# Enhancing Fundamental Motor Skills Through Active Play: A Systematic Review and Meta-Analysis of Educational Contexts


## Abstract

This study examines the effectiveness of active play interventions to enhance Fundamental Motor Skills (FMS) in children aged 2 to 5 and compares different intervention modalities. It also explores the moderating role of world region and the use of recess in educational contexts. A systematic review and Bayesian meta-analysis were conducted, using data from MEDLINE, Web of Science (WOS), Scopus, PsycINFO, Cinahl, and SPORTdiscus up to January 2023. Clinical trials with active play interventions in educational settings were included, excluding multicomponent interventions. Eighteen studies (2816 participants; 240 effect sizes) met the criteria. The overall average treatment effect (ATE) of active play versus control was 0.07 (95% CrI -0.004 to 0.15). Motor skills interventions showed a significant effect (SMD = 0.16, 95% CrI 0.01 to 0.29), especially when integrated into recess (SMD = 0.31, 95% CrI 0.03 to 0.62). The effectiveness varied across regions, highlighting the need for regional consideration in implementation.



**Keywords:** Child, preschool; Motor skills; Active play; Recess time; Physical Activity; Meta-Analysis.



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## Introduction

Fundamental movement skills (FMS) include stability (e.g., static or dynamic balance), locomotor (e.g., hopping, running, and jumping), and object-control skills (e.g., catching, throwing, and kicking) (Gallahue and Donnelly 2007; Rudd et al. 2015). Improving FMS in preschoolers is crucial for the acquisition of more advanced movement skills (Goodway and Robinson 2006; Dobell et al. 2023), increasing physical activity levels, and reaping various physical, cognitive, and social health benefits (Lubans et al. 2010; Donath et al. 2015). However, the type of active play interventions, defined as physical movement activities such as running and jumping, and its impact on FMS remain uncertain (Gordon et al. 2013; Hardy et al. 2014).

Theoretical models, such as the ecological systems theory (Bronfenbrenner 1989), suggest that children's development, including motor skills, is influenced by interactions within various environments, including the home, school, and community. From this perspective, *active play* serves as a tool for fostering physical, cognitive, and social skills, as it provides opportunities for both individual exploration and guided learning. Non-guided active play, defined as child-led physical activity that fosters creativity and exploration, occurring without structured instructions or adult supervision (i.e., unstructured playtime) reported positive impacts on children's physical activity and wellbeing, but it often lacks structured learning opportunities, while professionally-taught physical education classes often lack sufficient activity and practice time in preschoolers (Castelli 2019; Goodway, Ozmun, and Gallahue 2019; Lee et al. 2020). Mastering FMS requires instruction and practice (Johnson et al. 2023). The age range of 0 to 5 years is a critical period for the development of important physical, motor, social and cognitive skills (Black et al. 2017; Howard and Melhuish 2017) and physical activity contributes to positive developmental outcomes during this age period (Jones et al. 2013; Telama et al. 2014).

Guided active play, refers to physical activities directed by adults, shows promise in enhancing Fundamental Motor Skills (FMS) and increasing physical activity among preschoolers (Adamo et al. 2016; Johnstone et al. 2018). This aligns with the social cognitive theory (Bandura 1999), which emphasizes the importance of observational learning and reinforcement in skill development. Despite prioritizing physical activity and motor skills practice, the specific effects of such interventions on FMS remain unclear (Adamo et al. 2016; Truelove, Vanderloo, and Tucker 2017). Additionally, the effectiveness of guided active play in improving FMS aligns with debates on how educational contexts influence intervention outcomes (Goodway, Ozmun, and Gallahue 2019; Moghaddaszadeh and Belcastro 2021). Regional differences in educational recommendations, influenced by diverse curricular and pedagogical models and government policies, contribute to uncertainties in promoting physical activity (Pascal, Bertram, and Veisson 2018).

The increasing enrolment of children aged 2 to 5 in educational contexts has made it a primary setting for promoting physical activity during this stage (McConnell-Nzunga et al. 2020; Moghaddaszadeh and Belcastro 2021). Kindergarten plays a crucial role in monitoring and developing preschoolers, holding great potential to influence the long-term healthy growth and physical condition of preschoolers (Huang, Luo, and Chen 2022; Chen et al. 2022; Skarstein and Ugelstad 2020; Lee et al. 2020). However, kindergarten environments face challenges, with a lack of diverse spaces, equipment, sports games, active recess period and teaching methods to implement effective physical activity interventions, including active play (Ridgers, Stratton, and Fairclough 2005; Lee et al. 2020; Chen et al. 2022; Huang, Luo, and Chen 2022). The best approach for implementing physical activity interventions in this educational context remains unclear.

Considering the gaps identified above, through a systematic review and meta-analyses we aim to examine the effectiveness of active play interventions to increase FMS, as well as comparing different active play intervention types to determine the most effective approach. Furthermore, we aim to investigate the influence of the geographical context in which the intervention occurs, as well as the possible moderating role of active play interventions that are embedded within the educational curriculum. To enhance the understanding of the factors that may influence the effectiveness of active play interventions in preschoolers, we selected geographic region and recess inclusion as moderators based on their theoretical and empirical relevance. The geographic region was chosen due to the influence of regional educational systems and policies on physical activity interventions (Pascal, Bertram, and Veisson 2018). Ecological systems theory (Bronfenbrenner 1989) supports the idea that different environments, such as educational contexts, can impact motor skill development. Recess inclusion was considered as it provides unstructured play, which is important for motor skill development and aligns with social cognitive theory (Bandura 1999), highlighting the role of observation and reinforcement during physical activity (Ridgers, Stratton, and Fairclough 2005; Goodway, Ozmun, and Gallahue 2019).

## Methods

This pre-registered systematic review with meta-analysis (PROSPERO #CRD42022303693) was reported following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Page et al. 2021).

### *Search strategy*

A systematic search was conducted using six databases: MEDLINE, Web of Science (WOS), Scopus, PsycINFO, Cinahl, and SPORTdiscus. The searches were undertaken from inception to December 2023. The search strategy used across the different databases including search terms and dates is shown in online supplemental table 1. Additionally, reference lists of relevant articles and reviews were screened to identify any additional studies.

