

REVIEW

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Physical activity and mental health: a systematic review and best-evidence synthesis of mediation and moderation studies

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Abstract

Background While evidence consistently demonstrates that physical activity is beneficial to mental health, it remains relatively unknown how physical activity benefits mental health, and which factors influence the effect of physical activity on mental health. This understanding could vastly increase our capacity to design, recommend, and prescribe physical activity in more optimal ways. The purpose of this study was to systematically review and synthesise evidence of all mediators and moderators of the relationship between physical activity and mental health.

Methods Systematic searches of four databases (i.e., Scopus, PsycINFO, PubMed, and SPORTDiscus) identified 11,633 initial studies. Empirical studies that quantitatively assessed physical activity, or conducted a physical activity intervention, measured a mental health outcome, and tested one or more mediator or moderator of the relationship between physical activity and mental health were included. A total of 247 met the inclusion criteria; 173 studies examined mediation and 82 examined moderation.

Results Results of the best-evidence synthesis revealed strong evidence for 12 mediators including affect, mental health and wellbeing, self-esteem, self-efficacy, physical self-worth, body image satisfaction, resilience, social support, social connection, physical health, pain, and fatigue. Moderate evidence was identified for a further 15 mediators and eight moderators.

Conclusions Findings should inform the design of future physical activity interventions to ensure optimal effects on mental health related outcomes. Additionally, if health professionals were to take these mediators and moderators into consideration when prescribing or recommending physical activity, physical activity would likely have a greater impact on population mental health.

Keywords Exercise, Depression, Anxiety, Mediators, Moderators, Mechanisms, Wellbeing

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Background

Mental health disorders cause considerable burden of disease globally [1]. As such, the prevention and treatment of mental health disorders remains a high priority worldwide, as does the need to protect and promote positive mental health and wellbeing [2, 3]. Abundant evidence demonstrates that physical activity (PA) has the potential to offer a plethora of psychological benefits. As such, PA has become a universally accepted intervention for both the promotion of mental health and wellbeing, and the prevention of mental ill-health [4]. Despite this, evidence shows that not all PA is equal in terms of its effect on mental health (i.e., the strength and direction of the effect of PA on mental health outcomes varies considerably) [5]. Previous research aiming to understand this heterogeneity has focused on determining the ideal frequency, duration, and intensity of PA, but researchers have not been able to confirm an optimal dose for mental health benefits [6].

While many biophysical and psychosocial mechanisms of the effect of PA on mental health have been proposed [7, 8], it remains relatively unknown how PA contributes to positive mental health outcomes [9]. In-depth understanding of mediators can help to understand real-world mechanisms of influence [10], thereby identifying important factors that should be targeted in PA interventions, programs, and prescriptions, to ensure psychological benefits, or to maximise and strengthen benefits [11]. Indeed, many mediation studies have been conducted over the years, providing evidence of possible pathways between PA and, depression [12], anxiety [13], and psychological wellbeing [14]. However, these studies examine a variety of PA domains (e.g., leisure-time PA, active travel, physical education, occupational activity), mental health outcomes (e.g., depression, anxiety, wellbeing, life satisfaction), and mediators (e.g., self-esteem, fitness). This variability makes it difficult for researchers and practitioners to use mediation evidence to guide intervention development and mental health practice. Both Paluska [15] and Kandola [8] have conducted reviews where multiple proposed mechanisms are discussed and evidence on such mechanisms are presented. However, neither of these reviews were systematic reviews. While both papers advance our knowledge of possible mechanisms, these studies do not comprehensively discuss evidence of all tested mediators. Additionally, the review by Knadola et al. only discussed mechanisms of the effect of PA on depression. However, evidence has shown that PA is beneficial for the prevention of mental ill-health and the promotion of mental health [5]. While Paluska and Schwenk discussed mechanisms for a broader range of psychological outcomes, their paper was published in 2000 and far more mediation studies have occurred since 2000, than

prior to 2000. Unlike Paluska and Kadola, Lubans et al. [7] conducted a systematic review of mechanisms. However, this study only included children, and only included experimental studies. While experimental studies offer higher level evidence than observational studies, previously relying on experimental evidence only, has resulted in systematic reviews where it is not possible to confirm which factors are most important to the mental health benefits of PA [16]. In addition to this, observational studies are more likely to test moderation and mediation. Including evidence from a range of study designs would vastly increase the evidence base in which conclusions can be drawn from.

While mediation studies provide valuable evidence of factors that explain the positive effects of PA on mental health, recent research suggests that a range of other factors (i.e., moderators) might influence the strength of the effect of PA on mental health [17, 18]. Moderation analyses are therefore equally important because this evidence provides clinicians and practitioners (e.g., psychologists, exercise physiologists) with more detailed guidance around when, where, and with whom PA may be most beneficial for mental health. However, no study has systematically reviewed all moderators of the relationship between PA and mental health. Therefore, the aim of this systematic review was to combine and synthesise evidence of all mediators and moderators in the association between PA and mental health.

Methods

This research was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [19] and the PERSiST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidelines [20].

Eligibility criteria

Inclusion and exclusion criteria

This review aimed to include evidence of both mental health and mental ill-health. Positive outcome measures included mental health, mental wellbeing, and psychological wellbeing, as well as positive affect and life satisfaction as two core components of mental wellbeing [21]. Mental ill-health is defined as a broad term encompassing mental health disorders and preclinical mental health problems [22–25]. Therefore, negative outcome measures included psychological distress, stress, and negative affect, as well as depression (or depressive symptoms) and anxiety (or symptoms of anxiety), as these are the most common mental health disorders globally [26]. We did not specifically exclude any population group, as such, all populations and participants were able to be

included. The full inclusion and exclusion criteria are shown in Table 1.

Search strategy

We searched the following four databases from inception to July 2024: Scopus, PsycINFO, PubMed, and SPORTDiscus. Searches included keywords from three main groups, including mental health terms, physical activity terms, and terms reflecting mediation or moderation. The full search terms can be found in Additional File 1.

Study selection

After exporting records into Covidence, duplicate records were removed. Two reviewers then independently assessed each title and abstract, and we removed records recommended for exclusion by both reviewers. Two reviewers then independently assessed each of the remaining full text studies, recommending each for inclusion or exclusion. We removed studies recommended for exclusion by both reviewers, and rereviewed those where a discrepancy was present until consensus was reached.

Data extraction

Two reviewers extracted data from each included article into a pre-defined data extraction table, and a third reviewer checked the extracted data for accuracy. We extracted the numerical and textual results of mediation and moderation analyses in whichever format reported in the original study. We also extracted the year of publication, study design, sample characteristics (i.e., size, age, sex, and country), measure of physical activity and mental health, and what the mediator and/or moderator of interest was and how it was measured. All extracted data can be seen Additional File 4.

Study quality assessment

We used Risk of Bias criteria developed in a previous systematic review on a similar topic [5] to assess the quality of included studies. This risk of bias criteria was particularly valuable in this study as it was designed to assess quality across a range of study types including experimental and observational studies [5]. However, we needed to assess quality of the studies relative to mediation and moderation analyses, therefore we looked to relevant criterion from mediation study checklists developed by Lubans, Foster [27], Rhodes and Pfaeffli [28], and Cerin, Barnett [29] for an additional item to assess quality for mediation studies.. The full risk of bias criteria is listed in Table 2 and assesses quality across a range of study designs. Two reviewers independently assigned a 1 (present and explicitly explained) or a 0 (absent or inadequately described) for each study on the following seven criteria. We then categorised each study as high (a maximum of one criteria not met = score of 6 or 7), acceptable (most criteria met = score of 4 or 5), or low quality (some criteria met = score of ≤ 3) based on the total score [30].

Data synthesis

Given the broad variety of mediators and moderators examined in the included studies, meta-analyses were not possible as combining dissimilar studies statistically would not provide meaningful results [31]. Instead, we conducted a best-evidence synthesis. A best-evidence synthesis enables the reviewers to synthesise the results of the individual studies in relation to the certainty of those results. Rather than combining effects for different mediators and moderators that were measured differently, and among diverse populations, the reviewers made sense of the best available evidence for each mediator and moderator, in order to provide meaningful and clinically relevant findings that represent the literature

Table 1 Inclusion and exclusion criteria

Inclusion criteria

- 1 A quantitative assessment of physical activity, or an experimental study where the intervention was a PA intervention, and the intervention group was compared to a control group that did not undertake exercise
- 2 A quantitative assessment of at least one mental health outcome variable (i.e., mental health, mental wellbeing, psychological wellbeing, subjective wellbeing, life satisfaction, positive affect, negative affect, depression, anxiety, stress, or psychological distress)
- 3 A quantitative assessment of the relationships between physical activity, mental health, and at least one mediator or moderator
- 4 A cross-sectional, longitudinal, or experimental design
- 5 A full-text, peer reviewed journal article

Exclusion criteria

- 1 measured sedentary behaviour but not levels of physical activity
- 2 measured mental health specifically in terms of a particular setting or circumstance (e.g., job strain)
- 3 solely reported qualitative data
- 4 published in languages other than English

Table 2 Risk of bias criteria

Risk of bias criteria	
1	Participant eligibility criteria clearly stated and adequately described, and appropriate to the aims of the research.
2	Power calculation reported, and the study was adequately powered to detect mediation or moderation.
3	Valid measure of physical activity used. Objective measures of PA, self-report measures where the validity and reliability of the measures is cited, or experimental studies whereby participants are allocated to a PA intervention relative to a control condition are all considered a valid assessment of PA.
4	Valid measure used for the mental health outcome variable, or psychometric characteristics of the outcome variable reported and within accepted ranges (e.g., Cronbach's alpha and test-retest reliability > .60)?
5	Valid measure used to assess the mediator or moderator variable, or psychometric characteristics reported and within accepted ranges (e.g., Cronbach's alpha and test-retest reliability > .60)?
6	Statistically appropriate/acceptable methods of data analysis used for moderation or mediation.
7	Confounding factors/covariates adjusted for in analyses (e.g., sex, age, weight status).

[31]. Certainty of evidence was determined by three factors: the number of studies, the quality of the studies (risk of bias), and the consistency of findings. The evidence criteria for the best-evidence synthesis were adapted from previous studies and can be found in Table 3 [30, 32, 33].

While not combining effects statistically, to synthesise the results in a meaningful way and provide overarching conclusions based on evidence, we needed to group similar mediators and moderators. We used existing literature on mechanisms and contextual factors to create the following broad categories: psychological, social, behavioural, physiological, neurobiological, cognitive, environmental, and individual characteristics [7, 8, 15, 16]. Given the breadth and number of psychological mediators and moderators, we also grouped more similar variables together under subheadings to assist interpretation.

Results

Searches yielded 20,238 records, with 11,633 unique articles once duplicates were removed (Fig. 1). Following title and abstract screening, we reviewed 647 full-text articles. A total of 247 studies met the inclusion criteria [12, 13, 34–278], where 173 studies examined mediation and

82 examined moderation (a list of all included studies is available in Additional File 2). Publication dates ranged from 1986–2024, with 61% being published in the last 5 years. A total of 39 experimental studies, and 11 daily/weekly diary or ecological momentary assessment studies were included. Most studies were observational (80%) with 165 cross-sectional, 1 prospective, and 31 longitudinal. The sample sizes ranged from 12 to 727,865, with a total sample size of 2,436,311. Most studies also included general population participants, with 199 studies recruiting adults (81%), 35 studies recruiting adolescents (14%), and 11 studies recruiting children (4%). Of the 199 studies recruiting adults, 49 studies recruited College or University students (25%) and 24 studies recruited older adults (12%). A total of 34 studies (14%) specifically recruited clinical populations with a health or medical condition, including cancer ($n=7$), depression ($n=5$), multiple sclerosis ($n=3$), and spinal cord injury ($n=3$).

The most assessed outcome was depression or depressive symptoms, followed by psychological distress, life satisfaction, and anxiety. Twenty-three studies measured PA in terms of allocation to an exercise intervention group or to the control group and 20 studies measured PA with a device (e.g., accelerometer). All

Table 3 Evidence criteria for the best-evidence synthesis

Evidence category	Criteria
Very strong evidence	Four or more high quality studies, where $\geq 80\%$ of the findings consistently support moderation or mediation
Strong evidence	Four or more acceptable quality studies, where $\geq 80\%$ of the findings consistently support moderation or mediation
Moderate evidence	Two or more high/acceptable studies, where $\geq 60\%$ of the findings consistently support moderation or mediation OR Two or more low quality studies, where $\geq 80\%$ of the findings consistently support moderation or mediation
Limited evidence	Evidence provided by one study, or by all low-quality studies
Conflicting evidence	Inconsistent findings across multiple studies (< 60% of studies report consistent findings)
No evidence	No studies support mediation or moderation regardless of the number or quality of studies

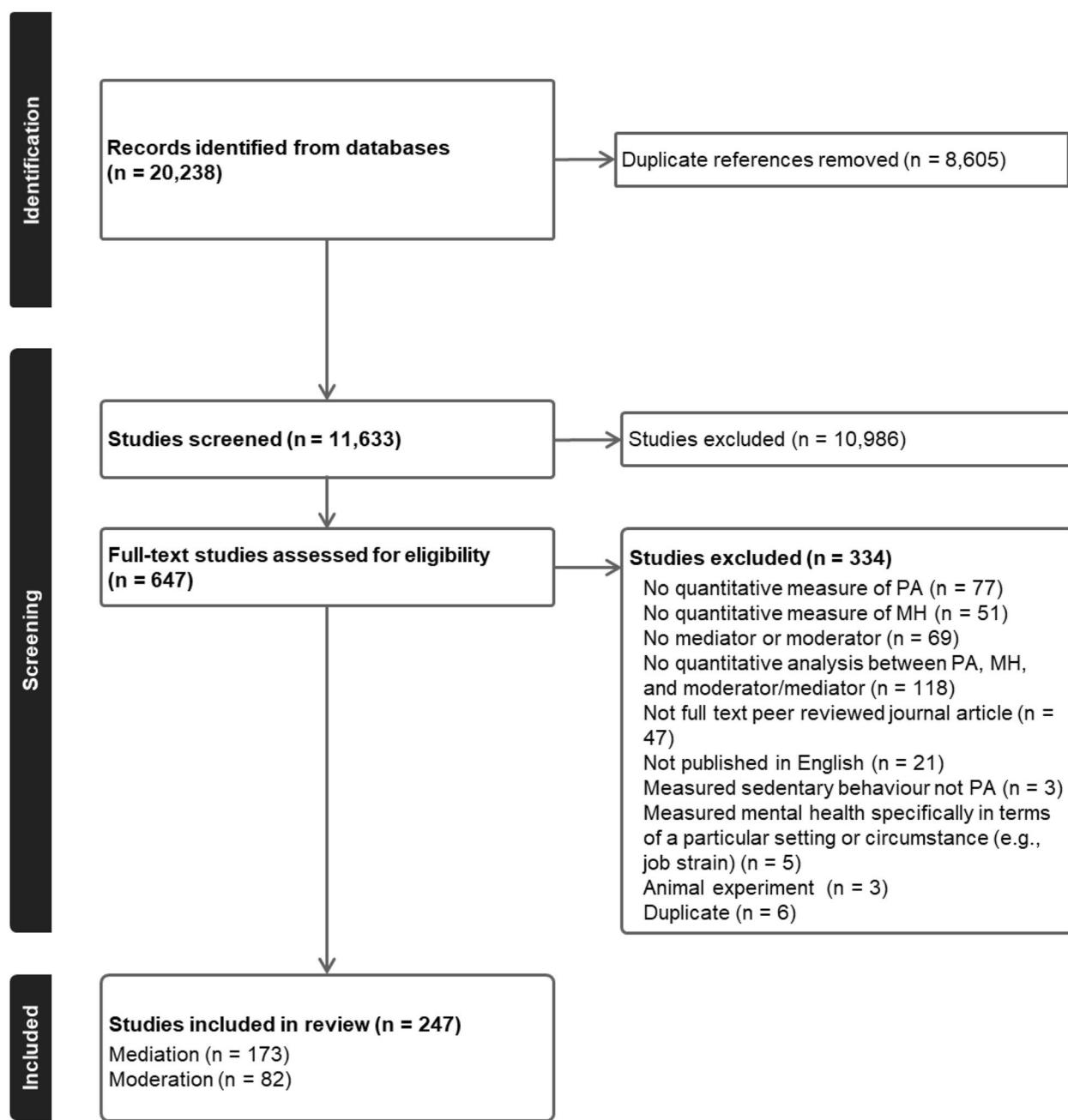


Fig. 1 PRISMA flow diagram of studies

other studies used self-report measures. The included studies also assessed a wide range of PA types, domains, and contexts. For example, of the 612 results extracted, 101 represent leisure-time PA, 15 active travel, 11 household/domestic PA, and 11 occupational PA. Only four results reflect physical education, three school sport, and a further five school PA. A total of 34 results reflects sport participation, with other results reflecting

walking (n = 16), running (n = 10), yoga (n = 5), Tai Chi (n = 2), swimming (n = 2), cycling (n = 1), dancing (n = 2), and Ba duan Jin (n = 2), and nature-based PA (n = 7). Nine results specifically reflected aerobic exercise and six resistance training. All other results reflect an assessment of total PA. The study characteristics of each study are included in Additional File 3.

