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The role of physical activity in relation to later suicidal outcomes. Longitudinal exploration using quantitative prospective cohort design.

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Submitted in partial fulfilment of the requirements for the degree of Doctorate in Clinical Psychology

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This thesis has been as much about resilience as it has been about research. It has challenged me, but most importantly, it reminded me how much I enjoy learning.

Kochani Rodzice,

ten doktorat jest podpisany również Waszymi imionami. Dziękuję Wam za nieprzerwane wsparcie, za miłość, która nigdy nie stawiała warunków, i za nieustanne poczucie, że jestem otoczona siłą, na której zawsze mogę się oprzeć. Wasza wiara we mnie nauczyła mnie wierzyć w siebie, a Wasza miłość stała się fundamentem, na którym mogłam budować wszystko inne. To osiągnięcie jest tak samo Wasze, jak i moje.

Maja

Chapter 1: Systematic Review

Longitudinal exploration of physical activity and subsequent suicidal ideation and behaviours. A systematic review of cohort studies.

Prepared in accordance with the author's requirements for
Journal of Affective Disorders
https://www.sciencedirect.com/journal/journal-of-affective-disorders/publish/guide-for-authors

Abstract

Background: While physical activity (PA) benefits mental well-being, its longitudinal relationship with suicidal ideation and behaviour (SIB; including self-harm, suicidal ideation, attempts and death) in the general population remains unclear. This systematic review explored the possible longitudinal association between PA and subsequent SIB, including healthy and clinical populations across all ages.

Methods: PRISMA 2020 guidelines were applied. Six major databases were searched (CINAHL, PsycArticles, MedLine, PsychInfo, Embase and Web of Knowledge) until the 4th of August 2024. Only studies using a prospective cohort design, written in English or Polish, which measured the PA at baseline and SIB at follow-up, were included. The JBI Critical Appraisal Checklist for Cohort Studies was used to appraise the methodological quality of each eligible study. This review used narrative synthesis.

Results: 14 papers reporting on 15 studies met the review criteria and were included in the review. These studies included 2,631,038 participants, with a follow-up period ranging from 7 days to 45 years. Seven studies reported a significant relationship between higher engagement with PA and lower later SIB. One study reported higher engagement with PA and higher later SIB in an eating disorder context. PA was more likely to be negatively associated with later suicidal attempts and death by suicide than when the outcome was suicidal ideation. No significant interactions were found for PA and subsequent self-harm.

Discussion: There was considerable heterogeneity between study measures and cohort populations. Future research should use validated, objective measures of PA. PA in a group setting was more frequently associated with less later SIB than individual PA.

Other: Funding: None. The review was conducted as part of the lead author's Doctorate in Clinical Psychology (University of Glasgow), submitted in partial fulfilment of the degree requirements. Prospero ID: CRD42024562803.

Keywords

Physical Activity, Suicide, Suicidal Ideation, Suicide attempt, Death by suicide, Self-harm, Self-injury, Review

Introduction

More than 720,000 people die due to suicide each year, as reported by the World Health Organisation (WHO, 2024). Suicide, defined as 'death caused by self-directed injurious behaviour with intent to die as a result of the behaviour' (National Institute of Mental Health, 2025) is recognised as a major global health issue (WHO, 2024). The number of actual suicides is estimated to be higher than the reported statistics due to ongoing stigma, misclassification and limits to record keeping (Lovero et al., 2023). Suicidal attempts take place significantly more often than deaths by suicide, with the estimates suggesting that for every suicide death, there are 20 suicide attempts (WHO, 2021). Worldwide, people who report suicidal ideation - a desire to end one's life - within the last year have a 15% - 20% higher prevalence of suicide (Borges et al., 2010). These ratios suggest that identifying people with suicidal ideation and behaviour (SIB) is a key component of suicide prevention (Bilsen et al., 2018). Based on the needs of suicide prevention highlighted above, strategies to prevent suicide are required.

The reasons for suicide are multi-faceted and are a combination of environmental, biological, social, cultural, and psychological factors (WHO, 2021). The Integrated Motivational-Volitional model (IMV; O'Connor, 2011 & O'Connor & Kirtley, 2018) offers an exploration of these factors and their relationship in the development of SIB. The model includes a stress-diathesis component, which posits that stress interacts with underlying vulnerabilities and cognitive appraisals to increase the propensity to suicide risk. The IMV model consists of three phases. The first phase (pre-motivational) encompasses the individual's biological and cognitive pre-dispositions. The second phase (motivational) focuses on psychological processes that lead to SIB development. The key drivers of the motivational phase are defeat and entrapment. The transition from defeat to entrapment to SI is consequential in the motivational phase; however, it is not inevitable as it is moderated by threat to self (TSM) and motivational moderators (MM). TSM moderate the relationship between defeat and entrapment; TSM includes coping abilities, problem-solving skills, ruminative processes and memory biases (Souza et al., 2024). MM moderates the relationship between entrapment and SI; MM includes thwarted belongingness, perceived burdensomeness, social support, and resilience. The third (volitional) phase reports the transition from SI to SB.

According to the IMV model, ones coping strategies can decrease or increase the chances of developing later SIB, specifically by impacting the relationship between defeat and entrapment. The evidence of the role of coping in the context of the IMV model is still limited (Souza et al., 2024), but coping flexibility - the ability to change coping strategies when needed to manage stressful situations - was found to significantly buffer the defeat - entrapment relationship cross-sectionally (Bannister, 2018). On the other hand, maladaptive coping (e.g. rumination, venting/emotional discharge, and confrontation) was not found to significantly impact the defeat-entrapment relationship (Zortea et al., 2020). Gomez-Tabares et al., (2022), among others, have also highlighted that SIB were negatively correlated with types of coping such as social support, emotional expression, problem-solving, cognitive restructuring and positively associated with problem avoidance and positively correlated with social withdrawal, self-criticism and desiderative thinking. Similarly, physical activity can be viewed as coping mechanism that helps with, e.g. problem-solving skills, self-regulation (Mikkelsen et al., 2017) and supports cognitive health (Kraal et al., 2021).

Caspersen et al. (1985) describe physical activity (PA) as 'any bodily movement produced by skeletal muscles that results in energy expenditure'. Physical activity has been shown to lessen depression symptoms (Recchia et al., 2023; Noetel et al., 2024), post-traumatic stress symptoms (Bjorkman et al., 2022); anxiety symptoms (Aylett et al., 2018), psychosis symptoms (Firth et al., 2015), sleep difficulties (Amiri et al., 2021), chronic somatic illnesses (Pedersen et al., 2015) and alcohol abuse (Cabe et al., 2021; Lardier, 2021), all of which are recognised risk factors of SIB. A systematic review by Vancampfort et al. (2018) of cross-sectional studies, observed a significant negative, association between PA and SI levels. Alternatively, Fabiano et al., (2023) and Fabiano et al., (2024) both explored the relationship between physical activity and SIB among people with mental and medical disorders with conflicting findings. Fabiano et al. (2023) reported that suicide attempts were significantly reduced in participants randomised to exercise groups rather than inactive controls. However, no significant findings were reported when SI was considered an outcome measure. Similarly, Fabiano et al. (2024) reported a significant association between PA and fewer likely suicidal attempts, with no significant results reported for the relationship between PA and SI and death by suicide.

These findings suggested that PA might have a different association with SIB depending on the type of SIB.

There is a need for longitudinal exploration using a prospective observational design to clarify if PA significantly impacts SIB over time. As Fabiano et al, (2023, 2024) focused their reviews only on clinical populations, similar research involving non-clinical groups would help determine whether the effects of PA vary between different populations. Additionally, although PA reduces symptoms of known risk factors for suicidal ideation, its direct effect remains unclear and requires further investigation.

Current study

This review was the first to explore the longitudinal relationship between physical activity (PA) and later suicidal ideation and behaviours (SIB) of prospective cohort studies across people with and without mental/physical health conditions. This review explored if PA and later SIB were significantly associated using a broad definition of suicidal behaviours that included self-harm, suicide attempts, and death by suicide. Self-harm is defined as 'intentional self-poisoning or self-injury, regardless of motivation or purpose' (NICE, 2024). Similar robust exploration aligned with previous research on SIB (e.g., McClelland et al., 2020) as it allowed to capture a full spectrum of suicidality. Therefore, this review aimed to explore available evidence to gain insight into the association between PA (predictor) and later SIB (outcomes). To do so, this review had the following research questions:

1. What prospective associations, if any, exist between physical activity and later suicidal ideation and behaviours?
2. Which types of physical activity and suicidal ideation and behaviours, if any, affect the relationship between physical activity and later suicidal ideation and behaviours?
3. Which types of individual characteristics, if any, affect the relationship between physical activity and later suicidal ideation and behaviours?

Methods

Registration

This review was registered on International Prospective Register of Systematic Reviews (Prospero) and approved on 02/07/2024 (Prospero ID: CRD42024562803). Please see Prospero application in Appendix A. Prospero was updated once on 04/02/2025.

Eligibility Criteria

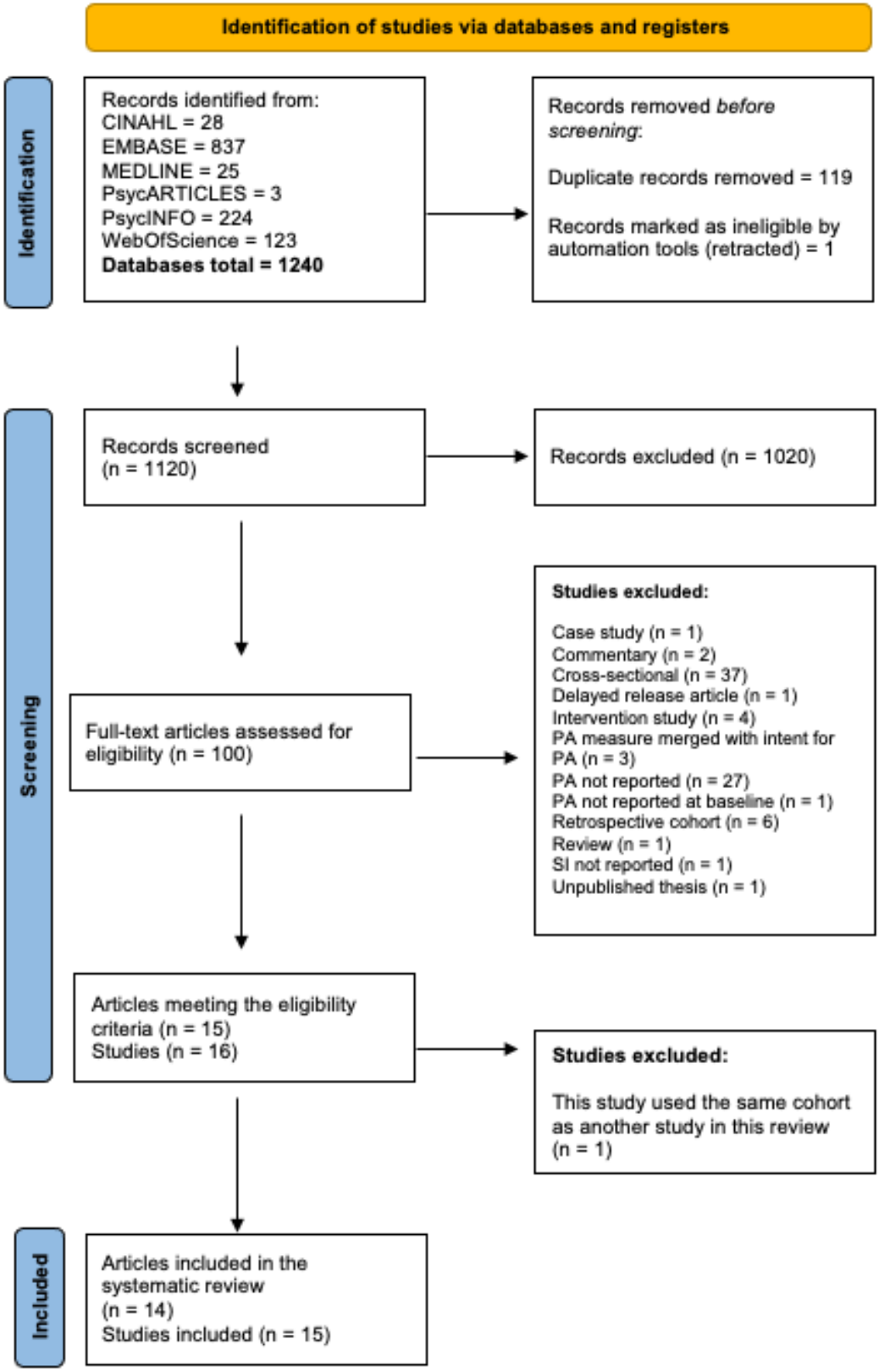
The review focused on the longitudinal association between PA and later SIB in clinical and non-clinical populations. The inclusion criteria required studies to be (I) an empirical paper, (II) written in English or Polish, (III) peer-reviewed, (IV) quantitative cohort studies, (V) reporting a prospective design (i.e. where PA was measured as a predictor of later SIB at a future time point) and (VI) reported of the relationship between PA at the baseline and SIB at follow up, (VII) reporting any effect size (VII) PA and later SIB assessments were both measured directly. Studies reporting suicidal ideation and all forms of suicidal behaviours (including death by suicide, suicide attempt and non-suicidal self-harm) were included. Equally, papers which met the inclusion criteria were excluded if I) they were a review paper and II) they explored assisted suicide. The lead and senior authors discussed any uncertainty regarding the inclusion or exclusion criteria until an agreement was reached.

Research Strategy

This review followed PRISMA 2020 guidelines for developing systematic review (Page et al., 2021). Please see completed PRISMA checklist in Appendix B. Six major psychological and medical databases (CINAHL, PsycArticles, MedLine, PsychInfo, Embase and Web of Knowledge) were used to search for papers on the 4th of August 2024. Subject heading terms (e.g., MeSH) were utilised in the databases to capture various terminologies used within the papers, however, all search terms stemmed from: (I) “exercise” OR “physical activity” OR “sports” AND (II)” suicide” OR “suicidal ideation” OR “self-injury” OR “self-harm”. For a detailed list of search terms for each database see Appendix C.

Phase 1 screening involved title and abstract screening. The first author conducted the initial screening of articles, with 20% of papers at each phase being independently screened for eligibility by the second reviewer. The second reviewer was independent of the project, held an MSc in psychology, and was a final-year clinical psychology trainee. In Phase 1, there was an 87.8% concordance rate prior to discussion between reviewers. All disagreements were resolved through discussion, achieving 100% post-discussion concordance. Phase 2 involved screening whole manuscripts. The concordance rate prior to the discussion decreased to 80% in Phase 2. In phase 2, the main discrepancies were based on the overinclusion of articles by the second reviewer due to the inclusion of interventional rather than cohort studies only.

Figure 1. *PRISMA 2020 flow diagram*



Data extraction

The author created a data extraction sheet encompassing relevant study information. These included authors, year, location, study aim, study design, methodology, cohort type, key findings and exposure and outcome measures (Table 1). Effect sizes and covariates used in adjusted models for each study were elaborated on in Appendix D.

Quality Assessment

We used JBI checklist for cohort studies (Joanna Briggs Institute, 2020) to critically appraise the studies in this review. The JBI tool was selected due to its application of a 4-point scale (yes/no/unclear/not applicable), which gave in-depth and more nuanced understanding of the evaluated studies relative to binary format response option scales. JBI also included specific questions about the validity and reliability of predictor and outcome measures. In psychological research, which can often rely on subjective self-measures, these questions give an insight into the appropriateness of measures used. The lead author completed quality assessments for all manuscripts, and the second reviewer reviewed 30% (n= 5) of the papers. All disagreements between reviewers were resolved by a discussion.

Based on the methodology used in previous studies (e.g. Butsling et al., 2024) overall rating for each study was obtained by calculating the % of 'yes' answers across all JBI questions (11 questions) where the below percentage formula was utilised:

Percentage Score = (Number of "Yes" answers ÷ Number of all JBI questions) × 100

Studies scoring above 70% were at low risk of bias, those scoring between 50% - 69% were deemed to be at moderate risk of bias, and those scoring below 50% were categorised as being at high risk of bias (Butsling et al., 2024; Moola et al., 2024). All the studies, regardless of the reported risk of bias, were included in this systematic review.

