REVIEW ARTICLE

Effect of Coordination Exercises on Hand Function in Patient with Developmental Coordination Disorders: A Systematic Review and Meta-Analysis

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ABSTRACT

Objective: Developmental Coordination Disorder (DCD) affects 5-6% of school-aged children, impairing motor control and coordination. This systematic review and meta-analysis examines the effectiveness of coordination exercises on improving hand function in individuals with DCD.
Methods: A comprehensive search was conducted across four databases: Scopus, PubMed, PEDro, and The Cochrane Library for interventional trials published between 2010 and April 2025. PRISMA guidelines were followed for the review, and the methodological quality of studies was assessed using the PEDro scale, GRADE system, Risk of Bias, and Level of Evidence. A random-effects model was used for meta-analysis, calculating standardized mean differences (SMD) with 95% confidence intervals (CI).
Results: Seven studies involving 361 children with DCD were included. Meta-analysis revealed a large effect of coordination exercises on hand function compared to control interventions (SMD = 1.13, 95% CI: 0.31 to 1.95, p = 0.0066). Interventions such as haptic perception training, adapted Taekwondo, gaze training, and pegboard tasks showed consistent improvements in fine motor skills. However, moderate-to-high heterogeneity was observed (I^2 = 70.8%), with sensitivity analysis revealing that two studies contributed over 90% of the total weight.
Conclusion: Coordination exercises significantly improve hand function in individuals with DCD, showing a large effect size. These exercises are effective in enhancing fine motor skills and manual dexterity.

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Introduction

Coordination disorder is a common neurodevelopment issue that is frequently disregarded, marked by ongoing challenges with motor coordination (1). It disrupts balance and inhibits both fine and gross motor skills (2, 3). Children between the ages of 5 and 11

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years are typically the ones that have diagnosed with Developmental coordination disorder (DCD). About 6% of youngsters reported to suffer from DCD (1). Among the numerous issues that people with DCD confront, deficiencies in hand function are very prevalent and devastating (4). Hand function is vital in daily activities such as writing, sketching, cutting, and buttoning, are sometimes challenging for people with developmental coordination disorder (5).Difficulties with fine motor skills not only impede scholastic progress and limit involvement in recreational activities, but they also cause significant dissatisfaction, low self-esteem, and social isolation (6). Therefore, therapies focused on boosting hand function in adults with DCD are vital for improving their overall well-being and providing greater autonomy in routine chores.

Coordination exercises are physical activities or motions that are intended to increase the synchrony and efficiency of muscle groups involved in coordinated movements, thereby addressing the fundamental motor impairments associated with DCD (6, 7). These exercises aim to improve motor abilities by focusing on certain areas of coordination such as balance, timing, rhythm, and spatial awareness. Coordination exercises may include tasks that require hand-eye coordination, fine motor control, dexterity, and overall hand strength (8). Despite the difficulties posed by Developmental Coordination Disorder, there is growing evidence that specialized therapies focusing on coordination exercises can significantly improve hand function and motor abilities in affected individuals (9, 10). However, despite the theoretical promise of coordination exercises, practical data for their usefulness in improving hand function in DCD patients is sparse and fragmented. While some studies have found positive results from coordination exercise programs, others have produced mixed or inconclusive findings. Furthermore, the processes by which coordination exercises affect hand function, as well as the best intervention settings (e.g., duration, intensity, specificity), have yet to be thoroughly understood.

The purpose of this review is to clarify the possible advantages, limitations, and therapeutic implications of coordination exercise therapies in this population by critically analyzing the methodology and results of relevant studies. Additionally, this review aims to improve evidence-based practice and the efficacy of therapies targeting hand function in people with DCD by highlighting areas for future study and addressing knowledge gaps. This review suggested that coordination-based exercises including gaze training, haptic feedback, and martial arts can significantly enhance fine motor skills and manual dexterity in children with DCD. These findings suggest that structured coordination training has meaningful potential for improving functional hand use in this population.

Methodology

Protocol and Registration

This review was conducted in accordance with the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analysis) criteria (11). Following these principles enhances the reliability and comprehensiveness of the review process. The review was registered in PROSPERO (12) on 20th may, 2024, under the PROSPERO ID (CRD42024543978), which can be accessed via PROSPERO (https://www.crd.york.ac.uk/prospero/#myprospero).

