Review Paper

Assessment of Gross and Fine Motor Skills in Children With Visual Impairment: A Systematic Review and Meta-analysis

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ABSTRACT

Background: Children with visual impairments often face challenges in developing motor skills compared to their sighted peers. Understanding these differences is crucial for designing effective interventions to support their development.

Objectives: This study aimed to compare the gross (locomotor) and fine (object) motor skills of children with visual impairments to those of sighted children through a comprehensive review and meta-analysis.

Methods: A systematic review and meta-analysis were conducted according to a registered protocol on the international prospective register of systematic reviews (PROSPERO) and in adherence with preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines. Three reliable databases were thoroughly searched for original and peer-reviewed articles. The included studies assessed motor skills using different methodologies, contributing to data heterogeneity. Egger's regression test was used to assess publication bias.

Results: A significant difference was found between low vision and visual groups in locomotor skills (P<0.001, 95% CI, 0.706%, 1.384%). In addition, the pooled analysis for object motor skills indicated a significant difference (P<0.001, 95% CI, 0.727%, 1.488%) among the considered groups. Evidence of publication bias was detected for locomotor skills comparisons (P=0.04). However, no significant publication bias was found for the meta-analysis of object motor skills (P=0.056) among the considered groups.

Conclusions: The results of the meta-analyses showed significant differences in locomotor (gross) and object (fine) control skills between sighted and visually impaired children. A possible explanation for these findings is that children with visual impairments, such as blindness or low vision, are more likely to experience difficulties in motor skills performance, such as locomotor and object control skills. Future studies should examine variables affecting the motor skills of visually impaired children, such as different medical conditions and interventions and some social and psychological factors.

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Introduction

Vision is crucial for navigating the world using environmental information [1]. Lack of visual information confines a child to the space their body inhabits, limiting their ability to explore. Visual information also helps a youngster move better and influences how human motor motions are organized [2]. Basic motor and visual motor skill development may be affected or delayed by an early decline in or absence of inter-sensorial coordination [3]. Children with visual impairments are at risk of weak motor skill performance [4, 5]. They are developmentally behind their sighted peers, which can hinder their ability to learn complicated motor skills and overall motor development [6-9]. According to a common definition, visual impairment, in which an individual's vision is below normal, is defined as having a visual acuity of less than 1/10 following all necessary eye corrections [10, 11]. An estimated 19 million of the world's children are visually impaired, while 1.4 million are blind [12, 13].

Motor skills play a critical role in the life course of individuals [14]. A person's growth and development may be significantly impacted by acquiring fundamental motor skills in childhood [15, 16]. Due to their lack of sensory input, children with limited vision frequently struggle with sensory integration [17]. It has been demonstrated that denying children practice and limiting their opportunities for movement can impair their ability to perform motor skills effectively [18]. Fundamental motor skills, typically divided into locomotor and object control skills, are the foundation for mastering more complex movement patterns, participating in sports, and playing games [19]. Research has demonstrated that children with visual impairments who engage in sports exhibit significantly greater object control skill scores than those who do not participate [4]. Additionally, some studies have reported that children without visual impairments outperformed their classmates regarding locomotor skills [9, 20, 21].

Individuals with visual impairments experience detrimental effects on their motor abilities during their developing period, including posture, flexibility, balance, walking, and limb strength [22]. Children with visual impairments often experience challenges with motor skills. These difficulties can include problems with acquiring a proper gait and maintaining good posture. They may also struggle with spatial orientation and organizing their sense of time. Additionally, coordinating perceptual information and adjusting it to the outside world can be particularly challenging for these children [23]. Studies have analyzed the changes in maintaining an orthostatic posture and the speed of adjusting to different positions [24, 25], postural control [26], manual dexterity [27], normal gait parameters [28] and gross motor skills [4].

