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Substantial Antidepressant Effects of Exercise in Adolescents: A Meta-Analysis of Age-Specific Studies

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Abstract

Adolescents are at heightened risk for depression and anxiety due to rapid neurobiological and social changes. Physical activity has been proposed as a promising mental health intervention. Yet existing evidence is inconsistent, and few studies focus exclusively on adolescent populations. This meta-analysis quantitatively synthesized physical activity effects on adolescent depression and anxiety by systematically searching PubMed and PsycINFO databases (January 2000–December 2024) following PRISMA guidelines, with eligible studies including randomized controlled trials, quasi-experimental, and controlled observational designs examining physical activity interventions on depressive or anxiety symptoms in adolescents aged 10–19 years. Effect sizes (Hedges' g) were calculated using random-effects models, with comprehensive heterogeneity and publication bias assessments, and ten studies (N = 1,510 experimental participants) met inclusion criteria. This study found that exercise produces large reductions in adolescent depression and moderate reductions in anxiety. These findings suggest that structured physical activity can serve as an effective, non-pharmacological strategy for youth mental health. Detailed statistical results are reported in the Results section. Structured exercise interventions produce clinically meaningful reductions in adolescent depressive and anxiety symptoms, demonstrating preventive and therapeutic potential as scalable, non-pharmacological interventions, warranting dose-response research examining intervention parameters.

Keywords: Physical activity, Exercise intervention, Depression, Anxiety, Adolescents, Meta-analysis

1. Introduction

Adolescence represents a critical developmental stage marked by rapid physical, psychological, and social changes. During this period, individuals are particularly vulnerable to a range of mental health challenges—such as depression, anxiety, stress, and diminished self-esteem. According to the World Health Organization (2021), one in seven adolescents worldwide experiences a mental disorder, underscoring the urgent need for effective preventive and therapeutic strategies. Considering that adolescent mental health problems can have long-lasting effects on academic achievement, interpersonal functioning, and overall life satisfaction, identifying modifiable factors that promote psychological well-being is a pressing public health priority (Patel et al., 2007).

Among the various determinants of mental health, physical activity has emerged as a consistently studied yet variably interpreted factor. Empirical evidence demonstrates that systematic physical activity engagement catalyzes mood enhancement through dual pathways: neurobiological restructuring and psychosocial reinforcement (Kandola et al., 2018; Lubans et al., 2016). These benefits are thought to arise through both biological mechanisms—such as endorphin release, neuroendocrine regulation, and increased neuroplasticity—and psychosocial pathways, including social connectedness, self-efficacy, and emotional regulation (Lubans et al., 2016). Despite these theoretical and empirical foundations, findings in the literature remain inconsistent: while some studies report robust positive associations, others find small or negligible effects. Such discrepancies may stem from variations in study design,

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measurement instruments, intervention types, cultural contexts, or sample characteristics (Biddle et al., 2019).

Meta-analysis offers a more rigorous alternative to narrative reviews by statistically combining results from multiple studies. This approach generates reliable effect size estimates and reveals patterns that individual studies may obscure. Previous meta-analyses have contributed valuable insights but also present notable limitations. Many included mixed-age samples that combined children, adolescents, and adults, thereby obscuring age-specific patterns (Carter et al., 2016; Lubans et al., 2016; Dale et al., 2019). Others focused narrowly on specific outcomes, such as depression or anxiety, without capturing the broader spectrum of psychological well-being. Moreover, few studies have systematically examined potential moderating factors—such as gender, activity type, or intervention intensity, that might explain variability in outcomes (Eime et al., 2013).

To address these gaps, the present study systematically reviews and quantitatively synthesizes empirical evidence on the relationship between physical activity and mental health outcomes among adolescents. By applying a random-effects meta-analytic model, this research aims to estimate the overall magnitude and direction of the association between physical activity and adolescent mental health, identify key moderators influencing this relationship, and offer practical implications for educators, policymakers, and mental health practitioners.

Through this integrative approach, the study seeks to contribute a comprehensive and age-specific understanding of how physical activity functions as a protective and promotive factor for mental well-being during adolescence. The findings are expected to inform evidence-based practices and policies that support adolescent development through accessible, sustainable, and psychologically beneficial physical activity interventions.