Search strategy

A comprehensive literature search was conducted in different databases - PubMed, PEDro, Cochrane and Scopus databases, for relevant studies published between January 2010 and April 2025. The search method was developed and refined by two reviewers (PN and NS) using the PICOS framework (Population, Intervention, Comparison, Outcome, and Study Design). Keywords including "Developmental Coordination Disorder," "Hand function", "Coordination exercise", "DCD", "Fine motor skills", "Hand movement", "Hand coordination". The search utilized the Boolean operator "AND" to combine terms with DCD, hand function and coordination exercises. The search only included specific condition; Randomized controlled/clinical trial, quasi experimental study, pilot RCTs study and English-language articles. The search approach utilized is shown in Supplementary Table 1.

Inclusion and exclusion criteria

The eligibility criteria for study selection were defined collaboratively by three reviewers (PN, NS, and SK) before the screening process. Studies that met the following criteria were included in the review: Interventional trials (RCTs, Pilot study, & Quasi-experimental study), interventions focusing on coordination exercises for hand function, participants diagnosed with developmental coordination disorders (DCD) aged 5 to 17 years, any validated outcome measure used to assess hand function, full-text articles published in English between 2010 and April 2025.

Exclusion criteria encompassed reviews (systematic, meta-analyses, narrative), abstracts, book sections, theses and dissertations, non-human studies, case reports or case series, observational studies (e.g., cohort, case-control, cross-sectional), articles not in English, studies without full-text availability, research not specifically addressing coordination exercises for

hand function in DCD patients, and studies with insufficient data for analysis. Gray literature (e.g., theses, dissertations, and conference abstracts) was excluded to ensure inclusion of studies with sufficient methodological details and peer-reviewed quality. This comprehensive set of criteria ensured a focused and relevant selection of studies for the review.

Study selection

Following the identification of literature from the four databases, all duplicates were deleted and each title and abstract was inspected and filtered to fulfill the selection criteria. Two reviewers (NS, PN) conducted the screening process. In the final step, the full text of the remaining articles was examined to determine whether they met the selection criteria.

Data extraction

Data extraction was conducted independently by two reviewers (PN and NS) using a standardized, pre-piloted data extraction form. Extracted information included; Study design, Sample size and demographics, Diagnostic criteria for DCD, Intervention and control/comparator details, Outcome measures [e.g., Movement Assessment Battery for Children (MABC), Jebsen-Taylor Hand Function Test (JTHFT), Bruininks-Oseretsky Test of Motor Proficiency (BOT-2)] duration and intensity of intervention, and key findings including statistical significance and effect sizes. To ensure accuracy and consistency, any discrepancies in extracted data were resolved through mutual discussion. If consensus could not be reached, a third reviewer (SK) was consulted to make the final decision. The finalized data were further cross-verified by two additional reviewers (PrK and PK) for completeness before synthesis.

Data Synthesis and Meta-Analysis

A meta-analysis was conducted to quantitatively assess the effectiveness of coordination exercises on hand function in children with developmental coordination disorder (DCD). Data from eligible randomized controlled trials (RCTs) were extracted and analyzed by two reviewers (PN and PrK) using MetaAnalysisOnline.com (15), an online tool designed for rapid meta-analysis of clinical and epidemiological studies.

For continuous outcomes related to hand function, standardized mean differences (SMDs) with 95% confidence intervals (CIs) were calculated. A random-effects model was employed to account for potential heterogeneity among studies. Statistical heterogeneity was assessed using the I^2 statistic, with values of 25%, 50%, and 75% representing low, moderate, and high heterogeneity, respectively. Forest plots were generated to visualize the effect sizes and assess the consistency of findings across studies. Sensitivity analyses were performed by two reviewers (PK and GS) to evaluate the robustness of the results by excluding studies with high risk of bias or those contributing to heterogeneity. Publication bias was assessed through visual inspection of funnel plots by another two reviewers (PN and SK).

Quality Assessment

The PEDro scale (16, 17), Risk of bias assessment (18), Grading of Recommendations, Assessment Development and Evaluation (GRADE) system (19) and Level of evidence of prognostic studies (20) were used to assess the methodological quality of trials. Three reviewers (PN, PrK, and NS) rated the articles independently, resolving any disputes through discussion or involving three other reviewers (SK, PK, GK) as needed.