***Selection criteria***

We included experimental studies with a control group that involved children aged between 2 and 5 years old that used any type of active play intervention in a childcare/kindergarten or educational context. Trials were required to report any outcome related to the Fundamental Movement Skills (e.g., throwing, jumping, catching), and were assessed using validated and reliable tests. We excluded studies that applied multicomponent interventions in kindergarten/childcare or educational settings where the effect of active play could not be isolated and studies that involve children diagnosed with a medical condition or illness. This exclusion criterion was necessary to ensure that the observed effects could be specifically attributed to active play interventions, rather than being confounded by other components (e.g., nutrition, classroom-based activities, or parental involvement). While this approach enhances internal validity, it may limit the generalizability of the findings to real-world settings where interventions often include multiple components.

***Data extraction and coding***

From each arm of the included studies, we extracted data on the world region where study was conducted, intervention parameters, control description, and descriptive statistics (i.e., means and standard deviations [SD]) from FMS outcomes data to calculate effect sizes. If data were not directly available, means and SDs from other statistics (e.g., median and interquartile range, standard errors, or 95% confidence intervals) were obtained using data transformation formulas detailed in the Cochrane Handbook for Systematic Reviews (Higgins et al. 2019).

Interventions were coded into two levels of specificity. At the first level (i.e., the general level), interventions were coded as "active play" when children engaged in a regimen of physical activity that could or could not be included in the designated recess time in the educational curriculum, understood as the suspension of classroom activities to engage in playful exercises that allow children to interact, move, and recharge their energy; and "control" when no modifications were made to the children's daily routines.

In the second level, active play was either classified as "motor skills" if the session was structured and activity-based, and focused on the development of fine and gross motor skills with a predetermined duration, which may or may not be included during recess stipulated by the educational curriculum, or "structured playtime" if the intervention protocol presented a structured play-based session, which had a specific number of sessions and a predetermined session duration which may or may not be included during recess stipulated by the educational curriculum. All analyses were performed in R 4.0.3 (2022). We used the *brms* package (Bürkner 2017) (version 2.18.0) to perform Bayesian meta-analysis models; the *tidybayes* package (Kay 2021) (version 3.0.2) to integrate Bayesian modeling into tidy data; the *marginaleffects* package (Arel-Bundock 2023) (version 0.13.0) to compute marginal means and treatment effects estimates; and the *ggplot2* package (Wickham 2011) (version 3.3.6) for data plotting and visualization. The code and data required to reproduce the results presented in this meta-analysis are available through public repository access (http://github.com/dangalgom).

***Data synthesis***

A Bayesian model was preferred over a frequentist model in this meta-analysis due to its ability to enhance the estimation of intervention effects in small or heterogeneous samples by allowing more flexible hierarchical modeling (Higgins, Thompson, and Spiegelhalter

2009). Additionally, they offer robust inference even in the presence of missing data, making them particularly suitable for complex real-world datasets.

We fitted Bayesian multilevel meta-analysis models (Higgins, Thompson, and Spiegelhalter 2009) (i.e., clustering data points within studies) to synthesize the effects of active play *vs.* control (at overall level), and the effects of different types of active play (i.e., motor skills and structured playtime) *vs.* control (at intervention-specific level) on FMS in preschool-aged children. Meta-analysis estimates were reported as standardised change scores (i.e., pre-post differences; SMD) due to the use of different scales across studies to assess FMS. The between-study heterogeneity was reported on SD units (tau), and 95% credible intervals (CrI) were used to assess the certainty of our estimates (Etzioni and Kadane 1995). Regarding prior information included in the models, we used (1) flat priors for all regression coefficients (i.e., no prior information is assumed), (2) weakly informative priors for the intercept of our model (i.e., centered at 0.3, with a SD = 2.50; set by default in the *brms* package), and a half student-t prior for standard deviation parameters enforcing weak regularization on random effects. We computed average treatment effects (ATE) across all possible pairwise comparisons calculating the difference between the two predicted averages (e.g., to estimate the active play *vs.* control ATE, we calculated the difference between active play average response and control average response). We used a Bayesian Forest plot to illustrate the expected posterior distributions for each arm of each study.

We also conducted Bayesian mixed multilevel meta-analysis models to adjust the predicted SMDs by world region due to existing differences in intervention protocols and educational policies systems, and whether the intervention was included in recess stipulated by the educational curriculum. We used a linear function based on the observed distribution of our effect modifiers.

### *Risk of bias assessment, sensitivity analysis and quality of evidence*

Two reviewers (JRM, FAB) independently assessed the risk of bias of included trials using the revised version of the Cochrane Risk-of-Bias Assessment Tool (RoB 2) (Higgins et al. 2011).

We conducted a sensitivity analysis that excluded studies from the meta-analyses that were rated as high-risk of bias to determine if they influenced the result. Publication bias was assessed by funnel plot asymmetry visualization. The Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system was used to rate the quality of evidence presented in this meta-analysis (Kavanagh 2009).

## Result

Overall, 3827 records were identified through the initial electronic searches. After removing duplicates, 3026 records were screened for titles and abstracts, and 351 full text articles were screened for eligibility. In total, 18 studies (Zhou et al. 2014; Wick, Kriemler, and Granacher 2021; Wasenius et al. 2018; Tan et al. 2017; Puder et al. 2011; Ozturk and Unver 2022; Matvienko and Ahrabi-Fard 2010; Li et al. 2022; Latorre-Román, Mora-López, and García-Pinillos 2018; Jones et al. 2016; Hacke et al. 2019; Donath et al. 2015; Branje et al. 2022; Battaglia et al. 2018; Bai, Huang, and Ouyang 2022; Alhassan, Sirard, and Robinson 2007; Jarraya, Jarraya, and Nouira 2022; Wang et al. 2023) involving 2816 participants (240 effect sizes) were included in the review. The full screening and selection process is shown in figure 1.

### *Characteristics of the included studies*

The summary of the characteristics of the included studies are shown in table 1. The year of publication ranged from 2000 to 2024. The average sample age was 4.67 ± 0.45 years old. There were 7 studies where the intervention was included within the educational curriculum. Regarding the continent where studies were conducted, 1 trial was conducted in Africa, 5 in Asia, 4 in America, 6 in Europe, 1 in Oceania, and 1 was mixed. Overall, there were 86 effect sizes corresponding to active play interventions, and 154 effect sizes corresponding to control. Additional information included studies in online supplemental table 2.

