

Systematic Review

Aerobic Training on Mental Health in Children and Adolescents: A Systematic Review with Meta-Analysis

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Abstract

Introduction: Mental health problems in children and adolescents are a growing public health concern. Aerobic physical activity has been identified as a promising, accessible, and low-cost intervention to promote psychological well-being. **Methods:** This systematic review and meta-analysis was conducted following PRISMA 2020 guidelines and a pre-registered PROSPERO protocol. We searched PubMed, Scopus, Web of Science, and CINAHL for randomized controlled trials published until December 2024, with no language restrictions. Eligibility criteria included interventions based on aerobic physical activity among children and adolescents (5–18 years) reporting outcomes on mental health (e.g., depression, anxiety, self-esteem, mood, resilience). Methodological quality was assessed with the PEDro scale. **Results:** From 828 initial records, 21 studies met the inclusion criteria and 19 were included in the meta-analysis. The trials, conducted in diverse countries and settings, applied structured aerobic interventions (e.g., running, dancing, cycling, active games) with durations of 6–30 weeks. The pooled results showed significant improvements in depression, anxiety, self-esteem, and stress, with the largest effects observed in stress reduction and self-esteem enhancement. **Conclusions:** Aerobic physical activity appears to be an effective and feasible strategy to improve mental health in children and adolescents. Its integration into school and community programs is recommended as a preventive and complementary approach to traditional treatments.

Keywords: aerobic training; children; adolescents; self-esteem; anxiety; depression; systematic review; meta-analysis



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1. Introduction

Mental health during childhood and adolescence has become a growing public health priority worldwide. It is estimated that around one in seven adolescents, approximately 166 million young people between 10 and 19 years old, suffer from a mental disorder, with emotional problems, such as anxiety and depression, being the most common [1]. Specifically, anxiety affects approximately 4.4% of children between 10 and 14 years old and 5.5% of adolescents between 15 and 19 years old, while depression has a prevalence of 1.4% and 3.2%, respectively, in those same age groups [2]. These internalizing disorders are associated with a variety of negative consequences, including poor academic performance, social isolation, emotional dysfunction, and, in the most severe cases, suicidal ideation and self-harm [3].

In the Spanish context, the data reflect an equally alarming situation. According to a recent report by UNICEF Spain [4], 41% of adolescents report having had or believed they had a mental health problem in the past year. Similarly, a study coordinated by seven Spanish universities indicates that more than 1.5 million adolescents between the ages of 12 and 18 present significant emotional symptoms, and more than half are undergoing psychological or pharmacological treatment. These data coincide with hospital records showing a sustained increase in pediatric psychiatric admissions over the past two decades [5]. This growing incidence underscores the urgent need to establish effective prevention, early diagnosis, and intervention strategies to adequately address mental health problems in this population.

Among the various strategies proposed to address mental health problems in children and adolescents, physical activity (PA) has gained increasing relevance as a preventative, therapeutic, accessible, and low-cost alternative [6]. PA is defined as “any bodily movement produced by skeletal muscles that results in energy expenditure greater than resting levels” [7]. This definition encompasses a wide range of activities that can be classified based on their intensity, duration, context, and purpose. Unlike organized physical exercise, which is planned, repetitive, and aims to improve one or more components of physical fitness, PA encompasses both organized activities (such as team sports or supervised classes) and informal activities (spontaneous games, active movements such as walking or cycling, and recreational activities such as dancing or running in the playground) [8]. What makes PA particularly attractive in the context of promoting children’s mental health is its inclusiveness, versatility, and adaptability to different educational, family, and community settings [9]. Unlike other more expensive or clinically structured interventions, PA can be relatively easily integrated into children’s daily routines, without the need for advanced technological resources or specialized supervision. This makes it a particularly suitable strategy for implementation in schools, where it can be part of the physical education curriculum, extracurricular programs, or specific school health interventions [10]. Several studies have shown that PA has the ability to modulate physiological, emotional, and social responses that directly impact children’s psychological well-being. Regular participation in physical activity is associated with a greater sense of belonging, improved body image, reduced social isolation, and higher levels of perceived competence [11]. Furthermore, it can promote the development of social skills, such as teamwork, respect for rules, and emotional self-regulation. Therefore, PA not only acts as a protective factor against emotional symptoms but can also play a crucial role in strengthening positive psychological resources, such as self-esteem, resilience, and self-efficacy [12,13]. These properties make physical activity an effective and multifaceted tool for promoting the comprehensive well-being of children and adolescents, and justify the growing interest in its evaluation within rigorous experimental frameworks such as randomized clinical trials [14].

To guide the interpretation of the evidence, this review is framed within the biopsychosocial model of mental health, which conceptualizes psychological well-being as the result of interactions between biological, psychological, and social factors. Aerobic physical activity represents a multidimensional intervention capable of simultaneously influencing these domains through physiological adaptations (e.g., regulation of neurotransmitters and neurotrophic factors), psychological mechanisms (e.g., improvements in self-esteem, emotional regulation), and social interaction (e.g., peer belonging and group cohesion). This integrative framework has been increasingly used to explain the role of physical activity in youth mental health.

Within the broad spectrum of physical activity modalities, aerobic exercise has been shown to be particularly effective in improving the mental health of children and adolescents [15]. This type of activity is characterized by sustained, cyclical movements

that mobilize large muscle groups, at moderate to vigorous intensity, which promotes both physiological and psychological improvements. Activities such as running, swimming, cycling, dancing, jumping rope, or participating in active games are common examples of aerobic exercise and can be performed in school, community, or recreational settings. Their accessible, dynamic, and adaptable nature makes them an ideal tool for implementation with young populations [14].

The effectiveness of aerobic exercise on mental health is supported by various neurobiological and psychosocial mechanisms. In physiological terms, this type of exercise has been shown to stimulate the release of neurotransmitters such as serotonin, dopamine, and norepinephrine, which are involved in emotional regulation and pleasure [16]. Furthermore, it increases the secretion of endorphins, substances that act as natural analgesics and generate feelings of well-being, and activates the endocannabinoid system, linked to the reduction in stress and anxiety [17]. Another key effect is the increase in the expression of BDNF (brain-derived neurotrophic factor), a neurotrophic factor that facilitates brain plasticity and emotional regulation [18]. Furthermore, aerobic exercise can regulate the activity of the hypothalamic–pituitary–adrenal axis, reducing cortisol levels and promoting greater stress tolerance [11,19]. At the psychosocial level, group aerobic interventions promote a sense of belonging, social support among peers, and perceived self-efficacy, all of which are protective factors against negative emotional symptoms [10]. Regular aerobic exercise has therefore been associated with significant decreases in depressive symptoms, anxiety, anger, emotional fatigue, and perceived stress, and with increases in self-esteem, physical self-concept, positive mood, and emotional resilience in healthy children and adolescents or those at clinical risk [12,20]. These findings, along with their practical applicability, consolidate aerobic exercise as a highly recommended intervention strategy for promoting psychological well-being during development.

Given the alarming epidemiological trends and the limitations of conventional treatments such as pharmacological and psychotherapeutic approaches, which are often costly, stigmatized, or difficult to access for children and adolescents, there is a growing need for effective, scalable, and preventive strategies [12,15]. Aerobic exercise emerges as a promising public health intervention with high feasibility in school and community settings. Nevertheless, the available evidence remains heterogeneous in terms of study design, intervention modalities, and reported outcomes. Therefore, a rigorous synthesis of findings through systematic review and meta-analysis is required to clarify the magnitude and consistency of the effects of aerobic physical activity on youth mental health. In this context, this systematic review and meta-analysis aims to synthesize the available evidence from randomized controlled trials (RCTs) evaluating the effects of aerobic physical activity interventions on mental health in children and adolescents (5–18 years). Unlike previous meta-analyses, our study provides an updated synthesis of the literature published up to 2024, includes only RCTs, applies rigorous RoB 2 and PEDro assessments, and explores potential dose–response relationships through meta-regression. This approach allows us to clarify the specific contribution of aerobic interventions to child and adolescent mental health and to strengthen the evidence base for school- and community-based implementation.

2. Materials and Methods

This review was conducted following the 2020 PRISMA statement guidelines [21] and adhered to a pre-registered protocol in PROSPERO (registration number: CRD420251116424). In addition, the methodological framework was guided by the recommendations outlined in the Cochrane Handbook for Systematic Reviews of Interventions [22].

2.1. Sources of Information and Search Strategy

A comprehensive search strategy was used to identify relevant studies in multiple electronic databases during the month of July. The following databases were consulted: PubMed, Scopus, Web of Science, and CINAHL. The search included articles published through December 2024 with no language or publication status restrictions.

The search strategy included the following combination of keywords and Boolean operators: (“aerobic exercise” OR “aerobic training” OR “cardiovascular exercise”) AND (“mental health” OR “psychological well-being” OR “emotional health” OR “depression” OR “anxiety” OR “self-esteem” OR self-concept OR stress) AND (“children” OR “child” OR “youth” OR “minors” OR “adolescents”).

2.2. Selection Criteria

To ensure the relevance and quality of the included studies, the following eligibility criteria were applied: (A) Inclusion criteria: (i) Studies evaluating the effects of aerobic exercise on the mental health of children and adolescents; (ii) Randomized controlled trials (RCTs); (iii) Studies with participants aged 5–18 years; (iv) Studies reporting quantitative data on mental health outcomes (e.g., depression, anxiety, psychological well-being); (B) Exclusion criteria: (i) Studies focusing on adult or older populations; (ii) Reviews, meta-analyses, conference proceedings, commentaries, editorials, or case reports; (iii) Studies that did not include physical activity interventions; and (iv) Studies with unclear outcomes, incomplete data, or data that could not be reliably extracted.