PEDro Scoring

PEDro scale consists of eleven items, the first of which is connected to external validity and is not included in the final PEDro score. Although the first item relates to external validity (eligibility criteria), it is not included in the final score. Therefore, the total score ranges from 0 to 10, based on the presence or absence of criteria such as random allocation, concealed allocation, baseline comparability, blinding (of subjects, therapists, and assessors), adequate follow-up, intention-to-treat analysis, between-group statistical comparisons, and reporting of point estimates and variability. Each study was independently assessed by two reviewers, and a point was awarded for each criterion met. The study quality was classified according to PEDro cut-off points: outstanding [9-10], acceptable [6-8], fair [4-5], and low [less than 4] (16, 17). Two reviewers (PN and PrK) independently assessed all included studies using the PEDro scale. Discrepancies were resolved through discussion and consensus by other reviewers (SK, and PK).

- Grading of Recommendations, Assessment, Development and Evaluations (GRADE)

The GRADE approach was used to assess the overall quality of evidence for each outcome, based on five domains: risk of bias, inconsistency, indirectness, imprecision, and publication bias. Evidence was rated as high, moderate, low, or very low quality. Randomized trials start as high quality but can be downgraded; observational studies start as low and may be upgraded if strong effects are observed (19). Two reviewers (NS and GS) applied the GRADE

criteria independently to all included studies, and any disagreements were resolved by discussion with the third reviewer (PK).

- Level of evidence

The level of evidence ranks the strength and reliability of findings based on study design and quality. Higher levels (1a–1c) include systematic reviews and well-conducted RCTs, while lower levels (2a–5) cover observational studies and expert opinions. This hierarchy guides confidence in results and supports evidence-based decision-making (20). This evaluation was performed independently by two reviewers (PK and SK).

- Risk of bias

Four reviewers (PN, NS, SK, PrK) assessed the internal validity of included studies using the Cochrane Risk of Bias 2 (RoB 2) tool, designed for evaluating randomized trials. RoB 2 covers key bias domains through signaling questions, with judgments categorized as 'Low risk,' 'High risk,' 'Some concerns,' or 'No information.' A traffic light plot was generated using the RoB 2 visualization tool (https://www.riskofbias.info/welcome/robvis-visualization-tool) (18). Any disagreements were resolved by discussion with other reviewers (PK and GS).

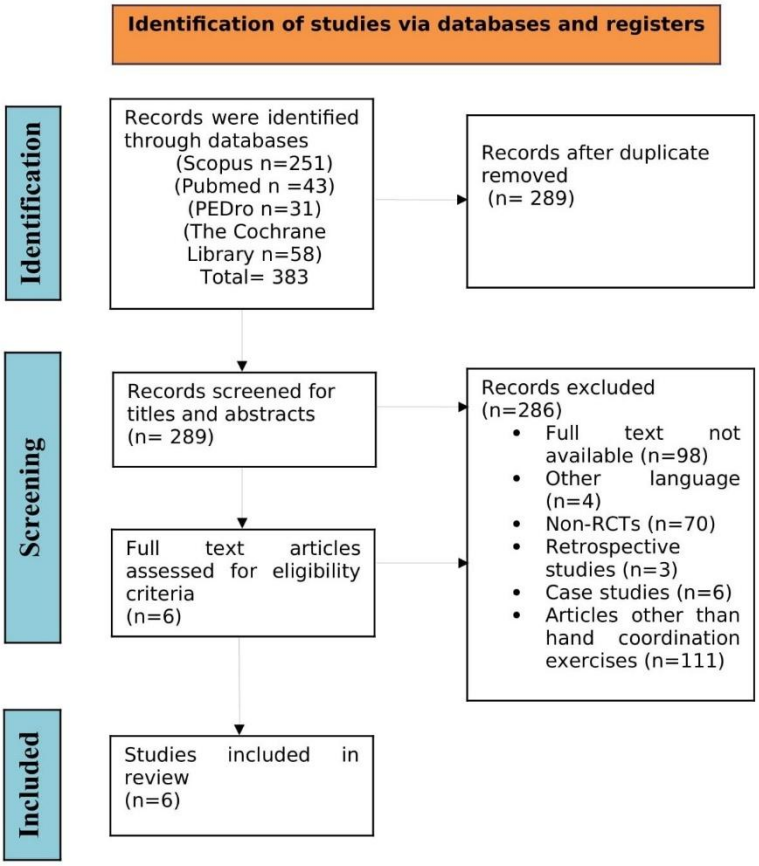

Figure 1: PRISMA flow diagram

Results

Participants and Eligibility Criteria of Included Studies

A total of 361 participants were included across the seven studies, ranging in age from 6 to 16 years. The majority were male (n = 266) and female participants numbered 95. All studies focused on school-aged children or adolescents formally diagnosed with Developmental Coordination Disorder (DCD). The diagnosis of DCD was primarily based on standardized criteria such as Diagnostic and Statistical Manual of Mental Disorders, (DSM-IV or DSM-5) (13, 14) guidelines and supplemented with motor function assessments like the (MABC or MABC-2), (BOT-2), or other validated tools.