2. Methods

This study adhered to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines to ensure a systematic and transparent review process. A comprehensive literature search was conducted in two major databases—PubMed and PsycINFO—covering studies published between January 2000 and December 2024. The search strategy combined terms related to population, intervention, and outcomes, using the following keywords and Boolean operators:

("Exercise"[Mesh] OR "Physical Activity"[Mesh] OR exercise[tiab] OR "physical activity"[tiab] OR sport[tiab]) AND ("Mental Health"[Mesh] OR anxiety[tiab] OR depression[tiab] OR stress[tiab] OR "self-efficacy"[tiab] OR motivation[tiab]) AND (adolescent[mh] OR adolescent[tiab] OR teenager[tiab] OR youth[tiab]).

All meta-analytic computations were conducted using R version 4.3.1 (R Core Team, 2023) with the metafor package (Viechtbauer, 2010). Effect sizes were calculated using the compute.es package, and publication bias analyses were performed using the metasens package.

Additionally, reference lists of relevant studies were manually screened to identify further eligible publications.

2.1 Eligibility Criteria

Studies were included if they met the following criteria: (1) participants were adolescents, operationally defined as chronological ages 10–19 years, consistent with WHO taxonomy; (2) physical activity, exercise, or sports participation was examined as an independent variable; (3) mental health outcomes—including but not limited to depression, anxiety, stress, self-esteem, or psychological well-being—were assessed as dependent variables; (4) sufficient statistical information was available to calculate effect sizes; and (5) articles were published in peer-reviewed journals in English.

Studies were excluded if they: (a) focused on children under 10 or adults over 20, (b) did not primarily investigate physical activity and mental health, (c) reported only qualitative or case-based findings, (d) were unpublished theses or conference proceedings, or (e) lacked sufficient statistical data.

No formal risk-of-bias assessment tool (e.g., Cochrane RoB 2.0 or Newcastle-Ottawa Scale) was applied in this study. This constitutes a methodological limitation, as study quality variability may have influenced the pooled estimates. Future syntheses should incorporate systematic quality appraisal.

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2.2 Data Extraction and Coding

Two independent reviewers extracted and coded data from the eligible studies. Extracted information included study characteristics (author, year, country), design (experimental, quasi-experimental, or correlational), sample characteristics (size, age, gender), independent variables (type, frequency, intensity, and duration of physical activity), dependent variables (specific mental health indicators), and statistical parameters required for effect-size computation (e.g., means, standard deviations, or correlations). Discrepancies between reviewers were resolved through discussion with a third researcher until consensus was achieved.

2.3 Effect Size Calculation and Analysis

Effect sizes were calculated using Hedges'g, which was employed to correct for small-sample bias inherent in Cohen's d, ensuring unbiased effect magnitude estimation across studies with varying sample sizes. A random-effects model was used to estimate the overall pooled effect, accounting for expected heterogeneity across studies. Heterogeneity was assessed using Cochran's Q statistic and the I^2 index. Potential publication bias was examined through visual inspection of funnel plots, Egger's regression test, and the trim-and-fill method. Subgroup analyses and moderator tests were conducted to determine whether effect sizes varied according to participant age, gender distribution, type of physical activity, or intervention frequency and duration.

2.4 Handling of Multiple Effect Sizes

When a single study reported multiple measures of the same outcome (e.g., multiple depression scales), a composite effect size was computed by averaging the standardized mean differences (Hedges'g) using inverse-variance weighting (Borenstein et al., 2021). This approach ensured that each study contributed only one statistically independent effect size per outcome domain (depression or anxiety) to the meta-analysis, thereby preventing violation of the independence assumption.

3. Results

3.1 Study Selection

A total of 91 records were identified through PubMed and PsycINFO database searches, and 5 additional records were identified through other sources. After removing 9 duplicates, 87 records remained for screening based on titles and abstracts. Of these, 22 records were excluded for not meeting the inclusion criteria, leaving 65 full-text articles assessed for eligibility. Following a detailed full-text review, 55 articles were excluded due to reasons such as irrelevant mental health outcomes (n = 8), lack of physical activity analysis (n = 7), non-adolescent samples (n = 26), insufficient statistical data (n = 9), or other reasons (n = 5). Ultimately, 10 studies met all inclusion criteria and were included in the final meta-analysis.

The overall process of study identification, screening, eligibility assessment, and inclusion is illustrated in Figure 1 (PRISMA flow diagram).