2.3. Data Extraction and Reliability

Data from the included studies were extracted using a standardized extraction form developed specifically for this review. The form captured relevant information such as: author(s), year of publication, country, sample size and characteristics, details of the intervention (type, frequency, duration), mental health outcomes assessed, measurement instruments used, and main findings. Two reviewers with expertise in systematic reviews and aerobic exercise extracted data to ensure consistency and reduce the risk of errors. Both had prior experience conducting meta-analyses in the fields of physical activity and mental health. Any discrepancies were resolved through discussion, and when necessary, a third senior reviewer with extensive experience in evidence synthesis was consulted to reach a consensus. To further enhance reliability, the results of the most recent psychology reviews were first summarized before selecting studies potentially relevant to the defined topics.

2.4. Assessment of Methodological Quality

The methodological rigor of the included trials was evaluated using the PEDro scale [23]. This instrument comprises 11 criteria, although only 10 contribute to the overall score since the first item (eligibility criteria) is reported separately and not counted. Each criterion is scored dichotomously (“Yes” = 1; “No” = 0), resulting in a total score ranging from 0 to 10. For interpretative purposes, studies were classified into four categories: poor (0–3), fair (4–5), good (6–8), and excellent quality (9–10). In addition, we applied the Cochrane Risk of Bias 2 (RoB 2) tool, which evaluates five domains: (i) randomization process, (ii) deviations from intended interventions, (iii) missing outcome data, (iv) measurement of the outcome, and (v) selection of the reported result. This dual approach allowed us to complement the PEDro scoring system with a more detailed risk-of-bias assessment.

2.5. Analytical Decisions for Meta-Analysis

The outcomes of the meta-analysis were summarized in forest plots, which detailed for each study the first author, year of publication, sample size, and the corresponding

effect sizes (Hedges' g). Each estimate was displayed with its 95% confidence interval and associated p -value, facilitating the interpretation of both magnitude and statistical significance. To test the robustness of the synthesis, we performed sensitivity analyses by sequentially excluding studies with overlapping samples, statistical outliers, or atypical values that could bias the pooled results. The comparison between these reduced models and the full dataset confirmed the stability of the overall effects. Additionally, subgroup analyses were performed, stratifying studies according to the nature of the outcome variables. Primary outcomes were defined a priori as depressive symptoms, anxiety, and self-esteem. Secondary outcomes included mood, stress, resilience, and executive functioning. All outcomes were analyzed at the post-intervention timepoint, as reported in the original trials. The first category included indicators related to mental health, such as emotional and behavioral symptoms (e.g., anxiety, depression, emotional regulation, and aggression). The second grouping focused on aspects of cognitive functioning, particularly executive skills such as working memory, inhibitory control, and cognitive flexibility. Separate meta-analyses were conducted for each of these subgroups, allowing for a deeper understanding of the differences in effects and a clarification of the specific impact that physical activity could have on each dimension. Given the diverse nature of the included studies, a random-effects model was used. This methodological choice allowed for the incorporation of potential real-world variations between the reported effect sizes, thus providing greater generalizability of the results. Statistical heterogeneity was analyzed using Cochran's Q test and the I^2 statistic [22]. An I^2 value greater than 50% was interpreted as indicating moderate or high heterogeneity, which could indicate differences in the methods, settings, or characteristics of the study populations. Finally, publication bias was examined using funnel plot analysis, which allowed us to visualize potential biases caused by the tendency to report statistically significant results. This visual assessment was complemented with statistical tests such as the Egger test, which served to detect potential asymmetries and confirm the presence of bias in the set of studies reviewed.

3. Results

3.1. Study Selection Process

A total of 828 records were initially retrieved through systematic searches conducted across four databases: PubMed (255 records), Scopus (218), Web of Science (167), and CINAHL (188). After applying predefined filters, such as study type (randomized controlled trials and original research articles), language (English and Spanish), and target population (children and adolescents), the dataset was refined. Further screening involved the removal of duplicate entries and the assessment of titles and abstracts based on relevant keywords, resulting in 282 unique records. In the first selection stage, 154 articles were identified as potentially relevant and subjected to full-text review. Following this in-depth evaluation, 21 studies met all inclusion criteria and were included in the qualitative synthesis and meta-analysis. The remaining 97 studies were excluded primarily due to methodological limitations, irrelevant outcome variables, or lack of focus on physical activity interventions. The complete selection process is illustrated in Figure 1, according to the PRISMA 2020 guidelines.

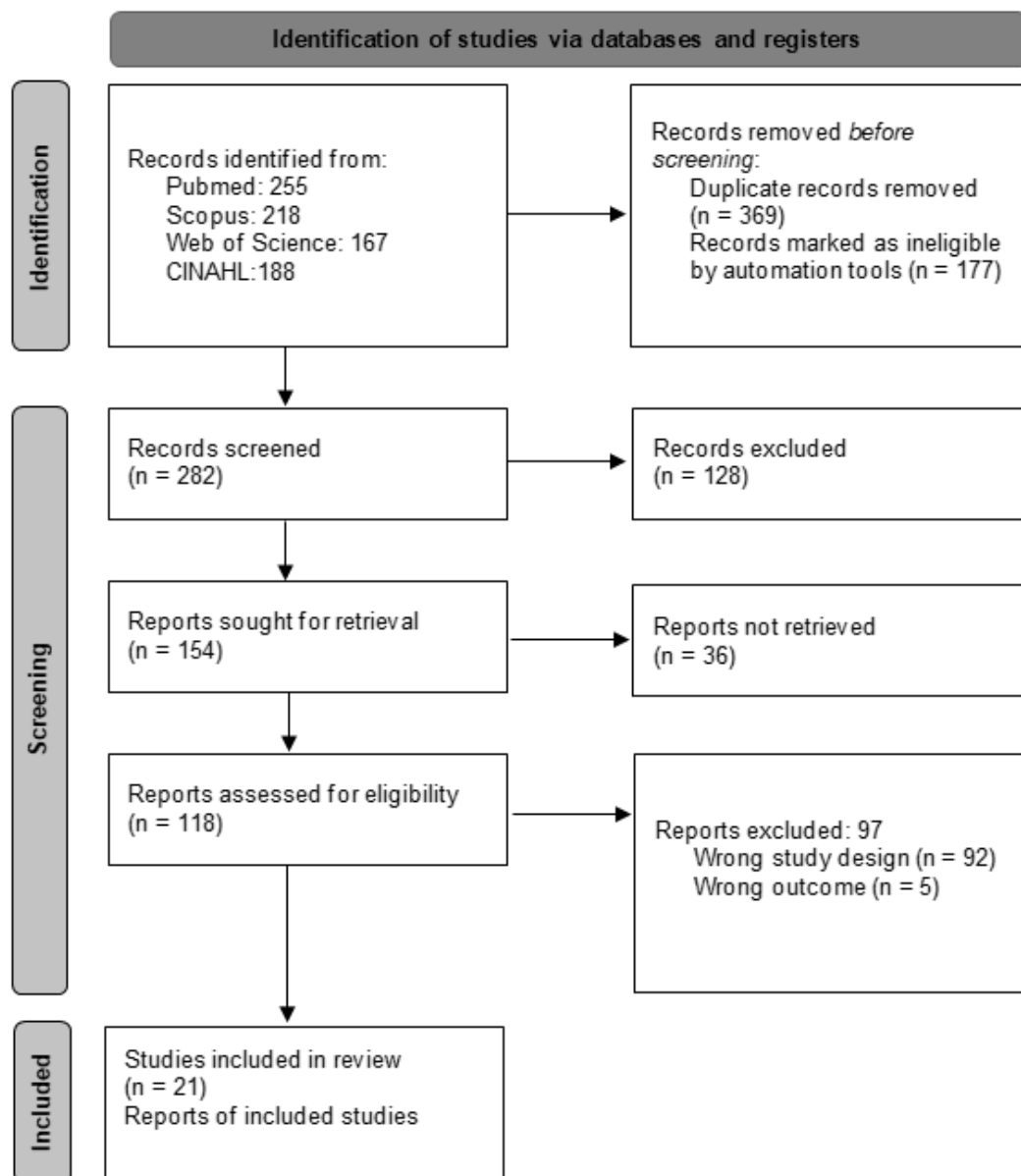


Figure 1. Study selection process flow chart.