Table 1. *Summary of studies included in review including sample demographics and characteristics, study methods, measures used, results and quality appraisal scores (%).*

Study Country QA	Sample demographics at baseline (n, % female, age)	Cohort type	Follow-up time	Physical Activity measures	Suicide measures	Results
1. Batty et al. (2023); Finland; Europe QA = 55%	N = 2613 0% female Age (mean) = 45.4 years)	Former professional athletes that represented Finland in Olympics	up to 45 years	Professional sport participation (yes/no); 'yes' on this measure was inclusion criteria for this study.	Death by suicide: Death certificate. Suicide attempt: Hospital records	Unadjusted: Not available. Adjusted: Participation in sports did not significantly increase the risk of death by suicide for a whole sample. However former American football players exhibited a significantly lower risk of suicide at follow-up than controls ($p < 0.01$)
2. Brailovskaia et al. (2022), Germany; Europe QA = 64%	N = 237 79.4% female Mean (SD) age = 22.85 (4.05)	Germany; university students	3 years	Frequency. “How frequently do you engage in physical exercise (e.g., swimming, cycling, jogging)?” 1-item; validated;	Suicidal ideation and/or suicide attempt: “Have you ever thought about or attempted to kill yourself?” 1-tem; SBQ-R (Osman et al., 2001)	Unadjusted: The basic relationship between physical activity at baseline and SIB at follow-up was significant ($p < .001$). Adjusted: This direct effect was no longer significant when positive mental health was included in mediation model.
3. Dugas et al. (2012); Canada; North America QA = 34%	N = 1293 54% female 12-13 years old	High school students	8 - 9 years	Participation in sports teams (yes/no) in and out of school. 1-iteam; not validated.	Suicidal Ideation: “In the past 12 months, how often did you feel suicidal?” 1-item; not validated.	Unadjusted: Significant negative correlation for participation in sports in 8th grade and suicidal ideation in adulthood ($p = 0.002$) Adjusted: Significant negative correlation for participation in sports

						in 8th grade and suicidal ideation in adulthood (p = 0.002)
4. Garcia-Hermos et al. (2023); USA; North America QA = 55%	N = 20 745 56.8% female Mean age = 15.35	High school students without suicidal ideation and depression at baseline; White 4997 (71.6%); Black 1412 (20.2%)	21 - 24 years	Frequency. 3-item; validated (Gordon-Larsen et al., 2004)	Suicidal ideation: "During the past 12 months, did you ever seriously think about committing suicide?" 1-item with a dichotomic yes/no response option; not validated.	Unadjusted: Not available. Adjusted: Adolescents who met physical activity guidelines had a lower risk of suicidal ideation in adulthood compared to those who did not meet any guidelines (p = 0.049)
5. Hogstrom at al. (2016); Sweden; Europe QA = 73%	N = 1 345 564 0% female Mean (SD) age = 18.3 (0.8)	Swedish men conscripted to military	Mean FU time = 28.8 years	Aerobic fitness. Electrically braked ergometer cycle test.	Suicidal death: National Registers	Unadjusted: Men in the highest fifth of aerobic fitness had a 59% lower risk of suicide compared to those in the lowest fifth. (P < 0.001) Adjusted: Those in the highest fifth of aerobic fitness had a 37% lower risk of suicide compared to the lowest fifth (P < 0.001)
6. Jee et al. (2011; South Koea; Asia QA = 64%	N = 1 234 927 36% female Mean (SD) age = 46.56 (11.6)	Korean population cohort: participant with low BMI, short stature, cancer, liver disease, CVD, or a	14 years	Exercise participation (yes, no); 1-item; binary; not validated.	Suicide death: National Registers.	Unadjusted: Not available. Adjusted: No significant association between exercise and suicide mortality.

		respiratory disease prior/at baseline excluded				
7. Latina et al., (2022); Sweden; Europe QA = 64%	N = 998 48% female Mean (SD) age = 13.94 (0.74)	High school students	1 year	Participation in organized sport. 2-item; not validated.	Self-harm: A shortened version of the original Deliberate Self-Harm Inventory translated into Swedish by Lundh and colleagues (Lundh et al., 2007).	Unadjusted: Not reported. Adjusted: No significant direct association between sport participation at baseline and later self-harm. Significant indirect effect of sport participation on self-harm mediated through self-esteem: (p = .02)
8. Paffenbarger et al., (1994); USA; North America QA = 64%	N = 21 569 0% female 35 - 74 years old	Harvard alumni	23 - 27 years	Frequency. Physical activity index was computed based on all types of physical activity engagement.	Suicide Death: Death certificates obtained from state and other legal registries.	Unadjusted: Not available. Adjusted: Not statistically significant across any PA metric
9. Perez et al., (2024); USA; North America QA = 45%	N = 52 72.3% female Age range 30+/- 10	Iowa State University students and wider community with a current/prior MDD diagnosis;	7 days	The activPAL micro, an accelerometer and inclinometer, assessed PA and sedentary time.	Suicidal Ideation: MINI: versions 6.0.0 or 7.0.2. MINI. Validated; multi-item.	Unadjusted: No significant results for the whole sample. Adjusted: No significant results for the whole sample. Light ambulatory physical activity during a current major depressive episode had a significant association with lower odds of suicidal ideation (SI) (p = 0.018)

10. Smith et al., (2013) [Study 2]; USA; North America QA = 45%	N = 171 80.1% female M (SD) age = 19.25 (3.21)	University undergraduates. Ethnicity: 83.4% non-Hispanic and 16.6% Hispanic. The racial composition: 87.3% Caucasian, 9.1% African American, 3% Asian American, and 0.6% American Indian/Alaskan Native.	3 to 4 weeks	Frequency of compulsory PA. OEQ EDEQ-4	Suicidal Ideation: ACSS	Unadjusted: Not available. Adjusted: Over-exercise (measured by EDEQ) at the baseline significantly predicted suicidal ideation at follow-up (p=0.05)
11. Smith et al., (2015); USA; North America QA = 45%	N = 179 48.6% female M(SD) age = 18.85 (0.92)	University undergraduates: The ethnic composition was predominantly non-Hispanic (98.7%). The racial composition was: 88% Caucasian, 2.7% African	4 - 5 weeks (average time between Time 1 and Time 2 was 31.01 days [SD = 5.57])	Frequency of compulsory PA. OEQ	Suicidal Ideation: ACSS	Unadjusted: Not significant correlations between baseline over-exercising and later SI. Adjusted: Not available.

		American, 8.7% Asian American, and .7% did not report a race.				
12. Taliaferro et al., 2011; USA; North America QA = 64%	N = 1608 54.6% female 12.8 years old	Middle and HS students. The data for this study came from Project EAT (Eating Among Teens)-I and Project EAT-II (31, 32).	5 years	1-item adapted from the Centers for Disease Control and Prevention's Youth Risk Behavior Survey: "During the past 12 months, on how many sports teams did you play?; validated	Suicidal ideation and attempt: "Have you ever thought about killing yourself?" (1 item) "Have you ever tried to kill yourself?" (1 item). Validated.	Unadjusted: Not significant PA and later SIB association. Adjusted: Not significant PA and later SIB association. Continuous PA participation during both T1 and T2 significantly reduced the odds of SIB at follow-up. Discontinuing PA after T1 significantly increased the odds of suicide attempts at T2
13. Themelis et al., (2023); UK; Europe QA = 64%	N = 524 80.15% female M(SD) age = 39.9	Adults with chronic pain; "89.89% White, 4.39% Asian/Asian British, 3.24% Multiple ethnic groups, and 2.10% Black/African/ Caribbean/Black British."	6 months	Physical activity levels in the past 7 days; IPAQ	Suicidal Ideation: SBQ-R (Osman et al., 2001); multi-item; validated.	Unadjusted: No significant interaction between baseline PA and follow up SIB found. Adjusted: Not available.
14. Zelkowitz et al., (2020) - study 1; USA; North America	N = 251 79.5% female M(SD) age = 19.07 (1.23)	Private university students; 65.7%	8 weeks	Frequency of compulsive exercise.	Self-harm: SITBI	Unadjusted: Not significant. Adjusted: The relation between baseline PA and SIB at follow up was not significant.

QA = 55%		Caucasian, 11.2% African American, 24.3% Asian or Asian American, 7.6% Hispanic or Latino, and 1.6% another		EDE-Q		
15. Zelkowitz et al., (2020) - study 2; USA QA = 55%	N = 307 88.8% female M(SD) age = 24.65 (3.58)	Community: 72.53% Caucasian, 14.31% Hispanic or Latino, 12.19% African American, 6.58% Asian or Asian American, 2.71% American Indian, and 1.55% another	4 weeks	Frequency of compulsive exercise. EDE-Q	Self-harm: SITBI	Unadjusted: Not significant. Adjusted: Not significant PA – later SIB

Note: Please refer to first column for assigned number for each study.

QA = Quality Appraisal.

SBQ-R = The Suicidal Behaviours Questionnaire revised (Osman et al., 2001)

OEQ = The Obligatory Exercise Questionnaire (Thompson & Pasman, 1991

EDEQ-4 = Eating Disorder Examination Questionnaire-4 (Feirburn & Beglin, 1994);

ACSS = Acquired Capability for Suicide Scale (Bender et al., 2011, Ribeiro et al., 2014).

EDE-Q = The Eating Disorder Examination-Questionnaire-6.0 (Fairburn & Beglin, 2008)

SITBI = Self-Injurious Thoughts and Behavior Interview (Nock et al. 2007)

IPAQ = The International Physical Activity Questionnaire (Craig et al. 2003)

Results

Search Results

The initial search yielded 1240 results. After removing the duplicates and excluding articles based on the phase 1 screening (title and abstract), the full text versions of 100 articles were retrieved. Of these, 85 articles were subsequently excluded, leaving 15 articles reporting on 16 studies meeting the systematic review criteria. However, Aberg et al. (2014) was excluded due to the use of the same cohort as Hogstrom et al. (2016). Hogstrom et al., (2016) was favoured over Aberg et al. (2014) due to a larger sample size and, thereby, more robust data, and the inclusion of people with a history of ongoing mental health difficulties, resulting in findings that can be more generalisable to the broader population. Additionally, Zelkowitz et al. (2020) reported two studies within the same paper. These will be referred to as Zelkowitz et al., 2020 study 1 and study 2 as in the original paper. Figure 1. presents the PRISMA flowchart for the study selection with the reasons for study exclusions. The 15 studies will be referenced throughout this review by their assigned numbers (1–15), which can be found in Table 1. Studies were published between 1994 and 2024. The follow-up period ranged from 7 days (9) to 45 years (1). The median follow-up period across 15 studies was 3 years. Collectively, these 15 studies included a total of 2,631,038 participants.

Narrative summary of study findings

This section discusses all 15 studies included in the review. The results are presented as follows:

I. Identification of PA and later SIB relationship
II. Evidence of PA - later SIB relationship in adjusted and unadjusted models
III. PA and SIB types affecting PA - later SIB relationship
IV. Participants' demographic affecting PA - later SIB relationship
V. Methodological quality

Identification of PA and SIB relationship

Eight of the 15 studies reported a significant relationship between engagement with PA and later SIB. Nine studies explored suicidal behaviour (SB), which included death by suicide, suicide attempt, and self-harm as outcomes. Four of these studies (1, 2, 5, 12) reported significant findings indicating that more PA was associated with lower subsequent suicidal deaths and attempts but not self-harm. Eight studies explored suicidal ideation (SI) as an outcome; five of these studies (2 - 4, 9, 10) reported significant findings. Of these (2,3,4,9), studies showed that PA was negatively associated with later SI, and one study (10) reported that more exercise (in the context of compulsive exercise and eating disorders; ED) was associated with later higher levels of SI. One study (2) measured SIB together using one item to measure both. Therefore, for this study, it is not possible to distinguish if the PA at baseline was associated with later SI or SB or both.

Adjusted and unadjusted models

Seven studies (2, 3, 5, 9, 12, 14, 15) reported both adjusted and unadjusted associations between PA and later SIB. Five of these studies (2,3,5,9,12) reported a significant interaction between higher PA and lower later SIB. Only one study (2) found that the significant interaction in the unadjusted model became non-significant in the adjusted model. In this adjusted model, positive mental health significantly moderated the relationship between PA and later SIB, with the direct effect of PA on later SIB no longer present. The remaining four studies (3,5,9,12) reported that the prospective PA - SIB relationship remained significant after controlling for various covariates (for a list of covariates, see Appendix D). Six studies (1,4,6,7,8,10) reported adjusted results only, of which three (1,4,10) reported a significant interaction between PA and later SIB. From these, one study (10) uniquely showed that higher levels of PA were associated with higher levels of later SIB and two other studies showed that higher levels of PA were associated with lower levels of later SIB. Two studies (11, 13) that included only unadjusted models did not report any significant PA - later SIB interaction.

PA Measures characteristics

To understand the association between PA and later SIB in more detail, we explored how this relationship varied depending on the PA measures used across studies. These PA measures were divided into subcategories of team/organised PA and frequency/engagement with PA. Thirteen different measures of PA were utilised across 15 studies. Only two studies relied on the use of objective measures of PA, and they employed a cardiovascular fitness test (5) and an inclinometer device (9). Both studies reported significant associations between higher PA and lower later SIB.

PA as Team/Organised Sports

Four studies (1, 3, 7, 12) used participation in team/organised sports as a measure of PA. All these studies found some significant relationship where participation in organised sport at baseline was associated with a lower SIB at follow-up. Study 12 found that discontinuing engagement with sports after middle school increased the risk of suicide attempts in high school and that participation in sports only during middle school (and not continuing in high school) was associated with an increase in suicide attempts in high school. The remaining two studies did not report a significant association between PA and SIB for the whole sample; however, significant associations were reported for subsamples. Specifically, among 13-14-year-olds, sports team participation was significantly associated with lower SI during adulthood; that effect was not found for adolescents older than 14 (3). Also, another study (7) reported a significant association between sports participation and lower levels of later self-harm, but only when self-esteem mediated the relationship for a sample of high school students. For adults, study 1 reported that professional participation in team sports was associated with a significantly lower risk of subsequent suicide death for a subsample of former American football players. No other subsample (including former boxers, wrestlers and soccer players) reported a significant association.

Among individual exercise, five (2, 4, 5, 9, 10) out of eleven studies reported significant findings, where four studies (2,4, 5, 9) showed higher levels of PA were associated with lower later SIB and one study (10) showing that higher levels of PA were associated with higher later SIB.

Frequency/engagement in exercise

Nine studies (2, 4, 6, 8, 10, 11, 13 - 15) investigated the frequency and overall engagement with PA, and they used seven different measures of PA frequency. The Eating Disorder Examination-Questionnaire-6.0 (EDE-Q, Fairburn & Beglin, 2008), which included questions on PA frequency, was the most used measure featured in three studies in this review (10, 14, 15). Only one study (10) used EDE-Q, and it reported a significant association between a higher frequency of compulsive exercise and higher levels of later SI. The Obligatory Exercise Questionnaire (OEQ; Thompson & Pasman, 1991) was used in two studies (10,11), and no analysis that used this questionnaire reported a significant interaction between PA and later SIB. Three studies (2, 4, 11) used different validated PA measures, with two of these studies (2, 4) showing a significant association between higher frequency of PA and lower levels of later SIB. However, in study 2 that relationship was no longer significant when positive mental health was included in the mediation model. Two studies (6, 8) did not include information about the validity of their PA measures and did not report any significant results on the PA-later SIB association.

Suicidal ideation and behaviours

The following results section reports the association of PA and later SIB based on SIB measures such as death by suicide, suicide attempt, suicidal ideation, and self-harm.

Death by suicide

Death by suicide was reported by four studies (1, 5, 6, 8) using the national records. Three of the studies (1, 5, 8) included men only, and only one study (6) included participants of different genders. Across these four studies, one study (5) identified a significant association where higher PA at the baseline was associated with a lower risk of death by suicide at the follow-up. The remaining three studies reported no significant association between PA - later SIB for the whole sample. However, study 1 reported that engagement with team sports was associated with a significantly lower risk of later suicide for a subsample of former American football players.

Suicide attempt

Suicidal attempts were measured in two studies (1, 12) by two different measures. Study 1 used hospital records, and study 12 relied on a 1-item validated measure to assess suicide attempts. Both studies showed some significant association between higher PA and a lower risk of later suicide attempts. Specifically, the significant findings were reported for a subsample of American football players (1) and for adolescents who participated in sports teams both in middle and high school (12).

Suicidal ideation

Suicidal ideation was measured in seven studies (3, 4, 9 - 13) across six different measures, all using self-report measures. The Acquired Capability for Suicide Scale (ACSS; Bender et al., 2011; Ribeiro et al., 2014) was used by two studies (10, 11). Study 10, which used ACSS, reported a significant association between higher levels of compulsive exercise and higher later SI. The other five studies used multi-item validated measures (9, 13) or 1-item validated measures (12), and two studies did not report on the validity of their 1-item measure (3, 4). Only three of these studies (3, 4, 12) reported a significant relationship between higher levels of PA and later suicidal ideation.

Suicidal attempt and ideation

One study (2) uniquely used a single item from a wider validated measure that encompassed both suicidal ideation and attempts. They found a significant association between higher physical activity and a lower likelihood of later SIB in unadjusted models. However, this association was no longer significant when positive mental health was included as a mediator. Since the study combined both aspects of SIB, it is unclear whether the findings specifically relate to suicidal ideation or suicide attempts.

Self-harm

Self-harm was measured in three studies (7, 14, 15) using two different measures. All studies used multi-item, validated measures to assess self-harm. None of the studies found a significant interaction between PA at baseline and self-harm at the follow-up. However, two studies (14, 15) specifically aimed to explore the association of compulsive overexercising in the context of compulsive exercise in ED with later SB, with no significant correlation between these measures reported.