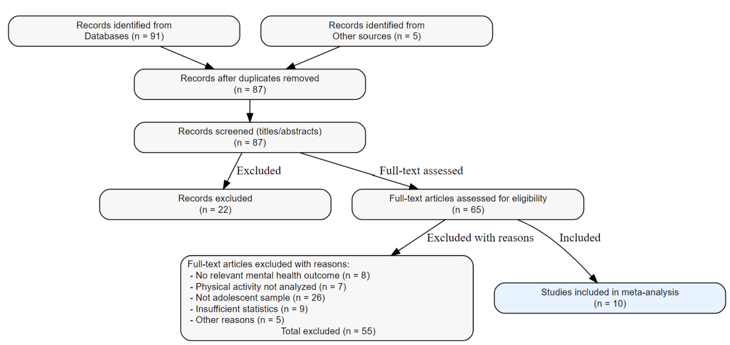

Figure 1. PRISMA flow diagram of the study selection process. Adapted from Page et al. (2021).

3.2 Effect of Exercise Interventions on Depression

I analyzed depression as a primary outcome, extracting nine effect sizes from experimental studies employing pretest–posttest control group designs—

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including 756 participants in experimental groups and 754 in control groups. The main results are summarized in Figure 2, Figure 3, and Table 1.

Philippot et al. (2022) reported five distinct depression scales (HADS-D, HAM-D, CDI, BDI, and SDS). To prevent statistical dependency within the same study, these measures were aggregated into a single composite effect size (Hedges' g = −0.33, SE = 0.11) and included in the meta-analysis. Similarly, Zhang et al. (2021) reported two depression measures (HAM-D and CGI), which were also combined into a single composite effect size (Hedges' g = −0.49, SE = 2.64) for inclusion in the meta-analysis. This approach ensured that each study contributed only one statistically independent effect size to the overall analysis of depression outcomes.

Heterogeneity indices revealed marked between-study variance ($I^2 = 92.1\%$), exceeding the 75% threshold conventionally interpreted as 'considerable' heterogeneity (Higgins et al., 2003). The Q statistic was significant ($Q(8) = 101.4$, $p < .001$), confirming that the true effect sizes were not homogeneous. Given this high level of heterogeneity, a random-effects model was applied to estimate the average effect size of exercise interventions on adolescents' depression.

To assess whether the pooled estimate was disproportionately influenced by individual studies, a leave-one-out sensitivity analysis was conducted. Results indicated that no single study substantially altered the direction or significance of the overall effect, though excluding Da Silva et al. (2020) reduced the pooled effect size from g = -1.36 to g = -1.17, suggesting a moderately elevated influence. Nevertheless, the effect remained large and statistically significant across all iterations, supporting the robustness of the findings.

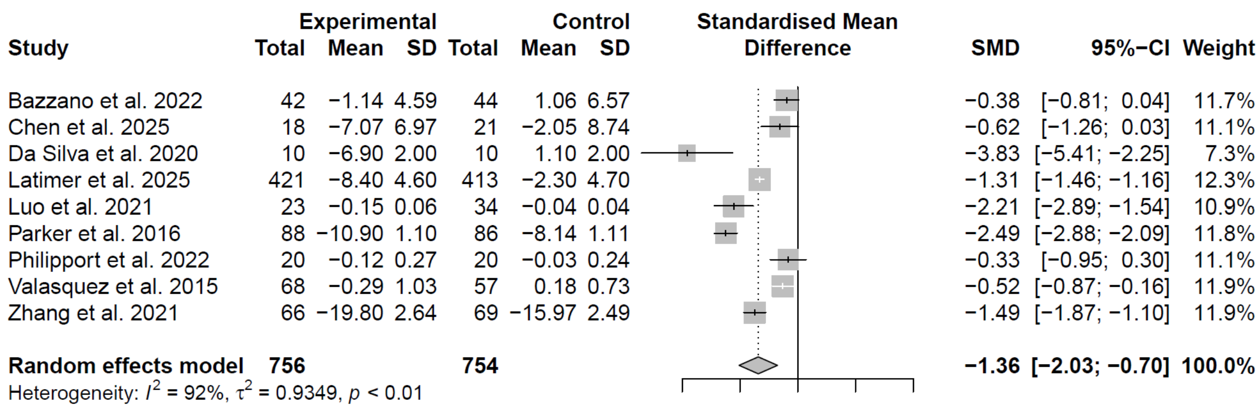

Figure 2. Forest plot showing the effects of physical activity on depression in adolescents.