3.2. Methodological Quality

The methodological rigor of the 21 studies reviewed in this systematic analysis was assessed using the PEDro scale, a tool designed to evaluate essential aspects of study design in randomized controlled trials. This scale produces scores from 0 to 10, excluding the eligibility criteria item, which does not contribute to the total. In this review, PEDro scores ranged from 2 to 7, indicating a generally moderate level of methodological quality. No study achieved the highest possible score, and only one study reached a score of 7, classifying it as high-quality. In contrast, three studies received scores of 3 or below, with one study obtaining the lowest score of 2. Overall, 57% of the studies scored between 5 and 6, suggesting adequate implementation of randomization, intergroup comparisons, and complete data reporting. However, 17% of the included articles scored 4 points, and 13% scored 3 or fewer, exposing significant methodological gaps. The most frequently observed shortcomings were the lack of blinding for participants, therapists, or assessors; insufficient allocation concealment; and limited application of intention-to-treat analyses. These methodological issues are consistent with previous systematic reviews in the field of pediatric exercise and mental health, which have similarly highlighted the frequent absence

of blinding and inadequate reporting of randomization procedures [24,25]. Although our assessments were conducted independently by two experienced reviewers using standardized tools (PEDro, RoB 2), and disagreements were resolved by consensus with a senior researcher, it must be acknowledged that critical appraisal inherently involves a degree of subjectivity. Nevertheless, the convergence of our observations with those reported in prior reviews suggests that these shortcomings represent structural limitations of the literature, rather than an overly rigorous or idiosyncratic assessment by our review team. These deficiencies heighten the potential for bias and diminish internal validity. Thus, although many of the studies utilized broadly acceptable research methodologies, their limitations should be acknowledged when interpreting the findings. It is essential that future trials investigating physical activity interventions in youth with neurodevelopmental disorders adopt more rigorous design frameworks to enhance the credibility of their outcomes. A comprehensive summary of quality assessment results can be found in Table 1.

Table 1. Methodological quality of the included articles.

Study	1	2	3	4	5	6	7	8	9	10	11	Total Score
Annesi et al. [26]	1	0	0	0	0	0	0	0	0	1	1	2/10
Bazzano et al. [27]	1	1	1	0	1	0	0	0	0	1	1	5/10
Bohnert et al. [28]	1	1	1	0	0	1	0	0	1	1	1	6/10
Burgess et al. [29]	1	0	0	0	1	0	0	0	0	1	1	3/10
Cowley et al. [30]	1	1	1	0	1	0	0	0	0	1	1	5/10
Crews et al. [31]	1	0	1	0	0	0	0	0	0	1	1	3/10
Eather et al. [32]	1	1	1	0	1	0	0	1	1	0	1	7/10
Gaurav et al. [33]	1	1	0	0	0	1	0	0	0	1	1	4/10
Jelanian et al. [34]	1	1	0	0	0	0	0	0	1	1	1	4/10
Khalsa et al. [35]	1	1	1	0	1	0	0	1	1	1	1	7/10
Lobo et al. [36]	1	1	1	0	0	1	1	1	0	1	1	7/10
Melnyk et al. [37]	1	1	1	0	1	0	0	0	0	1	1	5/10
Melnyk et al. [38]	1	1	1	0	0	1	0	0	0	1	1	5/10
Noggle et al. [39]	1	1	1	0	1	0	0	0	0	1	1	5/10
Olive et al. [40]	1	0	1	0	1	0	1	0	1	1	1	6/10
Sharma et al. [41]	1	0	1	0	0	0	0	0	0	1	1	3/10
Smith et al. [42]	1	1	1	0	1	0	0	0	0	1	1	5/10
Telles et al. [43]	1	1	1	0	1	0	0	1	1	1	1	7/10
Wassenaar et al. [44]	1	0	1	0	1	1	0	0	0	1	1	5/10
Ho et al. [45]	1	1	1	1	1	0	0	0	1	1	1	7/10
Wang et al. [46]	1	1	1	0	1	0	0	0	1	1	1	6/10

Scoring criteria: (1) eligibility specified; (2) random allocation; (3) concealed allocation; (4) comparable groups at baseline; (5) participant blinding; (6) therapist blinding; (7) assessor blinding; (8) adequate follow-up; (9) intention-to-treat analysis; (10) between-group statistical comparisons. Each item is scored as Yes = 1 or No = 0.

The overall risk of bias assessment using the Cochrane RoB 2 tool revealed a heterogeneous methodological quality across the included trials. High-quality studies, such as those conducted by Wassenaar et al. [44], Wang et al. [46] and Smith et al. [42], demonstrated a low risk of bias, largely due to robust randomization procedures, prespecified protocols,

appropriate handling of missing data, and the use of validated outcome measures. Conversely, earlier trials [26–28,31], frequently exhibited “some concerns”, primarily related to insufficient reporting of allocation concealment, lack of preregistration, and reliance on self-reported outcomes without assessor blinding. Studies involving yoga- or mindfulness-based interventions [35,39,43,45] also tended to fall into the “some concerns” category, given the challenges in participant blinding and the absence of detailed analytic protocols, despite showing adequate adherence and acceptable data completeness. Importantly, none of the included trials was judged to be at high risk of bias, and sensitivity analyses confirmed that excluding studies with greater methodological concerns did not substantially alter the pooled estimates. Overall, the evidence base can be considered moderately robust, with stronger confidence derived from more recent, preregistered school-based RCTs that reported outcomes in line with their protocols (Figure 2).

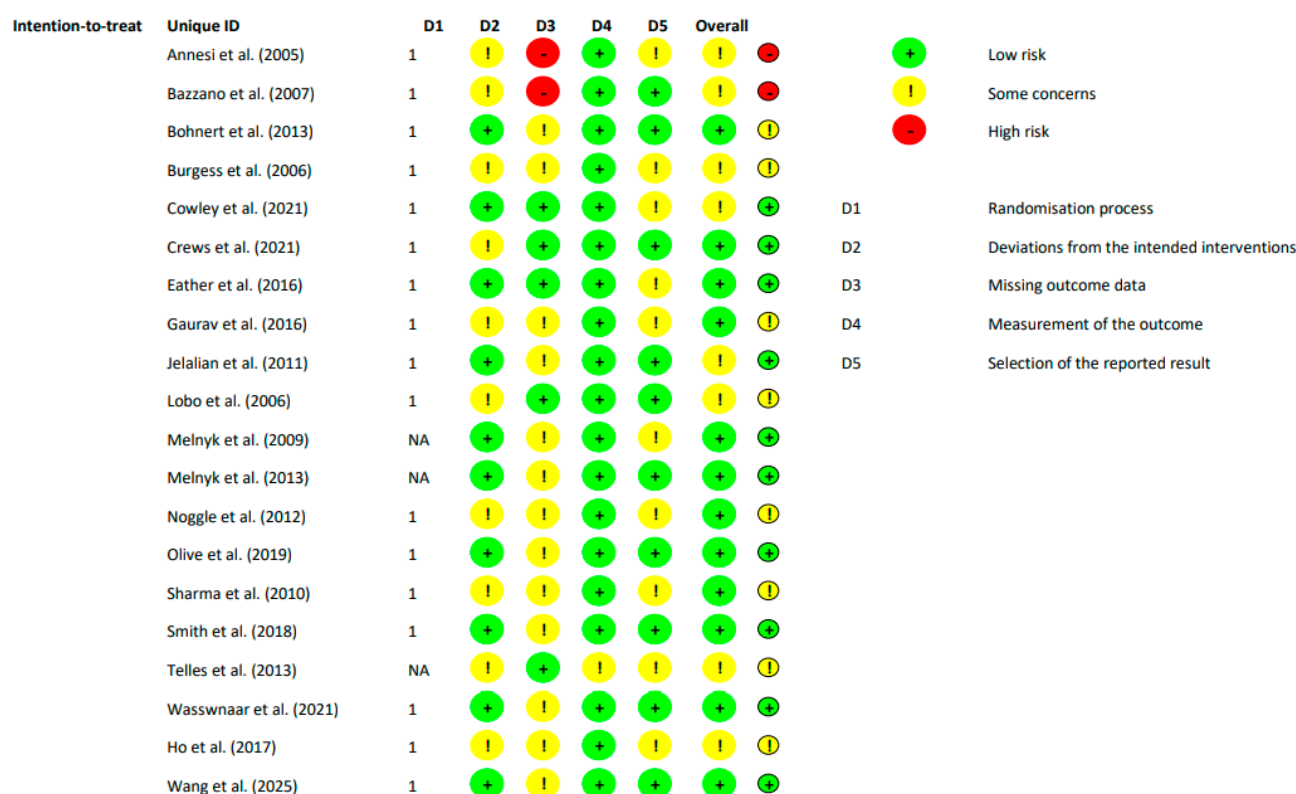


Figure 2. Risk of bias of the included articles [26–34,36–46]. D1: bias arising from the randomization process; D2: bias due to deviations from the intended intervention; D3: bias due to missing outcome data; D4: bias in the measurement of the outcome; D5: bias in the selection of the reported result.

3.3. Characteristics of the Studies

This systematic review included a total of 21 randomized controlled trials (RCTs) that investigated the effects of aerobic or movement-based physical activity interventions on the psychological and emotional well-being of children and adolescents. The studies were conducted between 2004 and 2025, and took place in a range of countries including the United States, United Kingdom, Australia, India, Mexico, China, and Iran, reflecting a geographically and culturally diverse research base. Participants across studies were predominantly school-aged children and adolescents, with mean ages ranging from 5.2 to 17.2 years. The sample sizes varied considerably, with studies enrolling between 19 and 627 participants. Most studies included comparable numbers of participants in the intervention and control groups, though some presented modest imbalances. The control conditions generally comprised standard school-based physical education classes, health education programs,

or wait-list groups, and in some cases, no active intervention. Intervention characteristics showed considerable variability. The type of physical activity was predominantly aerobic in nature but implemented through diverse formats, including traditional aerobic exercise sessions, yoga-based interventions, circuit training, or sport-related group activities. The frequency of sessions ranged from 1 to 6 times per week, while the duration of each session varied from 15 to 90 min. The total length of the interventions spanned from 6 to 30 weeks, with the majority of programs lasting between 8 and 12 weeks. The intensity of exercise was commonly classified as moderate to vigorous, although several interventions also included low-intensity components. Regarding the outcomes assessed, the studies employed a wide array of validated psychological and behavioral instruments. The most frequently measured variables included depressive symptoms, anxiety, self-esteem and self-concept, and mood states. Additional outcomes included stress, executive function, resilience, social skills, and quality of life, measured with tools such as the PSS, Stroop Test, SSRS, Ped-sQL, and others. Overall, the studies included in this review demonstrate considerable heterogeneity in terms of intervention design, duration, intensity, and outcome assessment. However, they share a common focus on evaluating the mental and emotional effects of physical activity in youth populations, and collectively provide a comprehensive view of its potential benefits in diverse educational and clinical settings (Table S1).