Common inclusion criteria across studies were: (i) formal diagnosis of DCD; (ii) scoring below the 15th percentile on standardized motor coordination assessments; (iii) age between 5 and 17 years; and (iv) no coexisting neurological or intellectual disabilities. Some studies further required that participants had no history of orthopedic impairments or visual/motor impairments that could confound the outcomes. Exclusion criteria typically included autism spectrum disorders, ADHD, or any diagnosed neurological

conditions unless specifically studied. Most trials also excluded children currently receiving other forms of therapy or medication targeting motor function.

Identification and selection of studies

A total of 611 records were identified through four electronic database searches and hand searching. After the removal of 315 records due to duplication (n = 227), irrelevance to the desired intervention (n = 61), and studies involving patients other than those with developmental coordination disorder (DCD) (n = 27), 296 records remained for title and abstract screening. 276 articles were excluded for not meeting the inclusion criteria. The remaining 20 articles were retrieved and assessed for eligibility. After full-text only 7 studies met the predefined eligibility criteria and were included in this systematic review. (Figure 1) The most frequent reasons for excluding full-text articles were: (1) lack of coordination exercise as the primary intervention for hand function, (2) inclusion of unrelated motor conditions or populations other than those diagnosed with Developmental Coordination Disorder (DCD), and (3) study design not meeting the inclusion criteria (e.g., case reports, observational studies, or protocols). In total, the included studies enrolled 323 participants aged between 6 and 16 years. All studies focused on interventions targeting hand function through coordination-based exercises. Supplementary Table 2 summarizes the characteristics of each included study, including authorship, year of publication, sample size, intervention types, outcome measures, and main findings.

Outcome measure

The study accepted various fine motor skill measurement methods, including Movement assessment battery for children (MABC) utilized by five studies (21-23, 25-27), while Jebsen Taylor Hand Function Test (JTHFT) was used by two studies (24, 26), and one study (26) used Bruininks–Oseretsky Test of Motor Proficiency as valid outcome measures. Some other outcome measures were also used to assess other variables in different studies.

Studies description

Across the seven included studies, a variety of coordination-based interventions were implemented to target fine motor and hand function deficits in children with DCD. Interventions ranged from technology-enhanced protocols (e.g., Leap Motion Controller and Wii-based games) to traditional therapies like adapted Taekwondo, Quiet Eye Training (QET), and Haptic Perception Training (HPT). Despite methodological differences, all studies reported significant improvements in at least one domain of hand function.

Manual Dexterity and Fine Motor Skills; four studies (24-27) demonstrated statistically significant improvements in manual dexterity as measured by the Movement Assessment Battery for Children (MABC), BOT-2, or Purdue Pegboard Test. Effect sizes reported were moderate to large (e.g., Cohen's d > 0.8 in the hepatic perception study). Eye-hand coordination was a targeted component in several interventions. The Quiet Eye Training study reported a significant between-group improvement (p = 0.032), while the Taekwondo-based intervention led to faster movement times in upper-limb coordination (p = 0.009 at 3 months and p = 0.016 at 6 months). Technology-Based Interventions like Leap Motion RCT and Wii-based training showed significant improvements in hand function and motor learning. The Leap Motion study reported significant improvements in MABC scores (p = 0.031) for the intervention group. The Wii training improved task-specific motor performance, particularly in activities involving fine hand control.

Several studies (21, 22, 25-27) reported not only improvements in trained tasks but also transfer to un-train or functional skills (one study reported transfer effects across both dominant and non-dominant hands and at 6-week follow-up (24)). Overall, these findings indicate that coordination exercises, especially those incorporating structured, repetitive movements and fine motor challenges can significantly enhance hand function in children with DCD.