Risk of bias

Initial agreement between the two reviewers was 80%, and the kappa coefficient ($\kappa=0.57$) indicated moderate agreement [279]. Upon discussion, 100% agreement was achieved. Of the included studies, 25.5% percent of studies were of high quality, 64.0% were acceptable, and 10.5% were of low quality. The complete results are included in Additional File 5.

Best-evidence synthesis

The full results from each included study are presented in Additional File 4. This file includes the specific mediation or moderation results of each study relative to the specific population, outcome, and assessment of physical activity. Those interested in the in-depth results relative to a specific mediator (e.g., resilience) can refer to Additional File 4 to see all results for the specific mediator, including the studies, populations, and measures that results are based upon.

Tables 4 and 5 provide a summary of these findings grouped under higher-level mediator and moderator categories. These tables include all data extracted from the 247 included studies regardless of study design or study quality, to best summarise the entire evidence base, however, the Additional Files provide more detailed granular results. The text-based results reported below use the six best-evidence synthesis categories (i.e., very strong, strong, moderate, limited, conflicting, and no evidence) to draw attention to mediators and moderators with strong or moderate evidence. As a summary, Table 6 lists all significant mediators and moderators.

Mediation results

Psychological factors

Affect, wellbeing, stress, and depression or anxiety

symptomology or sensitivity

Strong evidence suggests that affect mediates the relationship between PA and mental health. Six studies of acceptable quality reported nine individual effects with 89% supporting mediation. Significant mediation results were reported for depression, anxiety, mental health, and life satisfaction; however, only among adults, including those with depression, anxiety, and multiple sclerosis. Strong evidence suggests that mental health and wellbeing mediates the relationships between PA and other psychological outcomes including depression, anxiety, psychological distress, and life satisfaction. Six studies with five of acceptable or high quality, reported eight individual effects, with 88% supporting mediation. These results were only identified among adults, including those with major depressive disorder. Moderate evidence suggests that stress mediates the relationship between PA and mental health. Four studies (one high quality, two acceptable, and one low) reported

six individual effects with 67% supporting mediation. Significant mediation results were reported for depression, psychological distress, and life satisfaction, among adults, and those with a spinal cord injury. Moderate evidence suggests that life satisfaction mediates the relationship between PA and both, wellbeing, and psychological distress. Three studies, two of high quality, reported three individual effects, with 67% supporting mediation. Mediation results were only identified among young adults.

Self-esteem, self-worth, self-efficacy, and body image

Strong evidence suggests that self-esteem mediates the relationship between PA and mental health. Six studies (five acceptable quality and one of low quality) reported eight individual results, with 100% supporting mediation. Significant mediation results were reported for depression, anxiety, and wellbeing, among adults including those with a major depressive disorder. Strong evidence suggests that self-efficacy mediates the relationship between PA and mental health. Twelve studies (two of high quality, nine of acceptable quality, and one of low quality) reported 17 individual results, with 94% supporting mediation. Significant mediation was reported across depression, psychological distress, affect, mental health, wellbeing, and life satisfaction among adolescents and adults. Strong evidence suggests that physical self-worth mediates the relationship between PA and mental health. Four studies of high or acceptable quality reported five individual results, with 80% supporting mediation. Significant mediation was reported for depression, anxiety, and life satisfaction among adults. Strong evidence suggests that body image satisfaction mediates the relationship between PA and mental health. Eleven studies (one of high quality, eight of acceptable quality, and one of low quality) reported 18 individual results, with 94% supporting mediation. Significant mediation was reported across depression, anxiety, psychological distress, positive affect mental health, wellbeing, and life satisfaction among adolescents and adults, including cancer survivors.

PA self-efficacy, accomplishment, competence, and mastery

Moderate evidence suggests that physical or sport competence mediates the relationship between PA and mental health. Two studies of acceptable quality reported two individual results with 100% supporting mediation. Significant mediation was reported for positive affect and wellbeing only, among only adults. Moderate evidence suggests that mastery mediates the relationship between PA and mental health. Two studies of high or acceptable quality reported two individual results with 100% supporting mediation. Significant mediation was reported for depression and psychological distress only, among only adults but including cancer survivors.

Table 4 Summary of significant mediators in the association between physical activity and mental health

	Mediator	No. of studies	No. of effects	Sig. results	Outcome variables		Evidence
					Significant mediation	No significant mediation	
Affect, wellbeing, stress, and depression or anxiety symptomology or sensitivity	Internalizing problems	1	2	2/2	Life satisfaction [228]		Limited
	Externalising problems	1	2	2/2	Life satisfaction [228]		Limited
	Anxiety sensitivity	1	3	3/3	Psychological distress [26]		Limited
	Δ Psychological distress	1	1	1/1	Psychological distress [8]		Limited
	Depressive symptoms	1	1	1/1	Stress [58]		Limited
	Behavioural activation	1	3	3/3	Depression [210], Anxiety [210], Psychological distress [210]		Limited
	Psychological distress	1	1	1/1	Life satisfaction [243]		Limited
	Stress	4	6	4/6	Depression [120, 224], Psychological distress [234], Life satisfaction [167]	Life satisfaction [167]	Moderate
	Academic stress	1	1	1/1	Life satisfaction [207]		Limited
	Mental health/wellbeing	6	8	7/8	Depression [79, 245], Psychological distress [124], Life satisfaction [166]	Life satisfaction [146]	Strong
	Mental health difficulties	1	1	1/1	Life satisfaction [170]		Limited
PSYCHOLOGICAL	Affect & emotions	6	9	8/9	Depression [115, 175], Anxiety [93], Mental health [96], Life satisfaction [57, 107]	Depression [115]	Strong
	Flow	1	3	1/3	Psychological distress [210]	Depression [210], Anxiety [210]	Limited
	Vitality	1	1	1/1	Anxiety [93]		Limited
	Life satisfaction	3	3	2/3	Wellbeing [197], Psychological distress [127]	Affect [143]	Moderate
	Self esteem	6	8	8/8	Depression [79, 152, 182, 169], Anxiety [221], Wellbeing [36, 186, 221]		Strong
	Self-concept	1	1	1/1	Depression [238]		Limited
	Self-efficacy	12	17	16/17	Depression [11, 22, 129], Psychological distress [27, 28, 240], Affect [14], Mental health [94], Wellbeing [208], Life satisfaction [84]	Mental health [50]	Strong
	Physical self-worth	4	5	4/5	Depression [2], Anxiety [2], Life satisfaction [56, 57, 107]	Life satisfaction [56]	Strong
	Social Phisiue anxiety	1	3	2/3	Anxiety [82]	Panic disorder [92]	Limited
	Body image esteem/satisfaction	11	18	17/18	Depression [39, 77, 233], Anxiety [39, 233], Psychological distress [30, 104, 233], Mental health [41], Positive affect [64], Wellbeing [80, 186, 201], Life satisfaction [179]	Wellbeing [186]	Strong
Esteem and confidence related constructs in relation to PA	Task efficacy	1	1	1/1	Depression [182]		Limited
	Exercise self-efficacy	8	8	4/8	Depression [31], Mental health [198], Life satisfaction [57, 170]	Stress [76], Mental health [82, 113], Life satisfaction [107]	Conflicting
	Behavioural intentions	1	4	1/4	Depression [11]	Depression [11]	Limited
	Behavioural skills	1	4	0/4		Depression [11]	No evidence
	Physical/sports competence	2	2	2/2	Positive affect [64], Wellbeing [80]		Moderate
	Mastery	2	2	2/2	Depression [46], Psychological distress [27]		Moderate
	Accomplishment	1	1	1/1	Positive affect [192]		Limited
Personality	Neuroticism and Extraversion	1	2	0/2		Mental health [219]	No evidence
	Pleasure	1	1	0/1		Life satisfaction [185]	No evidence
	Centrality	1	1	0/1		Life satisfaction [185]	No evidence
	Sign	1	1	0/1		Life satisfaction [185]	No evidence
	Perfectionism	1	1	1/1	Wellbeing [78]		Limited
	Instrumentality	1	1	1/1	Wellbeing [80]		Limited
	Morale	1	2	2/2	Depression [118], Mental health [118]		Limited
	Approach-avoidance contrast temperament	1	1	1/1	Depression [29]		Limited
	Hope	2	3	3/3	Psychological distress [36], Wellbeing [237]		Moderate
	Self-enhancement	1	1	1/1	Anxiety [109]		Limited
	Motivation	1	2	2/2	Wellbeing [102]		Limited
	Intrinsic motivation	2	2	1/2	Wellbeing [101]	Wellbeing [189]	Conflicting

Table 4 (continued)

Psychological factors related to physical activity	Identified regulation	1	1		0/1	Wellbeing [189]	No evidence
	Introjected regulation	1	1		1/1	Wellbeing [101]	Limited
	PA liking Timepoint 2	1	1		0/1	Depression [116]	No evidence
	Psychological need satisfaction	1	1		1/1	Wellbeing [133]	Limited
	Autonomy	3	6		2/6	Mental health [52, 165]	Depression [145], Stress [145], Negative affect [145], Positive affect [145]
	Competence	3	6		2/6	Mental health [52, 165]	Depression [145], Stress [145], Negative affect [145], Positive affect [145]
	Relatedness	3	6		3/6	Mental health [52, 165], Positive affect [145]	Depression [145], Stress [145], Negative affect [145]
	Nature of engagement	1	1		1/1	Depression [35]	Limited
	Scheduling efficacy	1	1		0/1	Depression [182]	No evidence
	Satisfaction with perceived progress	1	5		5/5	Negative affect [162], Positive affect [162], Life satisfaction [162]	Limited
	Behavioural loyalty	1	1		0/1	Life satisfaction [185]	No evidence
	Exercise intensity tolerance and preference	1	1		1/1	Psychological distress [235]	Limited
	Exercise-specific affect regulation	1	1		1/1	Psychological distress [231]	Limited
	Enjoyment of PA	1	1		1/4	Depression [11]	Depression [11]
Other psychological factors	Psychological detachment	1	1		1/1	Positive affect [64]	Limited
	Recovery experience (i.e., psychological detachment, relaxation, mastery, control)	1	1		1/1	Wellbeing [75]	Limited
	Perceived restorativeness	1	4		2/4	Negative affect [149], Positive affect [149]	Negative affect [149], Positive affect [149]
	Mindfulness	3	5		3/5	Depression [119], Stress [76]	Depression [119], Wellbeing [201]
	Rumination	1	2		2/2	Depression [119]	Limited
	Sense of coherence	1	2		0/2	Depression [118], Mental health [118]	No evidence
	Sense of meaning	1	2		2/2	Wellbeing [36]	Limited
	Sense of control	2	5		5/5	Depression [176], Anxiety [176], Stress [176], Mental health [176], Life satisfaction [243]	Moderate
	Self-criticism	1	1		1/1	Anxiety [109]	Limited
	Emotion regulation/intelligence	3	5		5/5	Depression [196], Anxiety [196], Wellbeing [208], Life satisfaction [62]	Moderate
	Stress appraisal	1	3		1/3	Psychological distress [114]	Psychological distress [114]
	Resilience	10	11		11/11	Depression [118, 227], Anxiety [222, 242], Psychological distress [104, 131, 142, 235], Mental health [94, 118], Affect [143]	Strong
	Grit	1	1		1/1	Life satisfaction [10]	Limited
	Drive	1	1		1/1	Depression [127]	Limited
	Reward responsiveness	1	1		0/1	Depression [127]	No evidence
	Fun seeking	1	1		1/1	Depression [127]	Limited
	Health related quality of life	1	1		1/1	Depression [150]	Limited
	Health values	1	1		1/1	Wellbeing [247]	Limited
	Loneliness	2	2		2/2	Life satisfaction [183, 184]	Moderate
SOCIAL	Self-efficacy related to the management of illness	1	2		1/2	Mental health [82]	Conflicting
	Coping strategies/efficacy/styles	5	7		4/7	Stress [44], Psychological distress [148], Positive affect [175]	Psychological distress [142], Depression [175], Negative affect [175]
	Outcome expectancies	1	4		0/4	Depression [11]	No evidence
	Learning burnout	1	1		1/1	Psychological distress [126]	Limited
	Social context of PA	1	4		0/4	Depression [11]	No evidence
	Social support/network	7	8		7/8	Depression [195, 214, 227, 238], Anxiety [242], Subjective wellbeing [237], Life satisfaction [84]	Depression [214]
	Social connections	4	4		3/4	Depression [42], Mental health [94], Wellbeing [239]	Wellbeing [151]
	Class identity	1	1		1/1	Wellbeing [139]	Limited
	Socialising/social participation	2	8		8/8	Stress [204], Psychological distress [220]	Moderate

Table 4 (continued)