**Table 1.** Summary of the characteristics of the included studies.

| Author(s) | Year | Study Type | Region | Sample Size | Duration | Sessions per Week | Intervention Type | Main Findings |
|---|---|---|---|---|---|---|---|---|
| Alhassan | 2012 | RCT | America | 71 | 24 wks | 5 | Motor skills | Improved LMS, reduced sedentary time |
| Bai | 2022 | RCT | Asia | 62 | 8 wks | 3 | Structured playtime | Higher motor skills and EF increase in intervention group |
| Bataglia | 2019 | RCT | Europe | 119 | 16 wks | 2 | Motor skills | Health benefits for preschool children |
| Branje | 2022 | RCT | America | 178 | 24 wks | 5 | Motor skills | Improved fundamental movement skills |
| Donath | 2015 | RCT | Europe | 41 | 6 wks | 2 | Motor skills | Improved dribbling and catching |
| Hacke | 2019 | RCT | Europe | 135 | 24 wks | 2 | Motor skills | No significant effectiveness found |
| Jarraya | 2022 | RCT | Africa | 54 | 12 wks | 2 | Motor skills, structured playtime | Improved self-esteem and motor skills |
| Jones | 2016 | RCT | Oceania | 150 | 16 wks | 3 | Motor skills | No significant differences, but some effect sizes favor intervention |
| Latorre-Román | 2018 | RCT | Europe | 111 | 10 wks | 3 | Motor skills | Improved physical fitness |
| Li | 2022 | RCT | Asia | 58 | 10 wks | 2 | Motor skills | Improved manual dexterity and motor skills |

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|---|---|---|---|---|---|---|---|---|
| Matvienko | 2010 | RCT | America | 70 | 4 wks | 5 | Motor skills | Improved motor skills and fitness |
| Ozturk | 2022 | RCT | Europe | 66 | 10 wks | 2 | Motor skills | Alternative fun activity for children |
| Puder | 2011 | RCT | Multi-region | 655 | 42 wks | 4 | Structured playtime | Benefits in physical activity, media use, eating habits |
| Tan | 2016 | RCT | Asia | 104 | 10 wks | 5 | Motor skills | Improved physical fitness, especially in obese children |
| Wang | 2023 | RCT | Asia | 253 | 16 wks | 3 | Motor skills | Better physical fitness outcomes in preschoolers |
| Wasenius | 2017 | RCT | America | 215 | 24 wks | 5 | Motor skills | Increased locomotor skills |
| Wick | 2011 | RCT | Europe | 54 | 10 wks | 3 | Motor skills | Improved jump performance, attentional capacity |
| Zhou | 2014 | RCT | Asia | 357 | 48 wks | 5 | Structured playtime | Improved body composition and fitness |

***Intervention Characteristics and Outcomes***

At intervention-specific level, we extracted 107 effect sizes for motor skills, 108 effect sizes for structured playtime interventions and 25 effect sizes for control. Median duration of the interventions was 12 weeks (range for structured playtime = 8 to 48 weeks) and 16 weeks (range for motor skills = 4 to 24 weeks). The median frequency was 3 days per week (range for structured playtime = 2 to 5 days/week; range for motor skills = 2 to 5 days/week). The median time per session was 45 min for structured playtime (range = 30 to 50 min/session), and 30 minutes for motor skills (range = 20 to 105 min/session).

***Systematic Examination of Study Characteristics***

To further enhance the results section, we conducted an in-depth analysis of the studies by systematically examining sample characteristics, study designs, assessment instruments, intervention details (duration, frequency, and period), and intervention effectiveness.

***Study Design***

All included studies employed a randomized controlled trial (RCT) design, ensuring robust comparisons between intervention and control groups.

***Sample Characteristics***

Sample sizes ranged from 41 to 655 participants. Notably, larger sample sizes were observed in studies like Puder et al. (2011) (n = 655) and Zhou et al. (2014) (n = 357), potentially increasing statistical power and generalizability. Conversely, smaller sample sizes, such as Donath et al. (2015) (n = 41), may limit the strength of conclusions.

***Assessment Instruments***

The studies utilized a variety of validated assessment instruments to measure motor skills, physical activity levels, and executive function. The effectiveness of interventions was primarily evaluated through standardized motor skill assessments, locomotor skill development measures, and physical fitness tests.

***Intervention Effectiveness***

Most studies reported improvements in motor skills following intervention. For example, Alhassan et al. (2012) and Wasenius et al. (2017) reported significant enhancements in locomotor and fundamental movement skills. Similarly, Wang et al. (2023) found improved physical fitness outcomes in preschoolers. However, Hacke et al. (2019) did not observe significant intervention effectiveness, highlighting variability in study outcomes.

Structured playtime interventions also yielded positive effects, with Zhou et al. (2014) demonstrating improved body composition and fitness. Nevertheless, Jones et al. (2016) found no significant differences between groups, emphasizing the need for further exploration of moderating factors.

***Meta-analysis***

Active play and control presented predicted statistically significant responses on FMS ($SMD_{Active\ play}$ = 0.38, 95% CrI 0.27 to 0.49; $SMD_{Control}$ = 0.31, 95% CrI 0.20 to 0.42). We predicted a between-study heterogeneity of 0.36 (95% CrI 0.23 to 0.54). The active play *vs.* control ATE was 0.07 (95% CrI -0.004 to 0.15), the overall trend suggests a favorable effect of active play interventions. Study-specific ATE estimates were presented in online supplemental figure 1.

At intervention-specific level, interventions were ranked by predicted response as motor skills interventions (SMD = 0.44, 95% CrI 0.30 to 0.57), structured playtime (SMD = 0.32, 95% CrI 0.17 to 0.46), and control (SMD = 0.28, 95% CrI 0.16 to 0.40) (figure 2). The between-study heterogeneity estimate remained similar (tau = 0.36, 95% CrI 0.23 to 0.54) (figure 3), indicating some degree of variability across studies. This could reflect differences in study designs, participant characteristics, or contextual factors that may have influenced the observed effects. Computed ATEs *vs.* control showed a meaningful effect for motor skills interventions (SMD = 0.16, 95% CrI 0.01 to 0.29), and a non-significant effect for structured playtime interventions (SMD = 0.03, 95% CrI –0.06 to 0.14). All pairwise comparisons are shown in figure 4.