Statistical Analysis

A total of seven studies were included in the meta-analysis to evaluate the effect of coordination exercises on hand function in children and adolescents with developmental coordination disorder (DCD). The pooled analysis using a random-effects model showed a statistically significant improvement in hand function following coordination interventions, with a standardized mean difference (SMD) of 1.13 (95% CI: 0.31 to 1.95, $p = 0.0066$). This indicates a large effect size in favor of the intervention group. The overall test for effect was statistically significant ($Z = 2.71$, $p = 0.0066$). Moderate to substantial heterogeneity was observed among the included studies ($I^2 = 70.8\%$, $Tau^2 = 0.2487$, $Chi^2 = 3.43$, $p = 0.0642$), indicating variability in effect sizes across studies (Figure 2). The prediction interval ranged from -7.12 to 9.39, reflecting the wide range of true effects that might be expected in future similar studies and suggesting considerable heterogeneity in the intervention's effectiveness (15).

Sensitivity Analysis & Publication Bias

Sensitivity analysis and funnel plots were conducted to assess the robustness of the findings and potential publication bias. The sensitivity analysis revealed that two studies (26, 27) contributed the majority of the meta-analytic weight (55.6% and 44.4%, respectively), while the remaining studies had negligible weights due to zero standard deviations or small sample sizes. This indicates that the overall pooled effect is highly influenced by these two studies, and excluding either one may substantially alter the overall estimate, suggesting the results should be interpreted with caution.To examine publication bias, a funnel plot was constructed (Figure 3). However, due to the limited number of included studies (n = 7), the interpretation was inconclusive. The plot demonstrated visual asymmetry, largely because most studies contributed minimal weight, and only the same two studies (26, 27) had a significant impact on the overall effect. Given the small number of studies and their unequal influence, formal tests for funnel plot asymmetry were not performed.

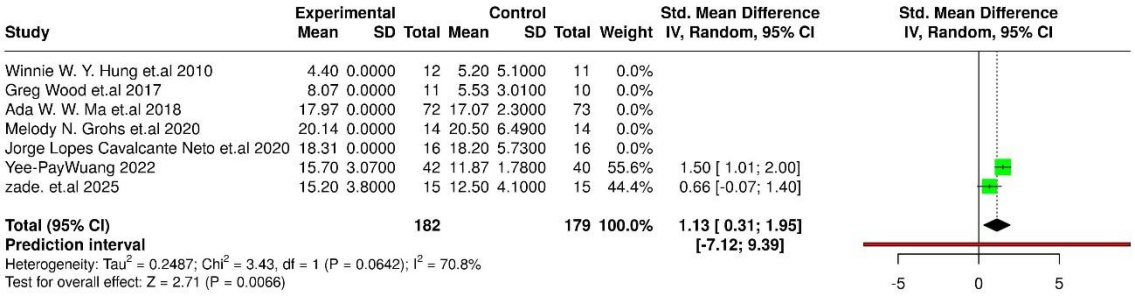

Figure 2: Forest plot of the included studies

Quality Assessment

- PEDro

The PEDro scores of the studies analyzed range from 5 to 8, indicating a spectrum of quality from fair to excellent. It is important to note that only one study had blinding for both participants and evaluators (24). Furthermore, none of the studies blinded their participants. Concerning subject allocation, 2 studies employed random allocation techniques (23, 24). (Supplementary Table 3)

- Level of Evidence (LoE) and GRADE

Six studies in the qualitative analysis demonstrated the highest quality of RCTs with a 1b level of evidence, while only one study presented a 2b level of evidence, albeit varying in the quality of evidence as per the GRADE system. The six studies demonstrated a moderate level of quality, indicating a moderate level of confidence in the relationship between the actual and estimated effect. One study illustrated low evidence, signifying low confidence (26). (Refer Supplementary Table 2 for the LoE and GRADE)

Risk of Bias

Figure 4 demonstrated that out of seven studies, one study (21) was found to have ‘Low’ risk of bias while two studies (23, 24) have ‘some concerns’ bias due to outcome data was not properly reported. Bias due to deviation from intended interventions was reported in two studies (22, 25) while three studies (24, 25, 27) exhibited bias in the outcome measurement. Another study (22) reported bias in the selection of reported result. One study (26) found to have ‘high’ risk of bias due to randomization process was not explained. Overall, the quality of all included studies was categorized as ‘low’ risk of bias.

Discussion

The findings of this systematic review of the existing literature is necessary to compile the information currently available about how well coordination activities work to improve hand function in people with DCD. To the best of our knowledge, this is the first systematic review concentrating solely on coordination exercises and their effects on hand function in children and adolescents with DCD. Prior reviews have typically assessed global motor skills or included heterogeneous interventions without distinguishing coordination-specific approaches. Our review thus provides a more refined and clinically actionable perspective.