BEHAVIOURAL	Sense of belonging	5	11	 10/11	Depression [12, 163, 210], Anxiety [163, 210], Psychological distress [210], Positive affect [64], Life Satisfaction [163], Wellbeing [178]	Depression [12] Moderate
	Social competence/relationship difficulties	2	2	 2/2	Depression [97, 245]	Limited
	Coach relationship	1	3	 1/3	Psychological distress [210]	Depression [210], Anxiety [210] Conflicting
	MVPA	1	1	 1/1	Mental health [52]	Limited
	Time spent on leisure activities	1	1	 1/1	Psychological distress [124]	Limited
	Sleep	12	22	 8/22	Depression [13], Anxiety [212], Psychological distress [18, 159], Stress [66], Subjective wellbeing [133]	Depression [108, 232], Anxiety [125, 232], Psychological distress [38, 236], Stress [123, 232], Mental health [50] Conflicting
	Sitting time	1	4	 0/4		Depression [11] No evidence
	Screen time	1	4	 0/4		Depression [11] No evidence
PHYSIOLOGICAL	Problematic phone/social media/internet use	3	4	 4/4	Psychological distress [126], Depression [103], Stress [177], Mental health [177]	Moderate
	Diet	4	9	 3/9	Depression [103, 230]	Depression [11, 230], Psychological distress [124] Conflicting
	Fitness	4	5	 2/5	Depression [171], Mental health [1]	Depression [135], Anxiety [135], Life satisfaction [194] Conflicting
	Physical health/medical status	6	7	 5/7	Depression [129], Psychological distress [124, 126, 159], Wellbeing [139]	Depression [9], Anxiety [9] Strong
	Function	3	4	 4/4	Depression [47], Psychological distress [128], Life satisfaction [153]	Moderate
	Disability	2	2	 0/2		Depression [16], Life satisfaction [153] No evidence
	Stiffness	1	1	 0/1		Depression [16] No evidence
	Pain	6	6	 5/6	Depression [74, 172], Psychological distress [38], Stress [120], Affect [14]	Depression [16] Strong
NEUROBIOLOGICAL	Fatigue	5	6	 4/6	Depression [5, 65, 180], Life satisfaction [153]	Depression [16, 65] Strong
	Body mass index	3	4	 3/4	Depression [55], Mental health [41], wellbeing [213]	Psychological distress [213] Moderate
	Weight perception	1	2	 2/2	Life satisfaction [155]	Limited
	Energy levels	1	1	 1/1	Subjective wellbeing [98]	Limited
	Glycaemic control	1	1	 0/1	Depression [246]	No evidence
	HPA axis functioning	1	1	 0/1		Depression (22) No evidence
	Cortisol reactivity	1	1	 0/1		Depression (22) No evidence
	Heart rate during social stress	1	1	 1/1	Depression (22)	Limited
COGNITIVE	Heart rate reactivity	1	1	 0/1		Depression (22) No evidence
	High sensitivity C-reactive protein	1	1	 0/1		Depression (22) No evidence
	Changes in N2 TFSF amplitude	1	1	 0/1		Depression (120) No evidence
	Inflammation	2	2	 2/2	Depression (98, 229)	Moderate
	Triglycerides	1	1	 1/1	Depression (98)	Limited
	APOE ε4 carrier status	1	1	 1/1	Psychological distress [83]	Limited
	BDNF Val66Met polymorphism	1	1	 0/1		Psychological distress [83] No evidence
	BDNF	1	1	 1/1	Depression [51]	Limited
ENVIRONMENT	Cognitive functioning	3	4	 2/4	Depression [20], Anxiety [49]	Psychological distress [213], Wellbeing [213] Conflicting
	Nature relatedness	1	2	 2/2	Wellbeing [102]	Limited
	Time spent in nature	1	1	 0/1		Subjective wellbeing [178] No evidence

PA physical activity; the numbers in parentheses in the 'outcome variable' column refer to the individual study IDs of the 247 included studies

Table 5 Summary of significant moderators of the association between physical activity and mental health

	Moderator	No. of studies	No. of effects	Sig. results	Outcome variables		Evidence
					Significant moderation	No significant moderation	
Affect, wellbeing, stress, and depression or anxiety symptomology or sensitivity	Depressive symptoms	3	3	2/3	Depression [25], Positive affect [218]	Negative mood [4]	Moderate
	Bipolar disorder	2	3	2/3	Depression [205, 206]	Depression [205]	Moderate
	Flow	1	1	0/1		Depression [132]	No evidence
	Positive affect	1	1	1/1	Positive affect [106]		Limited
Global self-esteem, self-worth, body image, and appearance	Body image	1	2	1/2	Anxiety [90]	Depression [90]	Conflicting
Esteem and confidence related constructs in relation to physical activity	Mastery	1	1	0/1		Negative affect [37]	No evidence
Personality	Extraversion	4	5	2/5	Life satisfaction [207], Subjective wellbeing [32]	Negative affect [72], Positive affect [72], Wellbeing [33]	Conflicting
	Agreeableness	3	4	1/4	Positive affect [72]	Negative affect [72], Subjective wellbeing [32, 33]	Conflicting
	Conscientiousness	2	3	1/3	Positive affect [72]	Negative affect [72], Subjective wellbeing [32]	Conflicting
	Neuroticism	2	3	2/3	Negative affect [72], Positive affect [72]	Subjective wellbeing [32]	Moderate
	Openness	2	3	1/3	Subjective wellbeing [32]	Negative affect [72], Positive affect [72]	Conflicting
	Control	1	1	0/1		Negative affect [37]	No evidence
	Preoccupation with food	1	1	0/1		Negative mood [4]	No evidence
	Emotional cravings	1	1	0/1		Negative mood [4]	No evidence
Psychological factors related to physical activity	Motivation	2	10	4/10	Negative affect [216], Positive affect [216]	Negative affect [121, 216], Positive affect [121, 216]	Conflicting
	Autonomous motivation	1	3	1/3	Life satisfaction [191]	Negative affect [191], Positive affect [191]	Conflicting
	Intrinsic motivation	2	2	1/2	Affect [188]	Positive affect [81]	Conflicting
	Identified regulation	1	1	0/1		Positive affect [81]	No evidence
	Introjected regulation	2	4	1/4	Positive affect [81]	Negative affect [144], Positive affect [191], Life satisfaction [191]	Conflicting
	External regulation	1	3	3/3	Negative affect [191], Positive affect [191], Life satisfaction [191]		Limited
	Motivation and energy	1	1	1/1	Depression [202]		Limited
	Exercise self-regulation	1	1	1/1	Stress [71]		Limited
Other psychological factors	Stressful life events	1	2	0/2		Positive affect [147]	No evidence
	Mother's perceived stress	1	2	1/2	Positive affect [211]	Negative affect [211]	Conflicting
	Psychological detachment	1	1	1/1	Negative affect [37]		Limited
	Relaxation	1	1	0/1		Relaxation [37]	No evidence
	Self-connection	1	5	1/5	Depression [111]	Anxiety [111], Negative affect [111], Positive affect [111], Life satisfaction [111]	Conflicting
	Quality of life	1	1	0/1		Mental health [140]	No evidence
	Loneliness	1	1	1/1	Depression [86]		Limited
	Distress tolerance	1	2	1/2	Mood [23]	Anxiety [23]	Conflicting
	Concern about COVID-19	1	1	1/1	Anxiety [222]		Limited
	Social context	2	3	1/3	Positive affect [54]	Negative affect [54], Anxiety/Depression [105]	Conflicting
SOCIAL	Social support	3	3	3/3	Psychological distress [85], Depression [158, 223]		Moderate
	Social isolation	1	1	1/1	Depression [86]		Limited
	COVID-19 isolation	1	2	0/2		Depression [24], Anxiety [24]	No evidence

Table 5 (continued)

BEHAVIOURAL	Sitting Time	1	3		3/3	Psychological distress [7], Anxiety [7], Depression [7]	Limited
	Sleep	3	3		3/3	Depression [86], Negative affect [37], Positive affect [3]	Conflicting
	Alcohol	1	1		1/1	Psychological distress [160]	Limited
	Smoking	1	1		1/1	Psychological distress [160]	Limited
	PA pre-covid	2	3		2/3	Depression [122], Positive mood [34]	Anxiety [122] Moderate
PHYSIOLOGICAL	Disability	2	4		0/4	Depression [18], Anxiety [18], Negative affect [72], Positive affect [72]	No evidence
	Multimorbidity	1	2		2/2	Depression [63], Wellbeing [63]	Limited
	Functionality	2	3		1/3	Depression [86]	Depression [18], Anxiety [18] Conflicting
	Pain	1	1		2/2	Depression [86]	Limited
	Strength	1	1		1/1		Depression [112] Limited
	Non-communicable diseases	1	2		1/2	Depression [18]	Anxiety [18] Conflicting
	Body mass index	3	5		1/5	Negative affect [190]	Depression [90, 181], Anxiety [90], Negative affect [190] Conflicting
	Impact of Weight on Quality of Life	1	1		0/1		Negative mood [4] No evidence
NEUROBIOLOGICAL	BDNF	1	1		1/1	Depression [53]	Limited
	Apolipoprotein E type 4 allele (APOE-e4)	1	1		1/1	Depression [117]	Limited
	Left versus right activated	1	1		1/1	Anxiety [173]	Limited
	Triglycerides	1	1		0/1		Depression [98] No evidence
COGNITIVE	Cognitive functioning	1	1		1/1	Depression [20]	Limited
ENVIRONMENT	Environment	4	5		2/5	Negative affect [54], Affect [70]	Anxiety/depression [21, 105], Positive affect [54] Conflicting
	Presence of neighbourhood resources for youth	1	1		0/1		Anxiety/depression [60] No evidence
	Perceived neighbourhood violence	1	1		0/1		Anxiety/depression [60] No evidence
	Neighbourhood walkability	1	1		1/1	Mental health [6]	Limited
INDIVIDUAL	Age	7	11		7/11	Depression [134, 144], Positive affect [95], Life satisfaction [146]	Depression [25, 77, 144, 209] Conflicting
	Sex/Gender	15	24		10/24	Negative affect [43] Depression [53, 59, 100], Anxiety [15, 59, 100, 199], Depression/anxiety [200]	Depression [25, 69, 73, 77, 89, 134, 168], Anxiety [59, 89], Stress [89], Negative affect [100], Positive affect [43], Subjective wellbeing [189] Conflicting
	Race	3	4		3/4	Depression [19, 141], Anxiety [19]	Depression [69] Conflicting
	Income	1	1		1/1	Psychological wellbeing [91]	Limited
	SES	4	6		3/6	Depression [19, 141], Anxiety [19]	Depression (123), Subjective wellbeing (139) Conflicting
	Occupation type	2	5		3/5	Psychological distress [216], Depression [215]	Depression [215] Moderate
	First responder role	1	1		1/1	Psychological distress [154]	Limited
	Swimming experience	1	1		1/1	State anxiety [17]	Limited
	PA identity	1	2		2/2	Depression [68]	Limited
	Exercise mode preference	1	2		1/2	Positive affect [157]	Negative affect [157] Conflicting

PA physical activity; the numbers in parentheses in the 'outcome variable' column refer to the individual study IDs of the 247 included studies

Table 6 Summary of evidence for significant mediators and moderators

Mediators	Moderators	
Strong evidence	Moderate evidence	Moderate evidence
<ul style="list-style-type: none"> • Affect • Mental health • Self-esteem • Self-efficacy • Physical self-worth • Body image satisfaction • Resilience • Social support • Social connection • Physical health • Pain • Fatigue 	<ul style="list-style-type: none"> • Stress • Life satisfaction • Physical/sport competence • Mastery • Hope • Mindfulness • Sense of control • Emotional regulation • Loneliness • Sense of belonging • Socialising • Problematic phone, social media, internet use • Functionality • BMI • Inflammation 	<ul style="list-style-type: none"> • Depressive symptoms • Bipolar disorder • Neuroticism • Social support • Sleep • Race • Age • Occupation <p><i>Although the direction is conflicting for sleep, race, age, and occupation.</i></p>

Personality

Moderate evidence suggests that hope mediates the relationship between PA and mental health. Two studies, one of low and one of high quality, reported three individual effects, with 100% supporting mediation. Significant mediation results were reported for psychological distress and wellbeing, among adults.

Psychological factors related to the PA experience

No evidence suggests scheduling efficacy or behavioural loyalty mediate the relationship between PA and mental health, and conflicting evidence exists for autonomy, competence, and relatedness.

Other psychological factors

Moderate evidence suggests that mindfulness mediates the relationship between PA and mental health. Three studies of high or acceptable quality reported five individual results with 60% supporting mediation. Significant mediation was reported for depression and stress only, among only adults, including advanced yoga participants. Moderate evidence suggests that a sense of control mediates the relationship between PA and mental health. Two studies of high or acceptable quality reported five individual results with 100% supporting mediation. Significant mediation was reported for depression, anxiety, stress, mental health and life satisfaction, although only among university students. Moderate evidence suggests that emotional regulation or emotional intelligence mediates the relationship between PA and mental health. Three studies of acceptable quality reported five individual results with 100% supporting mediation. Significant mediation was reported for depression, anxiety, wellbeing, and life satisfaction, among adolescents and young adults. Strong

evidence suggests that resilience mediates the relationship between PA and mental health. Ten studies (three of high quality, six of acceptable, and one of low quality) reported 11 individual results with 100% supporting mediation. Significant mediation was reported for depression, anxiety, psychological distress, mental health, and affect, among children, adolescents, and adults, including cancer survivors and children with ADHD. Moderate evidence suggests that loneliness mediates the relationship between PA and mental health. Two studies of high and acceptable quality reported two individual results with 100% supporting mediation. Significant mediation was reported for life satisfaction among adults only.

Social factors

Strong evidence suggests that social support mediates the relationship between PA and mental health. Seven studies, five of acceptable quality, reported eight individual results with 88% supporting mediation. Significant mediation was reported among adults for depression, anxiety, wellbeing, and life satisfaction. Strong evidence suggests that social connections mediate the relationship between PA and mental health. Four studies (three of high quality and one of acceptable quality) reported four individual results with 75% supporting mediation. Significant mediation was reported only among children and adolescents, for depression, and mental health and wellbeing. Moderate evidence suggests that a sense of belonging mediates the relationship between PA and mental health. Five studies, three of acceptable quality, reported eleven individual results, 91% supporting mediation. Significant mediation was reported for depression, anxiety, psychological distress, positive affect, life satisfaction, and wellbeing, among adults and adolescents. Moderate evidence

suggests that socialising/social participation mediates the relationship between PA and mental health. Two studies of high and acceptable quality reported eight individual results, with 100% supporting mediation. Significant mediation was reported among adults for stress and psychological distress.

Behavioural factors

Moderate evidence suggests that problematic phone, social media, or internet use mediates the relationship between PA and mental health. Three studies of high or acceptable quality reported four individual results with 100% supporting mediation. Significant mediation was reported for depression, stress, psychological distress, and mental health, among adolescents and adults. No evidence supported sitting time or screen time as mediators and evidence was conflicting as to whether sleep was a mediator.

Physiological mechanisms

Strong evidence suggests that physical health, or medical status, mediates the relationship between PA and mental health. Six studies (one of high quality, three of acceptable quality, and two of low quality) reported seven individual results with 71% supporting mediation. Significant mediation was reported for depression, psychological distress, and wellbeing, although only among university students. Strong evidence suggests that pain mediates the relationship between PA and mental health. Six studies (five of acceptable quality) reported six individual results with 83% supporting mediation. Significant mediation was reported for depression, stress, and psychological distress, among adults, including those with rheumatoid arthritis and spinal cord injury. Strong evidence suggests that fatigue mediates the relationship between PA and mental health. Five studies (two of high quality and three of acceptable quality) reported six individual results with 67% supporting mediation. Significant mediation was reported for depression and life satisfaction, although only among clinical populations diagnosed with Parkinson's, cancer, or multiple sclerosis. Moderate evidence suggests that functionality mediates the relationship between PA and mental health. Three studies, two of acceptable or higher quality, reported four individual results with 100% supporting mediation. Significant mediation was reported for depression, psychological distress, and life satisfaction, among adults, including breast cancer survivors. Moderate evidence suggests that BMI mediates the relationship between PA and mental health. Three studies of acceptable quality reported four individual results with 75% supporting mediation. Significant mediation was reported for depression, mental health, and wellbeing among children and adults.

Neurobiological mechanisms

Moderate evidence suggests inflammation mediates the relationship between PA and depression among adults. Two studies of high or acceptable quality reported two individual effects with 100% supporting mediation.

Cognitive factors

There is conflicting evidence as to whether cognitive function mediates the relationship between PA and mental health.

Environmental factors

No evidence suggests time spent in nature mediates the relationship between PA and mental health.

Moderation results

Psychological factors

Affect, wellbeing, stress, and depression or anxiety symptomatology or sensitivity

Moderate evidence suggests that depressive symptoms moderate the relationship between PA and mental health. Three studies of acceptable quality reported three individual results, with 67% supporting moderation. For example, Brière, et al. reported that the association between sport participation and subsequent reduced psychological difficulties was stronger in participants who had higher depressive symptoms at baseline [34]. Significant moderation results were only reported for depression and positive affect, among adolescents and adults. Moderate evidence also suggests that bipolar disorder moderates the effect of PA on mental health. Two studies of acceptable quality reported three individual results, with 67% supporting moderation. For example, PA was associated with a reduction in subsequent depressive symptoms for those with bipolar disorder more than those without [35, 36]. These results only examined depression as the outcome variable, among only young adults.