As shown in Figure 2, the random-effects analysis revealed that the mean effect size of exercise interventions on adolescents' depression was -1.36 (95% CI = [-2.03, -0.70]). According to Cohen's (1988) guidelines, this value exceeds an absolute magnitude of 0.8, suggesting a large effect size. Moreover, since the 95% confidence interval does not include zero, the effect is statistically significant.

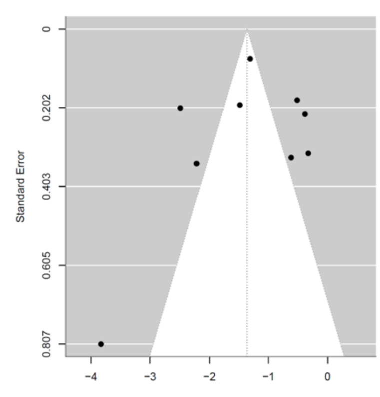

Figure 3. Funnel plot assessing publication bias in the meta-analysis of exercise interventions on depression

3.3 Publication Bias Assessment

To assess potential publication bias, a funnel plot was visually inspected, revealing a slight asymmetry with smaller studies tending to report larger negative effects of exercise on depression. Although Egger's regression approached but did not reach conventional significance (p = .078), the trim-and-fill imputation revealed negligible influence on pooled estimates, suggesting minimal practical impact (Sterne et al., 2011).

The trim-and-fill analysis estimated no missing studies on the right side of the funnel plot (0 imputed studies; SE = 1.90), and the adjusted random-effects model produced a comparable pooled effect size (g = −1.38, 95% CI [−2.03, −0.70]). This finding indicates that potential publication bias had a

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minimal impact on the overall estimate.

Furthermore, the Fail-safe N (1,138) substantially exceeded Rosenthal's criterion of 5k + 10 (55) (Rosenthal, 1979), corroborating result robustness. This large number supports the robustness and stability of the meta-analytic findings.

Table 1. Summary of meta-analysis results for depression outcomes.

Dependent variable	k	*Effect size (SMD)*	I^2 (%)	95% Confidence interval	
				LL	UL
Depression	9	-1.36	92.1	-2.03	-0.70

Note: *N*: Number of effect sizes, *ES*: Effect size, I^2: Heterogeneity, *Cl*: confidence interval, N_{fS}: Fail-Safe N

Taken together, these results suggest that although minor asymmetry was visually observed, the conclusions of the meta-analysis remain stable and not substantially influenced by publication bias. A summary of these results is presented in Table 1.

3.4 Effect of Exercise Interventions on Anxiety

I analyzed anxiety as a primary outcome, extracting ten effect sizes from experimental studies employing pretest-posttest control group designs, including 810 participants in experimental groups and 801 in control groups.

Philippot et al. (2022) reported two distinct anxiety measures (HADS-A and STAI). To avoid statistical dependency within the same study, these measures were aggregated into a single composite effect size (Hedges' g = −0.01, SE = 0.12) and included in the meta-analysis.

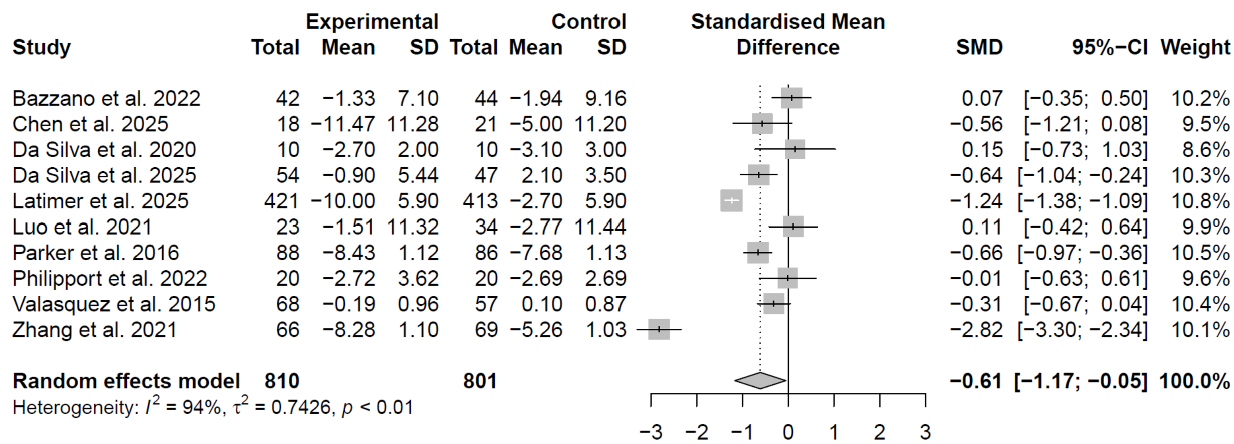

Figure 4. Forest plot showing the effects of physical activity on anxiety in adolescents