3.4. Study Results

This review included 21 randomized controlled trials that examined the impact of 268 structured aerobic or movement-based physical activity programs on the emotional and psychosocial health of children and adolescents. Overall, the interventions tended to reduce depressive and anxiety symptoms and promote self-esteem, self-concept, mood regulation, stress management, and resilience, although effect sizes and consistency varied according to intervention features and outcome measures. Depressive symptoms were evaluated in 11 of the included studies [26,27,29,31,33,35,37,38,40,44,46]. Of these, eight studies [27,30,32,37,38,40,45,46] reported statistically significant reductions in depression levels in the intervention groups compared to controls. These improvements were more evident in programs of moderate to vigorous intensity, conducted at least three times per week, and lasting 8 to 12 weeks. Interventions that incorporated not only physical exertion but also supportive or skill-building environments appeared particularly beneficial in reducing depressive symptomatology.

Anxiety was measured in 8 studies [26,27,31,35,37,38,41,46], using various standardized instruments including the STAIC, SCARED, and subscales of the BASC-2. Among these, five studies [27,35,41,45,46] reported significant reductions in anxiety levels among participants in the physical activity groups. These studies generally used structured, rhythmic, or mindfulness-based movement, such as yoga or aerobic exercise combined with relaxation or cognitive-behavioral components. Improvements were more likely when the interventions were delivered consistently (4–5 times per week) and included elements targeting emotional regulation.

Self-esteem and self-concept outcomes were assessed in 13 studies [26,28,30–32,34–36,42–46], using tools such as the Self-Perception Profile for Children (SPPC), CY-PSP, and SDQ-I. Six of these studies [28,32,36,45,46] found significant improvements in self-esteem or domain-specific self-concepts, particularly in physical self-perception, general self-worth, and social competence. Programs that promoted motor skill development, mastery experiences, and social interaction appeared to have the greatest impact on perceived competence and global self-esteem.

Mood and emotional state were examined in 7 studies [26,28,29,39,42] using tools such as the Profile of Mood States-Short Form (POMS-SF) and other emotion-related subscales.

Four of these studies [28,31,39,42] reported reductions in negative affect (e.g., tension, anger, fatigue) and/or increases in positive mood following the intervention. These findings were particularly associated with programs that combined movement with mindfulness, relaxation, or social-emotional learning components.

Stress was directly evaluated in 5 studies [33,35,36,41], and three of them [33,35,41] found significant reductions in perceived stress post-intervention. Notably, both of these studies incorporated yoga-based practices and cognitive-behavioral strategies, suggesting an additive benefit when physical activity is combined with psychological techniques targeting stress regulation.

Resilience was specifically assessed in 2 studies [37,38], both of which reported significant improvements in post-intervention scores. These findings support the hypothesis that regular physical activity may enhance adaptive emotional functioning, particularly when programs include components that foster coping skills and emotional awareness.

In general, studies with higher frequency and intensity, session durations of at least 45 min, and programs lasting more than eight weeks were more likely to produce significant psychosocial benefits. The heterogeneity of intervention formats, delivery settings, and outcome measures limits direct comparisons, but overall, the results suggest that structured physical activity interventions can positively influence emotional well-being and self-perceptions in youth.

3.5. Meta-Analysis

Although 21 randomized controlled trials were included in the qualitative synthesis, only 19 were retained in the quantitative meta-analysis. Two studies were excluded from the pooled analyses because they did not provide sufficient data to calculate standardized effect sizes, despite fulfilling all other eligibility criteria. The heterogeneity analysis yielded a Q value of 694.334 with 38 degrees of freedom, indicating substantial between-study variability. This is supported by the I^2 statistic of 94.53%, which suggests that a large proportion of the variability in effect sizes is due to true heterogeneity rather than chance. In addition, the Tau^2 was 0.593 and the Tau value was 0.770, indicating a considerable dispersion among the estimated true effects. Given this level of heterogeneity, a random-effects model was applied to obtain more accurate pooled estimates. The overall effect size was 0.081, with a 95% confidence interval ranging from 0.024 to 0.138. Figure 3 displays a forest plot summarizing these results, highlighting a general trend toward positive effects of aerobic physical activity on mental health outcomes, although with some variability across individual studies.

3.5.1. Subgroup Analysis

A subgroup analysis was performed considering the five variables included in the study. The results showed statistically significant effects in the domains of depression ($g = 0.132$; $p = 0.004$) and anxiety ($g = 0.314$; $p < 0.001$), with small to moderate effect sizes in the expected direction. However, in the subgroups corresponding to mood and self-esteem, the effects did not reach statistical significance. Even so, the effect sizes show a consistent trend across the different domains, which provide support for the robustness of the main findings.

Depression

The results of the meta-analysis showed an overall standardized effect size (g) of 0.132, indicating a small to moderate positive effect of aerobic interventions on depression levels in children and adolescents. This effect was statistically significant ($p = 0.004$), and the 95% confidence interval [0.042, 0.222] does not include zero, supporting the presence of a real effect (Figure 4). To assess between-study heterogeneity, the Q test was applied,

yielding a value of 188.146 with 10 degrees of freedom and a $p < 0.001$, indicating significant heterogeneity among the included studies. This conclusion is reinforced by the I^2 statistic of 94.69%, suggesting that approximately 95% of the observed variability among effect sizes is due to real differences between studies, rather than chance. The values of $\text{Tau}^2 = 0.482$ and $\text{Tau} = 0.694$ confirm a high degree of dispersion among the estimated true effects. Given this high level of heterogeneity, a random-effects model was used for the analysis, which is methodologically appropriate considering the variability between studies in terms of design, sample characteristics, and intervention applied. Although the Egger test showed $p = 0.054$, suggesting some possibility of publication bias, this evidence should be interpreted with caution due to the relatively small number of included studies and the high level of heterogeneity (Figure 5).

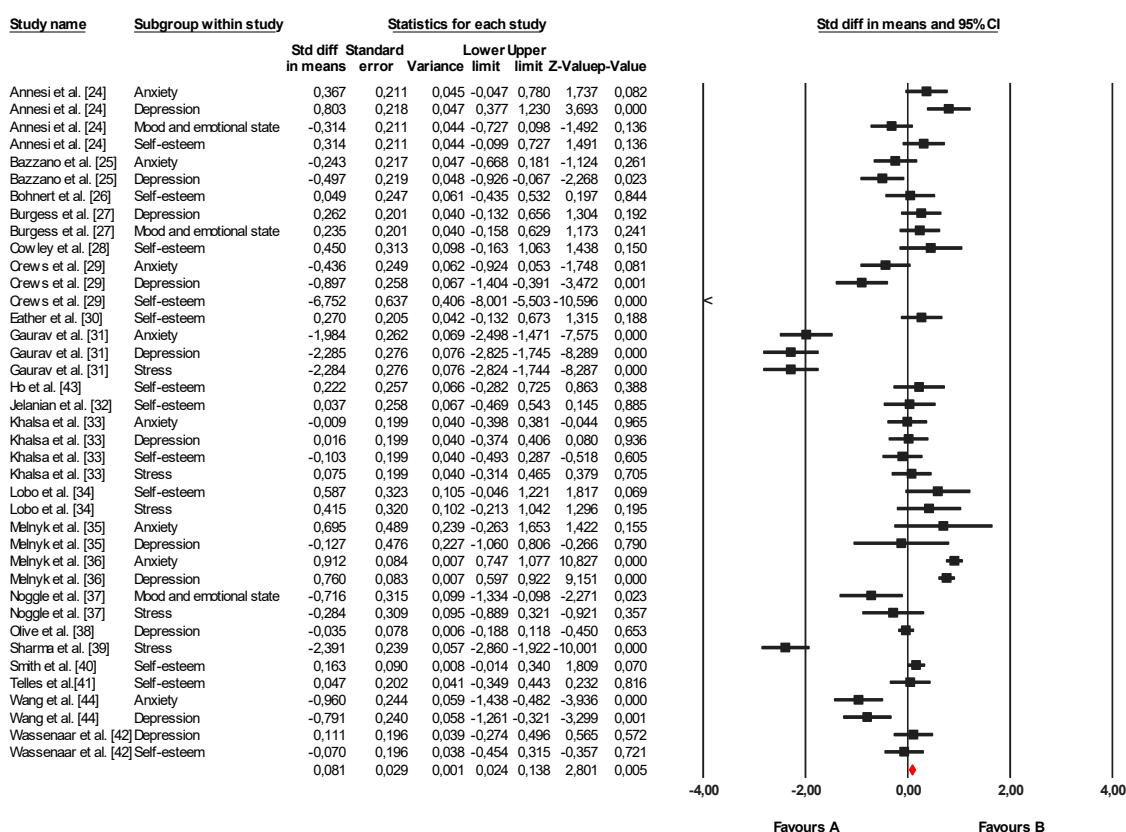


Figure 3. Forest plot of the meta-analysis on the effects of aerobics interventions on mental health in children and adolescents.