Personality

Moderate evidence suggests neuroticism significantly moderates the relationship between PA and mental health. Two studies of high and acceptable quality reported three individual results, with 67% supporting mediation.

Psychological factors related to the PA experience

Evidence is conflicting as to whether motivation moderates the relationship between PA and mental health with less than 50% of results supporting moderation.

Other psychological factors

No evidence suggests that stressful life events, relaxation, or quality of life moderate the relationship between PA and mental health, with 100% of results indicating no

moderation. Evidence is contradictory for mother's perceived stress, self-connection, or distress tolerance, with less than 50% of results supporting moderation.

Social factors

Moderate evidence suggests that social support moderates the relationship between PA and mental health. Three studies of acceptable quality reported three individual effects, with 100% supporting moderation. For example, Gyasi showed that the inverse relationship between PA and psychological distress was stronger as levels of perceived social support increased ($OR=0.651$; 95% CI=0.376, 0.727) [37]. Significant moderation results were reported for psychological distress and depression, although only older adults were recruited in these studies. Evidence is conflicting as to whether the social context of PA itself is a moderator.

Behavioural factors

Moderate evidence suggests sleep moderates the relationship between PA and mental health. Three studies of acceptable or high quality reported three individual effects, with 100% indicating moderation. However the role of sleep as a moderator was unclear, with one study showing PA was only associated with lower negative affect among those engaging in sufficient sleep [38] and another study reporting greater exercise-induced increases in positive affect among those with more sleep disturbances [39].

Physiological factors

No evidence suggests that disability moderates the relationship between PA and mental health. Evidence is conflicting as to whether functionality or BMI are significant moderators.

Neurobiological factors

No evidence suggests that triglycerides moderate the relationship between PA and mental health. Evidence for all other neurobiological factors is limited.

Cognitive factors

Evidence as to whether cognitive functioning moderates the relationship between PA and mental health is limited.

Environmental factors

No evidence suggests that the presence of violence or neighbourhood resources moderates the relationship between PA and mental health. However, evidence remains conflicting as to whether the environment itself moderates the effect of PA on mental health.

Individual characteristics

Moderate evidence suggests that race moderates the relationship between PA and mental health. Three studies of acceptable or high quality reported four individual results, with 75% supporting moderation. Significant moderation was reported for depression and anxiety; however, findings are inconclusive as one study reported a stronger association among white participants while another study found stronger associations among those from racial minority groups. Similarly, moderate evidence suggests age moderates the relationship between PA and mental health, however the evidence is conflicting as to whether younger or older populations benefit more. Moderate evidence also suggests that occupation type moderates the effect of PA on mental health. Two studies of high quality reported five individual results, with 60% supporting mediation. However, one study specifically examined work-related PA while the other study assessed multiple domains finding moderation for leisure-time PA, making results difficult to compare. Evidence is conflicting as to whether sex or socioeconomic status moderate the relationship between PA and mental health.

Discussion

Despite an increasing number of studies demonstrating positive effects of PA on mental health, the underlying mechanisms responsible for mental health benefits have still not been well established. Variables that influence the strength and direction of the relationship have also not been well understood. By systematically combining results from many studies, we now have more conclusive evidence of 27 different mediators, 12 with strong evidence and 15 with moderate evidence. Interestingly, seven of the 12 mediators with strong evidence are psychological mediators, two are social mediators, and three are physical. There is no strong evidence for any behavioural, neurobiological, cognitive, or environmental mediators. Only eight significant moderators were identified, although the direction was not consistent for four of them. Among the four consistent moderators, three were psychological moderators and one was social.

Self-efficacy, sleep, body image satisfaction, and resilience were the most examined mediators, with 10 or more studies examining each mediator. Self-efficacy theory [280] has been long-proposed as a possible mechanism for the effect of PA on mental health [15]. Given that PA poses a challenging task, successfully engaging in exercise may increase self-efficacy (i.e., confidence in one's ability to exercise), and this increased confidence in one's ability to exercise may produce improved mood [281, 282]. However, the mediation results reported in

this review indicated that global self-esteem (i.e., the way people feel about themselves overall), global self-efficacy, and physical self-worth were significant mediators, whereas evidence was conflicting for exercise self-efficacy. Moderate evidence did however suggest that both mastery and competence are more tenable mechanisms than exercise self-efficacy. For people to experience a sense of mastery or competence, activities and exercises need to be optimally challenging, group targets or goals should be avoided, and a task environment should be promoted [283, 284]. It's possible that a sense of mastery and accomplishment translates into improvements in global self-efficacy and self-esteem, more than exercise self-efficacy translates into global self-efficacy. However, the process by which mastery leads to global self-esteem or self-efficacy needs to be further understood.

Physical self-worth and body image satisfaction were also both strong mediators and may also both contribute to global self-esteem. However, very few studies have examined body related psychological variables alongside physical competence or mastery related variables, to understand how each contributes to global self-esteem or global constructs of mental health. It may be likely that the same strategies, behaviours, and PA environments similarly target all these mediators, however, the level of evidence to date is dictated by the number of studies and the quality of those studies, rather than which mediator truly plays a stronger role, as evidence is consistent for all of these mediators. While resilience has been well studied as an outcome of sport participation [285–287], it has been less-studies in relation to PA more broadly, meaning it's not entirely clear how resilience can be enhanced or developed through different exercise contexts. Therefore, further research should consider examining how different instructional styles and trainer behaviours, as well as individual actions of participants themselves, lead to the development of resilience.

Evidence is also rather consistent for both affect and mental health. For example, strong evidence showed that affect was a significant mediator of the associations between PA and, depression, anxiety, mental health, and life satisfaction. This suggests that temporary state-based moods, emotions, and affective experiences are an important element of the PA experience, and while they may be temporary, consistent experiences of positive affect contribute to overall positive mental health and wellbeing, and may protect against the onset of a mental health disorder, or reduce symptoms of depression and anxiety [288, 289]. There was also moderate evidence of existing mental health conditions moderating the effect of PA on mental health, whereby stronger effects were observed among those with existing symptoms or

pre-existing diagnoses. Therefore, PA represents a suitable mental health promotion strategy for the whole population, with possibly the greatest benefit obtained by those most in need of mental health improvements.

As early as the 1980's it was recognised that the group interaction and social attention one receives when exercising may be responsible for increased mood post-exercise [290, 291]. However, early research showed that exercise alone also facilitated mental health improvements [282]. Debate, and inconsistent findings, over the role of social interaction, continue today, with evidence still supporting both individual and group-based PA [16]. The results of this review mirror this debate, as there was conflicting evidence as to whether the social context moderates the effect of PA on mental health. There was, however, strong evidence that social *support* moderated the effect, such that the association between PA and mental health was greater among those reporting greater social support. Strong evidence also shows that both social support and social connection mediate the relationship between PA and mental health, and moderate evidence supports a sense of belonging and socialising as mediators. These findings collectively suggest that feelings of support and belonging may be more important to the mental health benefits of PA, than the mere opportunity for social interaction. Therefore, practitioners need to guide individuals toward selecting activities or exercise environments that are supportive, rather than encouraging group activities.

One of the earliest proposed psychological mechanisms was the cognitive-behavioural hypothesis. This hypothesis proposed that positive thoughts during PA break or interrupt the downward thought-affect spiral whereby negative thoughts lead to negative affective states, leading to depressive symptoms [282, 292]. However, no studies in this review measured distraction as a mediator. Moderate evidence did however suggest that mindfulness was a significant mediator. Results also suggested that reduced rumination and psychological detachment could be important mediators, although evidence is limited. Many aspects of the PA environment can enhance the distractive power of PA, or increase the possible mindfulness that come from reducing rumination and detaching from either work or stress, including nature, pleasant scenery, group interaction, and activities with high attention requirements [17]. These factors can be used to recommend engagement in activities that will likely provide a distraction. However, additional studies are needed to better understand the roles of rumination, mindfulness, distraction, and detachment, as evidence is limited although promising.

Interestingly, evidence regarding the role of motivation was contradictory, as was any evidence of the satisfaction of psychological needs (i.e., competence, autonomy,

and relatedness). It is important to note though, that all studies that assessed autonomy, competence, or relatedness as potential mediators, measured these constructs in relation to PA. While it is possible that autonomy, competence, and relatedness specifically in relation to one type of exercise might not enhance overall mental health, research shows that PA can be used as an opportunity to participate in an activity that satisfies people's overall psychological needs [17]. For example, people who are more active, may experience feelings of autonomy, competence, and relatedness more regularly on a weekly basis, and consequently experience greater mental health. However, for this to be determined, global need satisfaction would have to be examined as a possible mediator, rather than exercise-specific need satisfaction.

Given that PA elicits a wide variety of biochemical changes in the brain [8], many physiological, neurobiological, and biochemical mechanisms have been long proposed as responsible for the effect of PA on mental health [15]. These mechanisms include the release of endorphins [293], the transmission of monoamine neurotransmitters, including serotonin, dopamine, and norepinephrine [282], and more recently neuroplasticity, inflammation, and oxidative stress [8]. These mechanisms have all been criticised for oversimplifying the effect of PA, and evidence appears limited [15, 293]. This review supports the idea that neurobiological mechanisms may not be primary pathways by which PA benefits mental health as inflammation was the only neurobiological mediator with moderate evidence, despite 11 neurobiological mediators being examined. However, evidence is limited for many of them. Physical health, pain, fatigue, and functionality, however, did all mediate the relationship between PA and mental health, suggesting that PA may simultaneously improve aspects of physical and mental health; however, experimental or longitudinal studies are needed to determine whether PA leads to improved physical health, which leads to improved mental health. Overall, there is very little evidence for neurobiological or physiological mechanisms, relative to psychological and social mechanisms. This is advantageous to the future of mental health promotion through PA, as activities, exercises, instructional approaches, and environments can all be tailored to specifically target psychological and social mediators and moderators with strong evidence.

Strengths and limitations

This is the first systematic review to combine evidence of moderators and mediators. It presents the most comprehensive evidence to date, explaining the mechanisms that enable PA to benefit mental health, and the factors that influence the strength of this relationship. The broad

variety of mental health outcomes included is also a strength, as many studies examine mediators or moderators in relation to one particular outcome (e.g., depression). Nevertheless, several notable limitations exist. Firstly, a meta-analysis was not possible with the data obtained given the breadth of different mediators, moderators, and outcomes included. Perhaps, as the number of studies in this area expands, meta-analyses could be conducted across several mediators for each outcome. Secondly, most included studies were cross-sectional. While a review can only include studies existing in the literature, perhaps future experimental studies could consider testing the range of mediators examined in this review, and publish mediation findings whether significant or not, to help understand mechanisms from PA to mental health. Thirdly, several of the mediators and moderators reported in this review were only examined in one empirical study. This means evidence is limited for these constructs and it's unknown whether they could be significant mediators or moderators. All variables with limited evidence need further examination in future studies.

Conclusions

Despite PA becoming increasingly accepted and adopted as a mental health strategy in recent years, most recommendations only focus on the amount of PA needed for health benefits. This comprehensive review provides evidence of all mediators and moderators. Taking these findings into consideration when designing PA experiences, running exercise classes, or prescribing or recommending PA to clients, patients, or participants, will enable PA to have greater impacts on population mental health.

Abbreviation

PA Physical activity

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12966-024-01676-6>.

Additional file 1. Search Terms. Search terms. Includes the full search ran in Scopus to identify studies.

Additional file 2. Studies included in systematic review. List of all studies included in the review with their corresponding study number. A table presenting characteristics of each included study.

Additional file 3. Study characteristics Table 14AUG24. Study Characteristics Table. A table presenting characteristics of each included study.

Additional file 4. Results tables 16AUG24. Results tables. A file including the individual results extracted for each included study.

Additional file 5. Risk of Bias Table 14AUG24. Risk of Bias table. Results of the risk of bias assessment for each included study.

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Authors' contributions

Rhiannon L White: Conception and design of the work, acquisition and analysis (screening, risk of bias), interpretation of the data, drafted the manuscript, substantively revised the manuscript, approved the submitted version. Stewart Vella: Conception and design of the work, substantively revised the manuscript, approved the submitted version. Stuart Biddle: Conception and design of the work, substantively revised the manuscript, approved the submitted version. Jordan Sutcliffe: Acquisition and analysis (screening, risk of bias), substantively revised the manuscript, approved the submitted version. Justin M Guagliano: Acquisition and analysis (screening, risk of bias), substantively revised the manuscript, approved the submitted version. Riaz Uddin: Acquisition and analysis (screening, risk of bias), substantively revised the manuscript, approved the submitted version. Alice Burgin: Acquisition and analysis (screening, risk of bias), substantively revised the manuscript, approved the submitted version. Maria Apostolopoulos: Acquisition and analysis (screening, risk of bias), approved the submitted version. Tatiana Nguyen: Acquisition and analysis (screening, risk of bias), approved the submitted version. Carmen Young: Acquisition and analysis (screening, risk of bias), approved the submitted version. Nicole Taylor: Acquisition and analysis (screening, risk of bias), approved the submitted version. Samantha Lilley: Acquisition and analysis (screening, risk of bias), approved the submitted version. Megan Teychenne: Conception and design of the work, substantively revised the manuscript, approved the submitted version.

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Data availability

All data generated or analysed during this study are included in this published article (specifically, within Additional File 3).

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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References

* References marked with an asterisk indicate studies included in the systematic review.

- Rehm J, Shield KD. Global burden of disease and the impact of mental and addictive disorders. *Curr Psychiatry Rep.* 2019;21:1–7.
- Keyes CL, Dhingra SS, Simoes EJ. Change in level of positive mental health as a predictor of future risk of mental illness. *Am J Public Health.* 2010;100(12):2366–71.
- Herrman H, Saxena S, Moodie R. Promoting mental health: Concepts, emerging evidence, practice: A report of the World Health Organization, Department of Mental Health and Substance Abuse in collaboration with the Victorian Health Promotion Foundation and the University of Melbourne. Geneva, Switzerland: World Health Organization; 2005.
- Firth J, Solmi M, Wootten RE, Vancampfort D, Schuch FB, Hoare E, et al. A meta-review of "lifestyle psychiatry": the role of exercise, smoking, diet and sleep in the prevention and treatment of mental disorders. *World Psychiatry.* 2020;19(3):360–80.
- White RL, Babic MJ, Parker PD, Lubans DR, Astell-Burt T, Lonsdale C. Domain-specific physical activity and mental health: a meta-analysis. *Am J Prev Med.* 2017;52(5):653–66.
- Teychenne M, White RL, Richards J, Schuch FB, Rosenbaum S, Bennie JA. Do we need physical activity guidelines for mental health: what does the evidence tell us? *Ment Health Phys Act.* 2020;18:100315.
- Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: a systematic review of mechanisms. *Pediatrics.* 2016;138(3):e20161642.
- Kandola A, Ashdown-Franks G, Hendrikse J, Sabiston CM, Stubbs B. Physical activity and depression: Towards understanding the antidepressant mechanisms of physical activity. *Neurosci Biobehav Rev.* 2019;107:525–39.
- Dishman RK, O'Connor PJ. Lessons in exercise neurobiology: the case of endorphins. *Ment Health Phys Act.* 2009;2(1):4–9.
- MacKinnon DP, Luecken LJ. How and for whom? Mediation and moderation in health psychology. *Health Psychol.* 2008;27(2S):S99.
- Taylor AH, Faulkner G. Inaugural editorial. *Ment Health Phys Act.* 2008;1:1–8.
- * Pickett K, Yardley L, Kendrick T. Physical activity and depression: a multiple mediation analysis. *Ment Health Phys Act.* 2012;5(2):125–34.
- * Kayani S, Kiyani T, Morris T, Biasutti M, Wang J. Physical activity and anxiety of Chinese university students: Mediation of self-system. *Int J Environ Res Public Health.* 2021;18(9):4468.
- Lubans DR, Smith JJ, Morgan PJ, Beauchamp MR, Miller A, Lonsdale C, et al. Mediators of psychological well-being in adolescent boys. *J Adolesc Health.* 2016;58(2):230–6.
- Paluska SA, Schwenk TL. Physical activity and mental health. *Sports Med.* 2000;29(3):167–80.
- Vella SA, Sutcliffe JT, Fernandez D, Liddelow C, Aidman E, Teychenne M, et al. Context matters: a review of reviews examining the effects of contextual factors in physical activity interventions on mental health and wellbeing. *Ment Health Phys Act.* 2023;25:100520.
- White RL, Ryan D, Young C, Elston R, Rossi T. How does the context of physical activity influence perceived mood and wellbeing after exercise? *Ment Health Phys Act.* 2023;24:100504.
- Vella SA, Aidman E, Teychenne M, Smith JJ, Swann C, Rosenbaum S, et al. Optimising the effects of physical activity on mental health and wellbeing: a joint consensus statement from sports medicine Australia and the Australian Psychological Society. *J Sci Med Sport.* 2023;26:132–9.
- Moher D, Liberati A, Tetzlaff J, Altman DG. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *Ann Intern Med.* 2009;151(4):264–9.
- Ardern CL, Büttner F, Andrade R, Weir A, Ashe MC, Holden S, et al. Implementing the 27 PRISMA 2020 Statement items for systematic reviews in the sport and exercise medicine, musculoskeletal rehabilitation and sports science fields: the PERSIST (implementing Prisma in Exercise, Rehabilitation, Sport medicine and SporTs science) guidance. *Br J Sports Med.* 2022;56(4):175–95.
- Luhmann M, Hawkley LC, Eid M, Cacioppo JT. Time frames and the distinction between affective and cognitive well-being. *J Res Pers.* 2012;46(4):431–41.
- Barry MM, Jenkins R. Implementing mental health promotion. Philadelphia: Churchill Livingstone Elsevier; 2007.
- Fontaine KL. Mental health nursing. 6th ed. Upper Saddle River: Pearson Prentice Hall; 2009.
- World Health Organization. Promoting mental health: Concepts, emerging evidence, practice. Summary report. Geneva, Switzerland: World Health Organization; 2004.

