2010).

Researchers began reporting the psychological effects of exercise training and PA interventions around 60 years ago (Cureton, 1963; Epstein, 1986; Folkins, 1976; Folkins et al., 1972), alongside their mechanistic theories. One early proposal was that anxiety improved with training-induced electrophysiological changes: *“feedback from musculature, for example, heart and limbs ... when received at a cognitive level ... may be more reassuring when a person becomes more physically fit”* (Folkins et al., 1972, p. 508). The theories have greatly expanded since that time. The full range of neuroimaging techniques currently available were not available then; consequently, researchers have since identified functional and structural adaptations in the brain and have theorised how these might relate to psychological effects. A systematic review commented that the *“large antidepressant effects of exercise on depression”* may be due to an *“increase on neurotrophic markers”* (Schuch et al., 2016, p. 47). Meanwhile, changes in neurotransmitters, especially dopamine, are reliably related with PA, and this includes evidence from PA intervention trials (Marques et al., 2021). A review of these effects in children and adolescents identified two trials that had participants with mental health conditions (depression, all female) in which biochemical changes were measured along with improved psychological outcomes (Heinze et al., 2021).

Currently, then, the proposed biological and physical mechanisms of action centre around the effects on neurotransmitters and neuroplasticity (Smith & Merwin, 2021). This (the physical) domain is likely to remain an important part of the theory of psychological effects of PA interventions, which might be important in populations at risk of suicidal behaviour; nevertheless, other domains are also important to consider.

Psychological, Social and Behavioural Mechanisms of Action

PA interventions are complex, having multiple components beyond skeletal muscle contraction, such as social connection, enjoyment, and even the influence of the environment in which the activity takes place. In the last decade especially, research-based theories have been developed about psychological, social and behavioural mechanisms of action in PA interventions on mental health outcomes (Smith & Merwin, 2021). Although such outcomes are not specific to people with suicidal behaviours, there are interesting insights.

A systematic review on Major Depression commented, “*Among the explanations offered are enhanced self-esteem, increased self-efficacy, improved coping skills and stronger social support.*” (Nyström et al., 2015, p. 347). In anxiety disorders, as well, increased self-efficacy may be at work, as could an increase in symptom tolerance with exposure to physical training, a change in social behaviour away from a tendency to socially withdraw, or distraction from times spent in anxious rumination (Aylett et al., 2018). From a transdiagnostic perspective, evidence suggests that exercise interventions may improve general self-esteem, anxiety sensitivity, and stress reactivity (Jacquart et al., 2019) and several studies indicate that exercise enhances self-esteem in adolescents (Das et al., 2016). Evidence also suggests that self-regulation may improve in synergy with training-induced neuroplastic changes in the brain (Smith & Merwin, 2021).

There seems to be accepted that relational factors in PA interventions are important (Aycock et al., 2018); hence, many RCTs, by design, provide equivalent amounts of person-to-person interaction in their control condition. This is termed “attention control” or “attention placebo control” (Aycock et al., 2018), or is otherwise termed “time matching” (Aylett et al., 2018). It may be possible that group-based PA interventions work in part through the social connections between participants. This was suggested, for example, in a narrative review of sports interventions for functional recovery in people with first-episode psychosis (Brooke et al., 2019).

There are theories around the mechanisms by which PA interventions might influence SI, similar with those for mental health. Turning again to the review by Vancampfort et al. (2018), the authors discussed possibilities for self-esteem, social support, team participation, cognitive function, sleep, and levels of brain serotonin. That review's included RCT studies (Abdollahi et al., 2017; Sturm et al., 2012) had discussed further possibilities: enjoyment (which relates to mood), sense of control (self-efficacy), complex changes of cortisol with neurotransmitters (serotonin, dopamine and norepinephrine), reduced hopelessness, and the influence of the natural environment.

In summary, there is indirectly supportive evidence for a variety of mechanisms at work in PA interventions for suicide-related outcomes.

Possible Advantages of Physical Activity Interventions

The evidence from PA interventions targeting SI (especially the two RCTs identified by Vancampfort et al (2018)), as well as for conditions that have increased risk for SI, suggests this type of approach is feasible. Furthermore, the wide variety of targets for PA intervention (Posadzki et al., 2020) suggests this approach is transdisciplinary, thereby potentially removing a barrier for individuals who endorse SH or SI but who do not have a diagnosed illness or disorder. There have been several RCTs with more than 100 participants, including one with more than 200 (Petty et al., 2009), suggesting this approach is scalable. Finally, professionals found in disciplines that do not usually provide direct health care (for example, exercise physiologists) are appropriately qualified to lead PA intervention trials, suggesting an avenue for avoiding attitudinal barriers, including stigma, and increasing workforce availability.

CHAPTER 3: METHODS

Aims

The primary aim of this study is to examine, using systematic review methodology, if physical activity interventions decrease self-harm, suicidal ideation or any other suicide-related phenomenon.

The methods of this systematic review are based on the published methods of the Cochrane Collaboration (<https://www.cochrane.org/>) (Higgins et al., 2020).

Eligibility criteria for selecting studies

Study type

Studies were included if they tested the effect of a PA intervention using a randomised controlled design, whether parallel or crossover.

Type of participants

Studies were included regardless of the population; participants in the randomised controlled trials could be any age, any ethnicity, any gender, and have any condition.

Type of Intervention

Trials were included if they tested a PA intervention, adopting the following definition from a previous review:

“The terms physical activity and exercise were defined according to the American College of Sports Medicine (ACSM) definitions; physical activity is “any body movement that is produced by the contraction of skeletal muscles that increases energy expenditure,” whereas exercise is “a subset of physical activity that is planned, structured and deliberate.” We included all forms of physical activity that met these definitions. Aerobic, resistance-based, or mixed-type interventions were eligible, as well as interventions designed to increase incidental physical activity. Yoga and tai chi programs were included if the intervention was movement based. Exercise counseling [sic] and lifestyle change programs in which increasing physical activity participation was a significant aim of the intervention were included.” (Rosenbaum et al., 2014, p. 966)

Where a study report was unclear regarding intention to increase PA – for example, by not reporting baseline levels of PA – a judgment was made about whether the intervention/s aimed to increase energy expenditure for those participants. On this basis, for example:

- a study could be considered for inclusion if most of the participants were likely to be physically inactive at baseline
- a study would be excluded if none of the interventions were likely to increase habitual PA in the represented population.

Type of Comparison group

Studies were included where they had any type of control group, including no treatment, waitlist, active control (e.g. another type/amount of PA, psychological therapy or medication), usual care, or an attention placebo type condition.

A study was included if it compared a PA intervention with another active intervention, regardless of whether the study design treated PA as the intervention or the control condition.

Categorisation of Physical Activity

PA guidelines, including those recently updated by the recent World Health Organization (Bull et al., 2020), emphasise two types of activity: aerobic and muscle strengthening. It may sometimes be difficult to categorise an activity on this dichotomy; for example, New Zealand’s current PA guidelines for Adults explain that “*swimming, walking up hills and cycling up hills or into a head wind*” are examples of “*aerobic activities with an element of resistance*” (Ministry of Health – Manatū Hauora, 2020, p. 112). This review adopted the following decision-making process:

1. accept the categorisation (aerobic/strengthening, or equivalent terms) as stated by the study authors and if both types are reported, categorise as “mixed”
2. where study authors did not state the categorisation, identify the described activity for the majority time of the intervention, and then map that term onto its generally accepted categorisation
3. if unclear or evenly balanced, choose the “mixed” category.

Further, energy expenditure or activity intensity is typically categorised into light, moderate or vigorous. These same international guidelines recommend that people aim for a moderate or (for some) vigorous intensity and they recommend weekly total durations for aerobic activities (typically, 150 minutes). Therefore, this review adopted the following decision-making process:

- A PA intervention could be categorised as an active control if it was of a light, or unknown, intensity and was compared with a PA intervention of likely moderate or vigorous intensity, or if it was of the same intensity but significantly lesser duration.
- an intervention would not be categorized as PA (even though it involved skeletal muscle movement) if it was not judged likely to meaningfully increase PA in the represented population.

Primary Outcome

Studies were included if they measured one or more of the following (or closely related terms) at baseline and post-intervention: suicide attempt, self-harm, self-injury, self-poisoning, suicidal ideation, death wishes, suicide plan or preparatory suicidal behaviour (De Leo et al., 2021; McGrath et al., 2021). Any measurement tool, including a single item taken from a longer measure, was eligible.

Report type

Finally, only studies that had a full report, published in peer reviewed journal, were included. This was a requirement of the quality appraisal plan, outlined shortly. If a study was otherwise eligible, but a full report was yet to published in a peer review journal, it was treated as “ongoing” (rather than as “excluded”).

Search Strategy and Key Words

The main health research databases were considered a sufficient source for studies. There was no obvious rationale for imposing a date limit, nor age-group restriction. A language restriction was not applied; if the search were to yield reports written in a language other than English, I intended to ask for assistance from within the University of Auckland community for translation.

There were two broad subjects to articulate for the database searches: (1) physical activity (PA) and (2) suicide-related thoughts/ideation (SI), together with self-harm (SH) of any type. For much of the PA vocabulary, I drew on my physiotherapy background and general knowledge. For the vocabulary pertaining to suicide-related thoughts and behaviours, including SH, I mainly drew on the orientation my Supervisors provided, including the recommended text *The International Handbook of Suicide Prevention* (O'Connor & Pirkis, 2016). The search strategy thus started with many terms, especially considering the diverse terminology related to the primary outcomes and the ever-expanding types of PA interventions.

The Research Services Adviser, a health librarian, made additional vocabulary suggestions, identified the potentially relevant databases, and provided guidance on their semantics. I confirmed the final database choices and search terms (see Appendix A) in collaboration with my Supervisors.

Through experimental database searches, it became clear that their search-limiting tools for RCTs were not sufficiently reliable. The Technical Supplement to Chapter 4 in the Cochrane Handbook of Systematic Reviews of Interventions (Higgins et al., 2020) was very informative on this point, articulating “sensitivity strings” (for use with Medline, Embase and CINAHL) that remove search results that are not RCTs, as far as possible. Helpfully, a sensitivity string for PsycInfo had been published elsewhere (Ramos-Sanchez et al., 2021). With minor modifications, these sensitivity strings were applied to each of the specified database searches, except in the case of Cochrane CENTRAL, where it is unnecessary. The final search strategies for each database, together with the number of results for each, are presented in Appendix A.

The same database searches were re-run, but omitting the sensitivity strings, and limited to “Systematic reviews” (or “Systematic reviews” AND the keyword “interventions”) or “Reviews” (depending on the database). These results were screened for relevancy, then the included studies of the reviews were hand-searched for any additional relevant studies.

Selection of Studies

I performed the database searches, de-duplication (using EndNote X9 and then removing further obvious duplicates by hand), screening each record by title or title and abstract and hand-checking references cited in previous reviews. Associate Professor Sarah Hetrick and I independently examined the resulting full-text records for inclusion. In cases where there was any uncertainty, we reached consensus on whether to include or exclude, with reasons, after discussion with Dr Sarah Fortune.