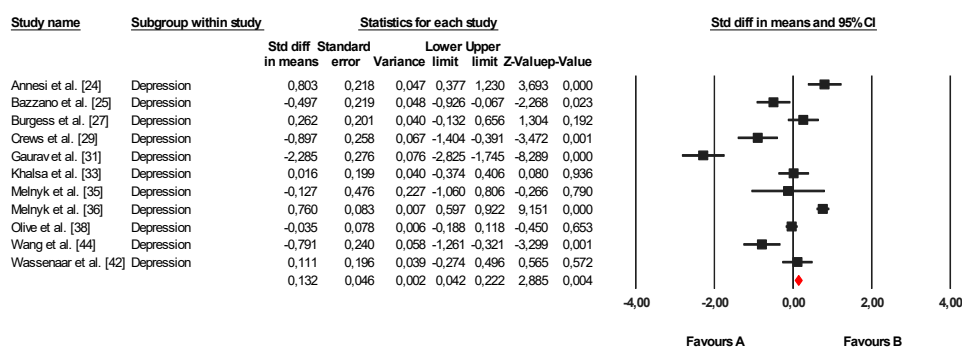


Figure 4. Forest plot of the meta-analysis on the effects of aerobics interventions on depression in children and adolescents.

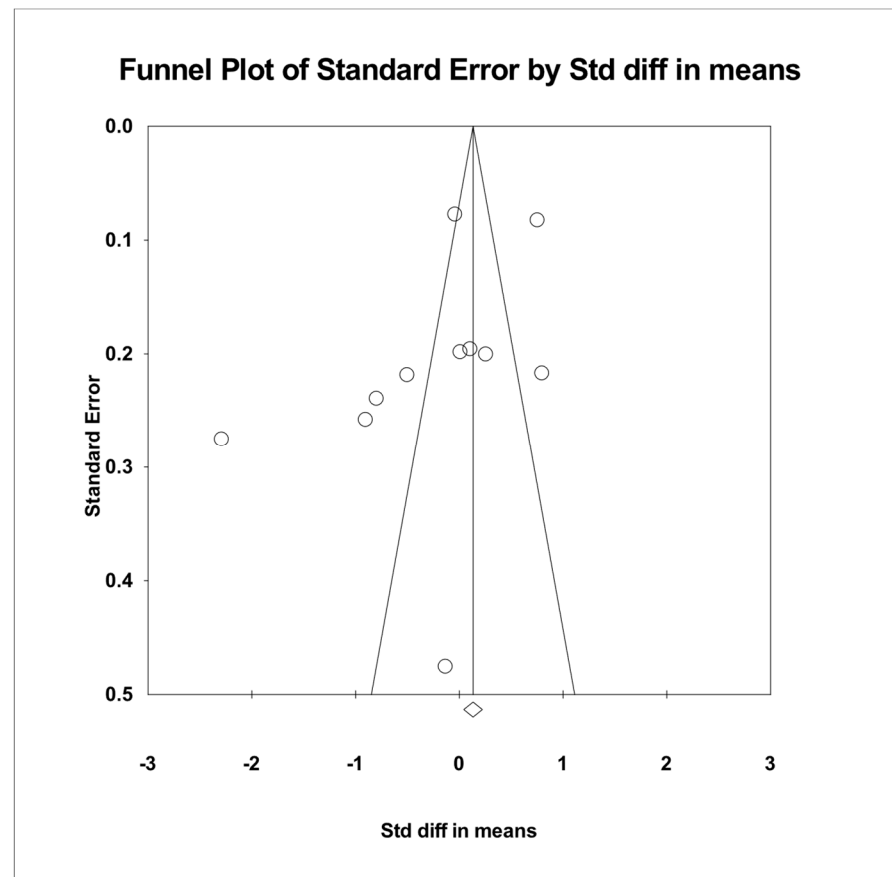


Figure 5. Funnel plot for depression.

Anxiety

The results of the meta-analysis indicated an overall standardized effect size (Hedges' g) of 0.314, representing a small to moderate positive effect of aerobic interventions on anxiety levels in children and adolescents. This effect was statistically significant ($p < 0.001$), and the 95% confidence interval [0.193, 0.435] excluded zero, supporting the presence of a real and reliable effect (Figure 6). To evaluate the degree of heterogeneity across studies, the Q test yielded a value of 173.626 with 7 degrees of freedom ($p < 0.001$), indicating significant between-study variability. This was further supported by an I^2 statistic of 95.97%, suggesting that nearly all the variability in observed effect sizes is due to actual differences between studies rather than random error. Moreover, the Tau^2 value of 0.943 and Tau value of 0.971 confirmed a high level of dispersion in the true effect estimates. Given the substantial heterogeneity, a random-effects model was employed, which the appropriate analytical approach is considering potential differences across studies in terms of sample demographics, study design, and implementation of interventions. Although Egger's test indicated potential publication bias ($p = 0.019$), this result should be interpreted with caution due to the small number of studies included in the analysis and the high degree of heterogeneity (Figure 7).

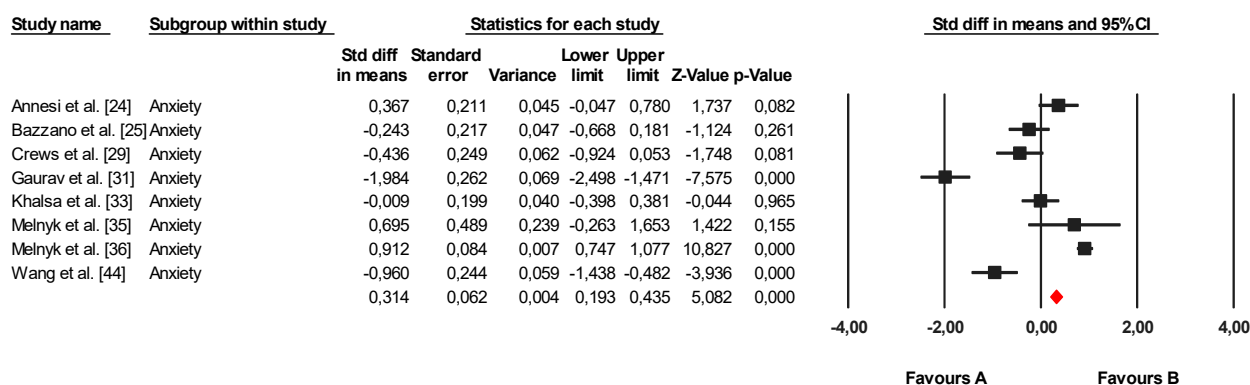


Figure 6. Forest plot of the meta-analysis on the effects of aerobics interventions on anxiety in children and adolescents.

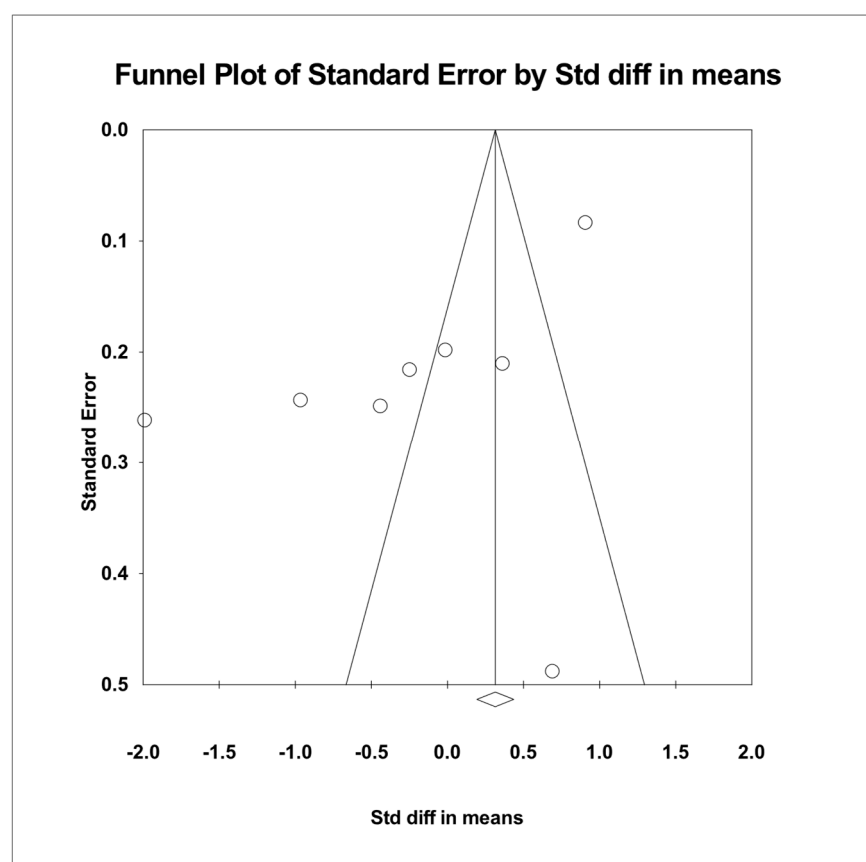


Figure 7. Funnel plot for anxiety.