***Effect modifiers: world region and intervention inclusion or not in the educational curriculum.***

Meta-analysis results showed differences in the effect of active play interventions across world regions. Predicted responses were 0.93 for interventions developed in America (95% CrI 0.47 to 1.34), 0.20 for those in Africa (95% CrI –0.46 to 0.85), 0.22 for those in Asia (95% CrI 0.006 to 0.48), 0.18 for those in Oceania (95% CrI -0,62 to 0.93), and 0.17 for those in Europe (95% CrI –0.25 to 0.63). Whether or not the interventions were included during recess by the educational curriculum resulted in effect variations. Motor skills intervention included during recess presented a statistically significant response ($SMD_{\text{Motor skills}}$ = 0.31, 95% CrI 0.03 to 0.62). However, Motor skills interventions outside recess did not present a statistically significant response ($SMD_{\text{Motor skills}}$ = 0.30, 95% CrI –0.11 to 0.78). Structured playtime did not present significant results either during or outside of recess time (figure 5). The introduction of these covariates to the model markedly reduced the between-study heterogeneity (tau = 0.25, 95% CrI 0.07 to 0.50). All predicted estimates were displayed in online supplemental figure 2. Numerical data is presented in the online supplemental table 3.

***Risk of bias assessment, sensitivity analysis and quality of evidence***

At overall level, 6 studies were classified as low-risk of bias, 3 studies as unclear-risk of bias, and 9 studies as high-risk of bias. Domain-level judgements for studies that performed an intent-to-treat analysis (n = 9) and those that performed a per protocol analysis (n = 9) are depicted in online supplemental figures 3 and 4. The overall-level risk of bias analysis for each study is shown in figure 6. The funnel plot did show a clear pattern of asymmetry. Overall, this corroborates that there could be small-study effects (online supplemental figure 5).

A sensitivity analysis that included only studies classified as low risk of bias demonstrated few fluctuations in intervention responses classified as motor skills (SMD = 0.44, 95% CrI 0.31 to 0.57), structured playtime (SMD = 0.32, 95% CrI 0.18 to 0.47) and control (SMD = 0.28, 95% CrI 0.17 to 0.40).

The effects of motor skills and structured playtime interventions compared with control remain similar ($SMD_{\text{motor skills vs control}}$ = 0.16, 95% CrI 0.02 to 0.29; $SMD_{\text{structured playtime vs control}}$ = 0.04, 95% CrI -0.06 to 0.14).

The GRADE approach defined the certainty of evidence presented in this meta-analysis as low. The certainty of the evidence was downgraded due to inconsistency between protocol parameters of interventions, indirectness, and publication bias. However, the model adjustment by plausible confounders (i.e., world region and whether included or not in the educational curriculum) upgraded the certainty of this body of evidence (supplemental text 1).

**Discussion**

This meta-analysis aimed to pinpoint the most effective interventions for enhancing Fundamental Motor Skills (FMS) in preschool-aged children and to uncover potential factors impacting their efficacy. Active play interventions, particularly those emphasizing motor skills, outperformed the control group although practical barriers like teacher training and space availability must be considered. Although some credible intervals include 0, the overall trend suggests a favorable effect of active play interventions. The ATE estimate (0.07, 95% CrI -0.004 to 0.15) indicates a potential benefit, though with some uncertainty. This finding aligns with previous research suggesting moderate improvements in FMS with active play interventions yet highlights the need for further studies to strengthen the evidence base. It is important to clarify that the effect sizes for different types of interventions vary, which may lead to apparent contradictions in the interpretation. Specifically, motor skills interventions and structured playtime interventions differ in their effect sizes. Motor skills interventions, which directly target specific motor skills through structured activities, showed a larger effect size compared to structured playtime interventions. This could explain why the motor skills interventions show a stronger impact on FMS development than the structured playtime interventions, which focus more on guided physical activity rather than specific skill development.

The geographic region of intervention and whether it was integrated into the educational curriculum emerged as significant factors influencing FMS enhancement. These findings offer valuable insights into effective interventions for preschool-aged children, potentially shaping the formulation of novel educational policies targeting early-life motor skill development, crucially linked to future health outcomes (Burton and Rodgerson 2001; Bremer and Cairney 2018). Given these results, it is essential for policymakers to consider integrating structured motor skill development programs into early childhood education. Policies that mandate teacher training in motor development and allocate resources for infrastructure and materials could enhance the effectiveness of these interventions. Furthermore, intersectoral collaboration between education and health ministries may ensure that motor skill development is prioritized as a key component of early childhood education (Barnett et al. 2016; Nonis and Tan 2010).

Previous meta-analyses did not show consistent results for active play interventions, suggesting caution in interpreting our findings due to insufficient evidence for conclusive conclusions (Wick et al. 2017; Johnstone et al. 2018; Li, Liu, and Ying 2021; Koolwijk et al. 2023). Specifically, Wick et al. (2017) found mixed effects across different study designs, while Johnstone et al. (2018) observed moderate effects, yet still highlighted a lack of sufficient evidence for firm conclusions. In contrast, our study's outcomes align with Johnstone et al. (2018), indicating that guided active play may positively influence the development of fundamental motor skills (FMS) in preschoolers. Moreover, our findings underscore the effectiveness of motor skills-based interventions in enhancing FMS, which is consistent with prior meta-analytic evidence (Wick et al. 2017). These interventions may have a significant impact, potentially due to their practical relevance to real-life activities. However, compared to Li et al. (2021) and Koolwijk et al. (2023), who reported limited effects, our findings provide stronger evidence of the positive role of motor skills interventions. Nonetheless, the comparative evidence regarding the effects of the tested covariates in this meta-analysis remains limited.

The variety of curriculum and pedagogical models for preschool education, supported by governmental policies, reflects recognition of diverse approaches to promoting physical activity in educational environments (Sollerhed et al. 2021). This diversity is influenced by differing educational opportunities between countries and variations in national education policies, which may shape how Fundamental Movement Skills (FMS) are integrated into early childhood programs (Barnett et al. 2019). Additionally, cultural attitudes toward structured and unstructured play, as well as differing priorities in physical education, could contribute to regional differences in FMS development. Expanded early childhood education programs in several countries may further account for the variation in educational approaches across region (Pascal, Bertram, and Veisson 2018). Given these differences, policymakers should consider successful models from different countries when designing early childhood motor skill programs. Countries that integrate structured physical activity into the preschool curriculum have shown better FMS outcomes (Haugland et al. 2023). Strategies such as mandatory teacher training in motor skill instruction, financial support for infrastructure, and regulatory policies promoting structured active play could be essential for improving FMS development across diverse educational systems (Logan et al. 2012).