25. Lubans D, Richards J, Hillman C, Faulkner G, Beauchamp M, Nilsson M, et al. Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics*. 2016;138(3):e20161642.
26. Tiller JW. Depression and anxiety. *Med J Aust*. 2013;199(6):S28–31.
27. Lubans DR, Foster C, Biddle SJ. A review of mediators of behavior in interventions to promote physical activity among children and adolescents. *Prev Med*. 2008;47(5):463–70.
28. Rhodes RE, Pfaeffli LA. Mediators of physical activity behaviour change among adult non-clinical populations: a review update. *Int J Behav Nutr Phys Act*. 2010;7(1):1–11.
29. Cerin E, Barnett A, Baranowski T. Testing theories of dietary behavior change in youth using the mediating variable model with intervention programs. *J Nutr Educ Behav*. 2009;41(5):309–18.
30. Asker M, Brooke HL, Waldén M, Tranaeus U, Johansson F, Skillgate E, et al. Risk factors for, and prevention of, shoulder injuries in overhead sports: a systematic review with best-evidence synthesis. *Br J Sports Med*. 2018;52(20):1312–9.
31. Bero L. Getting the systematic review basics right helps clinical practice: 4 common pitfalls for systematic review authors to avoid. *Br J Sports Med*. 2019;53(1):6–8.
32. Proper K, Brug J, Van Mechelen W, Singh A, Chinapaw M. Relationship between young peoples' sedentary behaviour and biomedical health indicators: a systematic review of prospective studies. *Obes Rev*. 2011;12(7):e621–32.
33. Teychenne M, Stephens LD, Costigan SA, Olstad DL, Stubbs B, Turner AL. The association between sedentary behaviour and indicators of stress: a systematic review. *BMC Public Health*. 2019;19(1):1–15.
34. * Briere FN, Yale-Soulière G, Gonzalez-Sicilia D, Harbec M-J, Morizot J, Janosz M, et al. Prospective associations between sport participation and psychological adjustment in adolescents. *J Epidemiol Community Health*. 2018;72(7):575–81.
35. * Walsh RFL, Smith LT, Klugman J, Titone MK, Ng TH, Goel N, et al. An examination of bidirectional associations between physical activity and mood symptoms among individuals diagnosed and at risk for bipolar spectrum disorders. *Behav Res Ther*. 2023;161:104255.
36. * Walsh RFL, Smith LT, Titone MK, Ng TH, Goel N, Alloy LB. The relationship between physical activity states and depressive symptoms: Using ambulatory assessment to characterize day-to-day associations among individuals with and without bipolar spectrum disorder. *Depress Anxiety*. 2022;39(12):835–44.
37. * Gyasi RM. Social support, physical activity and psychological distress among community-dwelling older Ghanaians. *Arch Gerontol Geriatr*. 2019;81:142–8.
38. * Cho S, Park Y. How to benefit from weekend physical activities: Moderating roles of psychological recovery experiences and sleep. *Stress Health*. 2018;34(5):639–48.
39. * Alfni AJ, Won J, Weiss LR, Nyhuis CC, Shackman AJ, Spira AP, et al. Impact of exercise on older adults' mood is moderated by sleep and mediated by altered brain connectivity. *Soc Cogn Affect Neurosci*. 2020;15(11):1238–51.
40. * Zuo Y, Zhang M, Han J, Chen KW, Ren Z. Residents' physical activities in home isolation and its relationship with health values and well-being: a cross-sectional survey during the COVID-19 social quarantine. *Health-care (Switzerland)*. 2021;9(7):795.
41. * Adams SC, Delorey DS, Davenport MH, Fairey AS, North S, Courneya KS. Effects of high-intensity interval training on fatigue and quality of life in testicular cancer survivors. *Br J Cancer*. 2018;118(10):1313–21.
42. * Aguiñaga S, Ehlers DK, Salerno EA, Fanning J, Motl RW, McAuley E. Home-based physical activity program improves depression and anxiety in older adults. *J Phys Act Health*. 2018;15(9):692–6.
43. * Annesi J. Moderating effects of depression, food cravings, and weight-related quality-of-life on associations of treatment-targeted psychosocial changes and physical activity in adolescent candidates for bariatric surgery. *J Phys Act Health*. 2018;15(12):946–53.
44. * Annesi JJ. Gender effects on theory-based psychosocial predictors of increased physical activity, and its subsequent influences on relations of fatigue with other psychosocial factors within Parkinson disease physical activity classes. *Minerva Psichiatr*. 2019;60(1):1–11.
45. * Asiamah N, Vieira ER, Kouveliotis K, Gasana J, Awuviry-Newton K, Edu-afio R. Associations between older African academics' physical activity, walkability and mental health: a social distancing perspective. *Health Promot Int*. 2022;37(2):daab093.
46. * Asztalos M, Cardon G, De Bourdeaudhuij I, De Cocker K. Cross-sectional associations between sitting time and several aspects of mental health in Belgian adults. *J Phys Act Health*. 2015;12(8):1112–8.
47. * Awick EA, Ehlers DK, Aguiñaga S, Daugherty AM, Kramer AF, McAuley E. Effects of a randomized exercise trial on physical activity, psychological distress and quality of life in older adults. *Gen Hosp Psychiatry*. 2017;49:44–50.
48. * Backström-Eriksson L, Bergsten-Brucefors A, Hjelte L, Melin B, Sorjonen K. Associations between genetics, medical status, physical exercise and psychological well-being in adults with cystic fibrosis. *BMJ Open Respir Res*. 2016;3(1):e000141.
49. * Bae MH, Zhang X, Lee JS. Exercise, grit, and life satisfaction among Korean adolescents: a latent growth modeling analysis. *BMC Public Health*. 2024;24(1):1392.
50. * Baker T, White R, Abbott G, Litterbach E, Teychenne M. Investigating psychosocial and behavioural mediators of the relationship between physical activity and depressive symptoms in women from socioeconomically disadvantaged neighbourhoods. *Ment Health Phys Act*. 2023;25:100560.
51. * Bang H, Chang M, Kim S. Team and individual sport participation, school belonging, and gender differences in adolescent depression. *Child Youth Serv Rev*. 2024;159:107517.
52. * Barham WT, Buysse DJ, Kline CE, Kubala AG, Brindle RC. Sleep health mediates the relationship between physical activity and depression symptoms. *Sleep Breath*. 2022;26(3):1341–9.
53. * Barr NG, Martin Ginis KA, Arent SM. The acute effects of arm ergometry on affect. *Comp Exerc Physiol*. 2010;7(3):117–25.
54. * Bartholomew JB, Linder DE. State anxiety following resistance exercise: the role of gender and exercise intensity. *J Behav Med*. 1998;21(2):205–19.
55. * Baruth M, Wilcox S, Schoffman DE, Becofsky K. Understanding the effects of a self-directed exercise program on depressive symptoms among adults with arthritis through serial mediation analyses. *Ment Health Phys Act*. 2016;11:13–8.
56. * Berger BG, Owen DR. Anxiety reduction with swimming: relationships between exercise and state, trait, and somatic anxiety. / Diminution de l'anxiété en natation: relations entre l'anxiété d'exercice et d'état de caractère et somatique. *Int J Sport Psychol*. 1987;18(4):286–302.
57. * Bhandari P, Paswan B. Lifestyle behaviours and mental health outcomes of elderly: modification of socio-economic and physical health effects. *Ageing International*. 2020.
58. * Biese KM, McGuire TA, Haraldsdottir K, Reardon C, Watson AM. The influence of race, socioeconomic status, and physical activity on the mental health benefits of sport participation during COVID-19. *Sports Health*. 2024;16(2):195–203.
59. * Birch K, ten Hoep M, Malek-Ahmadi M, O'Connor K, Schofield S, Coon D, et al. Cognitive function as a mediator in the relationship between physical activity and depression status in older adults. *J Aging Phys Act*. 2016;24(4):540–6.
60. * Bodin M, Hartig T. Does the outdoor environment matter for psychological restoration gained through running? *Psychol Sport Exerc*. 2003;4(2):141–53.
61. * Booij SH, Bos EH, Jonge P, Oldehinkel AJ. Markers of stress and inflammation as potential mediators of the relationship between exercise and depressive symptoms: Findings from the trials study. *Psychophysiology*. 2015;52(3):352–8.
62. * Borges AM, Uebelacker LA, Brown RA, Price LH, Abrantes AM. An examination of the effects of distress intolerance and rating of perceived exertion on changes in mood and anxiety following aerobic exercise among treatment-seeking smokers. *Psychol Health Med*. 2022;28(7):1720–8.
63. * Brady SM, Fenton SAM, Metsios GS, Bosworth A, Duda JL, Kitas GD, et al. Different types of physical activity are positively associated with indicators of mental health and psychological wellbeing in rheumatoid arthritis during COVID-19. *Rheumatol Int*. 2021;41(2):335–44.
64. * Broman-Fulks JJ, Abraham CM, Thomas K, Canu WH, Nieman DC. Anxiety sensitivity mediates the relationship between exercise frequency and anxiety and depression symptomatology. *Stress Health*. 2018;34:500–8.