Participants' demographic characteristics

To explore the association between PA and later SIB further, we explored this association in relation to demographic factors – age, gender, geographic location, ethnicity and cohort types.

Age

Across the four studies including participants under the age of 18, three (3, 4, 12) reported a significant association between more engagement with PA and lower later SIB. In contrast, among studies including adults (18+), only four (1, 2, 5, 9) out of eleven studies reported a significant association between PA and later SIB, with one study (10) showing significant interaction between higher levels of over-exercising and higher levels of later SIB. The studies, which included people under 18 years old, were more likely to find a significant association between higher engagement in PA and lower levels of later SIB compared to studies that included participants over the age of 18.

Gender

Twelve studies included men and women (2 – 4, 6, 7, 9 -15), with three studies including men only (1, 5, 8). Half of the studies (2 - 4, 9, 10, 12), which included men and women, reported a significant association between PA and later SIB. Of the men only studies, two studies (1, 5) reported a significant association between more PA and lower levels of later SIB. One of these men only studies (5) had the largest sample size across all the studies in this review and was the largest study that reported on a significant association between PA at baseline and later SIB. It was also the only study

that relied on objective measures (e.g. not relying on self-report) of both PA (aerobic fitness measured by ergometer cycle test) and later SIB (death by suicide from national registry). Study 6 was the largest cohort, which included men and women, and it did not report any significant associations of PA and later SIB for any gender.

Geographic region

All studies were based in high-income countries (see Table 1). Only one study (6) was based in Asia and did not report any significant association between PA and later SIB. All the other studies were based in western countries. Nine cohorts were recruited from North America (3, 4, 8 - 12, 14, 15) followed by five in Europe (1, 2, 5, 7, 13). Five (3, 4, 9, 10, 12) of the nine studies conducted in North America reported a significant relationship between physical activity and later SIB, with four (3, 4, 9, 12) of these studies reporting that more engagement with PA was associated with less later SIB. One study (10) uniquely reported on a significant relationship between higher levels of PA associated with higher levels of later SIB. Three (1, 2, 5) of the five studies conducted in Europe, reported a significant interaction of higher levels of PA and later lower levels of SIB.

Ethnicity

Ethnicity was reported in six studies, and apart from one study (13) which was based in UK, all studies reporting ethnicity were based in the USA (4, 10, 11, 14, 15). In the studies reporting ethnicity, most of the participants were of Caucasian/white descent, accounting from 65.7% (14) to 89.9% (13) of the participant sample. Due to variability in outcome measures and participant demographics, no inferences could be made about the role of ethnicity in the relationship between PA and SIB.

Cohort types

Four studies (2, 10, 11, 14) were conducted with university students, four studies with secondary school students (3, 4, 7, 12) and three studies with the general population (6, 9, 15). The rest of the studies included Harvard University alumni (8), Olympians (13), military members (5) and adults living with chronic pain (13). Three (3, 4, 12) out of four

studies which included secondary school pupils reported significant association between higher levels of PA and lower levels of later SIB. Similarly, of the studies which reported on university students, two (2, 10) out of four yielded significant interaction terms. Within these studies study 2 reported that higher levels of PA were associated with lower levels of later SIB whereas study 10 reported that higher levels of PA were associated with higher levels of later SIB. Of three studies that included general population only one (9) found significant association between higher levels of PA and lower levels of later SIB. Of the remaining four studies (1, 5, 8, 13) it was not possible to state if there was any pattern of significance due to the unique type of these cohorts represented in single studies however two of these studies (1, 5) showed significant association between higher PA and lower later SIB.

Pre-existing mental health

Depression and depressive symptoms were the most frequently measured pre-existing mental health conditions across the studies, with eight studies (1-4, 7, 9, 12, 13) measuring these symptoms at baseline. From these studies, only one (9) recruited participants specifically with a depression diagnosis, with the remaining studies routinely assessing for depressive symptoms across a general sample. Six studies (1-4, 9, 12) measuring depressive symptoms at baseline reported on a significant association between higher PA and lower later SIB. Two (4, 12) of the studies explicitly stated that they controlled for depression in their adjusted models.

Four other studies (10, 11, 14, 15) reported on participants' disordered eating behaviours at the baseline. One study (10) uniquely reported a significant association between higher levels of PA and higher levels of later SIB. Information on pre-existing mental health conditions was summarised in Appendix D.

Socioeconomic status (SES)

SES was measured in nine studies (1, 3 - 7, 9, 12, 13), however diverse indicators of SES were employed. Measures included the longest held job (1), mother’s education, (3), parental income (4), a combination of annual income, highest achieved education,

and disability pension (5), a combination of annual income and assets (6), parental employment (7), employment or university student status (9), combination of parental education, employment and eligibility for public assistance (12), educational attainment and employment status (13). SES details for each study can be accessed in Appendix D.

Across the fifteen studies included in the review, researchers did not stratify the relationship between PA and later SIB by SES. This lack of stratification prevented a direct comparison between high- and low-SES participants, and therefore limiting the interpretation of the results. SES was handled in four ways. One study (6) examined SES as an independent predictor of SIB, revealing a clear gradient; however, it did not present PA-later SIB estimates within those strata. In five studies (1, 3 - 5, 12), researchers included SES only as a confounding variable in the analysis, without reporting their individual coefficients. The remaining eight papers either omitted SES entirely (2, 8, 10, 11, 14, 15) or collected this information but did not use it analytically (9, 13).

Four studies (1, 7, 9, 13) explicitly reported their samples as primarily high-SES based on the qualitative measures. Among the eight remaining studies that did not report SES, five recruited only university students (2, 10, 11, 14) or Harvard alumni (8), groups generally considered high-SES due to their high educational attainment. Therefore, nine (1, 2, 7 - 10, 11, 13, 14) out of the fifteen studies in this review likely involved high SES cohorts. Within these nine studies, three (1, 2, 9) found that higher physical activity (PA) was associated with lower later SIB, while one study (10) reported the opposite pattern. The remaining five studies showed no significant association.

Methodological quality assessment of included studies

The risk of bias score (%) for each study is presented in Table 1. A detailed appraisal for each study based on JBI (2020) can be found in Appendix E. One study was at low risk of bias; ten studies were classified as moderate risk of bias, and four studies were at high risk of bias. The main source of bias was the lack of a control group in most

cohort studies in this field. Therefore, the questions about the compatibility of the two groups and whether PA was measured consistently across them were not applicable. Additionally, some cohorts were not free of the outcome (SI and self-harm) at the baseline. Studies scored highest on identifying confounding variables and stating strategies to address them. There was an 80% agreement between reviewers during the quality assessment. All disagreements were resolved through discussion with 100% agreement after the discussion. The main discrepancy involved item 6 on the JBI tool, which assessed if participants were free of the outcome (SIB) at the study's onset.

The singular study (5) of low risk of bias reported a significant finding where higher levels of PA were associated with lower levels of later SIB. This was the only study that relied on objective measures of both the predictor (PA measured through ergometer cycle test) and the outcome (SIB measured through national registers of suicide death) variables. Ten studies were classified as including moderate risk of bias (1, 2, 4, 6 - 8, 12 - 15). Of these, four studies (1, 2, 4, 12) reported significant results where higher levels of PA corresponded with lower levels of later SIB. Four studies (3, 9 - 11) were classified as having a high risk of bias. Of these, two (3, 9) reported a significant association between higher levels of PA and lower levels of later SIB. One study (10) uniquely reported a significant association between higher levels of PA and higher later SIB.

Two studies (5, 9) in this review included objective measures of PA (ergometer cycle test & accelerometer and inclinometer, respectively), with both studies reporting significant findings where higher levels of PA were associated with lower levels of later SIB. By comparison, thirteen other studies in this review used subjective, self-report measures of PA. From these, six studies (1-4, 10, 12) reported a significant association between PA and later SIB, and seven studies (6 - 8, 11, 13 - 15) reported that the association between PA and later SIB was not significant.

Discussion

The current review is the first to explore associations between PA and SIB among both those with and without mental health difficulties. This review aimed to narratively synthesise prospective cohort studies that investigated the role of PA in relation to later SIB (encompassing death by suicide, suicide attempt, suicidal ideation and self-harm). Among 15 papers included in this review, eight reported a significant association between PA and later SIB, while the remaining seven did not. This suggests an almost equal split between studies that reported significant and non-significant associations. However, a sub analysis revealed specific trends and directionality of these associations.

Of studies that reported significant associations, seven demonstrated that higher PA levels (measured by overall participation or frequency in individual or organised physical activity) were significantly associated with lower levels of death by suicide, suicide attempts and suicidal ideation. A similar significant association was not found for PA and later self-harm in any study. In contrast, Smith et al. (2013) uniquely highlighted a significant association between higher levels of exercise and increased later SIB in the context of compulsive exercise in eating disorders (ED) among adults. These findings suggest that PA might play a role in reducing the likelihood of later SIB. However, inconsistencies in the results of the included studies suggest that the relationship is complex and context dependent.

Significant PA – later SIB associations were typically observed among studies that used validated, reliable and/or objective measures of PA (as opposed to self-reports), which suggests the importance of using robust measurement methodologies. Equally, PA was more likely to be prospectively associated with fewer suicide attempts and death by suicide than in the studies that explored SI or self-harm as outcome measures. All four studies that used team sport participation as a PA measure reported significant associations between more PA and fewer later SIB. In contrast, only five out of eleven studies reported significant interaction when PA was individual.

The significant association between more PA and less later SI and attempts was more likely in studies involving adolescents (12 – 17 years) rather than adults, especially when these adolescents were involved in PA in a group context. Populations that were

most likely to report significant interaction between PA and later suicidal ideation and attempts were secondary pupils (which also coincided with age demographic). Male-only cohorts were more likely to report a significant association between more PA and less later suicidal attempts and death than studies reporting on both genders. The impact of other demographic characteristics, such as geography and ethnicity, on the relationship between PA and later SIB could not be identified. Establishing these trends was not possible due to the over-representation of Western countries and a wide methodological variety of studies reporting on ethnicity.

The significant association between more PA and less later SIB can be explored through several psychological theories and models. The stress-buffering hypothesis (Cohen & Wills, 1985) suggests that PA has the potential to mitigate the physiological and psychological impact of stress, a known risk factor for suicidality (Rebar et al., 2015; Howarth et al., 2020). Behavioural activation theory (Martell et al., 2001) provides another explanation, where PA has the potential to counter social withdrawal and inactivity, that is often a symptom of depression and suicidality (Mammen & Faulkner, 2013; Calati et al., 2019). In the Integrated Motivational-Volitional model (IMV; O'Connor, 2011; O'Connor & Kirtley, 2018), PA could influence key moderators in determining whether individuals progress to SIB. These would include PA's impact on an individual's coping skills (e.g. Mikkelsen et al., 2017), where PA could potentially be considered a threat-to-self (TSM) moderator.

PA could also impact social connectedness in the context of team/organised activities (Andersen et al., 2018) and increase self-worth and sense of achievement (e.g. Zamani Sani et al., 2016). These in turn could counteract feelings of burdensomeness and thwarted belonging (motivational moderator – MM - in the IMV model). Indeed, participation in team sports was reported to help with the development of emotional intelligence and reasoning and was connected to reporting less SI, according to Oliveira et al. (2023).

It is worth recognising that not all findings supported the idea that more PA was associated with less late SIB. The link between more compulsive exercising and increased later SI was reported by Smith et al., 2013, which highlighted that moderation in PA might be important. Moreover, these findings suggest that the type of emotional

response related to PA engagement matters, and when PA is excessive, compulsive and/or maladaptive, as it is in the context of ED, it might increase distress and, consequently, the likelihood of later presenting with SIB. These findings are in line with the compulsive exercise model in the ED context (Mayer et al., 2011), where distress and preoccupation with weight and body shape, guilt, perfectionism and rigidity maintain the engagement in compulsive exercise.

Our review reported more frequent significant associations between PA and later suicidal attempts and death by suicide than the association between PA and later SI. These findings correspond to the findings of Fabiano et al., (2023) where suicide attempts, but not SI, were reduced for people in PA intervention (most frequently aerobic PA) compared to inactive controls. Fabio et al., (2024) also reported a more consistent significant association between PA on later suicidal attempts rather than PA and later SI. Research suggests that SI and suicide attempts might be influenced by different factors (Klonsky & May, 2015; O'Connor & Kirtley, 2018). Suicide attempts are often characterised by impulsivity (Lopez-Castroman et al., 2016), and an increased level of exercise was found to reduce emotional impulsivity (Javelle et al., 2022); therefore, it is possible that PA can act by alleviating impulsive tendencies as prior suicide attempts (Fabiano et al., 2023).

Contrary to Vancampfort et al. (2018), who reported a stronger association between higher PA and lower SI in adults, our review showed a stronger association between these variables for adolescents rather than adults. These differences might be due to the longitudinal design of this review, which suggests adolescence as a key period when the higher PA corresponds to lower later SIB. Additionally, in this review, most studies, which included samples of adolescents, used group PA as a predictor measure. Therefore, it is possible that team sport participation played a key role in the prospective association between PA and SIB for this age group. Group PA participation in adolescence offers benefits such as peer support, reduced isolation (Eimee et al., 2013), and peer belonging (Oberle et al., 2019). Dale et al., (2019) also reported that PA related to lower depression and improved physical self-concept for young people.

Male-only studies were more likely to report a significant association between higher PA and lower SIB than studies that included both genders. However, these male-only

studies that reported significant association were recruited from a unique population of Olympians and military where participation in PA might have had a more central role in their professional role and their identity (Haraldsdottir et al., 2021) than in the general population of men. Therefore, it is not possible to indicate if a similar effect of gender on the PA–SIB role would extend to the general population.

Limitations of the evidence included in the review

The limitation of this review was the heterogeneity in both PA and SIB measures used across the studies. Majority of studies used self-reported data, which is prone to biases such as underreporting due to stigma (e.g. in the context of SIB) and recall errors, potentially weakening the observed associations. Additionally, many studies of this review included PA as a secondary predictor measure rather than the primary predictor variable, which did not allow for an in-depth understanding of the type and/or dose of exercise required for PA to reach a significant protective effect. Another limitation is the variation in the follow-up time across studies used in this review. Shorter follow-up times fail to capture the long-term protective effects of PA, and simultaneously, the studies incorporating longer follow-ups are more exposed to the influence of confounding variables that might not have been included in the analyses. Additionally, the generalisability of the findings is constrained by the demographic profile of the included sample - namely, several studies focusing on specific men-only populations (e.g. military personnel, Olympians) where these cohorts may not fully represent broader populations. Nine studies did not report on the participants' ethnicity, and when they did, most participants were white. Six studies did not include specific SES measures, making examining SES as a modifier of PA and later SIB challenging and potentially non-generalisable. In the studies reporting the SES measures used, SES was often adjusted for rather than explored. Notably, disadvantaged groups were underrepresented; most cohorts originated from affluent, highly educated or occupationally privileged settings, limiting external validity. Low SES individuals were underrepresented. Additionally, the absence of a standardised SES indicator affected the ability to compare findings across studies. The majority of the included studies did not provide information on participants' broader social circumstances.

Methodologically, the predictor and outcome measures used across the studies showed a great variety, making the synthesis and interpretation of the results challenging.

Limitations of the Review Processes Used

Excluding non-English and non-polish studies might have introduced a language bias, potentially omitting studies not published in these languages. Secondly, the cohort studies, although prospective, cannot claim causation. Thirdly, the second reviewer screened a subsample of the studies rather than all identified papers. Although thorough, the use of a critical appraisal tool is partially open to the individual interpretation of the reviewers, which might introduce subjectivity bias. The Prospero application was altered once, with authors not adhering to the initial design by selecting different quality appraisal tool. The phase 2 screening reported 80% concordance rate between two reviewers. In the future calibration meetings should be employed to identify inconsistencies early.

Strengths

This systematic review is the first to explore a longitudinal relationship between baseline PA and SIB at follow-up across different populations (with and without mental health difficulties). The eligibility criteria in this review included English and polish studies, which allowed for broader search than inclusion of English-only studies. All studies that met the inclusion criteria were reported in this review, regardless of their methodological quality. Including all studies reduced the likelihood of selection bias and ensured that this review covered a wide range of available research. The review reported both the unadjusted and adjusted models, which helped provide an accurate overview of the results. A detailed narrative synthesis allowed to compare heterogeneous data, which helped to identify patterns and inconsistencies across the studies. Additionally, this review clearly stated its limitations, which increased scientific transparency and highlighted the areas of improvement in future research. In line with open science practice, the Prospero application and other relevant research documents were made publicly available online. The Prospero application was also updated when the authors selected a different quality appraisal tool than initially planned, which increased the research transparency.

Implications for Practice, Policy

Incorporating PA into suicide prevention strategies could offer a promising, cost-effective option for enhancing mental health resilience. Programs designed to promote PA, particularly in group formats (e.g. team sports), could help elevate key risk factors for SIB (such as low self-esteem and social isolation). Simultaneously, awareness is needed when recommending PA to individuals with vulnerabilities such as eating disorders, as excessive and/or compulsive exercise may increase psychological distress. On a policy level, the findings highlight the need for programmes that promote greater access to PA interventions across diverse populations. As highlighted by the World Health Organization in "Global Action Plan on Physical Activity 2018–2030: More Active People for a Healthier World", equitable access to safe and inclusive PA environments should be of pivotal importance (WHO, 2018).