Quality Appraisal Plan

Plainly, PA interventions are not exclusive to the practice of physiotherapy; however, they certainly fall within it. Therefore, there were two options for quality appraisal of the included studies: the revised Cochrane Risk of Bias tool (formally “CROB”, now “RoB 2” (Higgins et al., 2020)) or the Physiotherapy Evidence Database (PEDro) scale (The PEDro Partnership, 1999). Both methods have been used extensively: the Cochrane database now contains over 7,500 Cochrane Systematic Reviews (The Cochrane Collaboration) and the PEDro database holds appraisals of more than 40,000 trials (The PEDro Partnership, 2022). A recent meta-epidemiological study comparing these

two methods recalls that “*Blinding participants and personnel in trials of complex physical therapy interventions is difficult and, usually, not possible*”(Moseley et al., 2019, p. 3). With reference to the construct of blinding, the authors argued in favour of the PEDro scale. Overall, however, the authors recommended that “*neither can be considered the gold standard for risk of bias evaluation*”, and, in either case, they “*caution against the use of thresholds for “acceptable” risk of bias*” (Moseley et al., 2019, pp. 13, 14).

The PEDro scale is a checklist of 11 items, ten of which are scored, that are “*based on “expert consensus” not, for the most part, on empirical data*” (The PEDro Partnership, 1999). It covers constructs of internal validity, statistical interpretability and applicability. Each criterion is defined and is accompanied by an administration note. Significantly for this review, “*it is not possible to satisfy all scale items in some areas of physiotherapy practice*” (The PEDro Partnership, 1999, para 3), of which PA interventions would be included. PEDro raters must be certified through successful completion of the PEDro scale training programme.

Data Extraction Plan

The data were extracted from the published trial reports, from the relevant webpages in the Physiotherapy Evidence Database (PEDro) (for the quality appraisal), and there were additional data received by email for five of the included studies (Daley et al., 2015; Haussleiter et al., 2020; Nasstasia et al., 2019; Sturm et al., 2012; Taylor et al., 2020). Some other authors did not reply to my requests for additional data.

I created Microsoft Excel spreadsheets for collecting and organising the data and for performing simple calculations.

Study Characteristics

I extracted the following characterisation data from the included studies: country, setting (community, clinic, etc), design (parallel/crossover), number of intervention arms, recruitment period, participant inclusion and exclusion criteria, any other defining characteristics of study population (e.g. physical illness, stressors, etc.), number, age, and gender (% female) of participants, SH/SI or other suicide-related outcome measurement method/s, intervention and control conditions, duration, and (if applicable) follow-up time point.

I extracted further characterisation data about the PA interventions: mode of supervision (direct/indirect), setting (group/individual; indoor/outdoor), exercise type

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(aerobic/strengthening/mixed), session duration, intensity, and frequency, and qualifications of therapists.

Outcome Measures

For all outcome measures, I extracted the group numbers at randomisation, post-intervention and at follow-up (if applicable). In crossover trials, outcome data from the first phase prior to cross-over were extracted for the meta-analysis.

For continuous data (scores obtained from a scale), I extracted the mean and standard deviation values for each group, where available. For dichotomous data, I extracted the number of participants with any degree of a relevant phenomenon, such as SI. Where numbers of participants were reported in sub-groups of differing quality or severity, these were summed and totals were extracted for meta-analysis.

Where there were not data presented that could be used for meta-analysis, I contacted authors to request those data. Of note, where a study reported mean and standard deviation values for a single item (from a questionnaire) measured on a Likert scale, I requested further detail from the study author. The intention was to dichotomise the participant responses into “zero” versus “greater than zero”, in keeping with the working definitions of SH and SI for this review.

Associate Professor Sarah Hetrick peer reviewed the extracted outcome data for accuracy.

Quality Appraisal

I extracted the total PEDro scale score and the Yes/No result on each item from the “Detailed search results” webpage for each study. In every case, the PEDro score had already been confirmed by the PEDro Partnership (pedro.com.au).

Data Synthesis

For the dichotomous outcome for which meta-analysis was possible (presence or absence of SI), I measured treatment effects using risk ratios (RR) and calculating the effect size by the Mantel-Haenszel method. For the continuous outcome of SI, the standardised mean difference (SMD) was used (because SI was measured on a range of different scales), and the effect size was calculated by the inverse-variance method, using a random effects model with 95% confidence intervals for the post-intervention outcomes.

If a study reported more than one eligible outcome measure, the data from the measure that was most commonly used across all included studies was used.

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If the mean and standard deviation values or number of participants with the outcome of interest for each group could not be ascertained, I used a narrative summary.

I assessed heterogeneity of intervention effects by visually inspecting the overlap of confidence intervals on the forest plots, tested for heterogeneity using the Chi² test, and quantified heterogeneity using the I² statistic. Categories suggested in the Cochrane Handbook for Systematic Reviews of Interventions help to interpret the degree of heterogeneity: “0% to 40% might not be important; 30% to 60% may represent moderate heterogeneity; 50% to 90% may represent substantial heterogeneity; 75% to 100% considerable heterogeneity” (Higgins et al., 2020, Section 10.10.2).

For the overall assessment, I integrated the findings from the quality appraisal with the measures of effect by narrative summary.

CHAPTER 4: RESULTS

I found 1,887 records in the database searches, which were initially conducted on 22 October, 2021. The breakdown of records by database was: CINAHL (n = 178); Cochrane CENTRAL (n = 370); Embase (n = 854); Embase Classic (n = 3); Medline (n = 346) and PsycInfo (n = 136). A final search was concluded on 6 June, 2022, at which time no additional studies were found. After duplicate removal there were 1,551 records, six of which were records of study protocols and for which I was able to (separately) find the corresponding study reports. I excluded 1,511 records based on their titles or titles and abstracts. From this search, there were 40 records of completed studies, and a further 23 records were retained, which were treated as ongoing studies (see Appendix C).

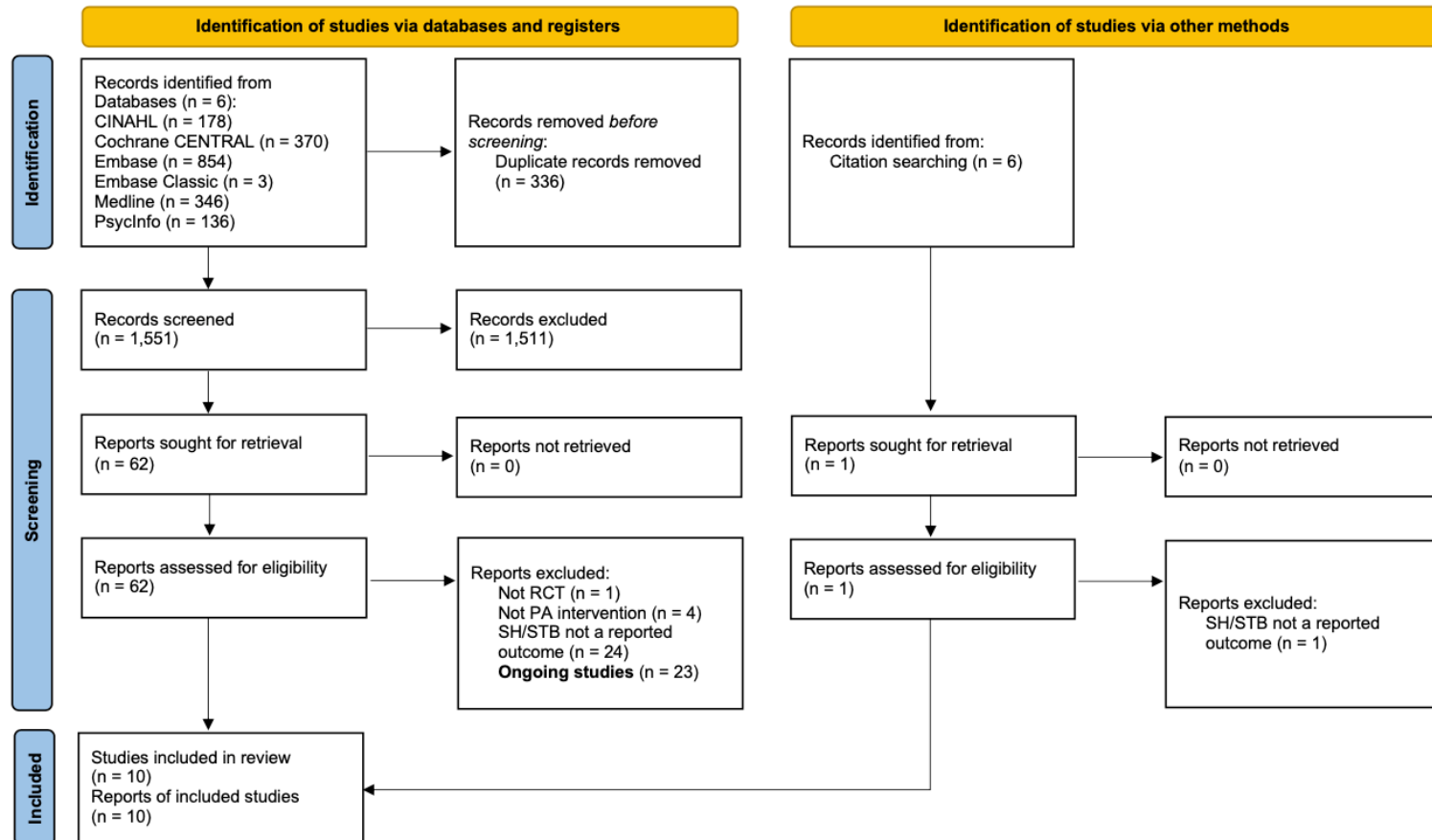
In parallel, the database searches for relevant systematic reviews yielded six records (Kawashima et al., 2019; Krogh et al., 2017; Natale et al., 2019; Ogg-Groenendaal et al., 2014; Vancampfort et al., 2018; Wegner et al., 2020). I hand-checked the references of their included studies, which yielded only one additional relevant study (Epstein, 1986) for full-text examination.

Following this, Associate Professor Sarah Hetrick and I examined the full texts for 41 records. After final discussion with Dr Sarah Fortune, we reached consensus on the decisions to include or exclude. Interestingly, the database searches had not found the complete published report for one eligible study (Nasstasia et al., 2019) but, instead, had located the corresponding conference abstract. (I readily obtained the published report.)

The flow diagram shown in Figure 5 is according to Page et al. (2021).

Figure 5

PRISMA Flow Diagram of Studies Retrieved and Screened



From: Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ* 2021;372:n71. doi: 10.1136/bmj.n71.

Description of Included Studies

The included studies' characteristics are presented in Table 1.

Ten studies were included: Abdollahi et al. (2017); Daley et al. (2015); Haussleiter et al. (2020); Nasstasia et al. (2019); Noh et al. (2020); Nyer et al. (2018); Sturm et al. (2012); Sun et al. (2017); Taylor et al. (2020) and Williams et al. (2019).

Design

Eight out of the 10 trials were parallel-group randomised trials and the other two had a crossover design.