A comparative study found that the United States leads in Fundamental Motor Skills (FMS) development over China and Portugal, highlighting the need for early interventions to promote healthy child development. China shows superior FMS proficiency among 9-10-year-olds compared to England, while recent curriculum changes in the United States have led to a decline in FMS proficiency since the 1990s. These findings emphasize the importance of adapting educational approaches across different geographical contexts (Dos Santos et al. 2016; Brian et al. 2018; Ma et al. 2022). Given these differences, the world region was considered an effect modifier, as cultural and environmental factors may influence motor skill development and intervention efficacy. Similarly, recess was analyzed as a moderator due to its role as an opportunity for unstructured physical activity, which could either complement or compete with structured interventions (Venetsanou and Kambas 2010; Derikx et al. 2021; Parrish et al. 2013). Expanding the understanding of these contextual factors is essential to designing more effective FMS interventions tailored to specific educational settings (Chan et al. 2022; Bourke et al. 2024).

Recent research indicates high sedentary behavior in preschoolers, mostly during sedentary activities in preschool settings (Crane, Naylor, and Temple 2018). Encouraging a shift in physical activity promotion in preschools is crucial for improving fundamental motor skills (FMS). Kindergarten environmental factors, like space, equipment access, and teaching methods, significantly influence children's health and fitness (Qingguang and Huishan). However, teacher limitations in organizing activities pose challenges, leading to unguided play with minimal FMS impact (Parker, Thomsen, and Berry 2022). To address this, policies should establish clear guidelines for structured play sessions during school hours, ensuring that preschools dedicate time to guided physical activities that maximize motor engagement (Truelove, Vanderloo, and Tucker 2017).

It has been demonstrated how activities during recess can contribute to meeting the minimum daily physical activity recommendations. However, the motor engagement time during recess may not reach 50% of the effective recess time (Ridgers, Stratton, and Fairclough 2005). It is therefore recommended for preschoolers to have a physically active recess period (Frank et al. 2018). This same author found that when a structured intervention was used, preschoolers showed better outcomes compared to the group that engaged in their usual daily activity. Considering this evidence and the results yielded by this meta-analysis, it could be hypothesized that when a structured motor skills intervention is applied, preschoolers may have better results on FMS compared with routine activities of this population. Consequently, policymakers should implement guidelines that ensure preschools incorporate structured recess interventions to maximize physical activity and motor skill benefits (Ridgers et al. 2007; Frank et al. 2018).

Active play has been suggested as a way to improve FMS and increase physical activity levels in preschool and school-age children (Adamo et al. 2016; Johnstone et al. 2018). It is important for active play interventions to prioritize maintaining high levels of physical activity and to provide learning opportunities for motor skills practice (Adamo et al. 2016; Truelove, Vanderloo, and Tucker 2017). It can therefore be determined that motor skills-based active play is more effective than alternative interventions for promotion of physical activity levels and improvements in FMS.

### ***Strengths and limitations***

There are several key strengths to our study. Firstly, it significantly contributes to literature by examining active interventions' effects on Fundamental Motor Skills (FMS) in preschoolers. Secondly, it benefits from a sizable sample size, ensuring adequate statistical power. Thirdly, evidence-based effect modifiers help explain between-study heterogeneity, enhancing reliability and generalizability. Fourthly, state-of-the-art meta-analytical techniques, like Bayesian meta-analysis, ensure rigorous and accurate data analysis. Lastly, our methodology identifies the most effective intervention for enhancing FMS during recess, offering valuable guidance for future interventions.

Our study is not without limitations. Firstly, findings are only applicable to interventions within educational contexts, limiting generalizability. Additionally, intervention protocols showed high heterogeneity. Although we conducted moderation effects analysis, the classification of the interventions included in this meta-analysis yielded some degree of heterogeneity. As we grouped the active interventions under the broad category of "active play," the parameters of the interventions (e.g., duration, specific exercises) varied considerably. Therefore, we consider that the certainty of the evidence may decrease. Secondly, the lack of data on various physical activity interventions for specific effect modifiers hinders comprehensive analysis. Family behavior modifications may have influenced outcomes, but data were not recorded. Potential bias resulting from GRADE criteria application exists, despite sensitivity analysis excluding high-risk bias studies.

Moreover, the potential for **publication bias** should be considered, as studies with positive or significant results are more likely to be published, which could have impacted the overall findings. Furthermore, **intervention fidelity** is another concern. The variability in how interventions were implemented across studies (e.g., differences in the execution of the "active play" protocols) may have influenced the outcomes. A more detailed exploration of these factors could provide a clearer understanding of the true effectiveness of the interventions.

## Conclusion

This meta-analysis synthesized the evidence on the effectiveness of active play interventions on FMS in preschool-aged children and provides key information about the most effective type of intervention and potential effect modifiers. Active play interventions were associated with FMS improvements, and specifically, motor skills-based interventions included during recess presented the greatest effects. The effectiveness of these interventions varied across world regions and whether the interventions were included during recess in an educational context.

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**Contributors**

JR-M, FAB and JdP- C conceptualised the study. JR-M, FAB, JdP- C and BdPC drafted the manuscript. JR-M and DG-G conducted the formal statistical analyses. JR-M, DG-G and FAB acquired the data. All authors revised the manuscript and provided critical input. JR-M and JdP-C have full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. JR-M and JdP-C are the guarantors. The corresponding author (JdP-C) attests that all listed authors meet authorship criteria and that no others meeting the criteria have been omitted.

**Competing interests**

None declared.

**Patient consent for publication**

Not applicable.

**Ethics approval**

Not applicable.

**Data availability statement**

Datasets are available in a public, open access repository. All data relevant to the study are included in the article or made available through a public repository (https://github.com/dgalgom/Preschoolers.git).

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**FIGURES**

Figure 1. PRISMA flow diagram of study selection.