Mood and Emotional State

The results of the meta-analysis indicated an overall standardized effect size (Hedges' g) of -0.147 , suggesting a small negative and non-significant effect of aerobic interventions on mood and emotional state in children and adolescents. This effect did not reach statistical significance ($p = 0.265$), and the 95% confidence interval $[-0.406, 0.112]$ includes zero, indicating uncertainty about the presence of a true effect (Figure 8). To assess heterogeneity among the included studies, the Q test yielded a value of 7.517 with 2 degrees of freedom ($p = 0.023$), indicating significant variability between studies. This finding is supported by an I^2 statistic of 73.39%, which shows that a considerable portion of the observed variance in effect sizes can be attributed to real differences rather than random error. Additionally, the τ^2 value of 0.153 and τ value of 0.391 reflect a moderate level of dispersion in the true effects. Given this level of heterogeneity, the use of a random-effects model was

justified, as it appropriately accounts for differences in study populations, designs, and intervention characteristics. Although Egger's test ($p = 0.208$) did not indicate clear evidence of publication bias, the limited number of studies and observed heterogeneity suggest that this result should be interpreted with caution (Figure 9).

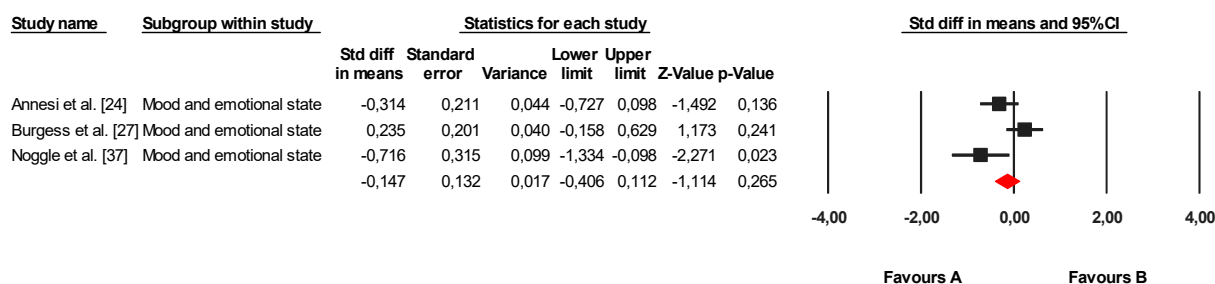


Figure 8. Forest plot of the meta-analysis on the effects of aerobics interventions on mood in children and adolescents.

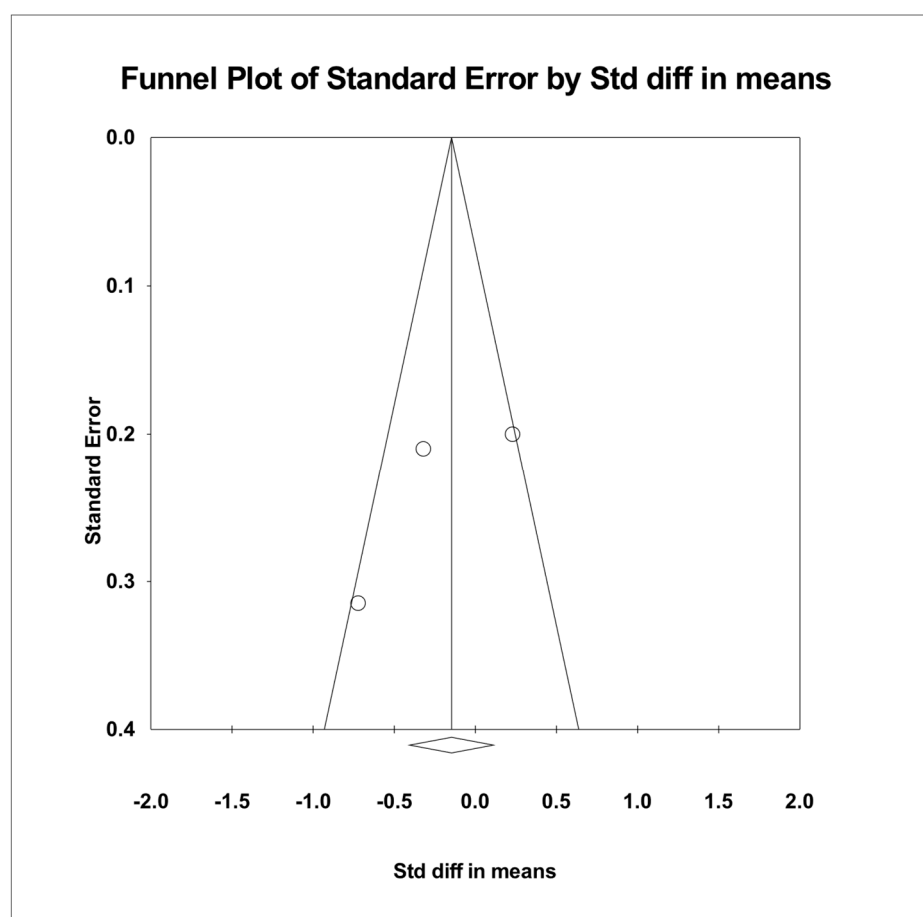


Figure 9. Funnel plot for mood.

Self-Esteem

The results of the meta-analysis indicated an overall standardized effect size (Hedges' g) of 0.091, suggesting a small and non-significant positive effect of aerobic interventions on self-esteem levels in children and adolescents. This effect did not reach statistical significance ($p = 0.107$), and the 95% confidence interval $[-0.020, 0.202]$ includes zero, reflecting uncertainty regarding the presence of a true underlying effect (Figure 10). To assess the degree of heterogeneity among the studies, the Q test produced a value of 123.528 with 11 degrees of freedom ($p < 0.001$), indicating substantial between-study variability.

This was further corroborated by an I^2 statistic of 91.10%, which suggests that a large proportion of the observed variation in effect sizes is due to real differences between studies rather than chance. The Tau^2 value of 0.444 and Tau value of 0.667 also indicate a moderate level of dispersion in the true effect estimates. Given the considerable heterogeneity, the application of a random-effects model was appropriate to account for variations in study populations, intervention protocols, and methodological approaches. Although Egger's test yielded a p -value of 0.077, which does not provide strong evidence for publication bias, this finding should be interpreted with caution due to the relatively small number of included studies and the high heterogeneity detected (Figure 11).

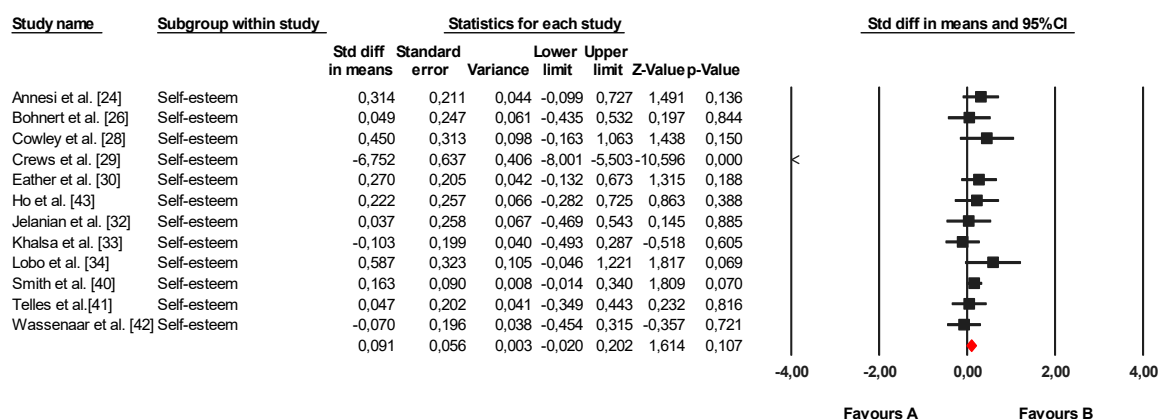


Figure 10. Forest plot of the meta-analysis on the effects of aerobics interventions on self-esteem in children and adolescents.

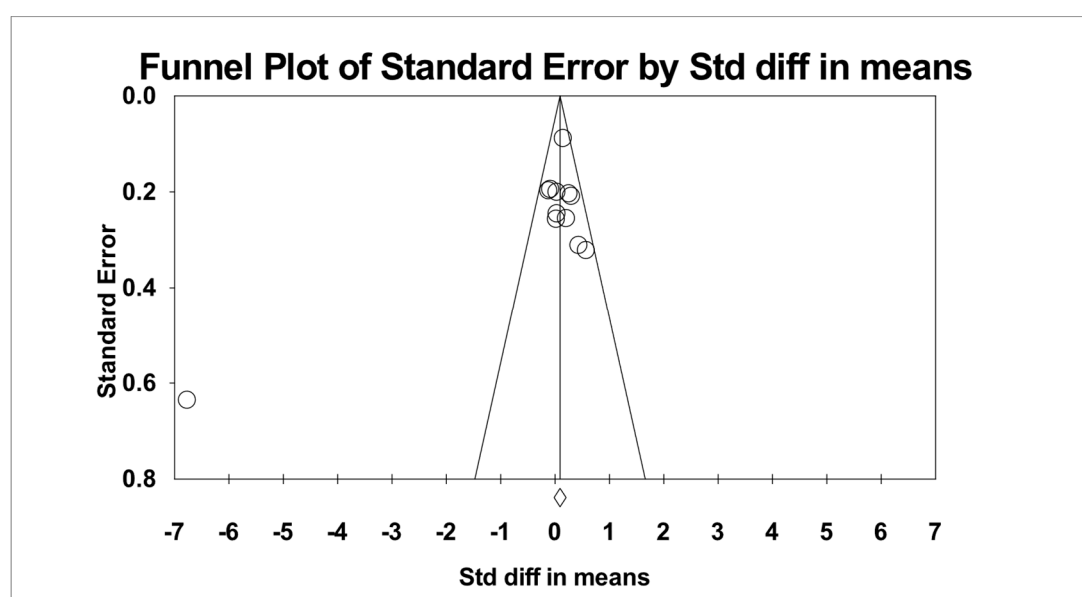


Figure 11. Funnel plot for self-esteem.