The trials included in this review compared: (1) physical activity with "usual care" (TAU) or no treatment (NT) or waiting list (WL) condition (Daley et al., 2015; Nasstasia et al., 2019; Noh et al., 2020; Sturm et al., 2012; Sun et al., 2017), (2) physical activity with an "active control" (AT/AP) condition (Haussleiter et al., 2020; Taylor et al., 2020), including physical activity plus psychotherapy with psychotherapy alone (Abdollahi et al., 2017), physical activity with an attention placebo/control (Williams et al., 2019) or an identical type of physical activity at different "dosages" (Nyer et al., 2018).

Every trial had two intervention arms.

Study Setting

The included trials were conducted in eight middle-to-high income countries (The World Bank, n.d.): Australia, Austria, Iran, Germany, South Korea, Taiwan, United Kingdom and the United States. Five trials recruited participants from community settings, while four trials recruited participants from clinical settings; although one was in cancer care (Sun et al., 2017) the others were in mental health care settings, and in one of these (Haussleiter et al., 2020), the participants were psychiatric inpatients during the intervention. One study (Noh et al., 2020) did not describe the recruitment method.

Participants

The number of participants randomised to the relevant arms in these trials ranged from 20 to 175 (median 68).

Eight studies recruited adults, with a mean age of 44.3 years and a mean age range from 30 to 58.8 years. One study recruited adolescents and young adults (mean age 20.8 years), and one study

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recruited children (mean age 9.6 years). None of this review's included studies targeted older adults.

Most trials reported that there were more female than male participants; in fact, three trials recruited only female participants (Daley et al., 2015; Noh et al., 2020; Sun et al., 2017). Apart from those three, the percentage of female participants ranged from 33 to 83 (median 70).

Participants with SH or SI were targeted for inclusion in four of the included studies (Abdollahi et al., 2017; Nyer et al., 2018; Sturm et al., 2012; Sun et al., 2017) and were explicit in their intention to test the effects of PA on SH/SI. Of these four studies, the intention of the study by Nyer et al. (2018) is more ambiguous, since the first inclusion criterion was depression, which has as one of its criterion symptoms suicidal ideation and is a known risk factors for SH and SI. The mention of SI in the title and the use of two measurement instruments for SI justify characterising this study as such.

The other six studies targeted a variety of conditions, most commonly (in three studies) depressive disorders (Daley et al., 2015; Haussleiter et al., 2020; Nasstasia et al., 2019). Other targets were: physical and mental health (Noh et al., 2020), burnout and traumatic stress (Taylor et al., 2020) and quality of life, mood, and self-worth (Williams et al., 2019).

Data for the proportion of participants with SI at baseline were not available for three studies (Abdollahi et al., 2017; Noh et al., 2020; Sturm et al., 2012); where they were, the range was from 13 to 64% (median 28).

Outcomes

Suicidal Ideation. SI was measured in a variety of ways, with some studies reporting use of more than one relevant measure. In relation to this review's primary outcome, there were eight distinct measurement tools, and seven of these were self-report questionnaires or scales. Three trials (Abdollahi et al., 2017; Sturm et al., 2012; Sun et al., 2017) used the Beck Scale for Suicidal Ideation, although each referenced a different version. Two trials (Nasstasia et al., 2019; Nyer et al., 2018) used the Beck Depression Inventory (BDI), in which item #9 relates to SI. One trial (Williams et al., 2019) used the Children's Depression Inventory, which includes items on thoughts or wishes of SH. One trial (Daley et al., 2015) used the Edinburgh Postnatal Depression Scale, item #10, which asks for a self-rating on the frequency of "*The thought of harming myself has occurred to me*" (Cox et al., 1987, p. 786). One trial (Noh et al., 2020) used the "simplified mental health test II", which the authors reported as a Korean translation based in the Symptom Checklist-90; it has

17 symptom groups, one of which is “Suicide”. One trial (Taylor et al., 2020) used the Suicidal Ideation Attributes Scale. Finally, one trial (Haussleiter et al., 2020) used the Hamilton Depression Scale, in which item #3 relates to SI; this was the only clinician-rated measure represented in the included studies. The study by Nyer et al. (2018) additionally reported outcomes from the Columbia-Suicide Severity Rating Scale but those data were not extracted, since this review’s methodology gave precedence to the measure more frequently used in the included studies, which (in this case) was the BDI.

In two of the studies, data for the outcome of interest were presented as continuous, which resulted in data handling difficulties. Haussleiter et al. (2020) reported the mean and standard deviation scores for the HAM-D item 3, which had a skewed distribution. Nasstasia et al. (2019) presented the BDI-II mean item change scores for the Intervention and Control groups, which could not be entered into RevMan. In both cases, additional data provided by the authors enabled dichotomous treatment of the scores; that is, 0 or >0.

For two of the studies (Daley et al., 2015; Sturm et al., 2012), the authors provided additional data about the numbers of participants in the groups at post-intervention, or at crossover.

Self-harm or Other Suicide-Related Behaviour. None of the included studies measured another type of suicide-related outcome, including any SH.

Follow-Up (Post-Intervention) Assessment. Three of the 10 included studies (Daley et al., 2015; Nasstasia et al., 2019; Sturm et al., 2012) reported post-intervention follow-up data but only one (Daley et al., 2015) reported a relevant outcome measure in both study groups.

The characteristics of the included studies are summarised in Table 1.

Table 1*Characteristics of Included Studies*

| Study | Country, Setting | Design | Inclusion and Exclusion criteria | N, Age M (SD), % female | % SI baseline | PA Intervention | Control (type) | SI Outcome Measure, Primary? | Duration |
|---------------------------|-----------------------------|------------|--|-------------------------|---------------|---|-------------------------|-------------------------------------|----------|
| Abdollahi et al. (2017) | Iran Clinical | Parallel | INCL: formal diagnosis of a major depressive episode; sedentary. EXCL: BDI-II score=>30; bipolar disorder, schizoaffective disorder, pregnancy or planned pregnancy | 70, 49.7 (7.2), 47.1 | - | "Combined CBT and exercise" | AT (Psychological) | BSSI, Yes | 12 weeks |
| Daley et al. (2015) | United Kingdom Community | Parallel | INCL: MDD (ICD 10 diagnosis) or mixed anxiety and depression; within 6 mo. of giving birth; age > 18 years, inactive. EXCL: pregnant again, psychotic symptoms, dependent on illicit drugs or alcohol. | 94, 30.5 (5.6), 100 | 34 | "Face-to-face personalized exercise consultations" + "telephone [support] calls" and "Participants were given a pedometer" + "Information leaflets were mailed" | TAU | EPDS item #10, No | 6 months |
| Haussleiter et al. (2020) | Germany Clinical | Parallel | INCL: moderate or severe major depressive episode (diagnosed by a trained psychiatrist); HAMD=>17. EXCL: "acute suicidality", severe comorbid psychiatric disorders. | 76, 45.3 (12.4), 33.3 | 61* | "Standardized guided exercise therapy", + TAU | AT (other PA), plus TAU | HAMD item #3, No | 6 weeks |
| Nasstasia et al. (2019) | Australia Community | Cross-over | INCL: MDD (DSM-IV disorders (SCID-1 Research version)); 15-25 years. EXCL: "significant psychiatric co-morbidities; or eating disorders, where exercise was contraindicated." | 68, 20.8 (2.6), 77.9 | 64** | "Motivational interviewing" + "multi-modal exercise" + "free, 12-week gym membership" | WL | BDI-II item #9, No | 12 weeks |
| Noh et al. (2020) | Korea - | Parallel | INCL: Menopausal; "lack of serious illness". EXCL: spinal cord injury, paralysis, history of antidepressant use, history of | 40, 58.8 (3.9), 100 | - | "SaBang-DolGi is a traditional Korean exercise" | NT | "Simplified mental health test II", | 12 weeks |

Table 1 (Continued)

| Study | Country, Setting | Design | Inclusion and Exclusion criteria | N, Age M (SD), % female | % SI baseline | PA Intervention | Control (type) | SI Outcome Measure, Primary? | Duration |
|---------------------|--------------------------------|------------|---|-------------------------|---------------|---|----------------|------------------------------|----------|
| | | | psychiatric disorders, history of hormonal therapy (HT) use; surgical menopause. | | | | | symptom "Suicide", No | |
| Nyer et al. (2018) | United States Community | Parallel | INCL: MDD (current SCID for DSM-IV Axis I) diagnosis; age <=65; stable dose of antidepressant. EXCL: "Affirmative answers to items 4 or 5 of the C-SSRS"; (other) treatment with antidepressants; psychotherapy for depression within previous 3 months; recent mind-body practices; current prayer practice; bipolar illness or psychosis; SI with intent within the last year"; alcohol or substance abuse or dependence. | 32, 36.6 (12.9), 83.3 | 28 | "Iyengar yoga and coherent breathing ... three 90-min classes and four 30-min homework sessions per week" | AT (other PA) | BDI-II item #9, Yes | 12 weeks |
| Sturm et al. (2012) | Austria Clinical | Cross-over | INCL: "history of at least one suicide attempt"; BHS >26; "living no more than 50 km away"; age =>18. EXCL: coronary heart disease; cognitive impairments; knee arthrosis. | 20, 43.1 (8.6), 70 | - | "Monitored [mountain] hiking program" | WL | BSSI, Yes | 9 weeks |
| Sun et al. (2017) | Taiwan Clinical | Parallel | INCL: breast cancer patient receiving intravenous chemotherapy; female; age=>20. EXCL: "not currently doing muscle relaxation and therapeutic walking"; "too weak to engage". | 87, 54.1 (7.7), 100 | 13 | "Muscle relaxation techniques" + "Therapeutic walking" | TAU | BSSI Chinese Version, Yes | 12 weeks |

Table 1 (Continued)

| Study | Country, Setting | Design | Inclusion and Exclusion criteria | <i>N</i> , Age <i>M</i> (SD), % female | % SI baseline | PA Intervention | Control (type) | SI Outcome Measure, Primary? | Duration |
|------------------------|----------------------------|----------|--|--|------------------|---|---------------------|---------------------------------------|----------|
| Taylor et al. (2020) | Australia Community | Parallel | INCL: "current employment as junior doctors at RPAH and capacity to attend the pilot sessions". EXCL: - | 21, 30 (4), 76 | 24*** | "group fitness ... interval and/or 'boxfit'" | AT (other PA) | SIDAS, No | 8 weeks |
| Williams et al. (2019) | United States Community | Parallel | INCL: age 8–11; BMI ≥ 85th percentile for age and sex; sedentary. EXCL: medical conditions or medications "that could affect growth, physical activity, nutritional status, or metabolism"; school not included; sibling enrolled. | 175, 9.7 (0.9), 61.2 | 21 | "playful instructor-led aerobic activities" + "[points] earned for a daily average heart rate ... redeemed for small prizes". | AP | CDI item for SI, No | 8 months |

SI, suicidal ideation; PA, physical activity; NT, no treatment; WL, wait-list; AP, attention/activity placebo; TAU, treatment-as-usual; AT, active treatment (being: other PA, psychological therapy or medication); BDI-II, Beck Depression Inventory-II; CBT, cognitive behavioural therapy; BSSI, Beck Scale for Suicidal Ideation; MDD, major depressive disorder; EPDS, Edinburgh Postnatal Depression Scale; GP, General Practitioner; DSM-IV, Diagnostic and Statistical Manual of Mental Disorders, 4th Edition; SCID I/II, Structured Clinical Interview for DSM-IV Axis I/Axis II Disorders; HAMD, Hamilton Depression Scale; IG, intervention group; CG, control group; SCL-95-R, Korea Symptom-Checklist-90-Revision; C-SSRS, Columbia-Suicide Severity Rating Scale; HDG, high dose group; LDG, low dose group; BHS, Beck Hopelessness Scale; BSSI-Chinese, Beck Scale for Suicide Ideation Chinese Version of the Guidebook; CDI, Children's Depression Inventory; RPAH, Royal Prince Alfred Hospital; SIDAS, Suicidal Ideation Attributes Scale; BMI, Body Mass Index; -, not reported.