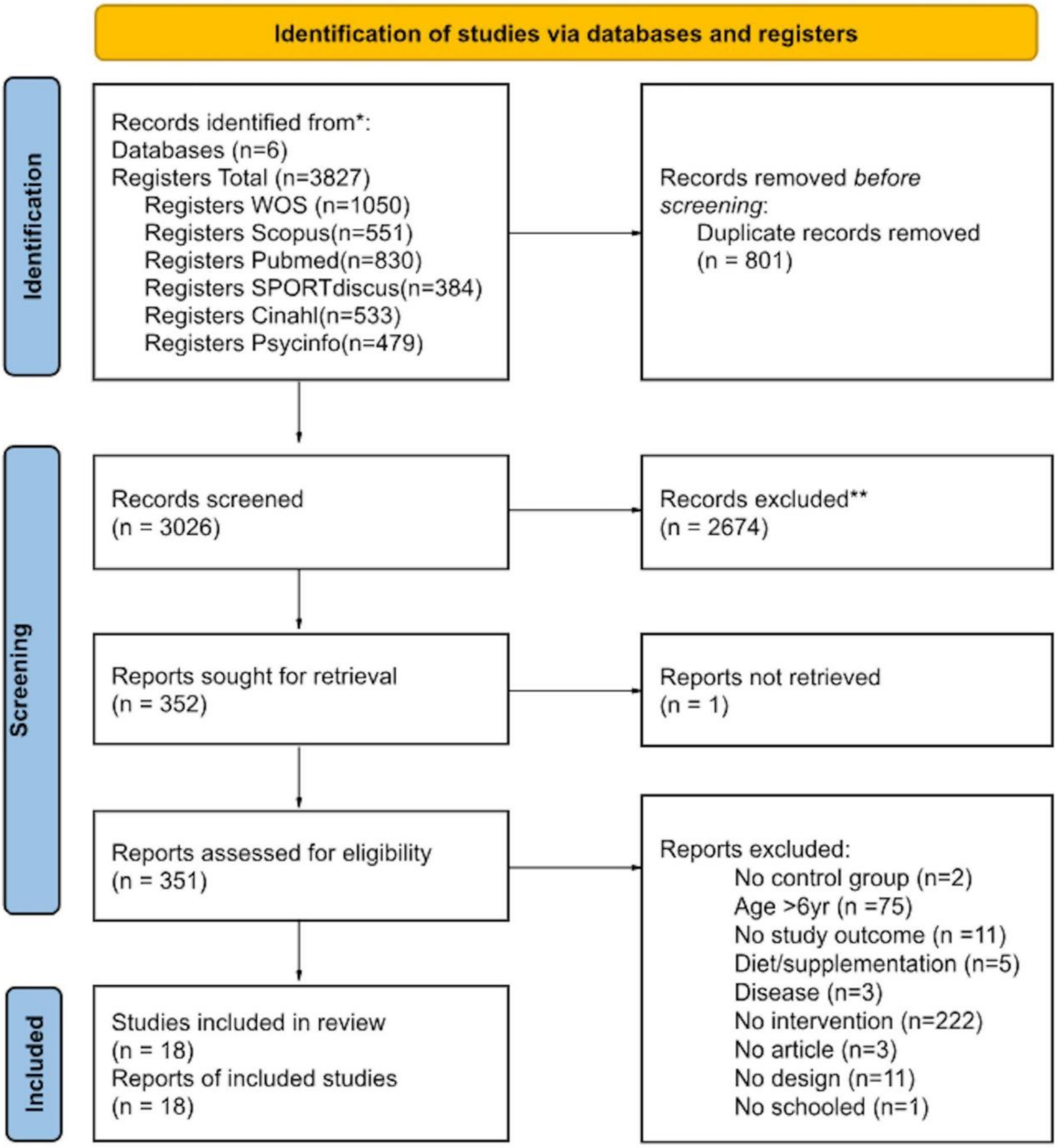

Figure 2. Predicted response of the included interventions at intervention-specific level.

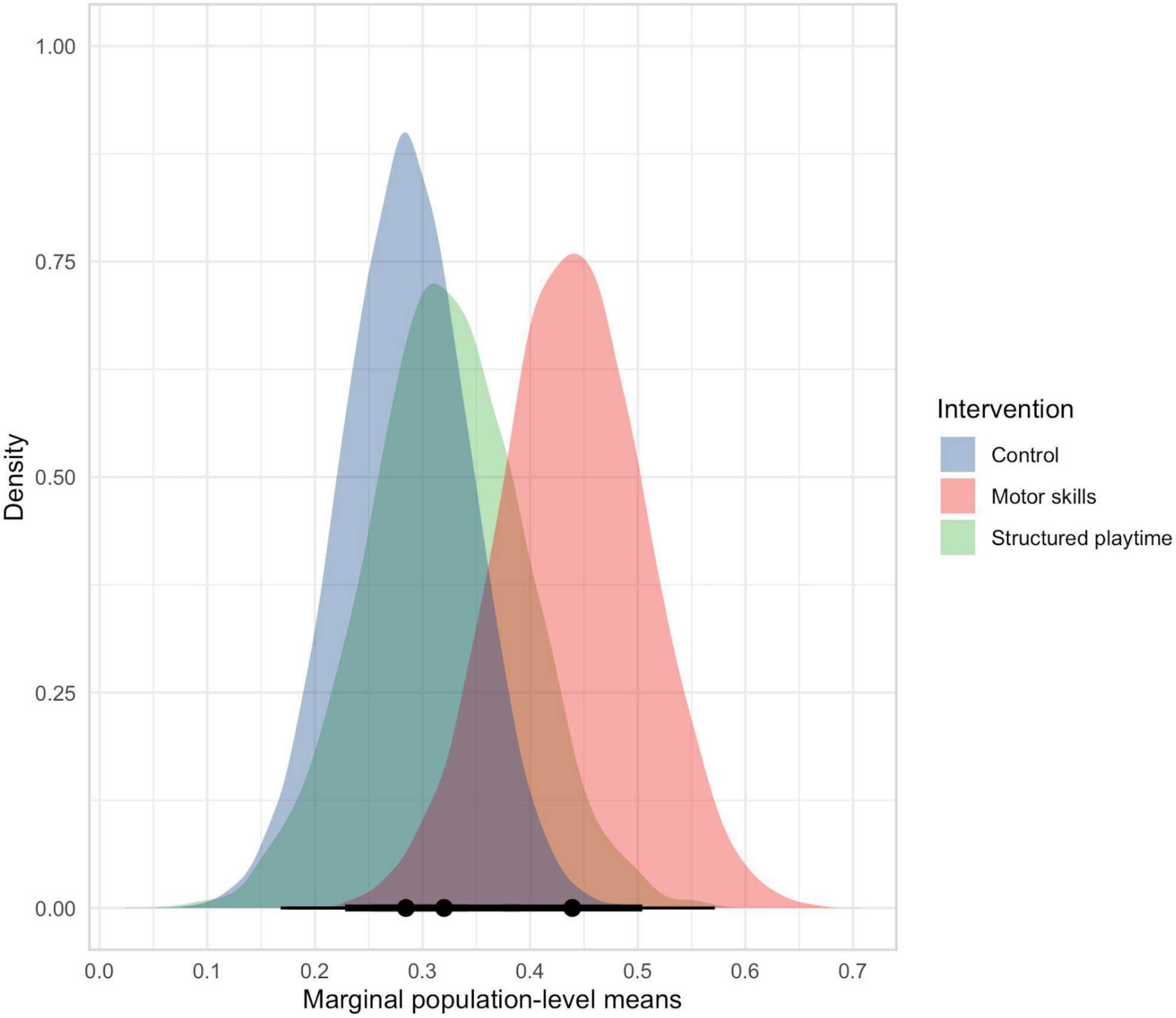

Figure 3. Heterogeneity of the included interventions at intervention-specific level.