Future Research

Future research should use standardised PA and SIB measures, which would help with comparison across studies and improve the reliability of findings. The incorporation of objective assessments of PA (e.g. through devices such as accelerometers) could be considered and prioritised over self-reports to reduce the bias. Inclusion of longitudinal representative studies based in non-Western countries, with diverse samples, would be required to explore the long-term effects of PA on SIB across different demographics and cultures. This research, conducted globally, could serve as a basis for further mental health promotion and prevention strategies on an individual and community level (Peterson et al., 2016). Future research would benefit from quantitatively defining socioeconomic status (SES) and using a consistent SES metric (e.g. income or education-based) to facilitate reliable comparisons between studies. Future research should aim to recruit participants from a range of high- to low-SES backgrounds so that more accurate data interpretations can be drawn. Additionally, gathering information about participants' social circumstances may further add to the evidence base by enhancing our understanding of how various social factors might influence the PA-later SIB relationship. Future research should also encompass the role of contextual factors, such as PA in a group setting, that could support people through positive interactions

with others and increase their sense of belonging. As 73% of suicides take place in low- and middle-income countries (World Health Organisation, 2021), the available data suggests a discrepancy between where most of the research is conducted and where the highest levels of suicides are observed, missing the opportunity of exploring and employing PA related interventions.

Conclusion

This is the first systematic review that explored the longitudinal relationship between physical activity (PA) and subsequent suicidal ideation and behaviours (SIB) among people with and without mental or physical health difficulties in prospective cohort studies. The findings highlight the potential of PA to reduce the chances of future suicidal attempts and death by suicide. Notably, no significant association was found between PA and future self-harm. PA in a group setting might be a key driver to later SIB reduction, as it impacts individuals' sense of belonging and increases social support. However, these findings are limited to Western populations, where the studies were conducted. Future research is needed, and it should employ validated measures, with a particular emphasis on objective assessments of PA. Additionally, studies should compare different types of PA to understand their impact better. Future research also must be conducted in low and middle-income countries, as this is where 73% of suicides take place.

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Chapter 2: Major Research Project

Exploring the Role of Physical Activity in Relation to later suicidal ideation in the Context of the Integrated Motivational-Volitional Model. Longitudinal analysis of the UK COVID-19 Mental Health and Wellbeing cohort study.

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Plain Language Summary

Title: Exploring the Role of Physical Activity in Relation to later suicidal ideation in the Context of the Integrated motivational-volitional Model. Longitudinal analysis of the UK COVID-19 Mental Health and Wellbeing study.

Background: People who feel beaten down by life and feel trapped in their situation are more likely to think about suicide than people who do not feel this way. Some things called protective factors, might help people to break the cycle and prevent these thoughts. Being physically active is known to support mental health and well-being, so researchers wanted to find out if exercise could help people feel less beaten down and trapped and reduce suicidal thoughts over time.

What We Did: We studied data coming from a large UK mental health questionnaire taken during the COVID-19 pandemic. Almost 2000 people answered questions about their physical activity, mental health, and suicidal thoughts at two different times. We used a statistical programme to look for patterns and connections.

What We Found: Exercise did not seem to protect against suicidal thoughts the way we expected. People who were more active at the start of the study were not less likely to have suicidal thoughts later on**.** Based on the questionnaires we used, exercise did not seem to help people feel less beaten down or trapped.

What This Means: The way physical activity was measured did not include important details like how intense or what type of exercise people did**.** We think that future studies should look at whether certain types of exercise, like team sports or group workouts, are more helpful in reducing suicidal thoughts than other types of exercise (e.g., individual).

Abstract

Background: The integrated Motivational (IMV) model of suicide suggests that in its motivational phase, feelings of defeat and entrapment contribute to the development of suicidal ideation. Threat-to-self moderators (TSM) impact the relationship between defeat and entrapment. Physical activity (PA) supports mental well-being, and we propose that it might act as a potential TSM, reducing the risk of transitioning from defeat to entrapment. The primary aim of this study was to explore the longitudinal relationship between PA and later suicidal ideation and explore if PA is a TSM. The secondary aim was to explore the longitudinal relationship between the established drivers of the IMV model (distress, defeat, entrapment) and subsequent suicidal ideation.

Methods: This project involved secondary data analysis from a prospective, nationally representative cohort study. Data from waves 1 and 8 of the UK COVID-19 Mental Health and Wellbeing Study was used. 3077 participants completed the baseline measures. Statistical analysis included regression models and moderation analysis.

Results: Results did not demonstrate that physical activity acted as a TSM in the defeat–entrapment relationship. Physical activity at baseline was also not significantly associated with later suicidal ideation.

Limitations: Limiting factors of the present study are measures of physical activity that do not account for a context or dose of PA.

Conclusions: Future research should establish the type of physical activity (e.g., dose, group/individual setting, frequency, intensity) and explore its long-term effects on suicidal ideation and behaviours while prioritising interventions targeting defeat and entrapment in suicide prevention.

Keywords

Integrated motivational-volitional model of suicidal behaviour, Physical Activity, Suicidal Ideation, Defeat, Entrapment, Distress

Introduction

Suicide

Suicide is a global, major public health concern, with more than 720,000 people dying by suicide each year worldwide and 20 times that number of people attempting suicide (World Health Organisation [WHO], 2021; 2024). Globally, suicide is the second leading cause of unnatural death (WHO, 2021). Suicide and suicidal behaviour can lead to psychological distress at the individual, local (e.g., friends/ family) and national level (Jacob et al., 2019) and pose a considerable national financial strain. Indeed, suicide resulted in an estimated economic burden of at least £9.58 billion across the UK in 2022, and each death by suicide incurs an average cost of approximately £1.46 million (Samaritans, 2024).

Suicide attempts are defined as self-inflicted harm with the intention to die (De Leo et al., 2021). Suicide attempts are associated with adverse long-term outcomes, including repeated suicide attempts, hospitalisation, unemployment and enduring mental health difficulties such as suicidal ideation (Goldman-Mellor et al., 2014; van Ballegooijen et al., 2025). Suicidal ideation (SI) - thinking about suicide with or without suicidal intent - affects 1% to 3% of the population annually and approximately 10% of the population over a lifetime (Nock et al., 2008; Ten Have et al., 2009). In the clinical population, the prevalence of SI increases to 20% (Rossom et al., 2017). SI is a robust risk factor for both suicide attempts and deaths across the lifespan (Rossom et al., 2017). People who report suicidal thoughts within the past year have a 15 - 20% higher chance of death by suicide (Borges et al., 2010). Therefore, reducing SI is an important therapeutic goal that may help prevent more severe suicidal behaviours (SB; encompassing suicidal attempts, self-harm and death by suicide) (Ordonez-Carrasco et al., 2022).

Physical Activity (PA) and mental health

Physical activity *(PA)* is regularly reported to support mental health (e.g. Aylett et al., 2018; Bjorkman et al., 2021; Noetel et al., 2024). Unlike medications for mental health, PA is rarely associated with major side effects (Vancampfort et al., 2018). PA is described by Caspersen et al. (1985) as “any activity that involves bodily movement

produced by skeletal muscles and that requires energy expenditure". Research indicates that PA is associated with reduced symptoms of different mental health disorders, such as depression (Noetel et al., 2024) and anxiety (Aylett et al., 2018). Research exploring the link between PA and SI is limited, however, some research suggests that PA can be delivered as a low-cost, non-stigmatising intervention for SI in contrast to traditional mental health approaches (Vancampfort et al., 2018). Vancampfort et al. (2018) conducted a meta-analysis of cross-sectional studies, which showed that meeting PA guidelines (moderate exercise 3 times per week) significantly reduced SI. In contrast, a recent meta-analysis by Fabiano et al. (2023) of randomised controlled studies (RCTs) found no significant difference in SI between exercise (mainly aerobic exercise) and inactive control groups. Additionally, in their systematic review of observational studies, Fabiano et al (2024) reported no significant longitudinal association between PA and later SI. Notably, both studies (Fabiano et al., 2023; 2024) focused exclusively on clinical populations, highlighting the need for future research inclusive of the general population. The mixed findings presented above encourage longitudinal investigation, where a causal relationship between PA and later SI could be explored.

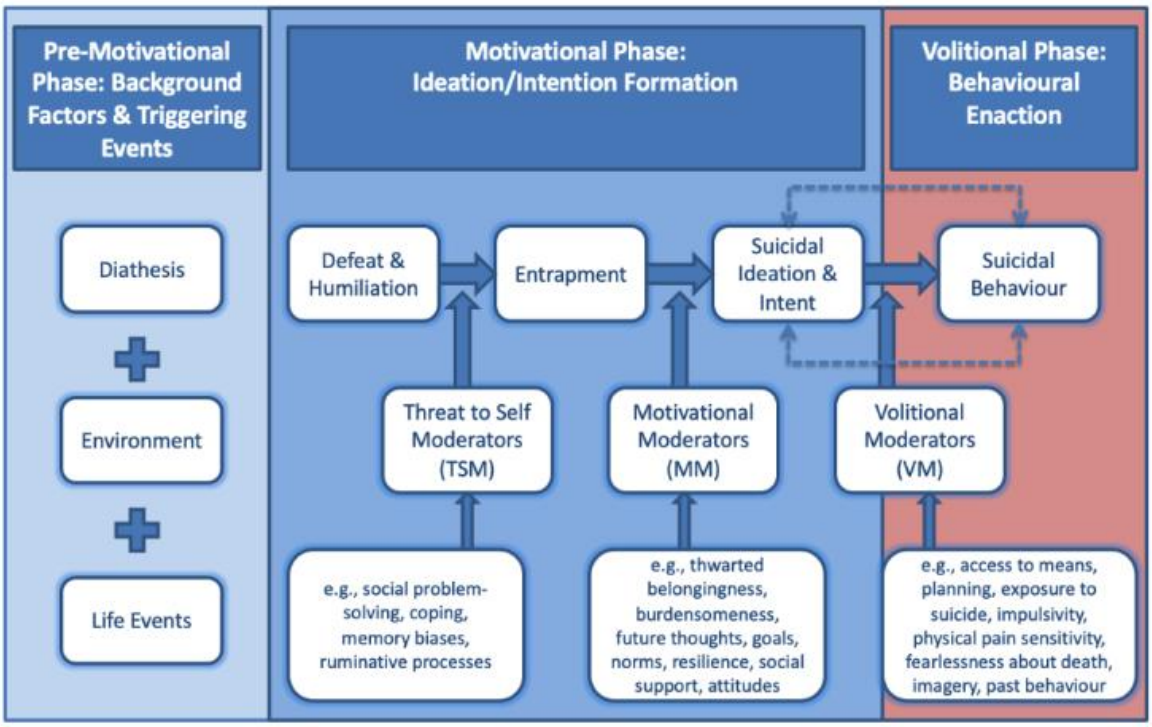
The complexity of suicide risks and the need for a theoretical framework

The knowledge of risk factors related to suicide has significantly grown in recent decades; however, the statistical accuracy of predicting and preventing suicide has not improved in the last 50 years (Franklin et al., 2017). This is mainly because individual risk factors alone do not fully explain how SI develops or how they lead to SB (Millner et al., 2020). The pathways to suicide are complex, with psychological, biological and contextual factors interplaying and influencing one's propensity for suicide (Hawton et al., 2012; O'Connor & Nock, 2014; Turecki & Brent, 2016). Effective suicide prevention requires theoretical frameworks that account for both long-term and immediate influences while explaining how SI progresses to SB (Souza et al., 2024).

The Integrated Motivational-Volitional (IMV) model

The Integrated Motivational-Volitional (IMV; O'Connor, 2011; O'Connor & Kirtley, 2018; see Fig. 2) model is a leading model of predicting suicidal ideation and behaviour (SIB) that uses a biopsychosocial approach to explain suicide. The model adopts a three-phase structure. First, the pre-motivational phase, which captures biological, genetic or cognitive predisposition that increases the risk of suicide. The second phase - the motivational phase - focuses on the feelings of defeat and entrapment, which are the key drivers to SI. The third volitional phase summarises the transition from SI to SB.

Figure 2. *The Integrated Motivational-Volitional Model (IMV; O'Connor & Kirtley, 2018)*



Defeat and Entrapment in the IMV model

Defeat describes the sense of failed struggle and powerlessness arising from the loss or major disruption of social status, identity, or hierarchical aspirations (Gilbert & Allan, 1998; Gilbert, 2000). The key element distinguishing defeat from feelings of loss or failure is the perception of struggling against or being beaten by triggering experiences (Taylor et al., 2011). Entrapment describes the feeling when an escape from threat or stress is blocked due to a low likelihood of self-agency or help from others (Dixon,

1998). Entrapment differs from hopelessness as it involves a strong desire to escape and a sense of reduced status (Gilbert & Allan, 1998). Defeat and entrapment illustrate the ‘tunnel vision’ often observed in people experiencing suicidal distress, where suicide becomes the only perceived solution to escape the distress and are the key drivers of the IMV model (IMV; O’Connor, 2011; O’Connor & Kirtley, 2018).

Stress, distress, the IMV model and suicide

Stress is a ‘state of worry or mental tension caused by a difficult situation (WHO, 2023). Stress had been established in the IMV model research as a risk factor, where stress acts as a trigger in the motivational phase for SI. Stress and distress are often used interchangeably; however, distress refers to individuals' negative responses to stressors that result in a detrimental affect on individuals’ mental health (Merion et al., 2021). However, to date, research has yet to explore the interactions between distress and later SI.

Threat-to-self moderators in the IMV model

In the motivational phase of the model, the relationship between defeat and entrapment is moderated by threat to self-moderators (TSM). TSM include problem-solving skills, coping abilities, and memory biases (Souza et al., 2024). Additionally, the relationship between entrapment and SI is moderated by motivational moderators (MM). MM include perceived burdensomeness, thwarted belongingness and resilience. In the IMV model, both TSM and MM play a regulatory role in either increasing or decreasing the suicidal outcomes (IMV; O’Connor, 2011; O’Connor & Kirtley, 2018). A recent systematic review of 98 studies referencing the IMV model supports the defeat-entrapment-SI pathway (Souza et al., 2024). However, most studies were retrospective cross-sectional, not allowing for causal conclusions and raising limitations of recall bias (Talari & Goyal, 2020). Souza et al. (2024) noted that while retrospective cross-sectional research overwhelmingly supported the pathway, limited prospective studies reported mixed results. These findings highlight the need for prospective research employing real-time measures to identify modifiable risk factors and goals for future interventions.

Physical activity models and suicidal ideation

Several psychological models and theories offer explanations on why PA could offer protection from the development of SI. The stress-buffering hypothesis (Cohen & Wills, 1985) reflects on PA having the potential to mitigate stress's physiological and psychological impact, which is an established factor for suicidality (Rebar et al., 2015; Howarth et al., 2020). The stress buffering element of PA would also fit within the IMV model as a TSM through increasing coping abilities. Another explanation is offered by the Behavioural activation theory (Martell et al., 2001), where PA plays a role in countering inactivity and social withdrawal, frequent symptoms of depression and suicidality (Mammen & Faulkner, 2013; Calati et al., 2019). Broaden-and-build theory (Fredrickson, 2001) suggests that engagement with physical activity elicits positive emotions (e.g. joy), which build upon thought-action capacities and build long-lasting psychological resources (such as resilience and coping skills). These capacities contribute to mental well-being over time and provide support in undoing negative emotions, helping emotional recovery and overall mental health.

The current study's aim

The main objective of this study is to explore the longitudinal relationship of PA and later SI within the context of the IMV model. We aim to explore if PA fits within the motivational phase of the model, specifically by moderating the relationship between defeat and entrapment as a potential TSM. We hypothesise that PA as TSM could aid problem-solving coping skills (e.g. through self-regulation; Belcher et al., 2024; Mikkelsen et al., 2017) and memory biases (e.g. by supporting cognitive health; Kraal et al., 2021). We hypothesise that as a potential TSM, PA could decrease the likelihood of defeat progressing into entrapment, sequentially lowering the risk of SI. Understanding TSM is particularly relevant in a clinical context, as these moderators are believed to be key therapeutic targets for interventions (Ordonez-Carrasco et al., 2021). Establishing whether PA functions as TSM within the IMV model would help establish if PA is a valid therapeutic intervention for people at risk of suicidal outcomes. This, in turn, would support its integration into health promotion and early intervention programmes for the general public. As a secondary objective, we will explore a prospective relationship

between distress, defeat, and entrapment in the context of later SI. Conceptually, we believe that distress fits in the IMV model as it connects with individuals' responses to stress (individuals coping with stress) and will, therefore, impact the perception of defeat and entrapment.