Note: Age (*M* and *SD*) is stated for the two groups combined, either (1) as reported, or (2) calculated using the following formulae:

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Table 1 (Continued)

$$M = (N_1M_1 + N_2M_2)/(N_1 + N_2)$$

$$SD = \sqrt{\frac{(N_1 - 1)SD_1^2 + (N_2 - 1)SD_2^2 + \frac{N_1N_2}{N_1 + N_2}(M_1^2 + M_2^2 - 2M_1M_2)}{N_1 + N_2 - 1}}$$

(Higgins et al., 2020, Section 6.5.2).

Note: “Gender (% female)” stated for the two groups combined, either (1) as reported, or (2) calculated using the reported data or (3) calculated using additional data provided by study authors.

Note: Additional data provided by authors’ emails indicate:

* 68/111 scored >0 at baseline for HAMD item 3,

** 45/70 scored >0 at baseline for BDI item 9, and

*** 5/21 scored >0 at baseline on SIDAS.

Note: ***This review substitutes the Taylor et al. (2020) study’s CG for its IG, and vice versa, in keeping with the methodology for categorising relative energy expenditure.

Table 2 (Continued)

Interventions

The characteristics of the PA interventions are detailed in Table 2.

The physical activities varied considerably – from simply walking, through culturally-informed and structured exercise to active games. Most trials (8/10) had supervised group activity sessions; one of these (Nasstasia et al., 2019) also had an individualised component (motivational interviewing).

Five studies were conducted indoors, one (Haussleiter et al., 2020) included a mixture of indoor and outdoor activities (data supplied by author) and one (Sturm et al., 2012) was conducted outdoors, on mountains. Three studies (Haussleiter et al., 2020; Nasstasia et al., 2019; Williams et al., 2019) stated the categorisation of physical activity (that is, aerobic, aerobic and strengthening, or “mixed”). In six studies the activity mode was mapped onto its generally accepted type, and in only one case, which was for yoga (Nyer et al., 2018) the exercise type could not be identified (and was categorised as “mixed”). On this basis, six trials used mainly aerobic-based physical activity; the remaining four trials had mixed types of exercise. Although no study used predominantly strengthening (resisted) exercises, one (Nasstasia et al., 2019) reported a clear protocol for progressing the strength-based component. The intensity of activity, for the majority time, was moderate in four trials (Abdollahi et al., 2017; Daley et al., 2015; Williams et al., 2019), vigorous in two trials and light or light-to-moderate in one trial, each. Where reported, session duration ranged from 35 minutes to 3 hours. Most (6/10) trials reported a frequency of three days per week, with the range from one to five days per week. Intervention periods ranged from six weeks to eight months. Five trials employed research staff with sports- or exercise-related training or qualifications (Abdollahi et al., 2017; Haussleiter et al., 2020; Nasstasia et al., 2019; Noh et al., 2020; Nyer et al., 2018); a further trial employed staff with health qualifications (Sturm et al., 2012).

One study (Nyer et al., 2018) compared two different dosages of Iyengar yoga. It was included in this review because of an assumption that even the low-dosage yoga would probably increase habitual PA for these participants. That is, individuals with major depressive disorder have low levels of PA, along with excessive sedentary time, as demonstrated by a recent cross-sectional study, employing objective measurement (Helgadóttir et al., 2015). In characterising yoga, I relied on a recent systematic review (Larson-Meyer, 2016), which concluded that it is typically a light-intensity PA. The Nyer et al. (2018) report described the difference in dosage; therefore, this review classified the low dose condition as “active treatment”.

Table 2 (Continued)

Another study (Taylor et al., 2020) compared two different activity types for junior doctors working in a busy city hospital – yoga and fitness training. Again, it would be reasonable to classify the intensity of yoga as light but this contrasts with the vigorous intensity of the fitness group comparator. For this review, therefore, “personalised yoga” was treated as the control condition (“active treatment”) and fitness training was treated as the experimental intervention.

The characteristics of the PA interventions are summarised in Table 2.

Table 2*Characteristics of Physical Activity Interventions*

| Study ID | Description | Indirect / direct supervision | Group / individual setting | Indoor/ outdoor | Aerobic/ strengthening/ mixed | Session duration, intensity, frequency | Programme duration | Qualifications of therapists |
|---------------------------|--|-------------------------------|----------------------------|-------------------|-------------------------------|---|--------------------|---|
| Abdollahi et al. (2017) | “Exercise program” | Direct | Group | Indoor | Aerobic, 2 | 35 minutes, Moderate, 3 days/week | 12 weeks | PhD in sport science |
| Daley et al. (2015) | “Facilitated exercise” | Indirect | Individual | - | Aerobic, 2 | N/A, Moderate, 3 days/week | 6 months | - |
| Haussleiter et al. (2020) | “Standardized guided exercise therapy” | Direct | Group | Indoor + Outdoor* | Mixed, 1 | 50 minutes, -, 3 days/week | 6 weeks | Certified exercise therapists |
| Nasstasia et al. (2019) | “Motivational interviewing” + “multi-modal exercise program” | Direct | Individual + Group | Indoor | Mixed, 1 | 1 hour, Vigorous, 3 days/week | 12 weeks | “Suitably qualified” personal trainers |
| Noh et al. (2020) | “SaBang-DolGi walking exercise program” | Direct | Group | Indoor | Mixed, 2 | 60 minutes, light-moderate, 3 days/week | 12 weeks | Qualified professional instructor |
| Nyer et al. (2018) | High-dose (vs Low-dose) Iyengar yoga and coherent breathing | Direct | Group | Indoor | Mixed, 3 | 90 minutes, Light, 3 days/week | 12 weeks | Certified, trained yoga instructors |
| Sturm et al. (2012) | Mountain hiking | Direct | Group | Outdoor | Aerobic, 2 | 2 - 3 hours, Moderate, 2-3 days/week | 9 weeks | Director of the study (qualification not stated) + “a nurse, a psychotherapist, or a physician” |

Table 2 (Continued)

| Study ID | Description | Indirect / direct supervision | Group / individual setting | Indoor/ outdoor | Aerobic/ strengthening/ mixed | Session duration, intensity, frequency | Programme duration | Qualifications of therapists |
|------------------------|--|-------------------------------|----------------------------|-----------------|-------------------------------|--|--------------------|------------------------------|
| Sun et al. (2017) | Muscle relaxation techniques and therapeutic walking | Indirect | Individual | - | Aerobic, 2 | N/A, -, variable | 12 weeks | - |
| Taylor et al. (2020)* | Group fitness sessions | Direct | Group | - | Aerobic, 2 | 45–60 minutes, vigorous**, 1 day/week | 8 weeks | - |
| Williams et al. (2019) | After-school programme aerobic activities and active games | Direct | Group | Indoor | Aerobic, 1 | 40 minutes moderate 5 days/week | 8 months | - |

* This review substitutes the Taylor et al. (2020) study’s CG for its IG, and vice versa, in keeping with the methodology for categorising relative energy expenditure.

**Data supplied by email from authors.

-, not reported; 1, categorisation as stated by the study authors, or “mixed” if they stated both types; 2, categorisation by identifying the described activity for the majority time of the intervention and mapping that term onto its generally accepted categorisation; 3, categorisation unable to be identified.

Quality Appraisal Results

The PEDro scale results are presented in Table 3.

PEDro scale ratings had already been confirmed and published on individual webpages of the Physiotherapy Evidence Database (<https://pedro.org.au/>) for each of the included studies (The PEDro Partnership, 2021a, 2021b, 2021c, 2021d, 2021e, 2021f, 2021g, 2021h, 2021i, 2021j).

Three of the 10 studies received an overall rating of 6/10 and another three were rated 4/10. The scores ranged from 4/10 to 7/10. All studies demonstrated that the participants had been randomly allocated and they reported between-group statistical comparisons for at least one of their key outcomes (not, necessarily, the primary outcome for this review). Most reports (9/10) clearly described the source of the participants and the criteria used to determine who was eligible to participate in the study. Most reports (9/10) demonstrated that the participant groups were similar at baseline regarding the most important prognostic indicators. Also, most reports (9/10) clearly provided both point measures and measures of variability for at least one key outcome. Only four reports demonstrated concealed allocation of participants (Daley et al., 2015; Nasstasia et al., 2019; Nyer et al., 2018; Sturm et al., 2012) and only two reports demonstrated blinding of the assessors who measured at least one key outcome (Nasstasia et al., 2019; Sun et al., 2017). As would be reasonably expected, no study reports demonstrated there was blinding of all participants or all therapists.

Six (out of ten) reports were rated as satisfying the measure “Adequate follow-up”; that is, six reports were found to have “*explicitly [stated] both the number of subjects initially allocated to groups and the number of subjects from whom key outcome measures were obtained*”, also that “*a key outcome [was] measured in more than 85% of subjects at one [point]*” (The PEDro Partnership, 1999, Criterion 8).

Every included study reported it obtained ethics committee approval.

The PEDro ratings are collated and summarised in Table 3.

Table 3*PEDro Scale Results of the Included Studies*

| Study | Eligibility criteria | Random allocation | Concealed allocation | Baseline comparability | Blind subjects | Blind therapists | Blind assessors | Adequate follow-up | Intention-to-treat analysis | Between-group comparisons | Point estimates & variability | Total score |
|---------------------------|----------------------|-------------------|----------------------|------------------------|----------------|------------------|-----------------|--------------------|-----------------------------|---------------------------|-------------------------------|-------------|
| Abdollahi et al. (2017) | Yes | Yes | No | Yes | No | No | No | No | No | Yes | Yes | 4/10 |
| Daley et al. (2015) | Yes | Yes | Yes | Yes | No | No | No | Yes | Yes | Yes | Yes | 7/10 |
| Haussleiter et al. (2020) | Yes | Yes | No | Yes | No | No | No | No | Yes | Yes | Yes | 5/10 |
| Nasstasia et al. (2019) | Yes | Yes | Yes | Yes | No | No | Yes | No | Yes | Yes | Yes | 7/10 |
| Noh et al. (2020) | No | Yes | No | Yes | No | No | No | No | No | Yes | Yes | 4/10 |
| Nyer et al. (2018) | Yes | Yes | Yes | No | No | No | No | Yes | No | Yes | No | 4/10 |
| Sturm et al. (2012) | Yes | Yes | Yes | Yes | No | No | No | Yes | No | Yes | Yes | 6/10 |
| Sun et al. (2017) | Yes | Yes | No | Yes | No | No | Yes | Yes | No | Yes | Yes | 6/10 |
| Taylor et al. (2020) | Yes | Yes | No | Yes | No | No | No | Yes | No | Yes | Yes | 5/10 |
| Williams et al. (2019) | Yes | Yes | No | Yes | No | No | No | Yes | Yes | Yes | Yes | 6/10 |
| Proportion Yes | 9/10 | 10/10 | 4/10 | 9/10 | 0/10 | 0/10 | 2/10 | 6/10 | 4/10 | 10/10 | 9/10 | |

Excluded Studies

There were 30 studies excluded by examination of the full text; the main reason (24/30) was that SI or SH (or some other suicide-related behaviour) was not reported as an outcome. Other reasons for study exclusion were that a PA intervention was not clearly reported (4/30) and ineligible study design (not an RCT, 1/30). The excluded studies, with reasons for exclusion, are listed in the Characteristics of Excluded Studies table (Table 4, Appendix B).