The motor skill training program included a variety of exercises targeting different areas like agility, balance, core stability, bilateral coordination, eye-hand coordination, etc. For eye-hand coordination specifically, exercises like throwing/catching balls/beanbags to different targets and bouncing/catching balls were included. The results showed that both the group-based and individual-based training groups showed significant improvement ($p<0.05$) in the manual dexterity subtest of the Movement Assessment Battery for Children (MABC)

after the intervention. This suggests that although the exercises mainly involved gross motor skills, the training also led to improvements in fine motor skills like manual dexterity. Authors cite previous evidence showing a study established potential relationship between proximal stability and distal fine motor control abilities and conclude that incorporation of eye-hand coordination exercises along with exercises promoting core stability, balance and whole-body coordination seems to have positively impacted hand dexterity in these children with DCD (21).

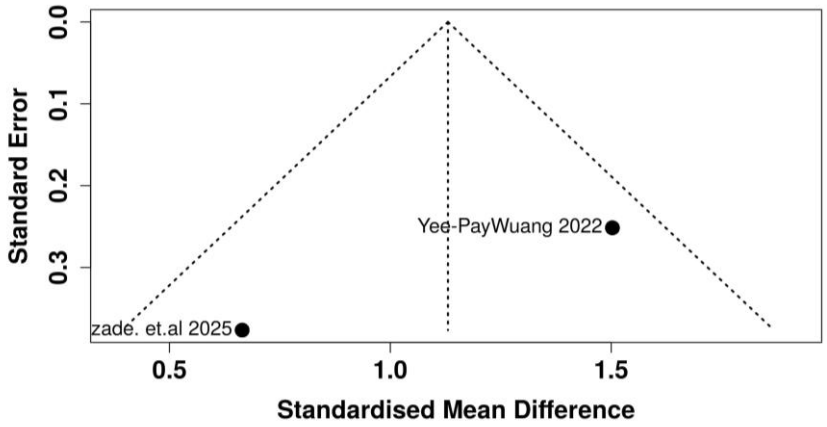

Figure 3: Funnel plot of the included studies

A study discussed the effects of a group-based gaze training intervention on children with Developmental Coordination Disorder (DCD). The intervention, called Quiet Eye Training (QET), involves teaching children to fixate on a target location on the wall prior to throwing a ball and to track the ball prior to catching it. The quiet eye training group was compared to a technical training (TT) group that received movement-related instructions via video and they found that children in the quiet eye training group showed significantly greater improvement in gaze control and catching coordination scores compared to the technical training group at delayed retention ($p = .032$). Improving these skills through QET could potentially lead to improvements in hand function for children with DCD. Overall, the study provides evidence for the effectiveness of a group-based gaze training intervention for improving coordination skills in children with DCD (22).

A study examining the effects of adapted Taekwondo training—a form of coordination exercise—on children with developmental coordination disorder (DCD) found significant improvements in eye-hand coordination movement time at 3 months ($p = 0.009$) and 6 months ($p = 0.016$). Although no significant changes were observed in reaction time or accuracy, the reduction in movement time suggests enhanced neuromuscular control and upper limb function. These improvements are likely attributed to the repetitive, structured motor practice inherent in martial arts, supporting the positive impact of coordination exercises on hand function in children with DCD (23).

A study investigating the effects of coordination exercises, specifically repetitive fine motor training using pegboard tasks, in children aged 8–12 years with developmental coordination disorder (DCD) demonstrated significant improvements in hand function and dexterity. These improvements extended beyond the trained non-dominant hand to untrained tasks involving the dominant hand and bimanual coordination. Gains were sustained at a 6-week follow-up, indicating lasting effects of the coordination training. Assessments using the Purdue Pegboard Test and the Jebsen-Taylor Test of Hand Function confirmed enhanced hand coordination and motor performance. Notably, pairing the training with anodal transcranial direct current stimulation did not yield additional benefits, emphasizing the effectiveness of coordination exercises alone in improving hand function in children with DCD (24).