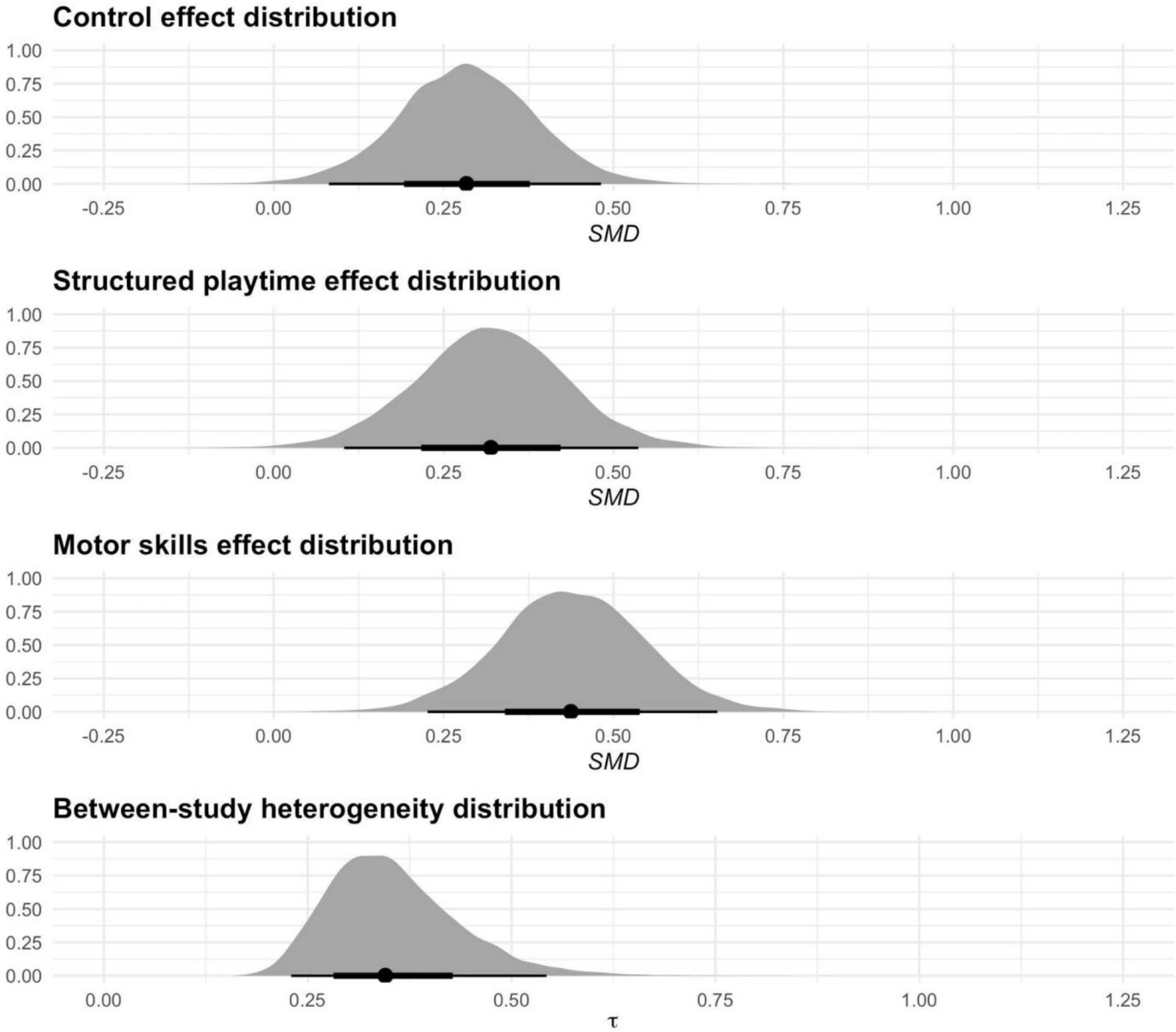

Figure 4. Predicted response referred to motor skills vs. control and structured playtime vs.