Ongoing Studies

There are 23 trials of relevance, for which there is not (yet) a report published in a peer-reviewed journal; they are tabled in Appendix C.

Effects of Physical Activity Interventions on Suicidal Ideation

PA interventions probably decrease the risk that someone would be experiencing SI post intervention (RR 0.43, 95% CI 0.23, 0.79, $k=5$, $N=460$). This meta-analysis used data from a small number of trials (five), representing 460 participants. Most estimates (4/5) were in the same direction as the Total, with a level of heterogeneity that probably is not important, as shown by the overlapping CIs and by statistical tests ($\text{Chi}^2 = 5.33$, $df = 4$ ($p = 0.26$); $I^2 = 25\%$). The PEDro scale scores for these trials indicated variable quality, with total scores ranging from 4/10 to 7/10. Of note, it would be exceptional for a PA intervention trial report to rate greater than 8/10 on the PEDro scale, and two of these trials scored 7/10. Also, a majority (4/5) of these trials satisfied the criterion “Concealed allocation”.

There was some evidence that SI scores may be reduced by PA interventions (Standardised Mean Difference -1.17, 95% CI -2.88, 0.54). This meta-analysis used data from just four trials, representing relatively few participants ($N = 129$). All of the estimates were in the same direction (favouring PA); however, the CI for the Total crossed the zero line. There was evidence of considerable heterogeneity in this analysis, shown by one outlying CI and by statistical tests ($\text{Chi}^2 = 48.67$, $df = 3$ ($p = 0.00001$); $I^2 = 94\%$). The PEDro scale scores for these trials, again, indicated variable quality, with total scores ranging from 4/10 to 6/10. Of note, two of these trials satisfied the criterion “Adequate follow-up”.

Outcome scores for the Beck Scale for Suicidal Ideation in the study report for Sun et al. (2017) were not included in the continuous outcomes meta-analysis because they were presented as mean rank and sum of ranks. In their statistical analysis (using Mann-Whitney U tests), the authors did not find a significant difference between the group scores at post-intervention.

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A meta-analysis of follow-up outcomes was not possible, since usable data were reported in only one of the included studies (Daley et al., 2015). Those data showed that three women in the intervention group and five women in the control group endorsed “thoughts of self harming” at 12 months post-randomisation, which was a reduction from four women and six women, respectively, at the post-intervention (6-month) assessment.

The forest plots are presented in Figure 6 (outcomes measured dichotomously) and Figure 7 (outcomes measured continuously).

Figure 6

Effect of Physical Activity Interventions on Suicidal Ideation Scores Measured Dichotomously (Risk Ratio, Mantel-Haenszel Method)

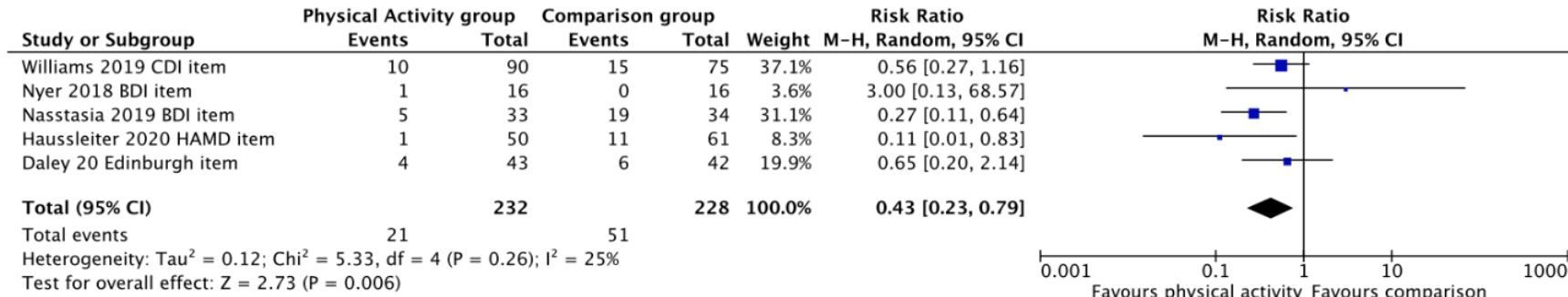
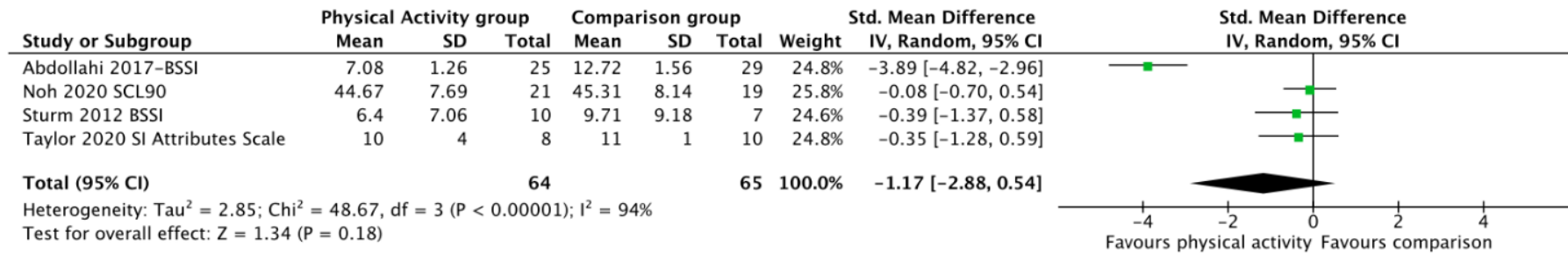


Figure 7

Effect of Physical Activity Interventions on Suicidal Ideation Scores Measured Continuously (Standardised Mean Difference, Inverse-Variance Method)



CHAPTER 5: DISCUSSION

Key Findings

This systematic review found ten eligible RCT reports of the effects of PA interventions on SI. The database searching did not find any RCTs that reported on other types of suicide-related outcome, including SH. By careful analysis of the primary research findings, the intention was then to answer the question: Do PA interventions reduce SI?

There may be positive impacts of PA interventions on SI, measured dichotomously; that is, the risk of having SI at the completion of a PA intervention is just 0.43 times the risk at the completion of a comparator condition. This statistical result is significant (CI 0.23, 0.79) and its heterogeneity unimportant. Granted, the effect on reduction of severity of SI is uncertain, due to high heterogeneity of the outcomes when measured continuously and the fact of the CI straddling the no-effect line; nevertheless, it is in the same (favourable) direction.

The interventions were very varied and were trialled across very different populations, but despite this heterogeneity there is indication that this is a promising intervention that deserves further examination. There is potential to reduce our suicide rate, given the link between SI and suicide. This finding adds to the literature and provides some novel avenues to pursue, given the literature to-date highlights relatively modest effects of existing treatments. Indeed, there is already widespread interest in PA interventions being used in this way; this study begins to build the supportive evidence.

Comparison with Standard Treatments

The review by Witt, Hetrick et al. (2021b) measured a clearly positive effect on level of SI from CBT-based psychotherapy (SMD -0.48, CI -0.68, -0.28), based on five studies, and with an unimportant level of heterogeneity. That result cannot be compared with PA interventions yet, since the effect when measured continuously is uncertain and the current level of heterogeneity is concerning. Conversely, when considering SI measured dichotomously, the effect of CBT-based psychotherapy is currently uncertain (OR 0.44, CI 0.08, 2.26), whereas the effect of PA interventions is positive (RR 0.43, 95% CI 0.23, 0.79). When thinking about the effects of pharmacological interventions on SI, the review by Witt, Hetrick, et al. (2021a) (which is restricted to clinical SH populations) found only two trials with relevant data; hence, those results are not comparable with this review of PA interventions.

Comparisons with Previous Reviews

The previous similar review (Vancampfort et al., 2018) had included two RCTs that are in common with this review (Abdollahi et al., 2017; Sturm et al., 2012). Now there are eight more eligible studies, and indications are that more will soon be published. This adds to the evidence in favour of feasibility, which had started with the study by Sturm et al. (2012) and that had already been indirectly supported by a considerable number of PA intervention trials for conditions with increased risk for SI.

PA interventions reduce some of the risk factors that contribute to deaths by suicide; these include depression (Bailey et al., 2018; Brown et al., 2013; Lee et al., 2021; Miller et al., 2020; Nyström et al., 2015; Oberste et al., 2020; Wegner et al., 2020), anxiety (Carter, 2021), and psychological symptoms associated with a variety of other important conditions (for example, schizophrenia or schizoaffective disorder (Firth et al., 2015; Rosenbaum et al., 2014), Multiple Sclerosis (Rietberg et al., 2005), breast cancer (Lahart et al., 2018), HIV/AIDS (O'Brien et al., 2010) or end-stage kidney disease (Natale et al., 2019)). Established benefits such as these indirectly support the findings of this review.

The findings from this review seem to converge with the supportive evidence from cross-sectional studies. That is, evidence already suggested that PA is associated with lower odds of concurrent SI (Vancampfort et al., 2018) and, now, the results of this review show that PA interventions may reduce SI. There are several indicators of high quality RCT conduct and reporting, enhancing confidence that PA interventions may reduce SI, measured dichotomously.

It is unclear whether PA interventions might be any more feasible than the standard interventions for SI. Acceptability seems likely, since this approach might present less attitudinal barriers, bypassing stigma as well as hospitals. In fact, people might feel such an approach is desirable, given that PA is generally promoted. Qualitative studies of people who participate in PA interventions for mental disorders (generally) are very supportive (Mason & Holt, 2012). PA interventions might have lower costs per capita, through being amenable to group implementation together with delivery by other allied professionals. However, there are other costs to consider, like access to venues, and, in any case, it is not possible to predict whether funders would make significant resources available to provide real access to those who need it.

Only one included study explicitly compared the effects of a PA intervention plus psychological treatment (CBT) with psychological treatment alone. Therefore, without enough studies of this sub-

type for a meta-analysis, it is not yet possible to recommend whether, or not, these two different approaches might have similar benefit for SI. The same kind of limitation has previously been found when considering PA interventions for treatment of depression in young adults (Bailey et al., 2018).

Strengths and Limitations

A strength of this review is that it was conducted using the Cochrane methodology, which is internationally recognised as the gold standard approach for intervention reviews. This review has been conducted with meticulous attention to detail, supervised by an experienced expert in systematic reviews (Associate Professor Sarah Hetrick), and all measures have been taken to clarify and check pertinent detail, including correspondence with a number of authors of included studies.