It is hoped that the study findings will help with understanding if PA engagement can protect against the development of SI during future times of heightened stress. The current study aimed to address these four questions:

1. Is level of engagement with physical activity at baseline associated with SI at follow-up?
2. Is level of engagement with PA at baseline independently associated with SI at follow-up when accounting for other psychological factors?
3. Does PA moderate the relationship between defeat and entrapment as a potential TSM in the IMV model?
4. Are levels of distress, defeat, and entrapment at baseline associated with the levels of SI at follow-up?

Key Hypotheses:

1. Higher levels of physical activity at the baseline will be associated with lower SI at the follow-up.
2. Higher levels of physical activity at the baseline will be independently associated with lower SI at the follow-up when accounting for other psychological factors.
3. Physical activity will moderate the relationship between defeat and entrapment as a TSM in the IMV model.
4. Higher levels of distress, defeat and entrapment at the baseline will be associated with a higher SI at follow-up.

Methods

Study Design

This study was conducted in line with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies (von Elm et al., 2007). The completed STROBE checklist is available in Appendix F. This study focused on secondary data analysis and utilised data from two waves of the UK Covid-19 Mental Health and Well-being Study (UK COVID-MH; O'Connor et al., 2021; Wetherall et al., 2022), a nationally representative dataset spanning eight waves. For this study, Waves 1 and 8 were selected to allow for the most longitudinal exploration of the relationships between the variables of interest. Wave 1 data were collected between 31 March and 9 April 2020. Wave 8 data were collected between 2 June and 9 July 2022 (Wilding et al., 2022). The total follow-up time was 2 years and 4 months. For clarity, Wave 1 will be referred to as the baseline and Wave 8 as the follow-up throughout this manuscript.

Participants and recruitment

Data collection methods have been detailed previously (O'Connor et al.; 2021), however in brief, the dataset recruited a nationally representative sample of UK adults (18+ years old) at baseline via a survey research company. A quota sampling methodology was employed at baseline based on age (18–24 years: 12%; 25–34: 17%; 35–44: 18%; 45–54: 18%; 55–64: 15%; 65:20%), gender, socioeconomic grouping and region of the UK. Participants were invited to participate in an online survey exploring health and well-being. 3077 participants were recruited at baseline, with 65% retention at follow-up (n=1944).

Research procedures

The researchers of UK COVID-MH were approached to ask permission to use the UK COVID-MH dataset. This was completed by emailing the researcher involved in the UK COVID-MH. Data was stripped of any identifiable markers, and it can be requested from the original researchers upon reasonable request. The final approved MRP proposal can be accessed in Appendix G.

Measures

The original UK-COVID-MH (O'Connor et al., 2021) questionnaire can be obtained by contacting the original authors. A range of psychological and social measures were included in the original survey (e.g. related to depression, anxiety and Covid-19); however, for the purposes of the current study, the following variables of interest were explored:

Physical Activity (PA)

Engagement with physical activity was assessed using a single-item continuous measure: "'How many days last week did you do moderate or vigorous physical activity for 15 minutes or more (Activity that raises your heart rate and makes you breathe faster and feel warmer)?". The available responses ranged from 0 to 7 days. The PA measure used in this study comes from baseline data.

Suicidal Ideation (SI)

SI was assessed via a single-item adapted from the Adult Psychiatric Morbidity Survey (McManus et al., 2014): "How often have you thought about taking your life in the last week?" The available responses were "one day", "several days", "more than half the days", "nearly every day", "never", "I would rather not answer". This data was recoded into a new dichotomous outcome: ever/never had thoughts of suicide in the past week? The SI measure used in this study comes from baseline and follow-up data.

Distress

Distress was assessed using a single-item measure: "How distressed have you been in the past week?" The available responses ranged from 0 to 10, with 0 representing "no distress and 10 representing "extreme distress". The distress measure used in this study comes from baseline data.

Defeat

Feeling of defeat was assessed using a four-item previously validated measure (Griffiths et al., 2015). Examples of defeat-related items include "I feel defeated by life"

and “I feel like I am ones of life’s losers”. We computed Cronbach's Alpha to assess the internal reliability of the defeat subscale, which demonstrated a high level of internal consistency (α = .90). The defeat measure used in this study comes from baseline data.

Entrapment

Entrapment was assessed using the Entrapment Scale Short-form (De Beurs et al., 2020), a four-item previously validated measure. Examples of entrapment-related items include: “I often have the feeling that I would just like to run away” and “I feel like I am in a deep hole I can’t get out of”. We computed Cronbach's Alpha to assess the internal reliability of the entrapment subscale, which demonstrated a high level of internal consistency (α = .90). The entrapment measure used in this study comes from baseline and follow-up data.

Covariates

The analyses controlled for gender (female, male), age (<30; 30 - 59; 60<), and socioeconomic group (high/low). UK-COVID-MH researchers categorised socioeconomic groups (SEG) as high (A + B + C1) and low (C2 + D + E) based on the National Readership Survey (2016). These covariates were selected in this study because previous research established gender (Bommersbach et al., 2022), age (Beghi et al., 2021), and socioeconomic factors (Qin et al., 2022) as key predictors for SIB.

Equality, diversity and inclusion considerations

O’Connor et al. (2021) invited 7471 panel members to participate in their study, ultimately including 3,077 in the final sample (they aimed for 3,000 participants). Among the 4394 excluded, 3527 were screened out due to quota limits, and 867 dropped out. O’Connor et al., (2021) explained that they chose quota sampling over probability sampling because of the study's time-sensitive nature, which enabled them to quickly recruit a well-stratified UK sample during the early phase of the Covid-19 lockdown.

Ethics, Governance and Data Protection

The ethics committee of the University of Glasgow's Medical, Veterinary and Life Sciences (MVLS) School granted ethical approval for secondary data analysis of this

project (Approval number: 200230208). Please refer to Appendix H to access the ethics approval letter. The relevant permissions to access the dataset were sought and obtained from the researchers involved in the UK-COVID-MH. The dataset was already stripped of any identifiable markers. The current study did not require a Data Protection Impact Assessment (DPIA). Please see Appendix I for a detailed data Management Plan. At the time of recruitment, participants of UK COVID-MH consented to their data being used in secondary analyses.

Statistical Analyses

Statistical analyses were conducted using SPSS version 29 (IBM Corp., 2023). The data analysis plan is available in Appendix J. Multiple Imputation (MI; Sinharay et al., 2001) was already applied in the original UK COVID-MH (O'Connor et al., 2021) study to manage the missing data. Participants were dichotomised according to their reported suicidal ideation (outcome variable) as suicidal ideation present during the last week (yes/no). Covariates were reported by frequency for categorical variables. These categorical demographic variables were gender (female, male), age (<30; 30 - 59; 60<), and socioeconomic group (high/low).

Preliminary analysis

Wilcoxon signed-rank test was used to compare the covariates between baseline and follow-up; Pearson's correlations were conducted to examine the associations between all continuous study variables.

Primary analysis

Univariate binary logistic regression with odds ratio was conducted to explore the association between levels of PA at the baseline and later SI. Multilevel binary logistic regression was utilised to enquire whether the association between levels of PA at the baseline and later SI was present when controlling for other psychological factors in adjusted models. In these analyses, in order to control for their effects, SI at baseline was entered in block 1, demographics (gender, age, SEG) were entered in block 2 and predictors of interest (distress, defeat, entrapment, and PA) entered at block 3.

Hayes (2022) PROCESS macro for SPSS was used to test whether PA acted as a moderator between defeat and entrapment.

Secondary analysis

A set of univariate binary logistic regressions was used to identify the independent associations between levels of distress, defeat and entrapment at baseline with the levels of SI at follow-up in the unadjusted models. Multivariate binary regression was used to explore if these psychological variables have an association with later SI when all the variables (distress, defeat, entrapment) are accounted for.

Sample Size Analysis

An a priori power analysis was conducted using G*Power version 3.1. (Faul et al., 2007) for sample size estimation, based on data with nine predictor variables and one dependent variable (SI). The effect size f^2 was .35, which was considered a large effect using Cohen's (2013) criteria. With a significance criterion of $\alpha = .05$ and power = .95, the minimum sample size needed with this effect size was $N = 77$.

Results

Descriptive information

The syntax with all analyses is available in Appendix K. 3077 participants were included in this study. At baseline, the sample consisted of 1692 (55%) women, 1381 (44.9%) men, and 4 (0.1%) participants who preferred not to state their gender. 847 (27.5%) participants were aged 18-29 years, 1636 (53.2%) were aged 30- 59, and 597 (19.3%) were aged over 60 years old. At the baseline, 1758 (57.1%) participants were of a high SEG, and 1319 (42.9%) were of a low SEG background. At follow-up, the number of participants was reduced to 1944.

Wilcoxon signed-rank test showed that the difference between all demographic variables between baseline and follow-up was not statistically significant ($p > .05$) , indicating that the distribution of demographic variables was stable over time. Pearson's

correlations (Appendix M) were in the expected direction. Nine out of ten correlations reached statistical significance.

1. *Is level of engagement with physical activity at baseline associated with SI at follow-up?*

Univariate binary logistic regression indicated that the level of engagement with PA did not significantly predict the likelihood of engaging in SI at follow-up (PA; Table 2).

Table 2. *Results of a set of univariate binary logistic regressions between none and any SI measured at follow-up (N = 1944) from unadjusted models.*

IVs				95% CI (OR)		
	β	SE	W	*LL*	*UL*	*p* value
PA	-.06	.03	2.8	.89	1.01	.09
Distress	.23	.03	65.28	1.19	1.32	< .001**
Defeat	.22	.02	137.51	1.2	1.29	< .001**
Entrapment	.18	.02	141.37	1.17	1.24	< .001**

Note: *p<.05; **p<.001; β = beta; W = Wald; OR = Odds ratio; IVs – Independent variables.

2. *Is level of engagement with PA at baseline independently associated with SI at follow-up when accounting for other psychological factors?*

A multilevel binary logistic regression was conducted, with SI at baseline entered in block 1, demographics (gender, age, SEG) entered at block 2 and predictors of interest (distress, defeat, entrapment, and PA) entered at block 3 (Table 3). The results of this analysis demonstrate that when controlling for an SI at baseline and a range of demographic variables, the level of engagement with PA at baseline was not independently associated with subsequent SI.

Across all three blocks, only SI and age measured at baseline continued to be significantly associated with later SI. In block 3, higher levels of SI at baseline were associated with higher levels of later SI ($\beta = 1.99$, Wald = 75.91, $p < .001$) and higher age at baseline was associated with lower later SI ($\beta = -.658$, Wald = 19.01, $p < .001$). No other predictor variables were significantly associated with later SI in block 3.

Table 3. *Results of the multilevel binary logistic regression between none and any SI for the full sample (N=1900).*

	Block 1						Block 2						Block 3					
				95% CI (OR)						95% CI (OR)						95% CI (OR)		
IVs	**β**	**SE**	**W**	**LL**	**UL**	**p**	**β**	**SE**	**W**	**LL**	**UL**	**p**	**β**	**SE**	**W**	**LL**	**UL**	**p**
Constant	-2.71	.1	757.37	-	-	<.001**	-1.23	.28	19.17	-	-	<.001**	-2.02	.37	30.33	-	-	<.001**
SI (T1)	2.754	2.75	194.89	10.67	23.11	<.001**	2.6	.2	164.27	8.97	19.8	<.001**	1.99	.29	75.91	4.67	11.43	<.001**
Age	-	-	-	-	-	-	-.79	.14	30.21	.34	.60	<.001**	-.66	.15	19.01	.39	.39	<.001**
Gender							-.07	.18	.14	.66	1.33	.71	.06	.19	.12	.74	1.54	.73
SEG	-	-	-	-	-	-	.22	.18	1.65	.89	1.76	.2	.11	.18	.35	.78	1.58	.55
Distress	-	-	-	-	-	-	-	-	-	-	-	-	.03	.04	.56	.96	1.11	.45
Defeat	-	-	-	-	-	-	-	-	-	-	-	-	.05	.04	1.84	.98	1.14	.18
Entrapment	-	-	-	-	-	-	-	-	-	-	-	-	.06	.03	3.14	.99	1.13	.08
PA	-	-	-	-	-	-	-	-	-	-	-	-	-.01	.04	.13	.91	1.06	.72

Note: *p<.05; **p<.001; β = beta; CI = confidence interval; *LL* = lower limit; *UL* = upper limit; W = Wald; T1 = measured at baseline.

3. *Does PA moderate the relationship between defeat and entrapment as a potential TSM buffer in the IMV model?*

There was no moderating effect of PA on the relationship between defeat at baseline and entrapment measured at follow-up (Table 4). Please see Appendix K for SPSS outputs for the moderation analysis.

Table 4. *Results of moderation analysis of defeat x PA measured at baseline on entrapment measured at follow-up.*

			95% CI (OR)		
Effect	**β**	**SE**	***LL***	***UL***	**p**
Defeat	.73	.02	.69	.76	< .001**
PA	.08	.03	- .05	.07	.79
Defeat x PA	.001	.01	- .01	.02	.89
Constant	3.44	.07	3.3	3.59	<. 001**

Note: *p<.05; **p<.001; β = beta; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

4. *Are levels of distress, defeat, and entrapment at baseline associated with the levels of SI at follow-up?*

The results of set of univariate binomial logistic regressions found that in unadjusted models there were significant positive associations between baseline levels of distress (β = .23, p < .001, OR: 95% CI 1.19 -1.32), defeat (β = .22, p < .001, OR: 95% CI 1.97 - 1.29), and entrapment (β = .18, p < .001, OR: 95% CI 1.17 - 1.24) and SI at follow-up (Table 2). Higher levels of distress, defeat and entrapment at baseline were associated with higher levels of SI at follow-up in unadjusted models.

The results of multivariate binary logistic regression (adjusted model) reported that while significant positive associations between baseline levels of defeat (β = .11, p = .001, Odds ratio: 95% CI 1.05 - 1.20) and entrapment (β = .09, p = .003, Odds ratio: 95% CI 1.03 - 1.16) and SI at follow-up remained significant, this association was no longer significant for baseline distress and later SI (Table 5). Higher levels of defeat

and entrapment at baseline were associated with higher levels of SI at follow-up in adjusted models.

Table 5. *Results of a multivariate binary logistic regression between none and any SI measured at follow-up (N = 1944) from adjusted models.*

				95% CI (OR)		
IVs	**β**	**SE**	**W**	***LL***	***UL***	**p**
Distress	.05	.03	2.07	.98	1.23	.15
Defeat	.11	.04	10.58	1.05	1.2	.001*
Entrapment	.09	.03	8.59	1.03	1.16	.003*
PA	-.01	.04	.12	.92	1.06	.73

Note: *p<.05; **p<.001; β = beta; CI = confidence interval; *LL* = lower limit; *UL* = upper limit.

Discussion

This study explored a longitudinal relationship between PA measured at baseline and SI measures at follow-up using secondary data from the UK-COVID-MH (O'Connor et al., 2021). This is the first study that examined the specific impact that PA may have on the development of later SI in the context of the IMV model (O'Connor, 2011; O'Connor & Kirtley, 2018). In this study, we proposed four hypotheses. The first hypothesis explored whether higher levels of PA at the baseline were associated with lower levels of SI at the follow-up – this hypothesis was not supported. The second hypothesis, whether higher levels of PA at the baseline were associated with lower levels of SI at follow-up when accounting for other psychological variables (SI at baseline, age, gender, SEG, distress, defeat, entrapment), was not supported. The third hypothesis if PA moderated the relationship between defeat and entrapment as TSM buffer was not supported. The fourth hypothesis, if higher levels of distress, defeat, and entrapment at the baseline were associated with a higher level of SI at follow-up, was supported in unadjusted models. However, when controlling for other psychological variables in adjusted models, the relationship between distress and later SI was no longer significant. The other relationships (defeat and entrapment) remained significant in adjusted models.

Interpretation of findings

The findings of this prospective study were inconsistent with the cross-sectional findings reported by Vancampfort (2018). Specifically, our study did not report that more physically active individuals were less likely to report SI than those who were not active. On the other hand, a systematic review of cohort studies by Fabiano et al. (2024), reported an inconsistent association between PA and later SI. this may suggest that PA alone is insufficient to reduce the later SI, and it is possible that other psychological factors play a more robust role in reducing the risks of later SI. Research using the IMV model suggests that these psychological factors include problem-solving skills, coping abilities and memory biases (Souza et al., 2024). All these coping strategies will be, however, impacted by prolonged distress, feelings of defeat and entrapment (Souza et al., 2024); therefore, PA engagement might not be enough to offer a buffer from SI development. Indeed, our study found that PA was not a significant moderator of the defeat-entrapment relationship. Simultaneously, this study reported that defeat and entrapment showed a significant longitudinal

association with later SI, which corresponds with previous cross-sectional findings of the IMV model and adds to the new research that explores this relationship longitudinally (Souza et al., 2024). In our study, the feelings of defeat and entrapment might have been too intense and long-standing for the PA to counteract them.

People who experience defeat may find it more challenging to engage in PA due to low motivation, low self-efficacy and feelings of hopelessness and helplessness (Souza et al. 2024). This can prevent them from experiencing any of its potentially protective effects. For example, Brailovskaia et al. (2022) reported a significant protective effect of PA on later SI in their prospective cohort study. However, this effect was no longer significant after introducing positive mental health (individuals' subjective well-being) as a mediator.