65. * Buffart LM, Ros WJG, Chinapaw MJM, Brug J, Knol DL, Korstjens I, et al. Mediators of physical exercise for improvement in cancer survivors' quality of life. *Psychooncology*. 2014;23(3):330–8.
66. * Castan A, Bonilla I, Chamarro A, Saurí J. Psychosocial Outcomes associated with types and intensities of physical activity in people with spinal cord injury: the mediating role of self-efficacy and functionality. *J Phys Act Health*. 2024;21(5):481–90.
67. * Cecchini JA, Fernandez-Río J, Mendez-Gimenez A. Physical activity, approach-avoidance temperament and depressive symptoms. *Kinesiology*. 2019;51(1):60–9.
68. * Chae SM, Kang HS, Ra JS. Body esteem is a mediator of the association between physical activity and depression in Korean adolescents. *Appl Nurs Res*. 2017;33:42–8.
69. * Chair SY, Cheng HY, Chew HSJ, Zang YL, Siow EKC, Cao X. Leisure-time physical activity and depressive symptoms among patients with coronary heart disease: the mediating role of physical activity self-efficacy. *Worldviews Evid Based Nurs*. 2020;17:144–50.
70. * Chan BCL, Luciano M, Lee B. Interaction of physical activity and personality in the subjective wellbeing of older adults in Hong Kong and the United Kingdom. *Behav Sci*. 2018;8(8):71.
71. * Chan BCL, Luciano M, Lee B. A longitudinal study of physical activity and personality in the wellbeing of older adults. *J Aging Health*. 2023;36:484–91.
72. * Chang YK, Hung CL, Timme S, Nosrat S, Chu CH. Exercise behavior and mood during the COVID-19 pandemic in Taiwan: Lessons for the future. *Int J Environ Res Public Health*. 2020;17(19):1–17.
73. * Chen R, Liu YF, Huang GD, Wu PC. The relationship between physical exercise and subjective well-being in Chinese older people: the mediating role of the sense of meaning in life and self-esteem. *Front Psychol*. 2022;13:1029587.
74. * Chen YC, Putnam M, Lee YS, Morrow-Howell N. Activity patterns and health outcomes in later life: the role of nature of engagement. *Gerontologist*. 2019;59(4):698–708.
75. * Choi NG, Choi BY, Marti CN. Mediation of the association between physical exercise and depressive/anxiety symptoms by pain and sleep problems among older adults. *Gerontol Geriatr Med*. 2024;10:23337214241241396.
76. * Chu Q, Wong CCY, He G, Yang J, Chen C, He Y. Walking activity and emotional distress among breast cancer survivors: the parallel mediating effects of posttraumatic growth and body image. *Support Care Cancer*. 2023;31(3):180.
77. * Clément JF, Gallant F, Hudon C, Montiel C, Rigleau T, Berbiche D, et al. Use of physical activity as a coping strategy mediates the association between adolescent team sports participation and emerging adult mental health. *Ment Health Phys Act*. 2024;27.
78. * Condello G, Capranica L, Stager J, Forte R, Falbo S, Di Baldassarre A, et al. Physical activity and health perception in aging: Do body mass and satisfaction matter? A three-path mediated link. *PLoS One*. 2016;11(9):e0160805.
79. * Conley MI, Hindley I, Baskin-Sommers A, Gee DG, Casey BJ, Rosenberg MD. The importance of social factors in the association between physical activity and depression in children. *Child Adolesc Psychiatry Ment Health*. 2020;14(1):1–5.
80. * Costigan SA, Lubans DR, Lonsdale C, Sanders T, del Pozo CB. Associations between physical activity intensity and well-being in adolescents. *Prev Med*. 2019;125:55–61.
81. * Dahlstrand J, Friberg P, Fridolfsson J, Börjesson M, Arvidsson D, Ekblom Ö, et al. The use of coping strategies "shift-persist" mediates associations between physical activity and mental health problems in adolescents: a cross-sectional study. *BMC Public Health*. 2021;21(1):1104.
82. * Dang K, Ritvo P, Katz J, Gratzner D, Knyahnytska Y, Ortiz A, et al. The role of daily steps in the treatment of major depressive disorder: secondary analysis of a randomized controlled trial of a 6-month internet-based, mindfulness-based cognitive behavioral therapy intervention for youth. *Interact J Med Res*. 2023;12:e46419.
83. * Deng J, Liu Y, Chen R, Wang Y. The relationship between physical activity and life satisfaction among university students in China: the mediating role of self-efficacy and resilience. *Behav Sci*. 2023;13(11):889.
84. * Deng Y, Lee K, Lam MHS, Lee PH. Understanding sociobehavioral mitigators of depressive symptoms among US young adults. *Behav Med*. 2016;42(4):217–26.
85. * Deng Y, Paul DR. The relationships between depressive symptoms, functional health status, physical activity, and the availability of recreational facilities: a rural-urban comparison in middle-aged and older Chinese adults. *Int J Behav Med*. 2018;25(3):322–30.
86. * Dong RB, Dou KY, Luo J. Construction of a model for adolescent physical and mental health promotion based on the multiple mediating effects of general self-efficacy and sleep duration. *BMC Public Health*. 2023;23(1):2293.
87. * Dong Z, Wang P, Xin X, Li S, Wang J, Zhao J, et al. The relationship between physical activity and trait anxiety in college students: the mediating role of executive function. *Front Hum Neurosci*. 2022;16:1009540.
88. * Donyaei A, Kiani E, Bahrololoum H, Moser O. Effect of combined aerobic-resistance training and subsequent detraining on brain-derived neurotrophic factor (BDNF) and depression in women with type 2 diabetes mellitus: a randomized controlled trial. *Diabet Med*. 2024;41(3):e15188.
89. * Doré I, Sylvester B, Sabiston C, Sylvestre MP, O'Loughlin J, Brunet J, et al. Mechanisms underpinning the association between physical activity and mental health in adolescence: a 6-year study. *Int J Behav Nutr Phys Act*. 2020;17(1):9.
90. * Dotson VM, Hsu FC, Langaee TY, McDonough CW, King AC, Cohen RA, et al. Genetic moderators of the impact of physical activity on depressive symptoms. *J Frailty Aging*. 2016;5(1):6–14.
91. * Dunton GF, Liao Y, Intille S, Huh J, Leventhal A. Momentary assessment of contextual influences on affective response during physical activity. *Health Psychol*. 2015;34(12):1145–53.
92. * Eddolls WTB, McNarry MA, Lester L, Winn CON, Stratton G, Mackintosh KA. The association between physical activity, fitness and body mass index on mental well-being and quality of life in adolescents. *Qual Life Res*. 2018;27(9):2313–20.
93. * Elavsky S, Gold CH. Depressed mood but not fatigue mediate the relationship between physical activity and perceived stress in middle-aged women. *Maturitas*. 2009;64(4):235–40.
94. * Elavsky S, McAuley E. Physical activity, symptoms, esteem, and life satisfaction during menopause. *Maturitas*. 2005;52(3–4):374–85.
95. * Elavsky S, McAuley E, Motl RW, Konopack JF, Marquez DX, Hu L, et al. Physical activity enhances long-term quality of life in older adults: efficacy, esteem, and affective influences. *Ann Behav Med*. 2005;30(2):138–45.
96. * Evans M, Rohan KJ, Howard A, Ho SY, Dubbert PM, Stetson BA. Exercise dimensions and psychological well-being: a community-based exercise study. *J Clin Sport Psychol*. 2017;11(2):107–25.
97. * Fauth RC, Roth JL, Brooks-Gunn J. Does the neighborhood context alter the link between youth's after-school time activities and developmental outcomes? A multilevel analysis. *Dev Psychol*. 2007;43(3):760–77.
98. * Feng W, Zhao L, Ge Z, Zhao X, Li T, Zhu Q. Association between physical activity and adolescent mental health in the post COVID-19: the chain mediating effect of self-esteem and social anxiety. *PLoS One*. 2024;19(5):e0301617.
99. * Fernandes HM, Costa H, Esteves P, Machado-Rodrigues AM, Fonseca T. Direct and indirect effects of youth sports participation on emotional intelligence, self-esteem, and life satisfaction. *Sports*. 2024;12(6):155.
100. * Fessler L, Maltagliati S, Sieber S, Cullati S, Tessitore E, Craviari C, et al. Physical activity matters for everyone's health, but individuals with multimorbidity benefit more. *Prev Med Rep*. 2023;34:102265.
101. * Feuerhahn N, Sonnentag S, Woll A. Exercise after work, psychological mediators, and affect: a day-level study. *Eur J Work Organ Psy*. 2014;23(1):62–79.
102. * Fisher HM, Jacobs JM, Taub CJ, Lechner SC, Lewis JE, Carver CS, et al. How changes in physical activity relate to fatigue interference, mood, and quality of life during treatment for non-metastatic breast cancer. *Gen Hosp Psychiatry*. 2018;49:37–43.
103. * Fontana F, Bourbeau K, Moriarty T, da Silva MP. The relationship between physical activity, sleep quality, and stress: a study of teachers during the COVID-19 pandemic. *Int J Environ Res Public Health*. 2022;19(23):15465.
104. * Foroughi A, Henschel NT, Shahi H, Hall SS, Meyers LS, Sadeghi K, et al. Keeping things positive: affect as a mediator between physical activity and psychological functioning. *Eur J Investig Health Psychol Educ*. 2023;13(11):2428–59.

105. * Forshaw A, Lee Alfrey K, Maher JP, Rebar AL. But that's who I Am: The inability to enact physical activity identity is associated with depression and anxiety symptoms. *Ment Health Phys Act.* 2023;24:100524.
106. * Fredricks JA, Eccles JS. Is extracurricular participation associated with beneficial outcomes? Concurrent and longitudinal relations. *Dev Psychol.* 2006;42(4):698–713.
107. * Geniole SN, David JP, Euzébio RFR, Toledo BZS, Neves AIM, McCormick CM. Restoring land and mind: the benefits of an outdoor walk on mood are enhanced in a naturalized landfill area relative to its neighboring urban area. *Ecopyschology.* 2016;8(2):107–20.
108. * Gerber M, Lindwall M, Brand S, Lang C, Elliot C, Pühse U. Longitudinal relationships between perceived stress, exercise self-regulation and exercise involvement among physically active adolescents. *J Sports Sci.* 2015;33(4):369–80.
109. * Giacobbi PR Jr, Hardin B, Frye N, Hausenblas HA, Sears S, Stegelin A. A multi-level examination of personality, exercise, and daily life events for individuals with physical disabilities. *Adapt Phys Activ Q.* 2006;23(2):129–47.
110. * Giannotta F, Nilsson KW, Åslund C, Larm P. Frequency of vigorous physical activity and depressive symptoms across adolescence: disentangling the reciprocal associations between different groups and subtypes of symptoms. *Ment Health Phys Act.* 2023;25:100536.
111. * Ginis KAM, Latimer AE, McKechnie K, Ditor DS, McCartney N, Hicks AL, et al. Using exercise to enhance subjective well-being among people with spinal cord injury: the mediating influences of stress and pain. *Rehabil Psychol.* 2003;48(3):157–64.
112. * Ginoux C, Isoard-Gauthier S, Teran-Escobar C, Forestier C, Chalabaev A, Clavel A, et al. Being active during the lockdown: the recovery potential of physical activity for well-being. *Int J Environ Res Public Health.* 2021;18(4):1–14.
113. * Goldstein E, Topitzes J, Brown RL, Barrett B. Mediational pathways of meditation and exercise on mental health and perceived stress: A randomized controlled trial. *J Health Psychol.* 2020;25(12):1816–30.
114. * Gomez-Baya D, Mendoza R, de Matos MG, Tomico A. Sport participation, body satisfaction and depressive symptoms in adolescence: A moderated-mediation analysis of gender differences. *Eur J Dev Psychol.* 2019;16(2):183–97.
115. * González-Hernández J, Gómez-López M, Pérez-Turpin JA, Muñoz-Villena AJ, Andreu-Cabrera E. Perfectly active teenagers. When does physical exercise help psychological well-being in adolescents? *Int J Environ Res Public Health.* 2019;16(22):4525.
116. * Görgülü E, Bieber M, Engeroff T, Zabel K, Etyemez S, Prvulovic D, et al. Physical activity, physical self-perception and depression symptoms in patients with major depressive disorder: a mediation analysis. *Eur Arch Psychiatry Clin Neurosci.* 2021;271(7):1205–15.
117. * Greenleaf C, Boyer EM, Petrie TA. High school sport participation and subsequent psychological well-being and physical activity: The mediating influences of body image, physical competence, and instrumentality. *Sex Roles.* 2009;61(9–10):714–26.
118. * Guérin E, Fortier MS. The moderating influence of situational motivation on the relationship between preferred exercise and positive affect: an experimental study with active women. *SAGE Open.* 2013;3(4):2158244013508416.
119. * Guicciardi M, Carta M, Pau M, Cocco E. The relationships between physical activity, self-efficacy, and quality of life in people with multiple sclerosis. *Behav Sci.* 2019;9(12):121.
120. * Gujral S, Burns M, Erickson Kl, Rofey D, Peiffer JJ, Laws SM, et al. Dose-response effects of exercise on mental health in community-dwelling older adults: Exploration of genetic moderators. *Int J Clin Health Psychol.* 2024;24(1):100443.
121. * Guo S, Fu H, Guo K. Effects of physical activity on subjective well-being: the mediating role of social support and self-efficacy. *Front Sports Act Liv.* 2024;6:1362816.
122. * Gyasi RM, Quansah N, Boateng PA, Akomeah E, Yakubu AF, Ahiabl PA, et al., editors. Meeting the WHO physical activity guidelines is associated with lower odds of depression in older adults: potential psychosomatic mechanisms. 2024.
123. * Hachenberger J, Li YM, Lemola S. Physical activity, sleep and affective wellbeing on the following day: an experience sampling study. *J Sleep Res.* 2023;32(2):e13723.
124. * Hachenberger J, Teuber Z, Li YM, Abkai L, Wild E, Lemola S. Investigating associations between physical activity, stress experience, and affective wellbeing during an examination period using experience sampling and accelerometry. *Sci Rep.* 2023;13(1):8808.
125. * Halliday AJ, Kern ML, Turnbull DA. Can physical activity help explain the gender gap in adolescent mental health? A cross-sectional exploration. *Ment Health Phys Act.* 2019;16:8–18.
126. * Han B, Du G, Yang Y, Chen J, Sun G. Relationships between physical activity, body image, BMI, depression and anxiety in Chinese college students during the COVID-19 pandemic. *BMC Public Health.* 2023;23(1):24.
127. * Hayes D, Ross CE. Body and mind: the effect of exercise, overweight, and physical health on psychological well-being. *J Health Soc Behav.* 1986;27(4):387–400.
128. * Herring MP, Gordon BR, McDowell CP, Quinn LM, Lyons M. Physical activity and analogue anxiety disorder symptoms and status: Mediating influence of social physique anxiety. *J Affect Disord.* 2021;282:511–6.
129. * Herzog E, Voß M, Keller V, Koch S, Takano K, Cludius B. The benefits of physical exercise on state anxiety: exploring possible mechanisms. *Ment Health Phys Act.* 2022;23:100478.
130. * Ho FKW, Louie LHT, Chow CB, Wong WHS, Ip P. Physical activity improves mental health through resilience in Hong Kong Chinese adolescents. *BMC Pediatr.* 2015;15(1):1–9.
131. * Hogan CL, Catalino LI, Mata J, Fredrickson BL. Beyond emotional benefits: physical activity and sedentary behaviour affect psychosocial resources through emotions. *Psychol Health.* 2015;30(3):354–69.
132. * Hogan CL, Mata J, Carstensen LL. Exercise holds immediate benefits for affect and cognition in younger and older adults. *Psychol Aging.* 2013;28(2):587–94.
133. * Hou B, Wu Y, Huang Y. Physical exercise and mental health among older adults: the mediating role of social competence. *Front Public Health.* 2024;12:1385166.
134. * Huang JH, Li RH, Tsai LC. Relationship between depression with physical activity and obesity in older diabetes patients: inflammation as a mediator. *Nutrients.* 2022;14(19):4200.
135. * Huang Y, Xu P, Fu X, Ren Z, Cheng J, Lin Z, et al. The effect of triglycerides in the associations between physical activity, sedentary behavior and depression: an interaction and mediation analysis. *J Affect Disord.* 2021;295:1377–85.
136. * Hunt-Shanks T, Blanchard C, Reid RD. Gender differences in cardiac patients: a longitudinal investigation of exercise, autonomic anxiety, negative affect and depression. *Psychol Health Med.* 2009;14(3):375–85.
137. * Jenkins M, Houge Mackenzie S, Hodge K, Hargreaves EA, Calverley JR, Lee C. Physical activity and psychological well-being during the COVID-19 lockdown: relationships with motivational quality and nature contexts. *Front Sports Act Living.* 2021;3:637576.
138. * Jenkins M, Lee C, Houge Mackenzie S, Hargreaves EA, Hodge K, Calverley J. Nature-based physical activity and hedonic and eudaimonic well-being: the mediating roles of motivational quality and nature relatedness. *Front Psychol.* 2022;13:783840.
139. * Ji L, Ren Z, Chen J, Zhao H, Zhang X, Xue B, et al. Associations of vegetable and fruit intake, physical activity, and school bullying with depressive symptoms in secondary school students: the mediating role of internet addiction. *BMC Psychiatry.* 2024;24(1):419.
140. * Jia Y, Gao X. A chained mediator model: the effect of physical activity on negative emotions in obese adolescents. *Gazzetta Medica Italiana Archivio per le Scienze Mediche.* 2024;183(3):146–53.
141. * Johansson M, Hartig T, Staats H. Psychological benefits of walking: Moderation by company and outdoor environment. *Appl Psychol Health Well Being.* 2011;3(3):261–80.
142. * Johnson MN, Maher JP, Meadows CC, Bittel KM, Hevel DJ, Drollette ES. Positive affect moderates inhibitory control and positive affect following a single bout of self-select aerobic exercise. *Psychol Sport Exerc.* 2022;60:102141.
143. * Joseph RP, Royse KE, Benitez TJ, Pekmezi DW. Physical activity and quality of life among university students: exploring self-efficacy, self-esteem, and affect as potential mediators. *Qual Life Res.* 2014;23(2):661–9.
144. * Kaseva K, Dobewall H, Yang X, Pulkki-Råback L, Lipsanen J, Hintsa T, et al. Physical activity, sleep, and symptoms of depression in adults – testing for mediation. *Med Sci Sports Exerc.* 2019;51(6):1162–8.