Stress

The results of the meta-analysis indicated an overall standardized effect size (Hedges' g) of -0.904 , reflecting a large and statistically significant reduction in stress levels among children and adolescents following aerobic interventions. This effect was statistically significant ($p < 0.001$), and the 95% confidence interval $[-1.129, -0.680]$ did not include zero, confirming the presence of a true and robust effect (Figure 12). To evaluate heterogeneity among the included studies, the Q test yielded a value of 109.020 with 11 degrees of freedom ($p < 0.001$), indicating substantial variability between studies. This conclusion is

further supported by an I^2 statistic of 96.33%, showing that the vast majority of observed variance across studies is due to real differences rather than sampling error. Additionally, $\text{Tau}^2 = 1.785$ and $\text{Tau} = 1.336$ reflect a high degree of dispersion in the true effect sizes. Given the magnitude of heterogeneity, the use of a random-effects model was appropriate, accounting for differences in study design, intervention types, and sample characteristics. Although Egger's test yielded a p -value of 0.475, suggesting no strong evidence of publication bias, this result should still be interpreted cautiously due to the small number of studies and the high heterogeneity observed (Figure 13).

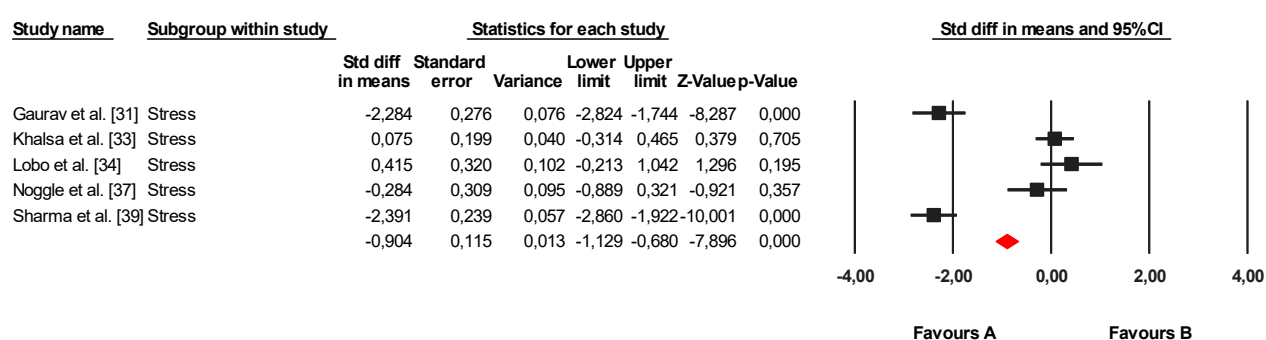


Figure 12. Forest plot of the meta-analysis on the effects of aerobics interventions on stress in children and adolescents.

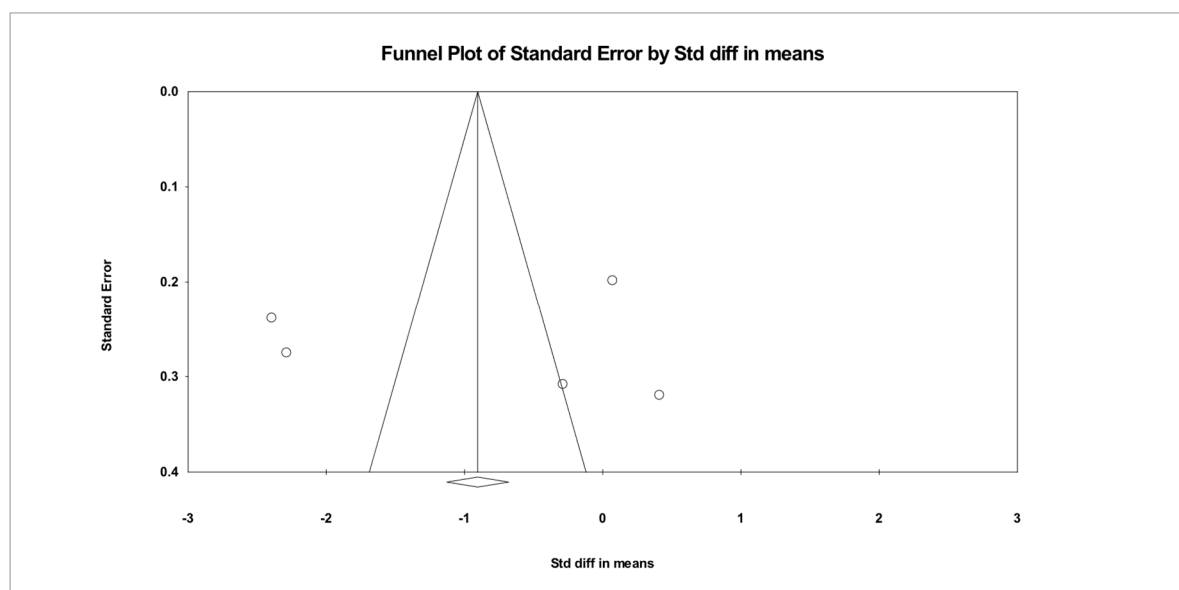


Figure 13. Funnel plot for stress.

3.5.2. Sensitivity Analyses

To assess the robustness of the findings, several sensitivity analyses were conducted. First, studies with duplicate or overlapping samples were excluded to avoid redundancy in effect estimates. Second, statistical outliers presenting extreme effect sizes were removed to evaluate their influence on the pooled results. Third, interventions primarily based on yoga or mindfulness were excluded, since these could be considered conceptually distinct from conventional aerobic training.

The exclusion of duplicate or overlapping studies did not substantially modify the overall effect sizes across outcomes. Similarly, the removal of outliers slightly reduced heterogeneity values but did not change the direction or statistical significance of the

results. Regarding the exclusion of yoga/mindfulness-based interventions, the pooled effect on anxiety decreased modestly (from Hedges' $g = 0.31$ to $g = 0.26$) but remained statistically significant, supporting the robustness of the association between aerobic activity and improved mental health outcomes. Overall, these analyses confirmed that the main conclusions of the meta-analysis were not driven by any single study or subgroup of interventions.

3.5.3. Meta-Regression

To explore the high level of heterogeneity observed in the main analyses ($I^2 > 90\%$), meta-regressions were performed to explore potential sources of heterogeneity. Variables included were intervention duration (weeks), frequency of weekly sessions, mean age of participants, and intervention type. The duration of the interventions (weeks) did not show a significant association with the outcomes (coeff. = -0.0208 ; 95% CI: -0.0829 to 0.0413 ; $p = 0.511$), explaining zero proportion of the variance between studies ($R^2 = 0.0\%$). Similarly, the mean age of participants was not found to be a significant moderator (coeff. = 0.0105 ; 95% CI: -0.0755 to 0.0965 ; $p = 0.811$), with no reduction in heterogeneity ($R^2 = 0.0\%$). Regarding the type of intervention (aerobic, school-based, combined), the comparisons did not reach overall statistical significance ($Q = 1.75$; $p = 0.781$), indicating that the exercise modality did not consistently explain the variability in the effect sizes. In contrast, the number of sessions per week emerged as a significant moderator. The analysis showed that a higher number of sessions was associated with a reduced effect size (coefficient = -0.3499 ; 95% CI: -0.5068 to -0.1930 ; $p < 0.001$), explaining approximately 24% of the variance between studies ($R^2 = 0.24$). Overall, the analyses suggest that the weekly frequency of sessions may be a determining factor in the magnitude of the observed effects, while duration, participant age, and intervention type did not appear to significantly influence the effect size.

4. Discussion

The primary objective of this systematic review and meta-analysis was to evaluate the effects of aerobic physical activity-based interventions on multiple dimensions of mental health in children and adolescents, including depressive symptoms, anxiety, self-esteem, mood/emotional state, and resilience. The systematic review was designed to provide a comprehensive synthesis of the available randomized controlled trials, mapping the breadth and quality of the evidence. The meta-analysis aimed to quantitatively pool the results in order to estimate the overall magnitude of the effects, explore sources of heterogeneity, and identify potential dose–response patterns. Conducting both approaches in parallel allowed us not only to summarize the existing literature but also to generate robust effect estimates and examine moderators that cannot be addressed through qualitative synthesis alone. The main findings indicate that these interventions produce small to moderate benefits on most of the variables analyzed, with the most consistent effects being improved self-esteem and stress reduction. Although the magnitude of the effects varies across studies, the results support the integration of regular aerobic programs as a preventive and therapeutic tool for the psychological well-being of children and adolescents.