It is important to note that the data for the current study were collected during COVID-19 restrictions when PA mainly consisted of individual exercise rather than group activities. Engaging in PA in a group setting might affect subsequent SI differently, as it provides opportunities for social interactions and support. Research by Miller et al. (2015) suggests that these social connections can independently reduce SI. Indeed, a recent study showed that participation in team sports helped with the development of reasoning and emotional intelligence and was connected with reporting less SI (Oliveira et al., 2023). Additionally, participation in organised sports during secondary school was shown to be significantly correlated with less SI during adulthood (Dugas et al., 2012). The advantage of the team format of PA over the individual approach is regular, face-to-face contact with others, shared rituals and a sense of ‘us’ (Eather et al. 2023). These aspects effectively combat feelings of isolation, a risk factor for suicide in both the IMV model (O’Connor, 2011; O’Connor & Kirtley, 2018) and the Interpersonal-Psychological Theory of Suicidal Behaviour (Joiner, 2005). A systematic review of 29 studies found that team-sport participants reported higher levels of belonging and self-esteem and lower levels of depression, stress and anxiety than people engaging in individual exercise (Eather et al., 2023). Team sport participation also fosters collective efficacy, which can, in turn, sustain individual motivation to exercise even when individual drive is low (Eather et al., 2023). In groups, PA participants reported receiving emotional, information and

validation support in each PA group session (Golaszewski et al., 2022). Additionally, group PA boosted PA identity and motivation more than individual workouts, leading to greater benefits from regular participation (Rhodes et al., 2025). Therefore, PA in a group setting could be an opportunity for a social connection, which was limited or completely unavailable during the COVID-19 lockdown.

It is also possible that a specific dose of PA, including its intensity and frequency, could influence the likelihood of later SI. For example, Perez et al. (2024) found that individuals who accumulated more light PA over a week were less likely to report later SI. This distinction is important, as the present study measured the frequency of moderate to vigorous PA participation and did not account for the frequency of light PA. Although previous research mostly focused on moderate to vigorous PA and its relationship with health outcomes, including SI, it is possible that every day, frequent light movement is important in the SI context and behavioural activation (Perez et al., 2024).

However, it is possible that PA engagement has more of an ‘in the moment’ effect on the reduction of SI, as reported in cross-sectional research (Vancampfort et al., 2018), without having the same longitudinal effect. Therefore, PA participation could still offer a buffer to stress (Howarth et al., 2020), counter inactivity and social withdrawal (Calati et al., 2019) and evoke positive emotions (Fredikson, 2001), in the moment.

It is also possible that sustained engagement in PA plays a role in SI reduction. In their 5-year longitudinal population study, Taliaferro et al. (2011) reported that adolescents involved in sports in both middle and high school were less likely to report SI in high school, with no significant relationship between sport involvement only in middle school or only in high school and the SI at high school. It is important to consider how a decline in PA from baseline to follow-up might affect individuals’ self-perception and what psychological factors (including distress, defeat and entrapment) might contribute to their increased inactivity.

Maintaining PA is effortful, and theories such as the Theory of Effort Minimisation in Physical Activity (TEMPA) suggest that humans inherently avoid unnecessary physical effort and aim to preserve energy due to evolutionary pressures despite

understanding the benefits of PA (Maltagliati et al., 2024). As the baseline data for this study was collected at the onset of COVID-19 restrictions, it is possible that higher levels of PA were initially reported as people used PA as a means of coping due to lockdown, increased unpredictability, an increase in stress and social isolation. Additionally, the government encouraged PA engagement at the initial stages of the pandemic, which could make PA engagement more silent during this specific time. However, as the pandemic progressed, long-standing distress, fatigue and diminished social support may have made it more challenging to maintain a PA routine. TEMPA proposes that executive functioning (a set of cognitive processes that help individuals regulate their behaviours and decision-making and override their impulses) plays a crucial role in maintaining PA engagement however, high levels of distress, defeat, and entrapment may have impaired individual cognitive resources (O'Connor, 2011; O'Connor & Kirtley, 2018; Maltagliati et al., 2024).

Another point to consider is the individual motivation behind engagement with PA. Previous longitudinal research showed a significant association between excessive, compulsive and/or maladaptive PA in the eating disorders (ED) population and increased risk of SI (Smith et al., 2013). Therefore, it is possible that for some people in the current study, more engagement in PA could be synonymous with compulsive exercise as a part of their ED maladaptive coping. For these individuals, as described by the compulsive exercise model (Meyer et al., 2011), distress and preoccupation with weight, body shape, guilt, perfectionism and rigidity can perpetuate compulsive exercise. Therefore, engagement with compulsive exercise would elicit negative emotional responses and increase the likelihood of SI for these individuals.

This study reported that both defeat and entrapment, measured at baseline, strongly predicted later SI. These findings correspond with research on the IMV model (Souza et al., 2024) and contribute to the emerging research demonstrating the persistent influence of defeat and entrapment on later SI. Interestingly, distress measured at baseline had a significant association with later SI only in the unadjusted models. When we examined distress, defeat, and entrapment together in a statistical model, it became clear that defeat and entrapment provided a more robust explanation for the emergence of later SI than distress alone. The IMV model

(O'Connor, 2011; O'Connor & Kirtley, 2018) highlights that although distress can play an initial role at the beginning of a 'chain reaction' towards SIB, ultimately, specific motivational moderators (defeat, entrapment, hopelessness, burdensomeness) become more salient and predictive of SIB. Another theory that could explain our findings relates to the interpersonal theory of suicide, which suggests that when SI intensifies, people might become more emotionally numb, and their distress can decrease (Joiner, 2005; van Orden et al., 2010). This distress is then replaced with other cognitive states such as hopelessness, lack of belonging and burdensomeness, which are also psychological factors recognised in the motivational phase of the IMV model. This 'emotional blunting' is especially reported by people experiencing chronic SI. The nature of the measures used in this study could have also impacted the results. Defeat and entrapment were assessed using multi-item validated tools, whereas distress was measured using a single-item tool to measure experiences of distress within the past week. Moreover, the nature of the measures used in the study could have impacted the results. Defeat and entrapment were assessed using multi-item validated tools, with both concepts exploring more fixed and enduring perceptions of self (e.g. 'I feel defeated by life'). In contrast, distress was measured by a single-item tool querying about more changeable and fluctuating experiences of distress levels within the previous week ('How distressed have you been in the past week?').

Strengths

This study is the first to explore the relationship between PA and SI within the context of the IMV model. The current study included a large participant sample size, thereby enhancing the statistical power and generalisability of the findings. The prospective design allowed us to explore the changes over time. The use of validated and reliable measures of defeat and entrapment ensured measurement consistency. The reporting of adjusted and unadjusted statistical models ensures scientific transparency and integrity and acknowledges the established covariates (age, gender, SEG). This study also uses theory-driven research questions and adds to emerging evidence of suicide prevention strategies. The use of secondary data did not expose participants to any new ethical concerns.

Limitations

All the measurements used in the study relied on self-reported questionnaires, which may invoke recall bias, mood-congruent biases (Faul et al., 2023) and social desirability bias. The PA was measured using a single-item measure rather than a validated, multi-item questionnaire, restricting the depth of the assessment on what type, intensity, and duration of physical activity would be optimal for observing its benefit in relation to suicidal ideation. Only a baseline measure of PA was used in this study; therefore, we were not able to comment whether a change in PA (increase/decrease) in two years of follow-up impacted later suicidal ideation. The SI measure was dichotomised, which might have removed some nuances in the results. The use of a secondary dataset did not allow for the qualitative exploration to understand individuals' experiences in more depth. The study was marked by high attrition, with only 63.2% of people completing baseline and follow-up measures. As it was an observational study, causality could not be established. The study included the general population rather than a clinical sample. Therefore, the findings might not be generalisable to the clinical populations experiencing more severe or chronic mental health difficulties. The data used in the study is five years old and was collected during COVID-19, therefore limiting the generalisability of the findings as it reflected the experiences of the population affected by the pandemic at this specific time and context. The data was collected during COVID-19 restrictions, so PA in a group setting was mostly not possible.

Implications for policy, practice, and future research

This study adds further evidence for the IMV model by demonstrating that defeat and entrapment were the key longitudinal psychological drivers of SI. As defeat and entrapment were stronger predictors of SI than distress, the findings suggest that future interventions should prioritise breaking the pathway from defeat to entrapment rather than focusing on distress-reduction strategies only. Policies should support early intervention and detection programmes, where defeat and entrapment are routinely screened for as evidence of these factors being precursors to the development of SI. Routine screening could allow for interventions to be implemented before the possible onset of SIB.

The current study suggests that PA frequency might not be a sufficient intervention against the development of SI. Future research and policies should focus on identifying specific conditions under which PA could be beneficial. Future research should examine the potential differences between group-based versus individual PA on later SI, explore the optimal intensity and dose of PA (e.g. light vs moderate vs rigorous PA) and investigate whether long-term, continuous engagement in PA differs in its impact on SI compared to immediate or short-term PA. Future longitudinal research should incorporate repeated PA measures in the analysis to better understand the PA trajectories (e.g., sustained, declining, or newly initiated activity) rather than a PA measured at a single point. This approach could clarify whether the cumulative dose of PA, recent changes, or consistent maintenance of PA over time is the most beneficial in relation to later suicidal outcomes.

It is important to recognise that engagement in exercise, especially for high-risk people, will be more effortful and might involve more encouragement than for the general population. Warm social prescribing referrals (e.g. follow-up calls rather than leaflets) and asking people about the movement type that corresponds with their individual preference might improve PA attendance (Dash et al., 2024). Team PA can be co-designed, with low-skill weekly PA sessions (e.g., walking football, from the couch to 5k groups) and celebrating PA attendance. Recent research showed that peer-led WhatsApp PA groups lifted PA session adherence by 27 % in high-risk adults (Chan et al., 2024). Research should also consider individual attitudes and emotional responses towards PA when evaluating its effectiveness in SI reduction. Defeat and entrapment could also be explored through the lens of the transdiagnostic model (e.g. Roefs et al. 2022), where defeat and entrapment could be conceptualised as drivers underpinning a variety of mental health disorders.

Future research would benefit from incorporating physical movement devices such as accelerometers and inclinometers (e.g., in Perez et al. 2024) to utilise objective measures of PA and overcome the biases of self-reported data. This would have the potential to increase reliability and validity in the field. Furthermore, future research should incorporate a more longitudinal design and additional risk and protective factors. The life-course formulation of SI and behaviour has already been established academically and therapeutically in the IMV model (O'Connor, 2011;

O’Connor & Kirtley, 2018), which explained how different influences and individuals’ experiences across different stages shape their mental health outcomes. The same framework could also be applied in relation to PA and the wider model and explore how PA might influence SIB differently depending on an individual’s stage of life, prior experiences and current motivational-volitional states.

Conclusions

While PA was not identified as a significant predictor of later SI, defeat and entrapment showed strong predictive associations, highlighting their critical role in developing later SI in the context of the IMV model. The findings suggest that the presence of PA alone may not be enough to reduce later SI, but it might be context-dependent or short-term. Future research should investigate the specificity of PA (e.g. dose, type, frequency, intensity) and its possible impact over time on the development of SIB. These findings emphasise the need for targeted interventions addressing defeat and entrapment in suicide prevention and call for future research on PA’s methodological improvement.

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Appendix A. Prospero Application

Available online: https://github.com/mbwie/Physial-activity-and-later-suicidal-ideation-and-behaviours.-Systematic-review-of-cohort-studies.-/blob/efd10ead5e96d655e6586079d91afb7d4a426aad/prospero%20update%2004.02.25.pdf

Appendix B. PRISMA checklist

Section and Topic	Item #	Checklist item	Location where item is reported
TITLE			
Title	1	Identify the report as a systematic review.	6
ABSTRACT			
Abstract	2	See the PRISMA 2020 for Abstracts checklist.	10
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of existing knowledge.	8 - 9
Objectives	4	Provide an explicit statement of the objective(s) or question(s) the review addresses.	10
METHODS			
Eligibility criteria	5	Specify the inclusion and exclusion criteria for the review and how studies were grouped for the syntheses.	11
Information sources	6	Specify all databases, registers, websites, organisations, reference lists and other sources searched or consulted to identify studies. Specify the date when each source was last searched or consulted.	11
Search strategy	7	Present the full search strategies for all databases, registers and websites, including any filters and limits used.	11 – 12; Appendix C
Selection process	8	Specify the methods used to decide whether a study met the inclusion criteria of the review, including how many reviewers screened each record and each report retrieved, whether they worked independently, and if applicable, details of automation tools used in the process.	12
Data collection process	9	Specify the methods used to collect data from reports, including how many reviewers collected data from each report, whether they worked independently, any processes for obtaining or confirming data from study investigators, and if applicable, details of automation tools used in the process.	n/a
Data items	10a	List and define all outcomes for which data were sought. Specify whether all results that were compatible with each outcome domain in each study were sought (e.g. for all measures, time points, analyses), and if not, the methods used to decide which results to collect.	14 - 21
	10b	List and define all other variables for which data were sought (e.g. participant and intervention characteristics, funding sources). Describe any assumptions made about any missing or unclear information.	14 - 21
Study risk of bias assessment	11	Specify the methods used to assess risk of bias in the included studies, including details of the tool(s) used, how many reviewers assessed each study and whether they worked independently, and if applicable, details of automation tools used in the process.	14
Effect measures	12	Specify for each outcome the effect measure(s) (e.g. risk ratio, mean difference) used in the synthesis or presentation of results.	Appendix D
Synthesis methods	13a	Describe the processes used to decide which studies were eligible for each synthesis (e.g. tabulating the study intervention characteristics and comparing against the planned groups for each synthesis (item #5)).	n/a
	13b	Describe any methods required to prepare the data for presentation or synthesis, such as handling of missing summary statistics, or data conversions.	n/a
	13c	Describe any methods used to tabulate or visually display results of individual studies and syntheses.	Table 1
	13d	Describe any methods used to synthesize results and provide a rationale for the choice(s). If meta-analysis was performed, describe the model(s), method(s) to identify the presence and extent of statistical heterogeneity, and software package(s) used.	22
	13e	Describe any methods used to explore possible causes of heterogeneity among study results (e.g. subgroup analysis, meta-regression).	22
	13f	Describe any sensitivity analyses conducted to assess robustness of the synthesized results.	n/a
Reporting bias assessment	14	Describe any methods used to assess risk of bias due to missing results in a synthesis (arising from reporting biases).	n/a
Certainty	15	Describe any methods used to assess certainty (or confidence) in the body of evidence for an outcome.	n/a

Section and Topic	Item #	Checklist item	Location where item is reported
assessment			
RESULTS			
Study selection	16a	Describe the results of the search and selection process, from the number of records identified in the search to the number of studies included in the review, ideally using a flow diagram.	22; Fig 1
	16b	Cite studies that might appear to meet the inclusion criteria, but which were excluded, and explain why they were excluded.	22
Study characteristics	17	Cite each included study and present its characteristics.	Table 1 (15 – 21)
Risk of bias in studies	18	Present assessments of risk of bias for each included study.	Appendix E
Results of individual studies	19	For all outcomes, present, for each study: (a) summary statistics for each group (where appropriate) and (b) an effect estimate and its precision (e.g. confidence/credible interval), ideally using structured tables or plots.	Appendix D
Results of syntheses	20a	For each synthesis, briefly summarise the characteristics and risk of bias among contributing studies.	30 - 31
	20b	Present results of all statistical syntheses conducted. If meta-analysis was done, present for each the summary estimate and its precision (e.g. confidence/credible interval) and measures of statistical heterogeneity. If comparing groups, describe the direction of the effect.	22 - 31
	20c	Present results of all investigations of possible causes of heterogeneity among study results.	22 - 31
	20d	Present results of all sensitivity analyses conducted to assess the robustness of the synthesized results.	n/a
Reporting biases	21	Present assessments of risk of bias due to missing results (arising from reporting biases) for each synthesis assessed.	n/a
Certainty of evidence	22	Present assessments of certainty (or confidence) in the body of evidence for each outcome assessed.	n/a
DISCUSSION			
Discussion	23a	Provide a general interpretation of the results in the context of other evidence.	32 - 35
	23b	Discuss any limitations of the evidence included in the review.	35 - 36
	23c	Discuss any limitations of the review processes used.	36
	23d	Discuss implications of the results for practice, policy, and future research.	37 - 38
OTHER INFORMATION			
Registration and protocol	24a	Provide registration information for the review, including register name and registration number, or state that the review was not registered.	11
	24b	Indicate where the review protocol can be accessed, or state that a protocol was not prepared.	Appendix A
	24c	Describe and explain any amendments to information provided at registration or in the protocol.	36
Support	25	Describe sources of financial or non-financial support for the review, and the role of the funders or sponsors in the review.	7
Competing interests	26	Declare any competing interests of review authors.	n/a
Availability of data, code and other materials	27	Report which of the following are publicly available and where they can be found: template data collection forms; data extracted from included studies; data used for all analyses; analytic code; any other materials used in the review.	Appendix

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. This work is licensed under CC BY 4.0. To view a copy of this license, visit https://creativecommons.org/licenses/by/4.0/

Appendix C. Detailed Search Terms with MeSH terms.