145. * Kikkawa M, Shimura A, Nakajima K, Morishita C, Honyashiki M, Tamada Y, et al. Mediating effects of trait anxiety and state anxiety on the effects of physical activity on depressive symptoms. *Int J Environ Res Public Health.* 2023;20(7):5319.
146. * Klussman K, Langer J, Nichols AL. The relationship between physical activity, health, and well-being: type of exercise and self-connection as moderators. *Eur J Health Psychol.* 2021;28(2):59–70.
147. * Kong JY, Hong H, Kang H. Relationship between physical activity and depressive symptoms in older Korean adults: moderation analysis of muscular strength. *BMC Geriatr.* 2022;22(1):884.
148. * Konopack JF, McAuley E. Efficacy-mediated effects of spirituality and physical activity on quality of life: a path analysis. *Health Qual Life Outcomes.* 2012;10:1–6.
149. * Koziel Ly NK, Mohamud L, Villeneuve PJ, Matheson K, Anisman H, Chee MJ. Protective effects of physical activity on mental health outcomes during the COVID-19 pandemic. *PLoS One.* 2022;17(12):e0279468.
150. * Kratz AL, Ehde DM, Bombardier CH. Affective mediators of a physical activity intervention for depression in multiple sclerosis. *Rehabil Psychol.* 2014;59(1):57–67.
151. * Kruk M, Zarychta K, Horodyska K, Boberska M, Scholz U, Radtke T, et al. What comes first, negative emotions, positive emotions, or moderate-to-vigorous physical activity? *Ment Health Phys Act.* 2019;16:38–42.
152. * Ku PW, Steptoe A, Chen LJ. Prospective associations of exercise and depressive symptoms in older adults: the role of apolipoprotein E4. *Qual Life Res.* 2017;26(7):1799–808.
153. * Kukihara H, Yamawaki N, Ando M, Tamura Y, Arita K, Nakashima E. The mediating effects of resilience, morale, and sense of coherence between physical activity and perceived physical/mental health among Japanese community-dwelling older adults: a cross-sectional study. *J Aging Phys Act.* 2018;26(4):544–52.
154. * La Rocque CL, Mazurka R, Stuckless TJR, Pyke K, Harkness KL. Randomized controlled trial of bikram yoga and aerobic exercise for depression in women: efficacy and stress-based mechanisms. *J Affect Disord.* 2021;280:457–66.
155. * Latimer AE, Martin Ginis KA, Hicks AL, McCartney N. An examination of the mechanisms of exercise-induced change in psychological well-being among people with spinal cord injury. *J Rehabil Res Dev.* 2004;41(5):643–51.
156. * Lau SCL, Tabor Connor L, Baum CM. Motivation, physical activity, and affect in community-dwelling stroke survivors: an ambulatory assessment approach. *Ann Behav Med.* 2023;57:334–43.
157. * Laurier C, Pascuzzo K, Beaulieu G. Uncovering the personal and environmental factors associated with youth mental health during the COVID-19 pandemic: the pursuit of sports and physical activity as a protective factor. *Traumatology.* 2021;27(4):354–64.
158. * Leahy AA, Diallo TMO, Eather N, Duncan MJ, Smith JJ, Morgan PJ, et al. Mediating effects of sleep on mental health in older adolescents: Findings from the Burn 2 Learn randomized controlled trial. *Scand J Med Sci Sports.* 2023;33(11):2369–80.
159. * Levante A, Quarta S, Massaro M, Calabriso N, Carluccio MA, Damiano F, et al. Physical activity habits prevent psychological distress in female academic students: The multiple mediating role of physical and psychosocial parameters. *Heliyon.* 2024;10(4):1–14.
160. * Lewis R, Roden LC, Scheuermaier K, Gomez-Olive FX, Rae DE, Iacovides S, et al. The impact of sleep, physical activity and sedentary behaviour on symptoms of depression and anxiety before and during the COVID-19 pandemic in a sample of South African participants. *Sci Rep.* 2021;11(1):24059.
161. * Li B, Jiang W, Han SS, Ye YP, Li YX, Lou H, et al. Influence of moderate-to-high intensity physical activity on depression levels: a study based on a health survey of Chinese university students. *BMC Public Health.* 2024;24(1):1023.
162. * Li S, Wang X, Wang P, Qiu S, Xin X, Wang J, et al. Correlation of exercise participation, behavioral inhibition and activation systems, and depressive symptoms in college students. *Sci Rep.* 2023;13(1):16460.
163. * Li W, Gao Y, Liu G, Hao R, Zhang M, Li X. Shifting the paradigm: a fresh look at physical activity frequency and its impact on mental health, life satisfaction, and self-rated health in adolescents. *Int J Ment Health Promot.* 2024;26(2):83–92.
164. * Li Y, Sun Q, Sun M, Sun P, Xia X. Physical exercise and psychological distress: The mediating roles of problematic mobile phone use and learning burnout among adolescents. *Int J Environ Res Public Health.* 2021;18(17):9261.
165. * Li Z, Huang F. Mechanisms of the impact of sports participation on college students' psychological well-being. *Soc Behav Pers.* 2024;52(5):13119E–26E.
166. * Liang X, Qiu H, Sit CHP. The mediating role of resilience in the association between MVPA and psychological ill-being in children with ADHD. *Scand J Med Sci Sports.* 2023;33(4):485–94.
167. * Lin S, Li L, Zheng D, Jiang L. Physical exercise and undergraduate students' subjective well-being: mediating roles of basic psychological need satisfaction and sleep quality. *Behav Sci (Basel).* 2022;12(9):316.
168. * Lin ST, Hung YH, Yang MH. The relationships among sport participation level, flow experience, perceived health status and depression level of college students. *Int J Environ Res Public Health.* 2023;20(1):1–12.
169. * Lindwall M, Larsman P, Hagger MS. The reciprocal relationship between physical activity and depression in older European adults: A prospective cross-lagged panel design using SHARE data. *Health Psychol.* 2011;30(4):453–62.
170. * Lindwall M, Ljung T, Hadžibajramović E, Jónsdóttir IH. Self-reported physical activity and aerobic fitness are differently related to mental health. *Ment Health Phys Act.* 2012;5(1):28–34.
171. * Liu M, Liu H, Qin Z, Tao Y, Ye W, Liu R. Effects of physical activity on depression, anxiety, and stress in college students: the chain-based mediating role of psychological resilience and coping styles. *Front Psychol.* 2024;15:1396795.
172. * Liu M, Shi B. The effect of physical exercise on the anxiety of college students in the post-pandemic era: the mediating role of social support and proactive personality. *Front Psychol.* 2023;14:1128748.
173. * Liu N, Zhong Q. The impact of sports participation on individuals' subjective well-being: the mediating role of class identity and health. *Hum Soc Sci Commun.* 2023;10(1):1–9.
174. * Liu R, Menhas R, Saqib ZA. Does physical activity influence health behavior, mental health, and psychological resilience under the moderating role of quality of life? *Front Psychol.* 2024;15:1349880.
175. * Liu S, Ding M, Wang K, editors. The effects of physical exercise on anxiety among college students: the mediating role of psychological resilience. 2023.
176. * Liu X, Du Q, Fan H, Wang Y. The impact of square dancing on psychological well-being and life satisfaction among aging women. *Sci Rep.* 2024;14(1):10405.
177. * Liu Y, Feng Q, Guo K. Physical activity and depression of Chinese college students: chain mediating role of rumination and anxiety. *Front Psychol.* 2023;14:1190836.
178. * Liu Y, Ge X, Wang Y, Qiao S, Cai Y. How race and socioeconomic status moderate the association between moderate-to-vigorous physical activity and depressive symptoms: a cross-sectional study with compositional data. *Br J Sports Med.* 2024.
179. * Lopes MVV, Matias TS, da Costa BGG, Schuch FB, Chaput JP, Samara SK. The relationship between physical activity and depressive symptoms is domain-specific, age-dependent, and non-linear: An analysis of the Brazilian national health survey. *J Psychiatr Res.* 2023;159:205–12.
180. * Mack DE, Meldrum LS, Wilson PM, Sabiston CM. Physical activity and psychological health in breast cancer survivors: an application of basic psychological needs theory. *Appl Psychol Health Well Being.* 2013;5(3):369–88.
181. * Maher JP, Hevel DJ, Reifsteck EJ, Drollette ES. Physical activity is positively associated with college students' positive affect regardless of stressful life events during the COVID-19 pandemic. *Psychol Sport Exerc.* 2021;52:101826.
182. * Maher JP, Pincus AL, Ram N, Conroy DE. Daily physical activity and life satisfaction across adulthood. *Dev Psychol.* 2015;51(10):1407–19.
183. * Malek Rivan NF, Shahar S, Singh DKA, Ibrahim N, Mat Ludin AF, Yahya HM, et al. Mediation effect of coping strategies on general psychological health among middle-aged and older adults during the covid-19 pandemic. *Aging Ment Health.* 2021;26(10):2039–47.
184. * Marselle MR, Irvine KN, Lorenzo-Arribas A, Warber SL. Does perceived restorativeness mediate the effects of perceived biodiversity and perceived naturalness on emotional well-being following group walks in nature? *J Environ Psychol.* 2016;46:217–32.
185. * McIntrye E, Lauche R, Frawley J, Sibbritt D, Reddy P, Adams J. Physical activity and depression symptoms in women with chronic illness and

- the mediating role of health-related quality of life. *J Affect Disord.* 2019;252:294–9.
186. * McNeil DG, Singh A, Chambers T. Exploring nature-and social-connectedness as mediators of the relationship between nature-based exercise and subjective wellbeing. *Ecopsychology.* 2022;14(4):226–34.
 187. * McPhie ML, Rawana JS. Unravelling the relation between physical activity, self-esteem and depressive symptoms among early and late adolescents: a mediation analysis. *Ment Health Phys Act.* 2012;5(1):43–9.
 188. * Meadows R, Bonner T, Dobhal M, Borra S, Killion JA, Paxton R. Pathways between physical activity and quality of life in African-American breast cancer survivors. *Support Care Cancer.* 2017;25(2):489–95.
 189. * Meckes SJ, McDonald MA, Lancaster CL. Association between physical activity and mental health among first responders with different service roles. *Psychol Trauma Theory Res Pract Policy.* 2021;13(1):66–74.
 190. * Meyer S, Lang C, Ludgya S, Grob A, Gerber M. "What If Others Think I Look Like..." The moderating role of social physique anxiety and sex in the relationship between physical activity and life satisfaction in Swiss adolescents. *Int J Environ Res Public Health.* 2023;20(5):4441.
 191. * Meyer S, Weidmann R, Grob A. The mirror's curse: Weight perceptions mediate the link between physical activity and life satisfaction among 727,865 teens in 44 countries. *J Sport Health Sci.* 2021;10(1):48–54.
 192. * Miller BM, Bartholomew JB, Springer BA. Post-exercise affect: The effect of mode preference. *J Appl Sport Psychol.* 2005;17(4):263–72.
 193. * Moya CAM, Soares FC, Lima RA, de Barros MVG, Bezerra J. Depressive symptoms in older adults: the role of physical activity and social support. *Trends Psychiatry Psychother.* 2021;43:185–92.
 194. * Mu FZ, Liu J, Lou H, Zhu WD, Wang ZC, Li B. Influence of physical exercise on negative emotions in college students: chain mediating role of sleep quality and self-rated health. *Front Public Health.* 2024;12:1402801.
 195. * Mumba MN, Nancarrow A, Jaiswal JL, Hocchau E, Campbell MH, Davis LL. Moderation effects of substance use on physical and mental well-being in adults. *J Am Psychiatr Nurses Assoc.* 2021;30(1):37–43.
 196. * Mumba MN, Nancarrow AF, Jaiswal JL, Hocchau E, Campbell MH, Davis LL. Moderation effects of substance use on physical and mental well-being in adults. *J Am Psychiatr Nurses Assoc.* 2024;30(1):37–43.
 197. * Nezlek JB, Cypryańska M, Cypryński P, Chlebosz K, Jencyzlik K, Szatańska J, et al. Within-person relationships between recreational running and psychological well-being. *J Sport Exerc Psychol.* 2018;40(3):146–52.
 198. * O'Rourke RH, Sabiston CM, Trinh L, Arbour-Nicitopoulos KP. The indirect effects of basic psychological needs on the relationship between physical activity and mental health in adults with disabilities: a cross-sectional study. *Adv Rehabil.* 2023;37(4):1–11.
 199. * Oberle E, Ji XR, Guhn M, Schonert-Reichl KA, Gadermann AM. Benefits of extracurricular participation in early adolescence: Associations with peer belonging and mental health. *J Youth Adolesc.* 2019;48(11):2255–70.
 200. * Olson RL, Brush CJ, Ehmann PJ, Alderman BL. A randomized trial of aerobic exercise on cognitive control in major depression. *Clin Neurophysiol.* 2017;128(6):903–13.
 201. * Oshimi D, Kinoshita K. Relationship between residents' sporting life and hedonic and eudaimonic well-being in Hiroshima: the mediating role of PERMA in sport. *Managing Sport and Leisure.* 2022;1–16.
 202. * Pacewicz CE, Rowley TW, Savage JL. The role of physical activity on the link between stress, burnout, and well-being in athletic trainers. *J Athl Train.* 2022;58(4):374–80.
 203. * Pan Y, Zhou D, Shek DTL. After-school extracurricular activities participation and depressive symptoms in Chinese early adolescents: moderating effect of gender and family economic status. *Int J Environ Res Public Health.* 2022;19(7):4231.
 204. * Pascoe MC, Patten RK, Tacey A, Woessner MN, Bourke M, Bennell K, et al. Physical activity and depression symptoms in people with osteoarthritis-related pain: a cross-sectional study. *PLOS Glob Public Health.* 2024;4(7):e0003129.
 205. * Paxton RJ, Mott RW, Aylward A, Nigg CR. Physical activity and quality of life—The complementary influence of self-efficacy for physical activity and mental health difficulties. *Int J Behav Med.* 2010;17(4):255–63.
 206. * Perez-Sousa MA, Olivares PR, Gonzalez-Guerrero JL, Gusi N. Effects of an exercise program linked to primary care on depression in elderly: fitness as mediator of the improvement. *Qual Life Res.* 2020;29:1239–46.
 207. * Perez-Sousa MA, Pedro J, Carrasco-Zahinos R, Raimundo A, Parraca JA, Tomas-Carus P. Effects of aquatic exercises for women with rheumatoid arthritis: a 12-week intervention in a quasi-experimental study with pain as a mediator of depression. *Int J Environ Res Public Health.* 2023;20(10):5872.
 208. * Petruzzello SJ, Tate AK. Brain activation, affect, and aerobic exercise: an examination of both state-independent and state-dependent relationships. *Psychophysiology.* 1997;34(5):527–33.
 209. * Phillips SM, Wójcicki TR, McAuley E. Physical activity and quality of life in older adults: An 18-month panel analysis. *Qual Life Res.* 2013;22(7):1647–54.
 210. * Precht LM, Margraf J, Stirnberg J, Brailovskaja J. It's all about control: Sense of control mediates the relationship between physical activity and mental health during the COVID-19 pandemic in Germany. *Curr Psychol.* 2021;42(10):8531–9.
 211. * Precht LM, Stirnberg J, Margraf J, Brailovskaja J. Can physical activity foster mental health by preventing addictive social media use? - A longitudinal investigation during the COVID-19 pandemic in Germany. *J Affect Disord Rep.* 2022;8:100316.
 212. * Quarta S, Levante A, García-Conesa MT, Lecciso F, Scoditti E, Carluccio MA, et al. Assessment of subjective well-being in a cohort of university students and staff members: association with physical activity and outdoor leisure time during the COVID-19 pandemic. *Int J Environ Res Public Health.* 2022;19(8):4787.
 213. * Riddervold S, Haug E, Kristensen SM. Sports participation, body appreciation and life satisfaction in Norwegian adolescents: a moderated mediation analysis. *Scand J Public Health.* 2024;52:704–10.
 214. * Roppolo M, Mulasso A, Gollin M, Bertolotto A, Ciarano S. The role of fatigue in the associations between exercise and psychological health in Multiple Sclerosis: direct and indirect effects. *Ment Health Phys Act.* 2013;6(2):87–94.
 215. * Rutherford ER, Vandelanotte C, Chapman J, To QG. Associations between depression, domain-specific physical activity, and BMI among US adults: NHANES 2011–2014 cross-sectional data. *BMC Public Health.* 2022;22(1):1618.
 216. * Ryan MP. The antidepressant effects of physical activity: Mediating self-esteem and self-efficacy mechanisms. *Psychol Health.* 2008;23(3):279–307.
 217. * Santino N, Larocca V, Hitzig SL, Guilcher SJT, Craven BC, Bassett-Gunter RL. Physical activity and life satisfaction among individuals with spinal cord injury: Exploring loneliness as a possible mediator. *J Spinal Cord Med.* 2020;45(2):173–9.
 218. * Santino N, Larocca V, Hitzig SL, Guilcher SJT, Craven BC, Bassett-Gunter RL. Physical activity and life satisfaction among individuals with spinal cord injury: exploring loneliness as a possible mediator. *J Spinal Cord Med.* 2022;45(2):173–9.
 219. * Sato M, Jordan JS, Funk DC. A distance-running event and life satisfaction: the mediating roles of involvement. *Sport Management Review.* 2016;19(5):536–49.
 220. * Shang Y, Chen SP, Xie HD. The effect of physical exercise on subjective well-being in Chinese middle school students: the mediation roles of peer relationships and self-actualization. *Asia-Pacific Education Researcher.* 2024;33(3):615–23.
 221. * Shang Y, Xie HD, Yang SY. The relationship between physical exercise and subjective well-being in college students: the mediating effect of body image and self-esteem. *Front Psychol.* 2021;12:658935.
 222. * Shin M, Kim I, Kwon S. Effect of intrinsic motivation on affective responses during and after exercise: latent curve model analysis. *Percept Mot Skills.* 2014;119(3):717–30.
 223. * Smith JJ, Beauchamp MR, Faulkner G, Morgan PJ, Kennedy SG, Lubans DR. Intervention effects and mediators of well-being in a school-based physical activity program for adolescents: The 'Resistance Training for Teens' cluster RCT. *Ment Health Phys Act.* 2018;15:88–94.
 224. * Smith KE, Mason TB, O'Connor SM, Wang S, Dzubur E, Crosby RD, et al. Bi-directional associations between real-time affect and physical activity in weight-discordant siblings. *J Pediatr Psychol.* 2021;46(4):443–53.
 225. * Solberg PA, Halvari H, Ommundsen Y, Hopkins WG. A 1-year follow-up on effects of exercise programs on well-being in older adults. *J Aging Phys Act.* 2014;22(1):52–64.
 226. * Stuntz CP, Grosshans M, Boghosian R, Brendel A, Williamson MS. Exert more and feel better, not worse?: examining links among changes in