Although significant improvements were observed in domains such as anxiety and depressive symptoms, the pooled effects were small in magnitude ($g \approx 0.08$) and accompanied by substantial heterogeneity ($I^2 = 94.5\%$). These findings highlight the need for cautious interpretation. In particular, potential dose–response signals (≥ 45 min, ≥ 3 sessions/week, ≥ 8 weeks) require further confirmation, and methodological shortcomings such as limited allocation concealment, lack of blinding, and modest PEDro scores (mostly 5–6/10) limit the internal validity. Therefore, while aerobic interventions appear promising, the clinical

impact of the effects observed in this review should be considered modest and highly context-dependent. Depression in children and adolescents represents a critical public health problem, associated with low self-esteem, academic difficulties, social isolation, and risk of self-harm [47]. The present meta-analysis observed that aerobic exercise-based interventions generated a positive effect on depressive symptoms in this population, with small to moderate effect sizes. These findings are consistent with the results obtained by Korczak et al. [48], who in their systematic review concluded that aerobic physical activity programs produce significant improvements in mood in young people with mild to moderate depressive symptoms. Similarly, in a recent meta-analysis, Bailey et al. [8] highlighted that regular physical exercise is associated with a significant reduction in depression levels, particularly when interventions are implemented in structured and frequently supervised settings. Compared to psychotherapeutic treatments such as cognitive-behavioral therapy, aerobic exercise does not require specialized clinical infrastructure, facilitating its implementation in school or community settings. Notably, research such as that by Kvam et al. [49] showed that, although CBT remains an effective option, physical activity programs offer similar benefits, with fewer barriers to access. Studies such as that by Tan et al. [50], conducted in multicultural school settings, also corroborate that structured exercise improves not only mood, but also academic engagement and social interaction, acting as an integral psychosocial resource. Therefore, these findings suggest that aerobic exercise is an accessible, low-cost, and effective tool for the prevention and complementary treatment of depressive symptoms in children and adolescents.

Anxiety is one of the most common psychological conditions in adolescence, significantly affecting academic, social, and emotional functioning [51]. This stage of development is characterized by numerous neurobiological and psychosocial changes that increase the vulnerability to experiencing anxiety symptoms, both in their transient (state) and more stable and persistent (trait) forms [52]. In the present meta-analysis, the effects of aerobic interventions on anxiety levels were small and did not reach statistical significance. These findings align with those reported by Pascoe et al. [53], who indicated that the benefits of physical activity on anxiety in adolescents are modest, especially when the intervention does not include a specific emotion regulation component. The variability in results could be due, in part, to differences in the intensity, duration, and format of the interventions. Structured group programs that promote social cohesion and the perception of emotional safety often generate better outcomes compared to individual or unsupervised programs [54]. Furthermore, the lack of robust effects may be related to the type of anxiety assessed, given that measurement tools do not always accurately discriminate between trait and state anxiety [55]. Compared with treatments specifically designed to reduce anxiety, such as cognitive-behavioral therapy or mindfulness programs, aerobic physical activity may offer a lesser effect, although its inclusion within multicomponent interventions has been shown to be effective in enhancing overall mental health outcomes [56]. Therefore, although aerobic PA is not a specific treatment for anxiety, it does represent a preventive and complementary alternative that can benefit school and clinical populations when implemented appropriately.

Self-esteem is one of the central pillars of healthy psychological development during adolescence, as it influences emotional regulation, social behavior, and the ability to cope with stressful situations. Positive self-esteem has been associated with a lower risk of developing disorders such as depression, anxiety, and eating disorders [57]. In the present meta-analysis, aerobic interventions showed a moderate positive effect on self-esteem in children and adolescents, with notable consistency across the included studies. This finding is consistent with the results of Ekeland et al. [58], who in their Cochrane review emphasized that physical activity programs have a beneficial impact on general self-concept and

self-esteem, especially when implemented in educational settings. Furthermore, recent studies such as that of Gentile et al. [59] have identified that improvements in the perception of physical competence, one of the key dimensions of self-concept, mediate the relationship between physical activity and self-esteem. This improvement is enhanced when activities are perceived as enjoyable, challenging, and socially integrative. Interventions based on dance, functional training, or adapted sports have also demonstrated positive effects on body perception and self-image, as evidenced by the work of Fernández-Bustos et al. [60] and Saavedra et al. [61]. These findings suggest that, beyond the specific modality, regular participation in structured and supervised aerobic physical activity represents an effective strategy for strengthening self-esteem during adolescence, especially in vulnerable populations.

Resilience, defined as the ability to effectively cope with adverse situations and recover from them with positive adaptation, is considered an essential psychosocial competency in adolescent development. This skill acts as a protective factor against the onset of emotional disorders and facilitates better school and social integration [62]. Although it has received less attention than other psychological variables, the studies included in this review that measured resilience as an outcome showed positive effects derived from participation in aerobic interventions. These results are consistent with those proposed by Paulus et al. [3], who point out that physical activity promotes coping mechanisms, emotional strengthening, and perseverance, all of which are fundamental components in building resilience. Furthermore, research such as that of McMahon et al. [63] has proposed that physical exercise promotes resilience through neurobiological processes such as neurogenesis and regulation of the HPA (hypothalamic–pituitary–adrenal) axis, as well as by improving emotional regulation and perceived self-efficacy. Furthermore, regular structured physical activity, especially in group and supervised settings, has been shown to foster autonomy, decision-making, and problem-solving, all of which are key elements in resilient response [64]. While these findings are promising, it is necessary to increase the number and methodological quality of studies that explicitly assess this dimension as a primary variable, as well as to employ validated and standardized psychometric instruments in adolescent populations. This will consolidate the evidence on the role of aerobic physical exercise as an effective strategy for fostering resilience in young people.

Meta-regression analyses allowed for the exploration of dose–response signals. Weekly session frequency emerged as a significant moderator, indicating that interventions with ≥ 3 sessions per week produced more consistent effects. In contrast, total duration in weeks, participant age, and exercise type did not show significant associations. These preliminary findings suggest that program regularity, rather than duration alone, may be a key factor.

Despite the methodological soundness applied in this systematic review with meta-analysis, there are several limitations that should be considered when interpreting the results. First, the high heterogeneity observed in several analyses ($I^2 > 90\%$) suggests significant variability among the included studies, possibly attributable to differences in methodological designs, intervention characteristics, program durations, population types, and assessment tools used. Although random-effects models and subgroup analyses were applied, this heterogeneity could affect the generalizability of the results. Second, the limited number of studies per specific variable, especially in the case of resilience and emotional well-being, reduces the statistical power of the analyses and limits the ability to draw definitive conclusions about these dimensions. Furthermore, some studies lacked long-term follow-up, making it impossible to determine whether the observed positive effects are sustainable over time. Another relevant limitation is the lack of homogeneity in the measurement of psychological variables. Multiple instruments were used to assess similar constructs, such as self-esteem or mood, complicating direct comparison of results

across studies. Furthermore, not all included trials clearly reported exercise intensity, program adherence, or level of supervision, which affects intervention fidelity and replicability. Unlike previous reviews, the present study focused exclusively on randomized controlled trials in populations aged 5 to 18 years and included recent literature published since 2020. These criteria allow for a more up-to-date, rigorous, and targeted synthesis for mental health promotion in school settings.

5. Conclusions

This meta-analysis provides relevant evidence on the impact of aerobic physical activity interventions on the mental health of children and adolescents. The results suggest that these interventions have a moderate positive effect on self-esteem and depressive symptoms, and more modest effects on mood, anxiety, and resilience. These conclusions support the value of physical activity as a non-pharmacological tool for promoting psychological well-being in children and adolescents. Given its accessibility, low cost, and potential for implementation in school and community settings, aerobic physical activity represents a promising public health strategy. However, more studies with rigorous designs, larger samples, and longitudinal follow-up are needed, especially focusing on less-explored variables such as resilience and emotional well-being. Therefore, promoting regular aerobic exercise could constitute an effective intervention for strengthening mental health during key developmental stages such as childhood and adolescence. This strategy should be considered an integral part of educational and preventive programs aimed at promoting psychological well-being at early ages.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/app15179572/s1>, Table S1: Characteristics of the included studies.

Author Contributions: Conceptualization, M.d.C.C.-F.; methodology, F.H.-C.; formal analysis, A.A.-A.; writing—original draft preparation, F.H.-C.; writing—review and editing, M.d.C.C.-F.; supervision, A.A.-A. All authors have read and agreed to the published version of the manuscript.

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Abbreviations

The following abbreviations are used in this manuscript:

PA	physical activity
BDNF	Brain-derived neurotrophic factor
RCTs	Randomized controlled trials
PHQA	Patient Health Questionnaire–A
SCARED	The Screen for Child Anxiety and Related Emotional Disorders
SDQ	The Self-Description Questionnaire
SSRS	Social Skills Rating System
CY-PSPP	Children and Youth Physical Self-Perception Profile
PSDQ	Physical Self-Description Questionnaire
SAS–A	the Social Anxiety Scale for Adolescents
SPPA	Self-Perception Profile for Adolescents
BASC-2	Behavior Assessment System for Children–Second Edition

RS	Resilience Scale
PSS	The Perceived Stress Scale
BYI-II	The Beck Depression Inventory and The Beck anxiety Inventory
STAIC	The State–Trait Anxiety Inventory for Children
SDQ-I	Self-Description Questionnaire I
POMS-SF	Profile of Mood States–Short Form
CDI-2	Children’s Depression Inventory-2
ASS	the Academic Stress Scale
CDI	The Children’s Depression Inventory
ISEQ	the Indian adaptation of Battle’s self-esteem questionnaire
SPPC	Self-Perception Profile for Children
SF-12v2	Short Form-12 Health Survey version 2
RSES	Rosenberg Self-Esteem Scale
SEAS	Student Examination Anxiety Scale
ADSS	Anxiety, Depression and Stress Scale

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