Database name		Search results (number of papers)
	1. exercise OR High-Intensity Interval Training OR Exercise OR Muscle Stretching Exercises OR Resistance	256,286
	2. MHX=(Suicide, Completed OR Suicide OR Suicide, Attempted OR Suicidal Ideation OR Self-Injurious Behavior)	86,734
Web of Science - Advanced search MEDLINE	3. #1 AND #2	**123**
	1. exp aerobic exercise/ or exp anaerobic exercise/ or exp aquatic exercise/ or exp arm exercise/ or exp calisthenics/ or exp circuit training/ or exp closed kinetic chain exercise/ or exp continuous training/ or exp cool down/ or exp "cross training (sport)"/ or exp dynamic exercise/ or exp endurance training/ or exp exercise intensity/ or exp gymnastics/ or exp high intensity exercise/ or exp interval training/ or exp isokinetic exercise/ or exp leg exercise/ or exp low intensity exercise/ or exp moderate intensity exercise/ or exp muscle exercise/ or exp pilates/ or exp plyometrics/ or exp power training/ or exp resistance training/ or exp "squatting (exercise)"/ or exp static exercise/ or exp warm up/	102,760
	2. exp climbing/ or exp cycling/ or exp fighting/ or exp flight/ or exp jogging/ or exp jumping/ or exp lifting effort/ or exp nordic walking/ or exp racewalking/ or exp running/ or exp stretching/ or exp swimming/ or exp walking/ or exp weight lifting/	268,749
	3. exp athletics/ or exp ball sport/ or exp body building/ or exp calisthenics/ or exp climbing sport/ or exp collision sport/ or exp combat sport/ or exp contact sport/ or exp "cross training (sport)"/ or exp cycling/ or exp endurance sport/ or exp extreme sport/ or exp gymnastics/ or exp horseback riding/ or exp jogging/ or exp non contact sport/ or exp nordic walking/ or exp racewalking/ or exp racquet sport/ or exp roller skating/ or exp running/ or exp skateboarding/ or exp team sport/ or exp triathlon/ or exp water sport/ or exp weight lifting/ or exp winter sport/ or exp yoga/	178,693
	4. exp suicide/ or exp suicidal behavior/ or exp suicide attempt/	141,656

	5. exp suicidal ideation/	35,126
	6. exp automutilation/	27,379
	7. 1 or 2 or 3	429,040
	8. 4 or 5 or 6	157,770
	9. 7 and 8	1,479
	10. limit 9 to human	1,393
	11. limit 10 to "remove preprint records"	1,391
Embase 1947-Present	12. limit 11 to (article or article in press)	**837**
	1. (MM "Abdominal Exercises") OR (MH"Aerobic Exercises+") OR (MM "Anaerobic Exercises") OR (MM "Back Exercises") OR (MM "Callisthenics") OR (MM "Core Exercises") OR (MM "Endurance Training") OR (MM "Group Exercise") OR (MM "High-Intensity Interval Training") OR (MM "Lower Extremity Exercises") OR (MH "Muscle Strengthening+") OR (MM "Plyometrics") OR (MM "Stretching") OR (MH "Upper Extremity Exercises+") OR (MH "Walking+") OR (MM "Warm-Up Exercise") OR (MM "Amateur Sports") OR (MH "Aquatic Sports+") OR (MM "Athletic Performance") OR (MH "Athletic Training+") OR (MM "Body Building") OR (MM "Bowling") OR (MM "Caving") OR (MM "College Sports") OR (MH "Contact Sports+") OR (MM "Cycling") OR (MM "Endurance Sports") OR (MM "Fencing") OR (MM "Golf") OR (MM "Gymnastics") OR (MM "Handball") OR (MM "Martial Arts") OR (MH "Racquet Sports+") OR (MM "Rock Climbing") OR (MH "Running+") OR (MH "Skating+") OR (MH "Skiing+") OR (MM "Race Walking") OR (MM "Professional Sports") OR (MM "Mountaineering") OR (MM "Sports Participation") OR (MH "Team Sports+") OR (MM "Track and Field") OR (MM "Triathlon") OR (MM "Weight Lifting") OR (MH "Winter Sports+") OR (MM "Extreme Sports") OR (MH "Animal Sports+")	140,084
	2. (MM "Suicidal Ideation") OR (MM "Suicide Prevention") OR (MM "Suicide, Attempted")	14,268
	3. (MM "Injuries, Self-Inflicted")	2,108
	4. S2 OR S3	16,075
	5. S1 AND S4	41
CINAHL	6. S1 AND S4; Limiters - Peer Reviewed; Human	**28**
	1. (MM "Cool-Down Exercise") OR (MM "Warm-Up Exercise") OR (MM "Muscle Stretching Exercises") OR (MH "Walking+") OR (MM "Swimming") OR (MM "Running") OR (MM "Gymnastics")	97,618

	2. (MH "Athletic Performance+") OR (MM "Volleyball") OR (MH"Snow Sports+") OR (MH"Martial Arts+") OR (MH "Racquet Sports+") OR (MM "Wrestling") OR (MM "Weight Lifting") OR (MM "Track and Field") OR (MM "Soccer") OR (MM "Skating") OR (MH "Running+") OR (MM"Mountaineering") OR(MM "Hockey") OR (MM"Gymnastics") OR (MM "Golf") OR (MM "Football") OR (MM "Boxing") OR (MM "Bicycling") OR (MM "Basketball") OR (MM "Baseball") OR (MM "Rugby") OR (MM "Team Sports") OR (MM "Cricket Sport") OR (MH "Water Sports+") OR (MM "Dancing")	149,768
	3. (MM "Suicidal Ideation") OR (MM "Self-Injurious Behavior") OR (MM "Suicide, Attempted") OR(MM "Suicide Prevention") OR (MM "Suicide, Completed") OR (MM "Self Mutilation")	35,082
	4. S1 OR S2	216,183
	5. S3 AND S4	25
Medline	6. S3 AND S4; Limiters - Peer Reviewed; Human	**25**
	1. DE "Exercise" OR DE "Aerobic Exercise" or DE "Weightlifting" OR DE "Yoga" OR DE "Physical Activity" OR DE "Exercise"	60, 471
	2. DE "Sports" OR DE "Adaptive Sports" OR DE "Athletes" OR DE "Athletic Participation" OR DE "Athletic Performance" OR DE "Baseball" OR DE "Basketball" OR DE "College Sports" OR DE "Cycling" OR DE "Extreme Sports" OR DE "Football" OR DE "High School Sports" OR DE "Judo" OR DE "Martial Arts" OR DE "Professional Sports" OR DE "Soccer" OR DE "Swimminig" OR DE "Tennis" OR DE "Weightlifting"	49,682
	3. DE "Nonsuicidal Self-Injury" OR DE "Head Banging" OR DE "Self-Inflicted Wounds" OR DE "Self-Poisoning"	8, 557
	4. DE "Suicide" OR DE "Military Suicide" OR DE "Youth Suicide" OR DE "Suicidal Behavior" OR DE "Attempted Suicide" OR DE "Suicidal Ideation" OR DE "Suicide" OR DE "Nonsuicidal Self-Injury" OR DE "Head Banging" OR DE "Self-Inflicted Wounds" OR DE "Self-Poisoning" OR MM "Suicide Prevention"	60, 317
	5. MM "Suicidal Ideation"	11, 308
	6. S1 or S2	105, 269
	7. S3 OR S4 OR S5	60, 317
PsycINFO	8. S6 AND S7	**224**
	1. DE "Sports" OR DE "Adaptive Sports" OR DE "Athletes" OR DE "Athletic Participation" OR DE "Athletic Performance" OR DE Basketball" OR DE "Baseball" OR DE "College Sports" OR DE "Cycling" OR DE "Extreme Sports" OR DE "Football" OR DE "High School Sports" OR DE "Judo" OR DE "Martial Arts" OR DE "professinal Sports" OR DE "Soccer" OR DE "Swimming" OR DE "Tennis" OR DE "Weightlifting"	1, 063
	2. DE "Exercise" OR DE "Aerobic Exercise" OR DE "Weightlifting" OR DE "Yoga" OR DE "Physical Activity" OR De "Exercise"	1321

	3. MM "Running" OR MM "Walking" OR MM "Cycling"	233
	4. MM "Suicidal Ideation" OR MM "Suicidality" OR DE "Suicide" OR DE "Military Suicide" OR DE "Youth Suicide" OR MM "Suicide Prevention" OR DE "Nonsuicidal Slef-Injury" OR DE "Head Banging" OR DE "Self-Inflicted Wounds" OR DE "Self-Poisoning"	2,927
	5. S1 OR S2 OR S3	2,469
PsycArticles	6. S4 AND S5	**3**

Appendix D. Data extraction (expanded results and covariates for each study)

Author & year	Results (expanded)	Covariates	Pre-existing MH conditions	SES	Health Behaviours	Other social circumstances
1. Batty et al. (2023); Finland;	Former American football players exhibited a significantly lower risk of suicide. Summary Risk Ratio: 0.58 (95% CI 0.43, 0.80) p-value: <0.01. Adjusted Hazard Ratio (HR): 1.00 (reference) for the general population (controls). For participants of all contact sports combined: Adjusted HR: 1.14 (95% CI 0.60, 2.20). p-value: Not statistically significant (p > 0.05).	Age, socioeconomic status, Health Behaviours, Comorbidities,	**Depression:** Major depressive disorder (hospitalisation) OR = 6.41 (95% CI 3.82–10.75); depressive symptoms (via the Brief Symptom Inventory); No significant association between PA and later depression	**The longest-held job** was used as an SES indicator; SES was controlled for in adjusted models, and athletes had better SES than controls.	Heath behaviours (smoking and alcohol consumption); these were controlled for in adjusted models; relative to the general population, post-retirement, athletes tended to have a lower prevalence of smoking and heavy alcohol intake.	N/A
2. Brailovskaia et al. (2022), Germany;	Suicide-related outcomes at follow-up were significantly negatively correlated with physical activity at baseline (r = -0.260, p < 0.001). However, this association became non-significant (p = 0.215) after including PMH as a mediator. The direct effect of physical activity on suicide-related outcomes after accounting for PMH (mediator) was non-significant (p = 0.215)	Age, Gender	**Positive Mental Health (PMH)** was assessed at baseline using the PMH-Scale, which evaluates subjective well-being, life satisfaction, self-acceptance, and self-efficacy. Mean PMH score at BL: 18.40 (SD = 6.12), on a scale from 0 to 27. PMH at baseline was negatively correlated with SIB at follow-up (r = -0.469, p < .001). PMH was already accounted for in the mediator model.	N/A	N/A	N/A

3. Dugas et al. (2012); Canada;	OR = 0.6 (95% CI: 0.3–0.9, P = 0.02) (Significant) approx age at these 8 grades: Grade 8: 13–14 years old	Sex (male or female) Age (continuous variable) Mother's Education Level (university-educated or not) Language Spoken at Home (French or other) Born in Canada (yes or no)	**Depression**: measured across grades 7-11; validated 6-item scale; Depression symptoms in grades 9, 10, and 11 were independent predictors of suicidal ideation (OR 2.2; 95% CI 1.5 to 3.2, OR 1.6; 95% CI 1.0 to 2.5, and OR 1.9; 95% CI 1.1 to 3.4, respectively). Participants with a mood and (or) **anxiety disorder** were markedly more likely to report suicide ideation than participants without these disorders (31% to 36%, compared with 6% to 7%) (data not shown).	**Mother's Education:** Assessed as a binary variable (university-educated: yes/no). 45% of retained participants had university-educated mothers. Not significantly associated with SI in adjusted models. **Language Spoken at Home:** The Majority were French-speaking (31% of retained participants); this variable was not significantly associated with suicidal ideation. **Born in Canada:** 93%	Cigarette smoking and alcohol use were assessed in all grades but were not significant predictors in adjusted models. Grade 7 (BL) no significant difference between low/high alcohol/cigarette use participants; no data on the n of people smoking/drinking	**Family and Other Stress:** Measured with a 12-item scale across five years. Included stress from parental divorce, relationships with family and peers, schoolwork, and health issues. No cut-offs for high vs low family stress. Though significantly associated with SI in unadjusted models, stress variables were excluded from adjusted models due to high correlation with depression symptoms (r = 0.5–0.8).
4. Garcia-Hermos et al. 2023; USA;	Adolescents who met physical activity guidelines had a lower risk of suicidal ideation in adulthood compared to those who did not meet any guidelines (IRR = 0.74, 95% CI: 0.55 to 0.99, p = 0.049)	sex, race/ethnicity, parental income, age, depression score, alcohol consumption,	**Depression:** (self-report/antidepressant use) measured at FU; 21% of participants met the criteria. Analysis adjusted for depression.	Parental income (Wave 1) Mean ≈ 1 045 k USD ± 2 986 k USD. Analysis adjusted for parental income.	Alcohol consumption at wave 5. All analyses were adjusted by sex, race/ethnicity, parental income at Wave I, age at Wave V, depression score (5-item depression scale) at Wave V, and alcohol consumption at Wave V.	N/A

5. Hogstrom at al. 2016; Sweden	Men in the highest fifth of aerobic fitness had a 59% lower risk of suicide compared to those in the lowest fifth. Adjusted Hazard Ratio (HR) was 0.41 (95% CI: 0.36–0.47), with significant findings (P < 0.001)	BMI, Systolic and Diastolic Blood Pressure, Common diagnoses at baseline, Socioeconomic factors, Age, year of concription,	Pre-existing conditions (assessed by military physician) were: • Personality disorder – 0.7 % of the cohort • Neurosis (mainly anxiety disorders) – 2.6 % • Addiction (alcohol or drugs) – 1.4 %; Recognition that mild depression could not have been recorded.	Information on socioeconomic status, defined by annual income (no cut points), highest achieved education (4 categories of education) and disability pension (yes/no; yes: 1.2% of participants) 15 years after conscription, was gathered from the Statistics Sweden database using each participant's unique personal identification number. Table 1 in the study.	In comparison with the highest fifth, men in the lowest fifth of aerobic fitness had higher BMI, lower annual income, lower systolic and higher diastolic blood pressure, lower educational level and a higher percentage of musculoskeletal disorder (lumbago; P < 0.05 for all). 15 years after conscription: Annual income (mean ± SD): €24 600 ± 17 100 (2009 euros). Income rose step-wise from the lowest to the highest fitness quintile. Disability pension at year 15: 1.2 % overall (highest among the least-fit men).	The models simultaneously controlled for age, year of testing, BMI, blood-pressure, each of the psychiatric diagnoses, and the three socio-economic indicators (income, education, disability pension) when estimating the association between aerobic fitness and later suicide or other causes of death.
6. Jee et al. 2011; Korea	Men: No significant association between exercise and suicide mortality in either age-adjusted or fully adjusted models: Fully adjusted HR: 0.86 (95% CI: 0.69–1.07); p = 0.1582. Women: No significant association: Fully adjusted HR: 1.23 (95% CI: 0.66–2.27); p = 0.5166.	age, smoking status, alcohol drinking, exercise, body mass index (BMI), height, blood pressure, blood cholesterol, and blood glucose	N/A	Annual monetary contribution to medical insurance as SES. Based on income & assets. When grouped into quartiles, the lowest-SES men (< 29 921 Won) had a 65 % higher subsequent suicide risk than the highest-SES group (> 62 640 Won) after	Participants: 24.3% exercised; 47% never smoked; Alcohol intake (g/day), mean (SD) = 11.14 (27.13);	**Marital status:** self-reported at BL (married, never-married, remarried/separated/divorced, widowed). Being unmarried was associated with a higher—but imprecisely estimated—suicide risk in men (HR 1.60,

				multivariable adjustment. SES (insurance premium contribution, Won), mean (SD) = 51 163 (38 604);		95 % CI 0.83–3.06) and was too rare among women for stable estimates. Used as coveraite. 93.6% of participants were married
7. Latina et al., 2022; Sweden	No significant direct association between sport participation at baseline and self-harm a year later after controlling for self-harm at baseline and gender. β = -0.02, p = .48, 95% CI = -0.08 to 0.04. Indirect effect of sport participation on self-harm mediated through self-esteem: βindirect = -0.02, p = .02, 95% CI = -0.04 to -0.004"	Self-harm at baseline, Gender	Depressive symptoms: CES-DC mean = 1.70 (SD 0.64) at BL; no n provided	Country of birth: 85.3 % born in Sweden; Parental employment: fathers 89.4 % and mothers 73.2 % worked full-time. (The cohort was largely ethnically Swedish and come from households with high parental employment, indicating moderate–to–high socio-economic resources); these were not controlled for in adjusted analysis	N/A	**Family / living arrangements:** • 66 % lived with both parents • 14.4 % in joint custody • 17.3 % with mother only • 2.4 % with father only • ~1 % other custody. not controlled for in adjusted analysis