This review adopted inclusive definitions for SI, SH and any other suicide-related behaviour. By doing this, interventions for individuals with any possible degree of identified risk for suicide could be included. Research has identified that the motivations for suicide-related thoughts and behaviours are ambiguous in many cases; however, many clinical studies (including some in this review) state exclusion criteria around the concept of intent. By employing an all-inclusive approach, and making no exceptions on the bases of “intent” or motivation, this review’s methodology is in keeping with current understanding from research; that is, suicide risk prediction is inaccurate. In other words, SI (with or without a plan), SH (with or without endorsed SI) and other suicide-related behaviours are all risky. Such an approach also avoids inadvertently excluding research on the basis of different terms being used for similar phenomena. In any case, SH and suicide-related thoughts and behaviours are, of themselves, valid targets for amelioration. At the same time, this inclusive search strategy did not compromise on specificity; that is, closely-related outcome measures, such as, for example, the whole Beck Depression Inventory score, were not sought. This approach was appropriate for the complex nature of suicide-related phenomena, in which populations that have increased risk nevertheless include a significant proportion of individuals without suicidal behaviour.

This review had an expansive approach for finding types of PA interventions. The included studies reflect the situation that much PA advice, generally, favours walking for adults and active games for youth. The research also shows that interventions are usually structured, more akin to exercise prescription rather than being determined by participant preference. Therefore, in addition to the usual PA-related terms, this review specified terms including, for example, those related to PA in the creative arts (“dance”) or outdoor activities (“gardening”, “wilderness experience”).

Furthermore, physical activation is a relative goal, since (1) recommendations differ by populations and (2) background health and fitness vary amongst individuals. This is especially important to consider for people with serious mental illnesses or with chronic physical injuries or illnesses, who (generally) are very or profoundly inactive. Therefore, this review included terms for light-intensity activities, such as “yoga” and “activities of daily living”, in case such an approach had been trialled in a very inactive population.

Altogether, the database searches were improved with the expertise of a research librarian, identifying the most relevant electronic databases and maximising the likelihood of identifying eligible studies. Also, the final strategies were confirmed through a series of experiments with vocabulary, wildcards, specifiers and the like. The review by Vancampfort et al. (2018) did not include the study by Daley et al. (2015); while it is not possible confirm the reason for its absence, perhaps their search terms were too restrictive.

This review only includes RCTs, an established methodology for testing treatment effects, including effects of lifestyle change interventions. It incorporates a quality appraisal of such trials using an appropriate, recognised tool. The review used reliable, validated software for conducting the meta-analyses.

The outcome measures encompassed reduction (i.e., improvement) and “remission”, if it can be called that. A change from having SI during the past week to having no SI during the past week is important but is not guaranteed to endure. Meta-analyses were possible using data from a majority (nine out of the ten) of the included studies, with the median effect in all but one of these trending in favour of PA intervention.

Clearly, this review benefits from the recent increase of research into the effects of using PA to address psychological outcomes, including SI. Further, I made conscientious efforts to contact study authors for additional data and the five responses significantly enhanced the results. This is the first meta-analysis to examine the effects of PA interventions on SI.

Limitations

Notwithstanding the increase in research activity, this review identified only a small number of eligible studies, and in some of these the participant numbers were very low. The effect size calculated on continuous outcome measures is accompanied by significant heterogeneity; nevertheless, there were too few studies to explore this further by, for example, conducting a meta-

regression. Similarly, only one study compared different “dosages” of PA (yoga); therefore, it is not yet possible to recommend a threshold for the targeted increase in PA to reduce SI.

Evidence Gaps

None of the studies were conducted in low-income countries, although there was one study in a middle-income country (Iran (Abdollahi et al., 2017)). Given the emerging evidence that group-based PA interventions for addressing SI are feasible, perhaps researchers in places where resources are very limited might be encouraged to conduct RCTs.

Also, none of the included studies was conducted in Aotearoa New Zealand, thus precluding a discussion of how PA interventions might possibly contribute to reducing the disparity between Māori and non-Māori suicide rates. Nevertheless, one of the included studies found a favourable effect in youth (Nasstasia et al., 2019), a population here at increased risk of death by suicide (Glenn et al., 2020); therefore, PA intervention could be a promising avenue that deserves further evaluation locally.

Although the included studies report notable quality highlights, there were shortcomings. In particular, a majority (6/10) of study reports did not demonstrate concealed allocation, in which “*the person who determined if a subject was eligible for inclusion in the trial was unaware, when this decision was made, of which group the subject would be allocated to*” (The PEDro Partnership, 1999, Criterion 3). Such avoidable failures introduce bias (Schulz et al., 1995) and they may have inflated the observed effects in this review.

The effects of PA interventions on SI over the longer-term remain very unclear since, at this stage, data that would potentially contribute to a meta-analysis are currently available for only one trial. This is a significant gap, given the field of study is in lifestyle change.

As already mentioned, there was heterogeneity in the instruments used for measuring SI. There are both self-report and clinician-rated measures; also, the self-report measures comprise a mix of whole scales and single items. Measurement inconsistency hinders progress in suicide prevention research, whereas a small collection of psychometrically sound self-report measures has been identified for use in adult populations (Batterham et al., 2015). That review recommended the Suicidal Ideation Attributes Scale (SIDAS) as one of three brief measures, while the Beck Scale for Suicide Ideation (BSSI) was one of two preferred comprehensive measures. Either one of these scales was employed in 4/10 of the included studies.

It was not possible in this review to consider the mechanisms by which these PA interventions might have improved SI. Proponents of behaviour change techniques argue it is important to identify the “active ingredients” of lifestyle change interventions; however, the included studies barely discussed these in relation to the study design. Perhaps word limits in publications stifle such discussion. For example, the study by Daley et al. (2015) references its earlier, registered, study protocol (Daley et al., 2012), in which the authors had discussed their reliance on the Transtheoretical Model.

This review searched for but did not find any PA intervention trials that measured an effect on self-injury, self-poisoning, suicide attempt or death by suicide. We need specific studies to be able to draw any conclusions about the possible effects on any type or frequency of SH.

Impacts of Methodological Choices

The search strategy may have failed to find some relevant RCTs, since sources other than databases were not deliberately pursued. Even so, any such studies, if not also published in a peer reviewed journal, would not have been included in this review, since the PEDro scale was chosen for the quality appraisal. Thus, the PEDro scale has a more restrictive effect on study inclusion than does the Cochrane Risk of Bias tool. That said, only one study (Feldman et al., 2020b) could not be included in this review on that basis.

I did not analyse participant dropout, treatment adherence or adverse events, focussing instead on effect measures. PA interventions are generally safe; therefore, the omission of an adverse events analysis from this review may be a minor criticism. However, dropout and treatment adherence rate analyses would have likely been helpful, both for comparison with the standard treatments and for informing design in future PA intervention trials. In addition, such knowledge could contribute to the further refinement of behaviour change theory.

The health impacts of PA and sedentary behaviour are not interchangeable; instead, excessive sedentary behaviour is associated with a number of markers for poor health, independently from moderate-to-vigorous physical activity (Martin et al., 2015). Regarding the mental health of youth, extensive evidence favours a significant influence by sedentary behaviour, again, independently of time spent being physically active (Hoare et al., 2016). This review did not consider the effects on SI from interventions to decrease sedentary behaviour; such an approach would have would have given a better balance and would be an important focus of future research.

Recommendations For Practice

There might be three implications for the effect of PA interventions for SI. Firstly, that they work, as supported by the effect measured dichotomously. In that case, health professionals should help youth and adults with SI to become physically active. This would require knowledge of the specific motivating factors and barriers present in their clients (Firth et al., 2016). Also, practitioners should reflect on their own knowledge of PA and be equipped with information identifying local opportunities for PA engagement (West et al., 2021). Secondly, that they don't work, as could be proven by additional studies, or even one large trial. In that case, such an approach would still improve risk factors known to be associated with suicidal behaviour, such as depression (Bailey et al., 2018; Brown et al., 2013; Lee et al., 2021; Miller et al., 2020; Nyström et al., 2015; Oberste et al., 2020; Wegner et al., 2020), anxiety (Carter, 2021), schizophrenia (Firth et al., 2015; Rosenbaum et al., 2014), Multiple Sclerosis (Rietberg et al., 2005), breast cancer (Lahart et al., 2018), HIV/AIDS (O'Brien et al., 2010) and end-stage kidney disease (Natale et al., 2019). Meanwhile, we should retain the standard interventions while continuing the search for new ones. Thirdly, that the effect is unclear, as suggested by the continuous outcome data. In that case, there is absent evidence of serious harm with this type of intervention and it would likely improve other well-recognised health risk factors, such as blood glucose levels, and so on (Posadzki et al., 2020). Meanwhile, we must await further evidence, including publication of recent trials, to provide the much-needed clarity.

When implementing this clinically, and bearing in mind that PA interventions for addressing SH, SI or mental illness may well be non-stigmatising, it is important to ensure that PA interventions don't become stigmatised or stigmatising. Of course, the name given to an intervention programme, and its set up, must be carefully considered to avoid inadvertent stigmatisation. Some of the included studies in this review used creative names which veiled or re-framed the intention: "PAMPers" (Daley et al., 2015), "Healthy Body, Healthy Mind" (Nasstasia et al., 2019) and "SMART" (Williams et al., 2019) In practice, co-design might ensure that the programme and its name are non-stigmatising.

Implications for Practice and Future Research

PA interventions hold promise for making a meaningful contribution to suicide prevention. The available evidence, however, falls well short of investigating the efficacy of this approach in most of the recognised at-risk populations. Absent, to-date, are trials targeting populations that include the following: Māori, older adults, people who have experienced sexual abuse, people with chronic

or life-limiting physical illnesses (beyond breast cancer) or chronic pain, young people whose parents have mental disorders and people experiencing social adversity.

Also, since the size of the effect in the studied groups is somewhat uncertain, further trials in similar groups could diminish the current statistical uncertainty, with its heterogeneity, and might meaningfully inform the issue of dosage.

Further to the issue of measurement, future trials targeting SI should choose valid, reliable measurement tools (Batterham et al., 2015). Self-report tools do not provide for “assessor blinding”, which is important for reducing the potential for bias (Moseley et al., 2019), but they do support consistency and are less costly to employ; Batterham et al. (2015) have recommended a small suite from which to choose (in adult populations).

In addition, it would be unrealistic to assume that the present types of PA intervention would be universally applicable; this is because enablers of and barriers to behaviour change vary from person to person, affecting uptake, adherence, and post-intervention maintenance. This calls for a great variety of modes of delivery and strongly suggests the need for stakeholder engagement in programme design. For example, where SI relates to physical disability, adaptive equipment may be crucial. In another example, participants experiencing social adversity might need transport provided to an exercise venue. In yet another example, cultural values, particularly in indigenous populations, may call for community elders to actively guide programme development (Durie, 2017; Oosman et al., 2021; Sushames et al., 2016). Indeed, the disparity between, for example, Māori and non-Māori rates of SH underscores this unmet need for collaboration (Fortune & Hetrick, 2021).