A study discussed the effects of Wii training and task-specific training on motor learning in children with developmental coordination disorder (DCD). While motor learning improved with both interventions, the study found that TST led to greater benefits in motor learning, as assessed by games scores, than Wii training. However, the study also identified which tasks were more sensitive to training with Wii and the phase with the highest improvements in performance (25). Regarding hand function, the study included tasks such as table tennis and frisbee, which require hand-eye coordination and fine motor

skills. The results showed that Wii training elicited better performance in the archery and bowling tasks, whereas only task-specific trainings elicited improvements in the balance beam and table tennis tasks. This shows that task-specific training may be more beneficial for tasks requiring fine motor skills and balance, while Wii training may be advantageous for specific tasks requiring hand-eye coordination (25).

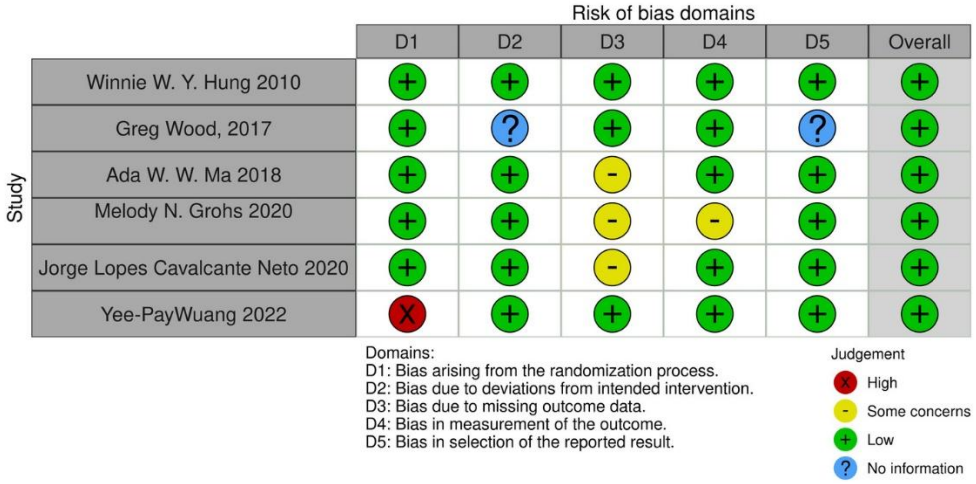

Figure 4: Risk of Bias summary

A study investigated the effects of Haptic Perception Training (HPT) programs on fine motor functions in adolescents with developmental coordination disorder. The HPT group showed significant improvements with large effect sizes (Cohen's d > 0.8)in fine motor control measures, like fine motor precision, integration, manual dexterity, and handwriting compared to standard occupational therapy group after the intervention. The findings suggested that Haptic perception training programs can be an effective alternative to hospital or school-based therapy for adolescents with developmental coordination disorder, with robust effect sizes across various skill domains. Incorporating haptic inputs through active touch and manipulation can be an effective therapeutic approach to improve hand functioning in coordination disorders (26).

This randomized controlled trial provides strong evidence supporting the efficacy of coordination exercises for improving hand function in children with developmental coordination disorder (DCD). The study demonstrates that both conventional task-oriented training and technology-enhanced coordination exercises using Leap Motion Controller significantly improve fine motor function and handwriting skills, with the technology-based intervention showing superior results for fine motor outcomes. These findings highlight the importance of incorporating structured coordination activities into rehabilitation protocols for children with DCD, while suggesting that interactive, engaging interventions may enhance treatment outcomes. The positive results achieved with a 4-week intervention period (30 minutes daily, 5 days per week) indicate that consistent, focused coordination training can yield meaningful improvements in hand function within a reasonable timeframe, offering valuable guidance for clinicians working with this population (27).

In the existing literature, previous research has highlighted the broad benefits of physical activity on motor proficiency in children with Developmental Coordination Disorder (DCD) (28). However, the present review specifically focuses on the role of coordination exercises in enhancing hand function outcomes. In addition, recent systematic reviews have shown that structured online coordination training programs, such as radio calisthenics, can be effective in improving coordination and hand-eye coordination in children with DCD. These findings emphasize the increasing relevance of remote therapeutic approaches in the management of DCD (29). Furthermore, studies examining virtual reality (VR) game training have demonstrated its potential to improve upper limb motor performance in children with DCD. VR-based interventions, which often incorporate coordination exercises, provide engaging and interactive environments that promote motor learning and skill acquisition, further supporting the efficacy of technology-driven interventions for improving hand function (30).