Heterogeneity indices revealed marked between-study variance (I² = 93.8%), exceeding the 75% threshold conventionally interpreted as 'considerable' heterogeneity (Higgins et al., 2003). The Q-statistic was significant (Q(9) = 144.4, p < .001), confirming that the true effect sizes were not homogeneous. Given this high level of heterogeneity, a random-effects model was applied to estimate the overall mean effect size of exercise interventions on adolescents' anxiety.

As shown in Figure 4, the random-effects analysis yielded a pooled effect size of g = −0.61 (95% CI [−1.17, −0.05]). According to Cohen's (1988) guidelines, this magnitude falls between 0.2 and 0.8 in absolute value, indicating a moderate and statistically significant reduction in anxiety following exercise interventions.

3.5 Publication Bias Assessment for Anxiety

As shown in Figure 5, the funnel plot for anxiety outcomes appears slightly asymmetrical, with smaller studies tending to report larger negative

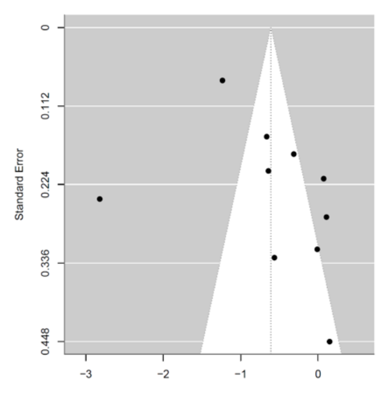

Figure 5. Funnel plot assessing publication bias in the meta-analysis of exercise interventions on anxiety

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effect sizes. This pattern may suggest a potential small-study effect; however, the overall distribution remains largely symmetrical around the pooled mean, indicating that any publication bias is likely minimal.

Egger's regression test confirmed the absence of significant funnel-plot asymmetry ($z = 1.00$, $p = .32$), suggesting that publication bias was unlikely to influence the meta-analytic results. The trim-and-fill analysis estimated no missing studies, and the pooled effect size remained unchanged after adjustment. Furthermore, the Fail-safe N (515) substantially exceeded Rosenthal's criterion of 5k + 10 (60), corroborating result robustness. This large number supports the robustness and stability of the findings despite minor visual asymmetry in the funnel plot. Taken together, these results indicate that the anxiety meta-analysis is not materially affected by publication bias, and the conclusions can be regarded as statistically reliable.

Table 2. Summary of meta-analysis results for anxiety outcomes.

Dependent variable	k	*Effect size (SMD)*	I^2 (%)	95% Confidence interval	
				LL	UL
Anxiety	10	-0.61	93.8	-1.17	-0.05

Note: *N*: Number of effect sizes, *ES*: Effect size, I^2: Heterogeneity, *Cl*: confidence interval, N_{fS}: Fail-Safe N

4. Discussion

This meta-analysis synthesized quantitative evidence on the relationship between physical activity and mental health among adolescents, offering the most temporally proximate and developmentally targeted synthesis to date. The findings revealed that exercise interventions had a large effect on depression and a moderate effect on anxiety, both statistically significant. These results support the hypothesis that regular physical activity contributes to improved emotional well-being during adolescence—a developmental stage characterized by heightened vulnerability to stress and affective disorders (Wegner et al., 2020).

4.1 Interpretation of Findings

The results align with the biopsychosocial model of mental health, suggesting that physical activity benefits adolescents through intertwined biological, psychological, and social mechanisms. Exercise improves mental health through three interconnected pathways. Physically, it raises serotonin and endorphin levels, which stabilize mood. Psychologically, it builds self-confidence and helps adolescents manage emotions. Socially, group exercise reduces loneliness by fostering peer connections

Importantly, the present analysis focused exclusively on adolescents, thereby avoiding the age heterogeneity that limited prior meta-analyses combining children and adults. By distinguishing depression and anxiety as separate outcome domains, this study demonstrates that the magnitude of exercise effects may vary by symptom type—stronger for depressive symptoms and moderate for anxiety—highlighting differential pathways and intervention sensitivities across emotional dimensions.