As discussed, only one of this review’s included studies specified a protocol for a strengthening-based component of the PA programme. The WHO physical activity guidelines (World Health Organization, 2020) recommend both aerobic and strengthening components, based largely on moderate certainty evidence. For example, the Guideline cites evidence that strengthening (or resistance) exercise interventions reduce symptoms of both depression and anxiety, and that a combined aerobic/strengthening approach improves quality of life for people living with HIV. However, there are gaps in this relatively newer area of understanding and, overall, more evidence is needed to for “*establishing minimal effective doses and maximum safety thresholds of physical activity for different population subgroups*” (World Health Organization, 2020, p. 36). Future PA interventions targeting SH or SI should plan to include both aerobic and strengthening components,

while careful reporting of exercise protocols would enable future recommendations to be more specific about dosage.

The current state of research comprises relatively small numbers of participants from very different populations; furthermore, these represent only a few of the populations with known increased risk for suicidal behaviour. Meanwhile, the trials are of several different physical activity types, rather than several studies of any one type, so it is not yet possible to recommend any “dosage” of PA. This is not to criticise what has been achieved but, rather, to encourage much more research participation in this field.

Altogether, many more, well-conceived trials are needed so we can understand the specific effects of specific types of PA interventions for specific populations.

Informing Theorised Mechanisms of Action

The factors that contribute to SH and SI are multiple and complex; future trials would be enriched by additional measurements of modifiable factors, like mood, neurotrophic markers, self-efficacy, hopelessness, and others. In fact, this review did not find reported data of the type (or quantity) that would substantially inform mechanistic theories, but such research would considerably advance understanding – from biological, psychological and social perspectives. Questions that could be posed include:

- How do PA interventions affect mood in people with SI?
- Are there changes occurring in neurotrophic markers due to PA interventions for SI, as have been discussed in relation to interventions for depression (Schuch et al., 2016)?
- How do PA interventions compare with psychological techniques for enhancing self-efficacy in people with SI?
- How might the effects (on SI) of a specified PA “dosage” performed in a group setting compare with an individual setting? Alternatively, along the lines of the study design reported by Williams et al., (2019), how might the effects of a PA intervention in a group setting compare with the effects of some other type of socially-based intervention (where session duration and frequency are kept constant)?
- Does reduced hopelessness contribute to the improvements that PA interventions bring to SI?
- Do participants have preferences for PA intervention compared with traditional psychological therapy interventions?

Recalling that the IPT suggests the importance of social connectedness (Hagan et al., 2016), it may be helpful that many modes of PA nurture opportunities for social connections. As an example, a systematic review of the reasons older persons participate in sport found strong evidence for “*socializing, community feeling, togetherness, and being part of a group*”, among others (Stenner et al., 2020, p. 538). People who have lived through or are living with their own or a loved one’s suicidal behaviour report it’s important they are able “have a connection” with the person offering to help them (Berg et al., 2017). PA interventions might create opportunities for clients to make meaningful connections with the health personnel (and with each other).

From a different perspective, the IMV model suggests the importance of positive future thinking (O’Connor et al., 2016) and one could imagine that PA interventions promote this. For example, a PA intervention in survivors of domestic violence found “*a sense of hope and healing as a result of their physical activity, a sense of true freedom, and the creation of a future self*” (Concepcion & Ebbeck, 2005, p. 203). Future trials might incorporate process evaluation (along with outcome measurement) to shed light on these theories.

PA interventions may reduce SI in affected individuals while such interventions are in place. Greater certainty would depend on whether the same direction is further replicated, and maintained, with provisos. That is, future RCTs should adhere to using recommended measurement tools and should stringently avoid bias. So far, there is insufficient primary research to inform a recommendation about maintained effect or about how the effect might differ by population, including age group; therefore, future study designs should consider maintenance of a physically active lifestyle in all such vulnerable people. At present there are no primary studies for the effects of these types of interventions on other suicide-related outcomes, including SH; this calls for studies that specify such outcome measures, which (in turn) would present greater opportunities for blinding of assessors.

Conclusions

For the first time, it was possible to quantify effects of PA interventions on SI, and this review has shown potential benefit. The popular notion that PA interventions “work” for SI now has empirical support. There is much more to learn about the role of PA interventions in the field of suicide prevention but we may now be cautiously optimistic that such an approach will enhance the established ongoing efforts.

APPENDICES

Appendix A: Database Search strategies and number of results at 22 October, 2021

1. Medline

| | |
|--------------------|---|
| Population | exp Self-Injurious Behavior/ or exp drug overdose/ or self mutilation/ or exp Suicide, Attempted/ or exp Suicidal Ideation/ or exp Suicide/ or Poisoning/ or (self?harm or suicid* or para?suicide or failed attempt* or failed completion or self?directed violence or lethal attempt* or death rehearsal or courting death or cry for help or morbid rumination* or self?injurious behavior*r* or self?murder or successful attempt or hastened death or self?destructive or self?mutilat* or self?poison* or self-injury or "self injury").mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] |
| Intervention | running/ or jogging/ or marathon running/ or swimming/ or walking/ or dependent ambulation/ or exercise/ or cool-down exercise/ or gymnastics/ or muscle stretching exercises/ or exp physical conditioning, human/ or stair climbing/ or warm-up exercise/ or camping/ or dancing/ or horticulture/ or gardening/ or "play and playthings"/ or games, recreational/ or exp sports/ or expeditions/ or exp Bicycling/ or (physical activit* or exercis* or sport* or danc* or swim* or walking or bicycl* or physical education or active transport or garden* or non?sedentary behavio* or martial art* or physical rehab* or other movement behavio*).mp. [mp=title, abstract, original title, name of substance word, subject heading word, floating sub-heading word, keyword heading word, organism supplementary concept word, protocol supplementary concept word, rare disease supplementary concept word, unique identifier, synonyms] |
| Sensitive strategy | Cochrane – Medline, Ovid (Lefebvre et al., 2020) |
| Total | 346 |

2. Embase, since 1980

| | |
|--------------------|--|
| Population | exp Self-Injurious Behavior/ or exp suicidal behavior/ or exp automutilation/ or exp suicide/ or exp suicide attempt/ or attitude to death/ or assisted suicide/ or suicidal ideation/ or (self-harm or selfharm or suicid* or parasuicide or failed attempt or failed completion or self-directed violence or selfdirected violence or lethal attempt or death rehearsal or courting death or cry for help or morbid rumination* or self-injur* or selfinjur* or self-murder or selfmurder or successful attempt or hastened death or self-destructive or selfdestructive or self-burning or selfburning or self-immolation or selfimmolation or self-inflicted lesion* or selfinflicted lesion* or self-poisoning or self-poisoning or nssi).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word] |
| Intervention | exp physical activity/ or exp exercise/ or exp sport/ or exp dancing/ or exp locomotion/ or exp physical education/ or gardening/ or camping/ or performing arts/ or (physical activ* or exercis* or sport* or danc* or swim* or martial art* or walk* or bicycling or cycling or wheeling or active transport or active travel or physical education or gardening or non-sedentary behav* or nonsedentary behavio*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word] |
| Sensitive strategy | Cochrane – Embase, Ovid (Lefebvre et al., 2020) |
| Total | 854 |

3. Embase Classic 1947 to 1973

| | |
|--------------------|--|
| Population | exp Self-Injurious Behavior/ or exp suicidal behavior/ or exp automutilation/ or exp suicide/ or exp suicide attempt/ or attitude to death/ or assisted suicide/ or suicidal ideation/ or (self-harm or selfharm or suicid* or parasuicide or failed attempt or failed completion or self-directed violence or selfdirected violence or lethal attempt or death rehearsal or courting death or cry for help or morbid rumination* or self-injur* or selfinjur* or self-murder or selfmurder or successful attempt or hastened death or self-destructive or selfdestructive or self-burning or selfburning or self-immolation or selfimmolation or self-inflicted lesion* or selfinflicted lesion* or self-poisoning or self-poisoning or nssi).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word] |
| Intervention | exp physical activity/ or exp exercise/ or exp sport/ or exp dancing/ or exp locomotion/ or exp physical education/ or gardening/ or camping/ or performing arts/ or (physical activ* or exercis* or sport* or danc* or swim* or martial art* or walk* or bicycling or cycling or wheeling or active transport or active travel or physical education or gardening or non-sedentary behav* or nonsedentary behavio*).mp. [mp=title, abstract, heading word, drug trade name, original title, device manufacturer, drug manufacturer, device trade name, keyword heading word, floating subheading word, candidate term word] |
| Sensitive strategy | Cochrane – Embase, Ovid (Lefebvre et al., 2020) |
| Total | 3 |

5. Cochrane CENTRAL

| | |
|---------------------|---|
| <p>Population</p> | <p>MeSH descriptor: [Self-Injurious Behavior] explode all trees OR MeSH descriptor: [Drug Overdose] explode all trees OR MeSH descriptor: [Self Mutilation] explode all trees OR MeSH descriptor: [Suicide, Attempted] explode all trees OR MeSH descriptor: [Suicidal Ideation] explode all trees OR MeSH descriptor: [Suicide] explode all trees OR MeSH descriptor: [Poisoning] explode all trees OR (self-harm) (Word variations have been searched) OR (suicid*) (Word variations have been searched) OR (*suicide) (Word variations have been searched) OR ("failed attempt") (Word variations have been searched) OR ("failed completion") (Word variations have been searched) OR ("self-directed violence") (Word variations have been searched) OR ("lethal attempt") (Word variations have been searched) OR ("death rehearsal") (Word variations have been searched) OR ("courting death") (Word variations have been searched) OR ("cry for help") (Word variations have been searched) OR ("morbid rumination") (Word variations have been searched) OR ("self-injurious behaviour") (Word variations have been searched) OR (self-murder) (Word variations have been searched) OR ("successful attempt") (Word variations have been searched) OR ("hastened death") (Word variations have been searched) OR (self-destructive) (Word variations have been searched) OR (self-mutilat*) (Word variations have been searched) OR (self-poison*) (Word variations have been searched) OR (self-injury) (Word variations have been searched)</p> |
| <p>Intervention</p> | <p>MeSH descriptor: [Running] explode all trees OR MeSH descriptor: [Jogging] explode all trees OR MeSH descriptor: [Marathon Running] explode all trees OR MeSH descriptor: [Swimming] explode all trees OR MeSH descriptor: [Walking] explode all trees OR MeSH descriptor: [Dependent Ambulation] explode all trees OR MeSH descriptor: [Exercise] explode all trees OR MeSH descriptor: [Cool-Down Exercise] explode all trees OR MeSH descriptor: [Gymnastics] explode all trees OR MeSH descriptor: [Muscle Stretching Exercises] explode all trees OR MeSH descriptor: [Physical Conditioning, Human] explode all trees OR MeSH descriptor: [Stair Climbing] explode all trees OR MeSH descriptor: [Warm-Up</p> |

| | |
|---------------------------|--|
| | <p>Exercise] explode all trees OR MeSH descriptor: [Camping] explode all trees OR MeSH descriptor: [Dancing] explode all trees OR MeSH descriptor: [Horticulture] 1 tree(s) exploded OR MeSH descriptor: [Gardening] explode all trees OR MeSH descriptor: [Play and Playthings] explode all trees OR MeSH descriptor: [Games, Recreational] explode all trees OR MeSH descriptor: [Sports] explode all trees OR MeSH descriptor: [Expeditions] explode all trees OR MeSH descriptor: [Bicycling] explode all trees OR ("physical activity*") (Word variations have been searched) OR (exercis*) (Word variations have been searched) OR (sport*) (Word variations have been searched) OR (danc*) (Word variations have been searched) OR (swim*) (Word variations have been searched) OR (walking) (Word variations have been searched) OR (bicycl*) (Word variations have been searched) OR ("physical education") (Word variations have been searched) OR ("active tra*") (Word variations have been searched) OR (wheeling) (Word variations have been searched) OR (garden*) (Word variations have been searched) OR ("non-sedentary behavio*") (Word variations have been searched) OR ("martial art*") (Word variations have been searched) OR ("physical rehab*") (Word variations have been searched) OR ("other movement behavio*") (Word variations have been searched)</p> |
| <p>Sensitive strategy</p> | <p>N/A</p> |
| <p>Total</p> | <p>370 (Trials)</p> |