The studies reviewed in this systematic review consistently highlight the effectiveness of coordination exercises in improving hand function in children with developmental coordination disorder (DCD). Key findings suggest that both gross and fine motor coordination exercises; such as eye-hand coordination tasks, task-specific training, and gaze training, lead to

significant improvements in fine motor skills, particularly manual dexterity and motor control. Interventions like Quiet Eye Training and task-oriented exercises, including activities like table tennis, have shown positive outcomes in hand function, underscoring the importance of targeting both motor skills in rehabilitation. Additionally, the incorporation of technological tools like the Leap Motion Controller and martial arts training (e.g., adapted Taekwondo) further supports the value of structured, engaging interventions in improving hand function. These findings strengthen the base that coordination exercises, particularly those involving a combination of gross and fine motor skills, can significantly benefit children with DCD. The positive effects observed, especially in eye-hand coordination, Haptic perception training program and task-specific performance, emphasize the potential of these interventions to enhance overall motor function and hand dexterity in this population.

This review highlights strong evidence supporting the use of coordination exercises to improve hand function in children with developmental coordination disorder (DCD). Interventions incorporating eye-hand coordination, task-specific training, and motor control exercises whether delivered through conventional therapy, martial arts, or digital tools demonstrated significant improvements in fine motor performance, particularly manual dexterity. These findings reinforce the importance of integrating coordination-based activities into therapeutic programs targeting hand function in children with DCD. Potential impact of cultural and socioeconomic factors on the effectiveness of coordination exercises should be considered. Different cultural contexts may affect how exercises are perceived and implemented, while socioeconomic factors could influence access to resources and adherence to intervention programs.

From a clinical perspective, these findings emphasize the need for individualized, flexible intervention approaches that consider the child's broader environmental and developmental context. Clinicians should be encouraged to adapt coordination-based interventions to fit the specific needs and circumstances of each child, using culturally appropriate methods and low-cost alternatives when resources are limited. Moreover, in children with co-occurring conditions like ADHD or ASD, coordination exercises may require additional behavioral or sensory accommodations to ensure engagement and maximize therapeutic benefit. Incorporating family education and home-based training programs can also help bridge gaps in access and reinforce intervention consistency.

Limitations and future recommendations

One common limitation across these studies was the relatively small sample sizes, which may limit the generalizability of the findings. Additionally, most studies focused on short-term outcomes, with few including follow-up assessments. Another limitation was the lack of direct comparisons between all these different intervention types within a single study. This makes it challenging to definitively state which approach is most effective, as each study used different outcome measures and protocols. The potential for placebo effects or the impact of increased attention and engagement during interventions should also be considered. It's possible that some improvements could be attributed to these factors rather than the specific intervention techniques.

Further research is needed to address these limitations. Long-term follow-up studies would be valuable to assess the durability of improvements. Studies with larger sample sizes and more diverse populations could enhance the generalizability of findings. Direct comparisons of multiple intervention types within the same study would provide clearer insights into their relative effectiveness. Additionally, investigating the optimal duration, intensity, and frequency of interventions could help in developing more efficient treatment protocols. Exploring combinations of different intervention types might also yield insights into potential synergistic effects. Future studies could also benefit from incorporating more functional, real-world outcome measures to assess how improvements in hand function and coordination translate into daily activities and quality of life for children with DCD. Lastly, considering the individual differences among children with DCD, research into personalized intervention approaches based on specific deficits or characteristics could lead to more targeted and effective treatments.

In Conclusion

This systematic review and meta-analysis provide robust evidence supporting the effectiveness of coordination exercises in improving hand function among children with Developmental Coordination Disorder (DCD). The interventions significantly enhanced fine motor skills, manual dexterity, and overall hand functionality across diverse clinical and community settings. Despite variations in assessment tools and intervention protocols, the consistent positive outcomes affirm coordination training as a practical and impactful therapeutic strategy.

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Author's Contribution

Priyanka Negi: Concept and design of the study, acquisition of data, or analysis and interpretation of data; Drafting the article

Nidhi Sharma: Concept and design of the study, data analysis and interpretation of data; Drafting the article or revising it critically for important intellectual content; Final approval of the version to be published.

Simranjeet Kaur: Drafting the article or revising it critically for important intellectual content, Final approval of the version to be published.

Preeti Kapri: Acquisition of the data, or analysis and interpretation of data; Drafting the article

Anshu Sharma: Acquisition of the data, or analysis and interpretation of data; Drafting the article

Parveen Kumar: Acquisition of the data, critical revision of the manuscript, final approval of the version to be published; and Aptitude to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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Conflict of interest

The authors made a declaration that there were no known conflicts of interest, either financial or personal, that would have affected the results of this study.

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