8. Paffenbarger et al., 1994; USA	Not statistically significant across any PA metric (p > 0.05 for all comparisons). Sports Participation (Hours/Week) None: Reference group (OR/HR = 1.00) 1–2: OR/HR = 0.50 (p = 0.140) ≥3: OR/HR = 0.88 Physical Activity Index (kcal/week) <1000: Reference group (OR/HR = 1.00) 1000–2499: OR/HR = 0.73 (p = 0.115) ≥2500: OR/HR = 0.84"	Age	N/A	SES not explicitly provided; although Harvard alumni	Smoking and alcohol. Alcohol (1977): 11 % abstainers, 43 % <150 g week, 46 % ≥150 g week (Table 2). Smoking (1962 or 1966): 42% never; 27% former; 11% <pack/day; 20% 1+ pack/day. Smoking increased the likelihood of later suicide, whereas moderate-to-higher alcohol consumption was associated with a reduced risk.	N/A
9. Perez et al., (2024); USA	Not significant for the whole sample. However light ambulatory physical activity during a current major depressive episode (MDE) was associated with lower odds of suicidal ideation (SI): Low SI compared to None: Odds Ratio (OR): 0.910 (95% CI: 0.841–0.984), p = 0.018 (adjusted) "	**sex, age, anti-depressants use**	All participants diagnosed with **major depressive disorder** (MDD), 80.9 % were in a current major-depressive episode (MDE);	**Employment:** 96% employed/university students	Excluded if pregnant; using tobacco; abusing alcohol; using illicit drugs; or if they had cardiovascular disease, autoimmune disease, cancer ≤ 5 y, or planned medication changes	N/A
10. Smith et al., 2013 [Study 2]; USA	Time 1 over-exercise (as measured by the EDEQ-4) significantly predicted Time 2 ACSS (β=0.19, t=2.00, p=0.05, f 2=0.03)	Dietary restraint (measured by the Eating Disorder Examination Questionnaire - EDEQ Restraint Subscale). Vomiting frequency	N/A for MH diagnosis; however disordered eating behaviours; Clinical cut-offs on the EDEQ subscales: 6.6% scored in the clinical range for Restraint; 2.4% for Eating Concern; 10.2% for Shape	N/A	N/A	N/A

		(measured by the EDEQ). Laxative use frequency (measured by the EDEQ)	Concern; 6.6% for Weight Concern			
11. Smith et al., 2015; USA	Women: Correlation between baseline over-exercise and SI at follow-up: r = 0.03, p > 0.05. Men: Correlation between baseline over-exercise and SI at follow-up: r = 0.19, p > 0.05.		N/A for MH diagnosis; however few instances of binging and no instances of purging in the sample; EDE-Q Restraint M = 1.42 (SD = 1.25) at baseline, well below clinical cut-offs	N/A	N/A	N/A
12. Taliaferro et al., 2011; USA	Participating in sports only at baseline and leter suicidal ideation: Model D: OR = 0.76 (95% CI: 0.42–1.38), p > 0.05; Participating in sports during both baseline and follow up and suicidal ideation: Model D: OR = 0.55 (95% CI: 0.30–1.00, p < 0.05; discontinuing sports after baseline and suicide attempts at follow-up: Model D: OR = 2.38 (95% CI: 1.04–5.41, p < 0.05)	gender, race/ethnicity, socioeconomic status (SES), depressive symptoms, and moderate-to-vigorous physical activity.	**Depressive-symptom burden:** mean = 11.5 (SD 3.1) on the 7-item Kandel & Davies scale (range 7–21). Boys: 10.8; girls: 12.0. Continuous covariate; no cut offs available. Depressive symptoms adjusted models.	SES from parental education, eligibility for free/reduced-price lunch or public assistance, and parental employment measured at BL. Weighted distribution: low 17.0 %, lower-middle 19.1 %, middle 30.5 %, upper-middle 18.1 %, upper 15.4 %. SES adjusted models.	N/A	N/A

13. Themelis et al., 2023; UK	For Low Physical Activity (IPAQ): (95% CI [0.89, 2.10], p = .160)	n/a	Anxiety symptoms (HADS-A) mean (SD) = 9.36 ± 4.67 ; Mean just above the clinical "borderline" cut-off (≥8); Depressive symptoms (HADS-D) mean (SD) - 7.90 ± 4.25; Borderline to mild depression on average;	Educational attainment: 88.55 % tertiary; 11.45 % secondary or below; Employment status: 39.69 % not working (includes students and medically retired)	Current smoker / vaper = 17.94 % ; Frequent alcohol use (≥3× week) = 13.74 %; Low physical-activity category (IPAQ) = 37.40 % ;	Social Activity Log (SAL) score = 15.33 ± 9.12 (scale 0–91; higher = more activity)
14. Zelkowitz et al., 2020 - study 1; USA	Odds Ratio (OR): Not explicitly provided in the text. P-value: The reported relation between Wave 1 exercise and Wave 2 NSSI was non-significant p > 0.05	Wave 1 NSSI: Baseline levels of nonsuicidal self-injury. Wave 1 Exercise: Baseline levels of exercise behaviour. Binge eating Fasting Purging	N/A for MH disorders; however, disordered eating and NSSI screening. Any fasting 22.8 %; Any binge-eating 38.5 %; Any purging 6.2 %; Any "compulsive" exercise 29.5 %; NSSI (past-month) binned; 2.5 %–3 % of the sample reported ≥1 episode (NSSI mean score = 0.03 on 0–3 scale)	N/A	N/A	psychology subject pool (82.9 %)
15. Zelkowitz et al., 2020 - study 2; USA	Odds Ratio (OR): Not explicitly provided in the text. P-value: The reported relation between Wave 1 exercise and Wave 2 NSSI was non-significant p > 0.05	Wave 1 NSSI: Baseline levels of nonsuicidal self-injury. Wave 1 Exercise: Baseline levels of exercise behaviour. Binge eating Fasting Purging	Eligibility required a lifetime history of (i) NSSI, (ii) disordered-eating (DE) behaviour, or (iii) both; groups balanced at entry (≈ 34 % NSSI only, 30 % DE only, 36 % both) BL: Any NSSI 16 % (mean binned score = 0.44); Fasting 56.7 %; Binge-eating 65.8 %; Purging 30.0 %; Excessive" exercise 48.4 %	N/A	N/A	N/A

Appendix E. JBI Quality Appraisal.

Author & year	1. Were the two groups similar and recruited from the same population?	2. Were the exposures (physical activity) measured similarly to assign people to both exposed and unexposed groups?	3. Was the exposure (physical activity) measured in a valid and reliable way?	4. Were confounding factors identified?	5. Were strategies to deal with confounding factors stated?	6. Were the groups/participants free of the outcome (suicide/SI) at the start of the study (or at the moment of exposure)?	7. Were the outcomes (suicide/SI) measured in a valid and reliable way?	8. Was the follow up time reported and sufficient to be long enough for outcomes to occur?	9. Was follow up complete, and if not, were the reasons to loss to follow up described and explored?	10. Were strategies to address incomplete follow up utilized?	11. Was appropriate statistical analysis used?	Risk of Bias Rating (%)
1. Batty et al. 2023	YES.	NOT APPLICABLE.	NO.	YES.	YES.	NO.	YES.	YES.	NOT APPLICABLE.	NOT APPLICABLE.	YES.	Moderate (55.%)
2. Brailovskaia et al. 2022	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	YES.	YES.	NOT APPLICABLE.	YES.	Moderate (64%)
3. Dugas et al. 2012	NOT APPLICABLE.	NOT APPLICABLE.	UNCLEAR/NO.	YES.	YES.	NO.	UNCLEAR.	Yes.	NO.	NO.	YES.	High (34%)
4. Garcia-Hermoso et al. 2023	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	YES.	UNCLEAR.	YES.	NO.	NO.	YES.	Moderate (55.%)
5. Hogstrom at al. 2016	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	YES.	YES.	YES.	YES.	NOT APPLICABLE.	YES.	Low (73%)
6. Jee et al. 2011	NOT APPLICABLE.	NOT APPLICABLE.	UNCLEAR.	YES.	YES.	YES.	YES.	YES.	YES.	NOT APPLICABLE.	YES.	Moderate (64%)
7. Latina et al., 2022	NOT APPLICABLE.	NOT APPLICABLE.	UNCLEAR.	YES.	YES.	NO.	YES.	YES.	YES.	YES.	YES.	Moderate (64%)
8. Paffenbarger et al., 1994	NOT APPLICABLE.	NOT APPLICABLE.	UNCLEAR.	YES.	YES.	YES.	YES.	YES.	YES.	NOT APPLICABLE.	YES.	Moderate (64%)
9. Perez et al., 2024	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	UNCLEAR.	NO.	YES.	YES.	High (45%)
10. Smith et al., 2013 (study 2)	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	UNCLEAR.	YES.	UNCLEAR.	NO.	NO.	YES.	High (45%)
11. Smith et al., 2015	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	UNCLEAR.	NO.	NO.	YES.	High (45%)
12. Taliaferro et al., 2011	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES	YES.	NO.	YES.	YES.	NO.	YES.	YES.	Moderate (64%)
13. Themelis et al., 2023	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	YES.	NO.	YES.	YES.	Moderate (64%)
14. Zelkowitz et al., 2020 (Study 1)	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	UNCLEAR.	NO.	YES.	YES.	Moderate (55.%)
15. Zelkowitz et al., 2020 (Study 2)	NOT APPLICABLE.	NOT APPLICABLE.	YES.	YES.	YES.	NO.	YES.	UNCLEAR.	NO.	YES.	YES.	Moderate (55.%)

Appendix F. STROBE

STROBE Statement—Checklist of items that should be included in reports of ***cohort studies***

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	47
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	49
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	50 - 54
Objectives	3	State specific objectives, including any prespecified hypotheses	54 - 55
Methods			
Study design	4	Present key elements of study design early in the paper	56
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	56
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	56
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	n/a
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	57 - 58
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	57 - 58
Bias	9	Describe any efforts to address potential sources of bias	57
Study size	10	Explain how the study size was arrived at	60
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	57 - 58
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	59 - 60
		(*b*) Describe any methods used to examine subgroups and interactions	
		(*c*) Explain how missing data were addressed	
		(*d*) If applicable, explain how loss to follow-up was addressed	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	60
		(b) Give reasons for non-participation at each stage	**
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	**
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	56
Outcome data	15*	Report numbers of outcome events or summary measures over time	

Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included (*b*) Report category boundaries when continuous variables were categorized (*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	61 - 65 58
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	61 - 65
Discussion			
Key results	18	Summarise key results with reference to study objectives	66
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	71
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	66 - 70
Generalisability	21	Discuss the generalisability (external validity) of the study results	71 - 73
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	n/a

*Give information separately for exposed and unexposed groups.

** Information included in the original study (O'Connor et al., 2021)

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at http://www.strobe-statement.org.

Appendix G. MRP Proposal

Available online: https://github.com/mbwie/PA-SI-longitudinal-association-IMV-model-MRP/blob/79174e5a9475e6a8ad532757366d067d255e236a/Final%20MRP%20Proposal%20-%202837977.pdf

Appendix H. Ethics approval letter

Content on page 98 removed due to confidentiality issues

Appendix I. Data Management Plan (DMP)

DOCTORATE IN CLINICAL PSYCHOLOGY

Data Management Plan (DMP)

Note:
This DMP template is adapted from the guidance provided here: https://www.gla.ac.uk/myglasgow/datamanagement/creatingyourdata/dataplanning/ Trainees should seek advice from their University Supervisor when developing the DMP. Examples of DMPs from different types of projects (including both quantitative and qualitative research) can be viewed here: https://www.dcc.ac.uk/resources/data-management-plans/guidance-examples The University of Glasgow data repository is Enlighten: http://researchdata.gla.ac.uk/

Title of project
Exploring the role of physical activity in relation to later suicidal ideation in the context of the integrated motivational-volitional model. Analyses of the UK COVID-19 Mental Health and Wellbeing study.
What data will be created? • Note the type and amount of data that will be created, e.g. assessment scores; transcripts; etc • Explain how you will capture the data, e.g. paper record forms; online survey; spreadsheet • What file formats will you use and why? e.g. "Microsoft Excel will be used as it is in widespread use" (adapt such statements to suit your project)
The study will use the pre-existing dataset from UK COVID-19 Mental Health and Well-being study (UK-COVID-MH) to conduct a secondary analysis. The responses from the eight waves of the study were anonymised and saved as an SPSS and excel files by the original researchers. The original questionnaire of UK-COVID-MH was distributed as an online survey. UK COVID-19-MH has been detailed previously (O'Connor et al., 2021, O'Connor et al., 2022) and the main research questions were preregistered at AsPredicted.org (#41910). Microsoft excel and SPSS version 28 will be used as they are in a widespread use for the quantitative research.
How will the data be documented and described? • What contextual details are needed? e.g. a written description of the data collection and analysis methods; dictionary of variable labels and values (e.g. category labels) • How will you document this? e.g. in the project write-up; in a 'readme' text file alongside the dataset(s)
Participant recruitment was conducted by Taylor McKenzie, a social research company, between during the height of the UK governments response to the global COVID-19 pandemic. Details of this are already summarised in published literature (O'Connor et al., 2021) The research will focus on the secondary analyses of pre-existing dataset. No new recruitment will be conducted. The data will already include the variable labels and variable key. The variables of interest were already described in detail in 'measures' section of the MRP proposal.

How will you manage ethics, governance and intellectual property?

- How will you safeguard the privacy of research participants? e.g. via informed consent (state if consent for future data sharing will be sought)
- What organisational approvals will you obtain?
- If any intellectual property is to be generated in the project, how will this be managed? e.g. if you are developing a novel questionnaire or a software app

From the original study: Participants provided written informed consent online. The authors asserted that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the University of Glasgow's Medical, Veterinary and Life Sciences Ethics Committee (approval number: 200190146) and participants consented for their data to be used in the research. Participants received £1.50 for the completion of each survey and were entered into prize draws.

Participants of the original study have already consented for the data to be used in the secondary analysis.

Current study: Following the successful approval of the MRP proposal in November 2023, ethical approval of a secondary data analysis of the UK COVID-19-MH dataset will be sought from University of Glasgow MVLS ethics committee. Access to the dataset will be requested by contacting MRP supervisor, who is a researcher involved in the original study and the MRP supervisor of the current study. The dataset has been already stripped from any personally identifiable markers.

Data Protection Impact Assessment (DPIA) will not be required in the current study.

What are the plans for data sharing and access?

- Who is expected to use the completed dataset(s) and for what purpose?
- How will the data be developed with future users in mind? e.g. use of widely-used or open source file formats
- How will you make the data available? e.g. deposit in a data repository; forward copies on request; create website
- If there are no plans for data sharing an appropriate justification must be provided

No new/novel dataset will be collected for this MRP. Current MRP does not involve recruitment of participants. This MRP is a quantitative study including a secondary analysis of an existing dataset (UK-COVID-MH). Syntax of this MRP will be available upon request.

What is the strategy for long-term preservation and sustainability?

- How will you store and back-up the data? e.g. University server with automatic back-up; University OneDrive account
- What are the plans for sustainability? e.g. choose open source file formats; deposit in data repository
- Which repository/data centre have you identified as a place to deposit your data? e.g. Enlighten; Open Science Framework
- How will you prepare data for preservation and sharing? Indicate the time and resource required for this
- How and when will you transfer ongoing responsibility for preservation/archiving to your University Supervisor?

No new/novel dataset will be collected for the current research. Current study does not involve recruitment of participants.

The data used in this MRP will be handled in line with the General Data Protection Regulation (GDPR) and University of Glasgow data retention policy.

Version Control v2 – Approved by Jessica Fish (26th September 2022)

Appendix J. Data analysis plan

Available at: https://github.com/mbwie/PA-SI-longitudinal-association-IMV-model-MRP/blob/79174e5a9475e6a8ad532757366d067d255e236a/Data%20Analysis%20Plan%20%20v2.pdf

Appendix K. Syntax & Moderation Analysis Output

Syntax available at: https://github.com/mbwie/PA-SI-longitudinal-association-IMV-model-MRP/blob/79174e5a9475e6a8ad532757366d067d255e236a/Syntax.sps

Moderation analysis output available at: https://github.com/mbwie/PA-SI-longitudinal-association-IMV-model-MRP/blob/f90edcb14f76f42055a21739459cd07e8143f128/moderation%20Defeat%20-%20Entrapment%20.spv

Appendix M. Pearson's correlations between continuous variables and descriptive analyses.

	Correlations					**Mean (SD)**
	1.	2.	3.	4.	5.	
1.Distress (W1)	-	.56**	.54**	-.06**	.19**	3.44 (2.79)
2. Defeat (W1)	.56**	-	.84**	-.12**	.29**	4.25 (3.93)
3. Entrapment (W1)	.54**	.84**	-	-.1**	.29**	3.96 (4.37)
4. Physical activity (W1)	-.06**	-.12**	-.1**	-	-.04	2.51 (2.36)
5. Suicidal ideation (W8)	.19**	.29**	.29**	-.04	-	.19 (.64)

Note: *p<.05; **p<.001;