7. PsycInfo

| | |
|--------------------|---|
| Population | exp Self-Destructive Behavior/ or exp Self-Injurious Behavior/ or exp Attempted Suicide/ or exp Self-Inflicted Wounds/ or exp Suicide/ or exp Suicidal Ideation/ or exp Patient Violence/ or exp Suicide Prevention/ or exp Psychological Autopsy/ or exp Self-Poisoning/ or (self harm or suicid* or parasuicide or failed attempt or failed completion or self directed violence or lethal attempt or death rehearsal or courting death or cry for help or morbid rumination* or self injur* or self-injurious behavio* or self murder or successful attempt or hastened death or intentional self murder or self destructive or self burning or self immolation or self-inflicted lesion* or self poisoning or nssi).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh] |
| Intervention | exp Physical Activity/ or exp Exercise/ or exp Sports/ or exp "Activities of Daily Living"/ or exp Wilderness Experience/ or exp Athletic Participation/ or exp Swimming/ or exp Martial Arts/ or exp Walking/ or exp Ground Transportation/ or exp "Commuting (Travel)"/ or exp Physical Education/ or exp Horticulture Therapy/ or (physical activ* or exercis* or danc* or sport* or physical activ* or swim* or martial art* or walk* or bicycling or cycling or wheeling or active tra* or physical education or gardening or non sedentary behav*).mp. [mp=title, abstract, heading word, table of contents, key concepts, original title, tests & measures, mesh] |
| Sensitive strategy | per (Ramos-Sanchez et al., 2021) |
| Total | 136 |

9. CINAHL

| | |
|---------------------|--|
| <p>Population</p> | <p>(MH "Injuries, Self-Inflicted") OR (MH "Self-Injurious Behavior") OR (MH "Risk for Self-Mutilation (NANDA)") OR (MH "Self Mutilation Risk (Saba CCC)") OR (MH "Risk for Violence, Self-Directed or Directed at Others (NANDA)") OR (MH "Suicide Self-Restraint (Iowa NOC)") OR (MH "Self-Mutilation Restraint (Iowa NOC)") OR (MH "Suicide+") OR (MH "Suicidal Ideation") OR (MH "Suicide, Assisted") OR (MH "Suicide, Attempted") OR (MH "Suicide Risk (Saba CCC)") OR (MH "Suicide Self-Restraint (Iowa NOC)") OR (MH "Suicide Prevention (Iowa NIC)") OR (MH "Risk for Violence, Self-Directed or Directed at Others (NANDA)+") OR (MH "Violence Risk (Saba CCC)+") OR (MH "Attitude to Death+") OR self-harm OR selfharm OR suicid* OR parasuicide OR “failed attempt” OR “failed completion” OR “self-directed violence” OR “lethal attempt” OR “death rehearsal” OR “courting death” OR “cry for help” OR “morbid rumination*” OR “self-injur*” OR “self-injurious behavio*” OR “self-murder” OR “successful attempt” OR “hastened death” OR “intentional self-murder” OR “self-destructive” OR “self-burning” OR “self-immolation” OR “self-inflicted lesion*” OR “self-poisoning” OR nssi</p> |
| <p>Intervention</p> | <p>(MH "Therapeutic Exercise+") OR (MH "Teaching: Prescribed Activity-Exercise (Iowa NIC)") OR (MH "Rehabilitation Exercise (Saba CCC)") OR (MH "Activity and Exercise Enhancement (Iowa NIC)+") OR (MH "Physical Education, Adapted") OR (MH "Physical Activity (Omaha)") OR (MH "Activities of Daily Living+") OR (MH "Teaching: Prescribed Activity-Exercise (Iowa NIC)") OR (MH "Motor Activity+") OR (MH "Dancing+") OR (MH "Games+") OR (MH "Activity Therapy (Iowa NIC)") OR (MH "Activity Care (Saba CCC)+") OR (MH "Balance Training, Physical") OR (MH "Activity and Exercise Enhancement (Iowa NIC)+") OR (MH "Exercise+") OR (MH "Exertion+") OR (MH "Horticulture") OR (MH "Physical Education and Training+") OR (MH "Transportation") OR (MH "Teaching: Prescribed Activity-Exercise (Iowa NIC)") OR (MH "Wheelchairs+") OR (MH "Step") OR (MH "Movement+") OR (MH "Ambulation Therapy (Saba CCC)") OR (MH "Walking+") OR (MH "Dancing+")</p> |

| | |
|--------------------|--|
| | OR (MH "Dance Therapy") OR (MH "Sports+") OR “physical activ*” OR “exercis*” OR “sport* OR danc* OR swim* OR martial art* OR walk* OR bicycling OR cycling OR wheeling OR “active transport” OR “active travel” OR “physical education” OR gardening OR “non-sedentary behav*” |
| Sensitive strategy | Cochrane – CINAHL (Lefebvre et al., 2020) |
| Total | 178 |

Appendix B: Reasons for Study Exclusion**Table 4***Reasons for Study Exclusion.*

| Study ID | Reason |
|--------------------------|--|
| Alegria (2014) | Self-harm (SH)/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where suicidal ideation (SI) is likely - and especially where they have excluded those with SI/suicide risk) |
| Bade et al. (2021) | SH/suicidal behaviour not a reported outcome (in a trial aimed at improving quality of life in people with cancer) |
| Baybutt et al. (2019) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Blumenthal et al. (2007) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Briggs (2016) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Callister et al. (2013) | Not a randomised controlled trial; rather, pre-post design (uncontrolled) |
| Daley et al. (2006) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Epstein (1986) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Färdig et al. (2011) | Not a physical activity intervention |
| Gerber et al. (2020) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Hoffman et al. (2010) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |

Table 4 (Continued)

| Study ID | Reason |
|----------------------------|---|
| Hoffman et al. (2011) | SH/suicidal behaviour not a reported outcome (and this study relates to Blumenthal et al. (2007), above) |
| Krogh et al. (2009) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Krogh et al. (2012) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk). |
| Lavretsky et al. (2021) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Legrand et al. (2020) | SH/ suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Martin et al. (2011) | Not clearly a physical activity intervention |
| Martiny et al. (2013) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| McGale et al. (2011) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Muhlmann et al. (2021) | Not a physical activity intervention |
| Neunhauserer et al. (2013) | SH/STB not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Parker et al. (2016) | SH/STB not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Perry et al. (2014) | Not a physical activity intervention |

Table 4 (Continued)

| Study ID | Reason |
|--------------------------|--|
| Rhodes et al. (2016) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Sadeghi et al. (2017) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Srinivasan et al. (2014) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |
| Stewart et al. (1994) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely) |
| Streeter et al. (2017) | SH/suicidal behaviour not a reported outcome (but this study relates to Nyer et al. (2018), which is an included study) |
| Streeter et al. (2020) | SH/suicidal behaviour not a reported outcome (but this study relates to Nyer et al. (2018), which is an included study) |
| Szuhany and Otto (2020) | SH/suicidal behaviour not a reported outcome (but we will take note of these trials and others like it where they were treating primary mental health conditions esp depression where SI is likely - and especially where they have excluded those with SI/suicide risk) |

Appendix C: Ongoing Studies**Table 5***Details of Ongoing Studies*

| Study ID | Title |
|--------------------------|--|
| Beck-Felts et al. (2020) | Suicide reduction in schizophrenia via exercise (SUnRISE): Study protocol for a multi-site, single-blind, randomized clinical trial of aerobic exercise for suicide risk reduction in individuals with schizophrenia |
| Brumby et al. (2011) | Reducing psychological distress and obesity in Australian farmers by promoting physical activity |
| Busch et al. (2019) | Effects of resistance training on depression and cardiovascular disease risk in black men: protocol for a randomized controlled trial |
| Currie (2019) | Trauma-informed interventions for cancer-risk behaviours among adults |
| Deady (2020) | Randomised controlled trial of an app-based intervention, Anchored, to support the mental health of Australians recently unemployed due to COVID-19 |
| Feldman et al. (2020a) | The impact of three distinct exercise types on fatigue, anxiety, and depression in parkinson's disease [Conference Abstract] |
| Giallo (2021) | Determining the effectiveness of working out dads to reduce mental health difficulties in fathers of young children |
| Huffman (2017) | Pragmatic collaborative care for cardiac inpatients with depression or anxiety |
| Janssen et al. (2017) | Behavioural activation by mental health nurses for late-life depression in primary care: a randomized controlled trial [Study Protocol] |
| Jarbin (2021) | Aerobic group exercise for adolescents with depression |
| Jaworska (2019) | Effects of aerobic exercise intensity on clinical & neural outcomes in depressed youth |
| Khani (2019) | The effect of exercise and meditation on post traumatic stress disorder in women with preterm delivery |
| McCann (2020) | Evaluation of a Tai Chi resilience training program on objective and subjective measures of post traumatic stress disorder severity |
| McKeon et al. (2019) | Mental health informed physical activity for first responders and their support partner: a protocol for a stepped-wedge evaluation of an online, codesigned intervention |
| Neves et al. (2018) | Aerobic exercise program with or without motor complexity as an add-on to the pharmacological treatment of depression - study protocol for a randomized controlled trial |
| Nilsson (2017) | Physical fitness and brain - Interventional study |
| Prado (2018) | Experience and health impact of university students accessing a digital nutrition, fitness and mindfulness platform |
| Rutherford (2020) | Levodopa and exercise for older adults with depression and psychomotor slowing |
| Scilingo (2017) | A multi-centre, parallel-group, randomised controlled trial to evaluate the NEVERMIND system in preventing and treating depression in patients with a severe somatic disease |
| Streeter (2018) | A randomized control trial treating depression with yoga and coherent breathing versus walking in veterans |
| Tsiouris et al. (2021) | An emotion-based online intervention for reducing anxiety and depression in cancer patients: Study protocol for a randomized controlled trial |
| Weinstock (2015) | Pilot study of adjunctive yoga for bipolar depression |
| Whitesell (2020) | Evaluation of Thiwáhe Gluwás' Akapi substance use prevention program |

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