4.2 Comparison with Previous Research

These findings corroborate Carter et al.'s (2016) meta-analysis reporting moderate-to-large effects, while extending evidence specifically to adolescent populations. The larger effect size observed for depression in this meta-analysis ($g = -1.36$) notably exceeds those reported in prior syntheses, including Wegner et al. (2020; $g \approx -0.67$) and Carter et al. (2016). Three factors may account for this discrepancy. First, the exclusive inclusion of adolescent-specific samples in the present study eliminates age-related variance that dilutes effect sizes in mixed-age meta-analyses. Second, several included studies recruited clinical or at-risk populations, where elevated baseline symptom severity tends to amplify intervention effects. Third, the extreme heterogeneity ($I^2 = 92.1\%$) across studies cautions against direct numerical comparison with prior meta-analyses, as pooled estimates reflect vastly different intervention contexts. Anxiety outcomes, by contrast, exhibited a moderate effect ($g = -0.61$), consistent with prior literature, possibly reflecting greater variability in anxiety measurement instruments and intervention sensitivity across studies.

4.3 Practical Implications

From an applied perspective, these findings underscore the preventive and therapeutic potential of structured physical activity. Evidence-based translation suggests implementing minimally 150 minutes/week of moderate-to-vigorous physical activity in school curricula, aligned with WHO adolescent activity guidelines. Such initiatives are cost-effective, scalable, and culturally adaptable (World Health Organization, 2020). Moreover, programs emphasizing group-based or moderate-to-vigorous activities appear most effective, as they combine physiological benefits with opportunities for social engagement and peer reinforcement. Policymakers should therefore view physical activity not merely as a means to improve physical health but as an integral component of youth mental health promotion.

4.4 Limitations and Future Directions

Despite the robustness of the overall findings, several limitations should be acknowledged.

First, although substantial heterogeneity ($I^2 > 90\%$) warranted moderator exploration, insufficient study-level data precluded comprehensive subgroup analyses. Unmeasured moderators—such as intervention duration, activity type, cultural context, or baseline symptom severity—may have influenced results. The extreme heterogeneity observed ($I^2 = 92.1\%$ for depression; $I^2 = 93.8\%$ for anxiety) reflects substantial between-study variability in exercise modality, session frequency, intervention duration, and baseline symptom severity. Consequently, the pooled effect sizes represent weighted averages across highly disparate contexts and should not be interpreted as a universal estimate. The random-effects model accommodates this variance statistically, but substantive caution is warranted when generalizing findings to specific populations or intervention types.

Second, no formal risk-of-bias assessment was conducted for the included studies. The absence of a structured quality appraisal tool—such as the Cochrane Risk of Bias 2.0 or the Newcastle-Ottawa Scale—means that methodological weaknesses in individual studies could not be systematically identified or weighted. This limitation may have contributed to the high heterogeneity observed ($I^2 > 90\%$) and potentially inflated the magnitude of pooled effect estimates. Future meta-analyses should incorporate validated quality assessment instruments to ensure greater methodological transparency.

Third, the predominance of self-report measures introduces shared-method variance and potential response bias, potentially inflating effect estimates.

Fourth, although publication bias tests suggested minimal impact on pooled results, the limited number of eligible studies underscores the need for broader, more transparent reporting of null findings.

Finally, the predominance of short-term or cross-sectional designs limits causal inference.

Future research should employ longitudinal and experimental designs to clarify causal pathways, utilize objective measures of physical activity (e.g., accelerometers), and test mechanistic models linking neurobiological and psychosocial processes. Furthermore, examining the dose–response relationship between exercise frequency/intensity and psychological outcomes will refine evidence-based recommendations for adolescent populations.

5. Conclusion

This synthesis furnishes empirically consolidated evidence that regular physical activity significantly improves adolescents' mental health, demonstrating a large effect on depression and a moderate effect on anxiety. These results highlight the potential of exercise-based interventions as both preventive and therapeutic strategies for emotional well-being during adolescence—a period marked by rapid biological, cognitive, and social transitions.

From a practical standpoint, the findings suggest that implementing structured and accessible exercise programs in schools, community centers, and healthcare settings can serve as a sustainable, non-pharmacological approach to reducing depressive and anxiety symptoms among youth. Policymakers and educators should therefore incorporate physical activity into broader mental health frameworks and adolescent welfare programs.

