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Effects of Exercise on Metacognitive Skills in Adolescents: A Systematic Review and MetaAnalysis

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Bao, L; Xie, H; Qiang, F; Zhang, J.

Corresponding author:
Lixia Bao

66299473@qq.com

Author Affiliation:
Department of Physical Education, Yuncheng University, Shanxi, China.

ADMINISTRATIVE INFORMATION

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Conflicts of interest - None declared.

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 8 September 2026 and was last updated on 8 September 2026.

INTRODUCTION

Review question / Objective Previous quantitative systematic reviews have only focused on the effects of metacognitive interventions on motor skills, while few studies have addressed the impacts of exercise on metacognitive skills. This study systematically evaluates the effects of exercise on metacognitive skills in adolescents aged 10–19 years through systematic review and meta-analysis.

Rationale Adolescence—as a "second window of opportunity" during the second decade of life—represents a pivotal developmental stage. This period is marked by pubertal maturation alongside progressive improvements in physical functioning, emotional regulation, and metacognitive capacity, thereby constituting a critical window for physical exercise interventions and investigations into psychological development.A substantial body of evidence indicates that physical exercise and activity exert beneficial effects on cognitive function in adolescents. Nevertheless, contemporary physical exercise and activity programs for adolescents, shaped by conventional pedagogical and training paradigms, tend to prioritize imitative learning and repetitive skill rehearsal while paying insufficient attention to the development of metacognitive skills—including self-monitoring, strategic adjustment, and self-reflection—that are fundamental to motor skill acquisition. Consequently, students often privilege technical mastery over critical thinking, resulting in an overemphasis on skill execution with limited transfer of learning. Autonomous learning frequently remains confined to the replication of movement techniques and adherence to prescribed training regimens, without the capacity to manage, evaluate, and generalize their learning processes. This study systematically evaluates the effects of exercise on metacognitive skills in adolescents aged 10–19 years through systematic review and meta-analysis.

Condition being studied This systematic review targets healthy adolescents aged 10 to 19 years old. Metacognition encompasses metacognitive knowledge and metacognitive regulation, which together support planning, monitoring and evaluation of cognitive behaviours. Executive functions (working memory, inhibitory control, cognitive flexibility) develop rapidly during adolescence. Physical exercise is a modifiable behavioural factor that may improve metacognitive and executive-function performance among adolescents without clinical disorders.

METHODS

Participant or population Adolescents aged 10–19 years, consistent with the WHO definition.

Intervention Structured exercise interventions (acute or chronic), unrestricted by modality.

Comparator Passive (no intervention) or usual activity control.

Study designs to be included RCTs and nRCTs, with no restrictions on duration, frequency, or setting.

Eligibility criteria Outcome: post-intervention data for ≥1 metacognitive skill dimension (knowledge, monitoring, behavior) or metacognition-related secondary outcomes (executive functions, problem-solving, self-regulation); Language: peer-reviewed articles in Chinese or English, without year limitation. Quasi-experimental studies without control groups, qualitative research, conference abstracts, books, book chapters, opinions, letters, and non-peer-reviewed publications were excluded.

Information sources Electronic databases including Web of Science, PubMed, Scopus, CNKI, and SPORTDiscus will be searched for eligible studies. In addition, trial registers such as PROSPERO will be checked to identify ongoing or completed unpublished systematic reviews. Reference lists of included articles and relevant reviews will be manually screened for additional records. Grey-literature sources including conference proceedings will also be retrieved. Corresponding authors will be contacted via email to obtain missing or incomplete data when necessary.

Main outcome(s) The primary outcomes are metacognitive skills and executive function among adolescents aged 10-19 years. Metacognitive skills includes metacognitive knowledge ,monitoring, or behavior . Executive function covers working memory, inhibitory control, and cognitive flexibility. Secondary outcomes include general metacognitive performance. Outcomes will be measured at post-intervention; follow-up data will also be extracted if reported in original studies. Standardised mean difference (SMD) with 95% confidence intervals will be adopted as the effect measure for continuous outcomes.

Quality assessment / Risk of bias analysis The methodological quality of all included studies was initially appraised using the QualSyst tool. Subsequently, risk of bias was assessed using the Cochrane Risk of Bias tool (RoB 2.0) for the individually randomized controlled trials (RCTs), and the Risk Of Bias In Non-randomized Studies of Interventions (ROBINS-I) tool for the non-randomized controlled studies (nRCTs).

Strategy of data synthesis Given the heterogeneity in measurement instruments and assessment paradigms across studies, the standardized mean difference (SMD), reported as Hedges' g, was adopted as the pooled effect size metric, as it incorporates a correction for small-sample bias and is the standard method for pooling heterogeneous cognitive data.Owing to both construct and measurement heterogeneity, cross-construct pooling was strictly prohibited. The RCTs underwent independent meta-analyses stratified by outcome construct: (1) metacognitive skills (metacognitive knowledge, monitoring, or behavior); (2) executive functions (working memory, inhibitory control, cognitive flexibility); and (3) problem-solving or self-regulation skills. Within each stratum, studies measuring the same construct were pooled using SMD regardless of instrument differences. Meta-analysis was conducted only when a subgroup included ≥3 studies; otherwise, qualitative synthesis was performed.Between-study heterogeneity was evaluated using Cochran's Q test and the I^2 statistic, with I^2 50% indicating low, moderate, and high heterogeneity, respectively. A random-effects model (DerSimonian–Laird estimator) was uniformly employed to enhance result robustness.

Subgroup analysis Subgroup analyses were pre-specified by exercise type or gender, and meta-regression examined total intervention duration and weekly frequency as continuous moderators. Publication bias was assessed via funnel plots and Egger's test only when a subgroup included ≥10 studies to ensure adequate statistical power.

Sensitivity analysis Sensitivity analyses will be conducted to assess the robustness of the pooled

results. First, the leave-one-out method will be used by sequentially removing each individual study to evaluate its influence on the overall effect size. Second, studies with high risk of bias will be excluded to examine whether the results remain stable. Third, the fixed-effect and random-effects models will be compared to verify the consistency of pooled estimates. Outliers will also be identified and removed to explore their impact on the overall conclusions.

Country(ies) involved This review is conducted in China. All authors are affiliated with institutions in China.

Keywords Exercise intervention; Adolescents; Metacognitive skills; Executive functions.

Contributions of each author

Author 1 - Lixia Bao.
Email: 66299473@qq.com
Author 2 - Huijuan Xie.
Author 3 - Qiang Feng.
Author 4 - Junlong Zhang.