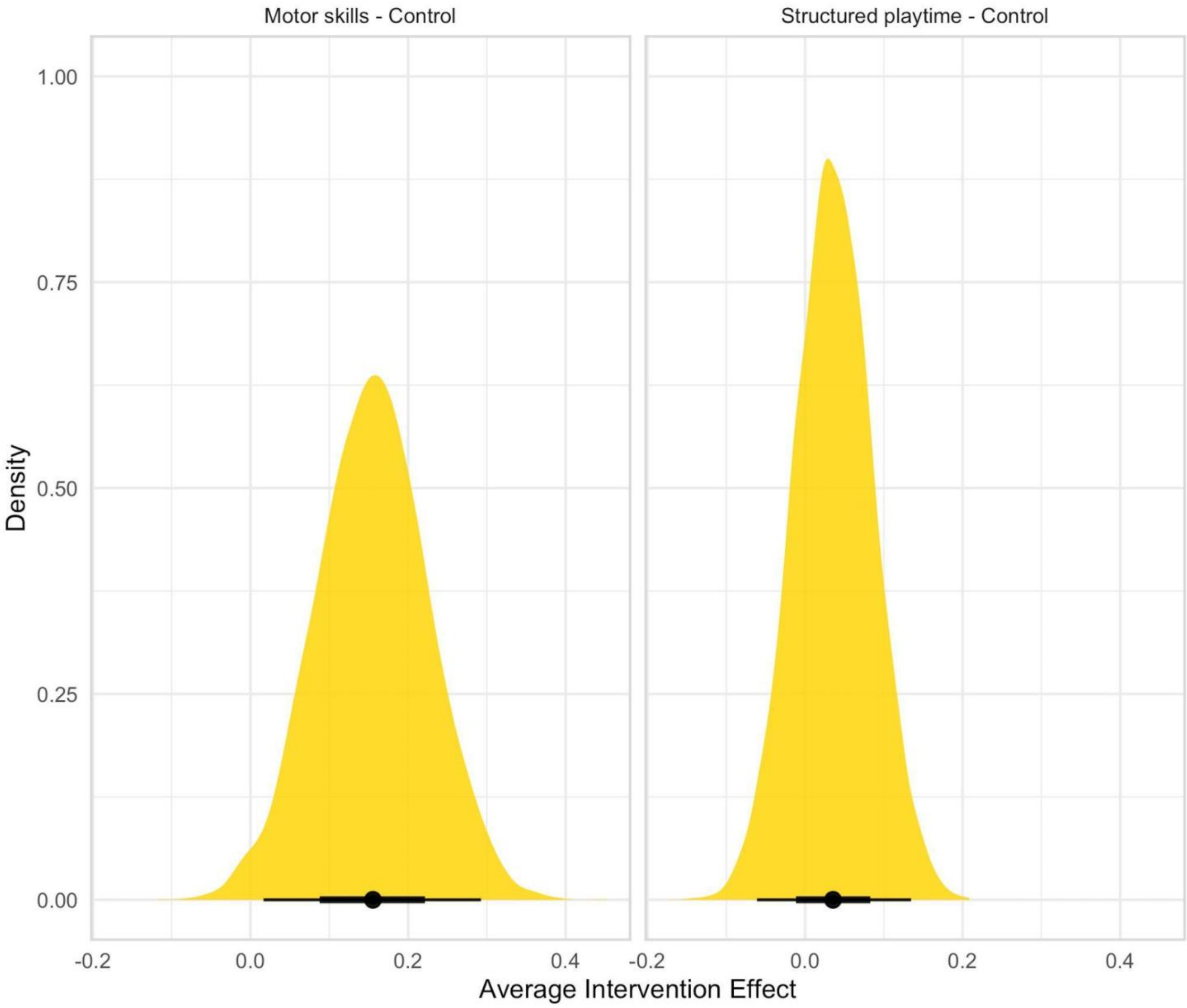

Figure 5. Predicted response of the interventions at intervention-specific level included or not

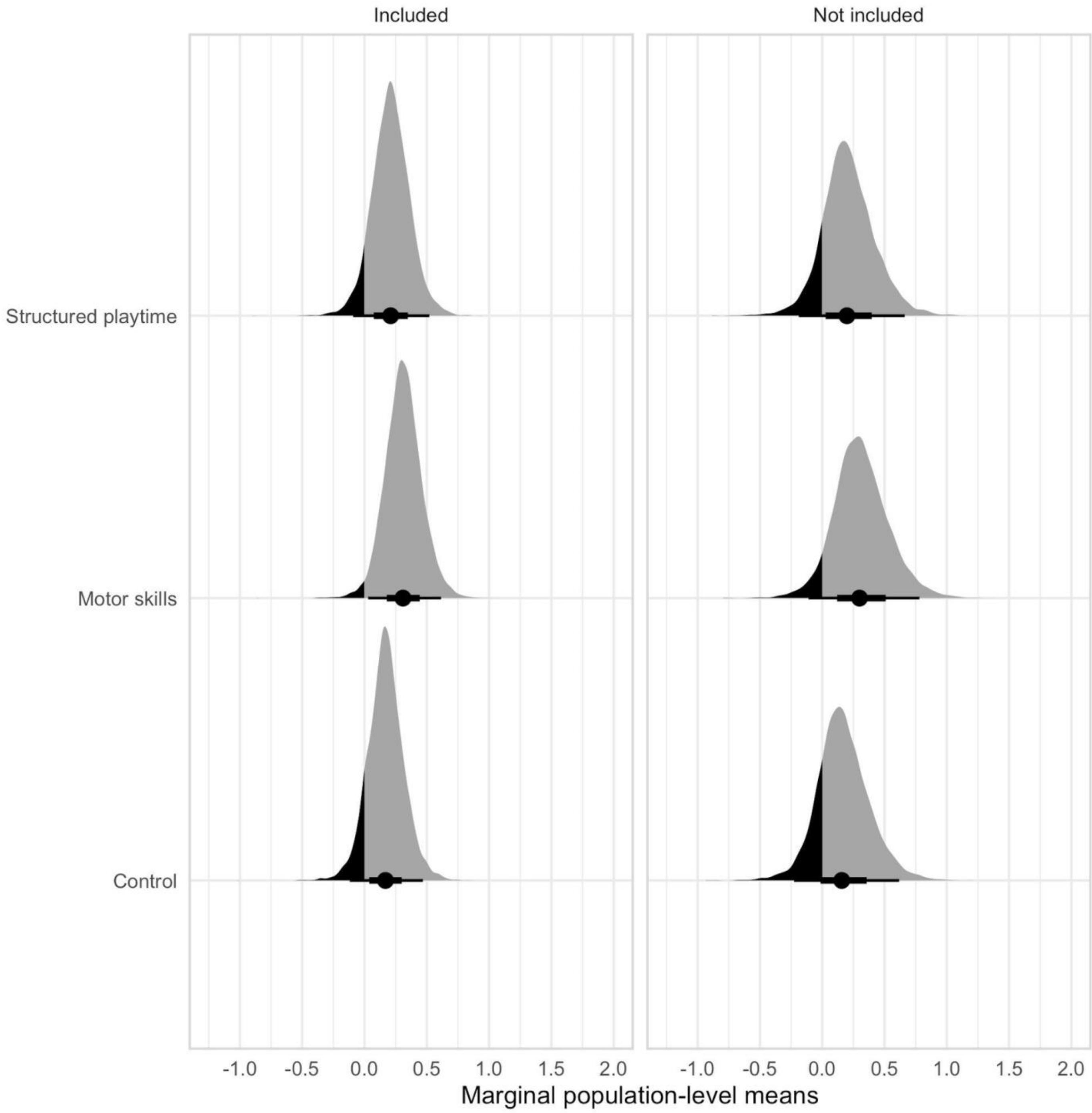

Figure 6. Cochrane Risk of Bias Tool.