Practical Recommendations: Educational institutions should integrate minimally 150 minutes/week of moderate-to-vigorous physical activity aligned with WHO guidelines. Community-based programs emphasizing group activities—team sports, dance, martial arts—maximize both physiological and psychosocial benefits. Healthcare providers should incorporate exercise prescription within adolescent mental health treatment protocols, particularly for subclinical depressive symptoms.

Beyond immediate mental health benefits, promoting physical activity at the population level may yield long-term societal advantages, including improved academic engagement, social cohesion, and reduced healthcare burdens associated with mood disorders.

Future scholarship must elucidate dose-response gradients, disentangle mediating mechanisms (e.g., BDNF modulation, social capital accrual), and test ecological implementation models across diverse socioeconomic strata, as well as individual-level moderators—such as gender, socioeconomic status, and baseline psychological health. Integrating biological, psychological, and social approaches will further advance understanding of how exercise fosters resilience and emotional stability in youth populations.

References

Biddle, S. J. H., et al. (2019). Physical activity and mental health in children and adolescents: An updated review of reviews and an analysis of causality. *Psychology of Sport and Exercise*, 42, 146-155. https://doi.org/10.1016/j.psychsport.2018.08.011

Borenstein, M., et al. (2021). Introduction to meta-analysis (2nd ed.). Wiley.

Eime, R. M., et al. (2013). A systematic review of the psychological and social benefits of participation in sport for children and adolescents: Informing development of a conceptual model of health through sport. International *Journal of Behavioral Nutrition and Physical Activity*, 10(1), 98. https://doi.org/10.1186/1479-5868-10-98

Harrer, M., et al. (2021). Doing Meta-Analysis with R: A Hands-On Guide. CRC Press.

Kandola, A., et al. (2018). Moving to beat anxiety: Epidemiology and therapeutic issues with physical activity for anxiety. *Current Psychiatry Reports*, 20(8), 63. https://doi.org/10.1007/s11920-018-0923-x

Latimer, K., et al. (2025). A sport-for-protection program reduces anxiety and depression in youth affected by displacement: A randomized controlled trial of the Game Connect program in Uganda. *Journal of Affective Disorders*, 376, 84-91.

Liu, C., et al. (2025). The effects of physical activity on mental health in adolescents with attention-deficit hyperactivity disorder: a randomized controlled trial. *International Journal of Behavioral Nutrition and Physical Activity*, 22(1), 47.

Lubans, D., et al. (2016). Physical activity for cognitive and mental health in youth: A systematic review of mechanisms. *Pediatrics*, 138(3), e20161642. https://doi.org/10.1542/peds.2016-1642.

Patel, V., et al. (2007). Mental health of young people: A global public-health challenge. *The Lancet*, 369(9569), 1302-1313. https://doi.org/10.1016/S0140-6736(07)60368-7

Philippot, A., et al. (2022). Impact of physical exercise on depression and anxiety in adolescent inpatients: A randomized controlled trial. *Journal of Affective Disorders*, 301, 145-153.

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin*, 86(3), 638-641. https://doi.org/10.1037/0033-2909.86.3.638

Da Silva, L. A., et al. (2020). Swimming training improves mental health parameters, cognition and motor coordination in children with Attention Deficit Hyperactivity Disorder. *International Journal of Environmental Health Research*, 30(5), 584–592. https://doi.org/10.1080/09603123.2019.1612041

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ISSN 2688-3651 [online]

Da Silva, J. M., et al. (2025). Effects of a school-based physical activity intervention on mental health indicators in a sample of Brazilian adolescents: a cluster randomized controlled trial. BMC Public Health, 25(1), 539.

Sterne, J. A. C., et al. (2011). Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. *BMJ*, 343, d4002. https://doi.org/10.1136/bmj.d4002

Wegner, M., et al. (2020). Systematic review of meta-analyses: Exercise effects on depression in children and adolescents. *Frontiers in Psychiatry*, 11, 81. https://doi.org/10.3389/fpsyt.2020.00081

World Health Organization. (2020). WHO guidelines on physical activity and sedentary behaviour. https://www.who.int/publications/i/item/9789240015128

World Health Organization. (2021). Adolescent mental health. https://www.who.int/news-room/fact-sheets/detail/adolescent-mental-health

Zhang, J., & Ji, W. (2021). Exercise intervention improves the quality of life, anxiety, and depression of adolescent depression patients. *Int J Clin Exp Med*, 14(2), 1292-1300.