- exertion, feelings of accomplishment, and feeling states. *Psychol Sport Exerc.* 2020;48:101657.
227. * Sun D, Zhu X, Bao Z. The relationship between physical activity and anxiety in college students: exploring the mediating role of lifestyle habits and dietary nutrition. *Front Psychol.* 2024;15:1296154.
 228. * Syue SH, Yang HF, Wang CW, Hung SY, Lee PH, Fan SY. The associations between physical activity, functional fitness, and life satisfaction among community-dwelling older adults. *Int J Environ Res Public Health.* 2022;19(13):8043.
 229. * Taliaferro LA, Dodd VJ. Potential mediating pathways through which sports participation relates to reduced risk of suicidal ideation. *Res Q Exerc Sport.* 2010;81(3):328–39.
 230. * Tang S, Chen H, Wang L, Lu T, Yan J. The relationship between physical exercise and negative emotions in college students in the post-epidemic era: the mediating role of emotion regulation self-efficacy. *Int J Environ Res Public Health.* 2022;19(19):12166.
 231. * Tao B, Chen H, Lu T, Yan J. The effect of physical exercise and internet use on youth subjective well-being—the mediating role of life satisfaction and the moderating effect of social mentality. *Int J Environ Res Public Health.* 2022;19(18):11201.
 232. * Theodoropoulou E, Stavrou NAM, Karteroliotis K. Neighborhood environment, physical activity, and quality of life in adults: Intermediary effects of personal and psychosocial factors. *J Sport Health Sci.* 2017;6(1):96–102.
 233. * Tian J, Yu H, Austin L. The effect of physical activity on anxiety: the mediating role of subjective well-being and the moderating role of gender. *Psychol Res Behav Manag.* 2022;15:3167–78.
 234. * Tiggelman D, van de Ven MOM, van Schayck OCP, Engels RCME. Moderating effect of gender on the prospective relation of physical activity with psychosocial outcomes and asthma control in adolescents: a longitudinal study. *J Asthma.* 2014;51(10):1049–54.
 235. * Tihanyi BT, Bör P, Emanuelson L, Köteles F. Mediators between yoga practice and psychological well-being: mindfulness, body awareness and satisfaction with body image. *Eur J Ment Health.* 2016;11(1–2):112–27.
 236. * Toups M, Carmody T, Greer T, Rethorst C, Grannemann B, Trivedi MH. Exercise is an effective treatment for positive valence symptoms in major depression. *J Affect Disord.* 2017;209:188–94.
 237. * Vandendriessche A, Ghekiere A, Van Cauwenberg J, De Clercq B, Dhondt K, Desmet A, et al. Does sleep mediate the association between school pressure, physical activity, screen time, and psychological symptoms in early adolescents? A 12-country study. *Int J Environ Res Public Health.* 2019;16(6):1072.
 238. * VanKim NA, Nelson TF. Vigorous physical activity, mental health, perceived stress, and socializing among college students. *Am J Health Promot.* 2013;28(1):7–15.
 239. * Wang GH, Li WD, Dou K. Extracurricular sports participation increases life satisfaction among Chinese adolescents: a moderated mediation model. *Soc Behav Pers.* 2020;48(8):1–1.
 240. * Wang K, Li Y, Zhang T, Luo J. The relationship among college students' physical exercise, self-efficacy, emotional intelligence, and subjective well-being. *Int J Environ Res Public Health.* 2022;19(18):11596.
 241. * Wassink-Vossen S, Collard RM, Penninx BW, Hiles SA, Oude Voshaar RC, Naarding P. The reciprocal relationship between physical activity and depression: does age matter? *Eur Psychiatry.* 2018;51:9–15.
 242. * Watt T, Kehoe EJ. Toward a mediated model of physical activity in relation to psychological distress. *Phys Act Rev.* 2022;10(1):52–9.
 243. * Wen CKF, Liao Y, Maher JP, Huh J, Belcher BR, Dzubur E, et al. Relationships among affective states, physical activity, and sedentary behavior in children: moderation by perceived stress. *Health Psychol.* 2018;37(10):904–14.
 244. * Werneck AO, Cunha PM, Silva DR. The mediation role of social network size and perception in the association between physical activity and depressive symptoms: a prospective analysis from the SHARE study. *Aging Ment Health.* 2023;27:1738–43.
 245. * Werneck AO, Schuch FB, Felez-Nobrega M, Araujo RHO, Szwarcwald CL, Stubbs B, et al. Does occupation moderate the association between domain-based physical activity and depressive symptoms? *Ment Health Phys Act.* 2023;24:100507.
 246. * Werneck AO, Silva DR, Malta DC, Lima MG, Souza-Júnior PRB, Azevedo LO, et al. The mediation role of sleep quality in the association between the incidence of unhealthy movement behaviors during the COVID-19 quarantine and mental health. *Sleep Med.* 2020;76:10–5.
 247. * Werneck AO, Stubbs B, Kandola A, Oyeyemi AL, Schuch FB, Hamer M, et al. Prospective associations of leisure-time physical activity with psychological distress and well-being: a 12-year cohort study. *Psychosom Med.* 2022;84(1):116–22.
 248. * White RL, Bennie J, Abbott G, Teychenne M. Work-related physical activity and psychological distress among women in different occupations: a cross-sectional study. *BMC Public Health.* 2020;20(1):1007.
 249. * White RL, Parker PD, Lubans DR, MacMillan F, Olson R, Astell-Burt T, et al. Domain-specific physical activity and affective wellbeing among adolescents: an observational study of the moderating roles of autonomous and controlled motivation. *Int J Behav Nutr Phys Act.* 2018;15:1–3.
 250. * Wichers M, Peeters F, Rutten BPF, Jacobs N, Derom C, Thiery E, et al. A time-lagged momentary assessment study on daily life physical activity and affect. *Health Psychol.* 2012;31(2):135–44.
 251. * Wilson KE, Das BM, Evans EM, Dishman RK. Structural equation modeling supports a moderating role of personality in the relationship between physical activity and mental health in college women. *J Phys Act Health.* 2016;13(1):67–78.
 252. * Wu B, Xiong G, Zhang P, Ma X. Effects of tai chi, ba duan jin, and walking on the mental health status of urban older people living alone: the mediating role of social participation and the moderating role of the exercise environment. *Front Public Health.* 2024;12:1294019.
 253. * Wu TM, Lee SW, Xu JB. Mental health of working adults during the COVID-19 pandemic: does physical activity level matter? *Int J Environ Res Public Health.* 2023;20(4):2961.
 254. * Xin S, Ma X. Mechanisms of physical exercise effects on anxiety in older adults during the COVID-19 lockdown: an analysis of the mediating role of psychological resilience and the moderating role of media exposure. *Int J Environ Res Public Health.* 2023;20(4):3588.
 255. * Xiong G, Wang C, Ma X. The relationship between physical activity and mental depression in older adults during the prevention and control of COVID-19: a mixed model with mediating and moderating effects. *Int J Environ Res Public Health.* 2023;20(4):3225.
 256. * Yang L, Liu Z, Shi S, Dong Y, Cheng H, Li T. The mediating role of perceived stress and academic procrastination between physical activity and depressive symptoms among Chinese college students during the COVID-19 pandemic. *Int J Environ Res Public Health.* 2022;20(1):773.
 257. * Yao Y, Chen J, Dong D, Feng Y, Qiao Z. The relationship between exercise and mental health outcomes during the COVID-19 pandemic: from the perspective of hope. *Int J Environ Res Public Health.* 2022;19(7):4090.
 258. * Yıldırım S, Özgökçe G. The relationship between physical activity and life satisfaction: the mediating role of social-physique anxiety and self-esteem. *Pamukkale J Sport Sci.* 2023;14(3):346–67.
 259. * Yoshikawa E, Nishi D, Matsuoka YJ. Association between regular physical exercise and depressive symptoms mediated through social support and resilience in Japanese company workers: a cross-sectional study. *BMC Public Health.* 2016;16(1):553.
 260. * You S, Shin K, Kim M. Long-term effect of physical activity on internalizing and externalizing problems and life satisfaction. *Sustainability (Switzerland).* 2021;13(4):1–12.
 261. * You Y, Chen Y, Yin J, Zhang Z, Zhang K, Zhou J, et al. Relationship between leisure-time physical activity and depressive symptoms under different levels of dietary inflammatory index. *Front Nutr.* 2022;9:983511.
 262. * You Y, Wang R, Li J, Cao F, Zhang Y, Ma X. The role of dietary intake of live microbes in the association between leisure-time physical activity and depressive symptoms: a population-based study. *Appl Physiol Nutr Metab.* 2024;49:1014–24.
 263. * Zeibig JM, Seiffer B, Frei AK, Takano K, Sudeck G, Rösel I, et al. Long-term efficacy of exercise across diagnostically heterogeneous mental disorders and the mediating role of affect regulation skills. *Psychol Sport Exerc.* 2023;64:102340.
 264. * Zhang B, Lei SM, Le S, Gong Q, Cheng S, Wang X. Changes in health behaviors and conditions during COVID-19 pandemic strict campus lockdown among Chinese university students. *Front Psychol.* 2022;13:1022966.

265. * Zhang J, Zheng S, Hu Z. The effect of physical exercise on depression in college students: the chain mediating role of self-concept and social support. *Front Psychol.* 2022;13:841160.
266. * Zhang M, Xu X, Jiang J, Ji Y, Yang R, Liu Q, et al. The association between physical activity and subjective well-being among adolescents in southwest China by parental absence: a moderated mediation model. *BMC Psychiatry.* 2023;23(1):493.
267. * Zhang X, Feng S, Peng R, Li H. Using structural equation modeling to examine pathways between physical activity and sleep quality among Chinese TikTok users. *Int J Environ Res Public Health.* 2022;19(9):5142.
268. * Zhang X, Pennell ML, Bernardo BM, Clark J, Krok-Schoen JL, Focht BC, et al. Body image, physical activity and psychological health in older female cancer survivors. *J Geriatr Oncol.* 2021;12(7):1059–67.
269. * Zhang X, Wang D, Li F. Physical exercise, social capital, hope, and subjective well-being in China: a parallel mediation analysis. *Int J Environ Res Public Health.* 2022;20(1):303.
270. * Zhang Y, Zhang H, Ma X, Di Q. Mental health problems during the COVID-19 pandemics and the mitigation effects of exercise: a longitudinal study of college students in China. *Int J Environ Res Public Health.* 2020;17(10):3722.
271. * Zhang Z, Wang T, Kuang J, Herold F, Ludyga S, Li J, et al. The roles of exercise tolerance and resilience in the effect of physical activity on emotional states among college students. *Int J Clin Health Psychol.* 2022;22(3):100312.
272. * Zhao H, Zhang B, Liu W, Jiang Y. The relationship between physical activity and depression in college students: the chain mediating role of mindfulness and meaning in life. *Current Psychology.* 2024;22797–807.
273. * Zhao Y. The Effect of Physical Exercise on College Students' Mental Health and General Self-efficacy. *Revista de Psicología del Deporte.* 2021;30(4):167–74.
274. * Zheng Y, Wen P, Wu J, Jia H, Lai D, Xun Y, et al. Physical exercise and anxiety: the chain mediating effect of social support and resilience. *Soc Behav Pers.* 2024;52(6):1–1.
275. * Zhou GY, Yang B, Li H, Feng QS, Chen WY. The influence of physical exercise on college students' life satisfaction: the chain mediating role of self-control and psychological distress. *Front Psychol.* 2023;14:1071615.
276. * Zhou Y, Guo K. Physical activity and depression: a chain mediation model. *Soc Behav Pers.* 2023;51(10):1–9.
277. * Zhu JH, Li SF, Wang P, Xin X, Zhao Q, Chen SC, et al. Correlation and pathways of behavioral activation systems mediating physical activity level and depressive symptoms among college students. *World J Psychiatry.* 2023;13(10):784–92.
278. * Zou Y, Meng F, Yan X. The combined association of adherence to recommended physical activity and glycemic control with depression: an exploratory study with mediation and moderation models. *BMC Public Health.* 2023;23(1):2146.
279. Cohen J. Weighted kappa: Nominal scale agreement provision for scaled disagreement or partial credit. *Psychol Bull.* 1968;70(4):213–20.
280. Bandura A. Self-efficacy: toward a unifying theory of behavioral change. *Psychol Rev.* 1977;84(2):191.
281. Gauvin L, Spence JC. Physical activity and psychological well-being: knowledge base, current issues, and caveats. *Nutr Rev.* 1996;54(4):S53.
282. North TC, McCullagh P, Tran ZV. Effect of exercise on depression. *Exerc Sport Sci Rev.* 1990;18(1):379–416.
283. Nicholls JG. The competitive ethos and democratic education. Cambridge, Massachusetts: Harvard University Press; 1989.
284. Deci EL, Ryan RM. Intrinsic motivation and self-determination in human behavior. New York: Plenum Press; 1985.
285. White RL, Bennie A. Resilience in youth sport: A qualitative investigation of gymnastics coach and athlete perceptions. *Int J Sports Sci Coach.* 2015;10(2–3):379–93.
286. Martinek TJ, Hellison DR. Fostering resiliency in underserved youth through physical activity. *Quest.* 1997;49(1):34–49.
287. Sarkar M, Fletcher D. Psychological resilience in sport performers: a review of stressors and protective factors. *J Sports Sci.* 2014;32(15):1419–34.
288. Watson D, Clark LA, Tellegen A. Development and validation of brief measures of positive and negative affect: The PANAS scales. *J Pers Soc Psychol.* 1988;54(6):1063.
289. Headey B, Kelley J, Wearing A. Dimensions of mental health: life satisfaction, positive affect, anxiety and depression. *Soc Indic Res.* 1993;29(1):63–82.
290. Doyne EJ, Chambliss DL, Beutler LE. Aerobic exercise as a treatment for depression in women. *Behav Ther.* 1983;14(3):434–40.
291. Ransford CP. A role for amines in the antidepressant effect of exercise: a review. *Med Sci Sports Exerc.* 1982;14(1):1–10.
292. Simons AD, Epstein LH, McGowan CR, Kupfer DJ, Robertson RJ. Exercise as a treatment for depression: an update. *Clin Psychol Rev.* 1985;5(6):553–68.
293. Morgan WP. Affective beneficence of vigorous physical activity. *Med Sci Sports Exerc.* 1985;17(1):94–100.

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