Physical health and gross motor abilities are crucial to the daily activities and lives of children with visual impairments [21]. If a child does not acquire proficiency in motor skills, it can impede their capacity to participate in adequate physical activity and maintain aspects of health-related physical fitness [29, 30]; the importance of motor skill proficiency is clear [31]. Different studies have declared that children with low vision and visual impairment have poorer gross motor skills, especially in balance [8], score lower in object control [21] and exhibit weaker writing performance [32, 33].

People with severe visual impairments experience delays in reaching their body's midline, which leads to low body awareness, difficulties with manual tasks, and challenges in manipulating objects with two hands [34]. Some studies have stated that severe visual impairment and lack of visual sensation negatively impact the development of participants' bilateral coordination [34, 35].

In summary, children with visual impairments are more likely to experience various health and motor issues that require different management forms. On one hand, these individuals have critical motor skill vulnerabilities that need to be carefully considered; on the other hand, the difference between gross and fine motor skills is not evident between visually impaired and sighted children. Therefore, we conducted a systematic review and meta-analysis to compare the fine and gross motor skills of children with visual impairments to those of their sighted peers. We applied the population, intervention, comparison, outcomes (PICO) format of questions to screen, choose and review the literature [36].

Methods

This study used the preferred reporting items for systematic reviews and meta-analyses (PRISMA) [37]. The review protocol was also prospectively registered in the international prospective register of systematic reviews (PROSPERO) database (CRD42024546060).

Eligibility criteria

One of the prerequisites for being included in the meta-analysis was having a cross-sectional, case-control, or cohort study design. Participants were children aged

six to twelve, both with and without visual impairment. Exposure and outcome criteria involved research comparing children with visual impairment to their sighted peers regarding motor and gross skills. Studies that relied on qualitative research, interventional studies, or randomized controlled trials (RCTs) were excluded from examination. Furthermore, non-English articles were excluded. Studies that did not compare the motor skills of children with and without visual impairment were also excluded from the analysis.

Search strategy

The search strategy was based on a combination of keywords related to motor skills and visually impaired children utilizing Boolean operators, quotation marks, and truncation to achieve a valid search strategy. The search strategies were conducted for the following databases: PubMed, Web of Science, Scopus and Google Scholar. In general, the following terms were included in searches: "Visually impaired" OR "visual impairment" OR "low vision" OR blind OR "partially sighted" OR blindness) AND ("child" OR child OR "minors" OR "puberty" OR "pediatrics" OR pediatric OR adolescent OR preschool OR "teenager" OR "teenagers" OR "teen" OR "boy" OR "boys" OR "school age" OR "teens" OR "girls" OR "boyhood" OR youth OR "girlhood" OR "girl" OR "school-aged" OR "kid" OR "kids" OR underage OR schoolchild OR juvenile) AND ("motor skill" OR "motor skill competency" OR "motor coordination" OR "motor development" OR "motor function" OR "motor performance" OR "motor abilities" OR "fine motor skill" OR "gross motor skill*" OR "locomotor skill" OR "object control skill".

Selection process

Two authors (Ebrahim Ebrahimi and Mohammad Salsali) separately scanned and selected the articles' titles and abstracts based on the inclusion criteria and PRISMA standard protocol [37]. All human studies and trials published until the end of the search period (February 2024), were included. All searched records were imported into EndNote software, version 20, which was used to remove duplicate articles.

Data collection process

Using a standard Excel data extraction sheet, two researchers (Ebrahim Ebrahimi and Mohammad Salsali) independently extracted the data and compared the findings to assess coherence. The following data were retrieved from the included studies: 1) Study characteristics (e.g. publication year, first author's name, sample size, study design, and variable measurement); 2) Participants' demographic information (i.e. sex and age); 3) Motor skill measurement (e.g. Bruininks-Oseretsky test of motor proficiency [BOTMP]), test of gross motor development-second edition (TGMD-2); 4) Visual impairment acuity (i.e. low vision, blind, sighted, visually impaired, etc.) and 5) Main outcomes (Table 1).

Risk of bias assessment

Two reviewers (Ebrahim Ebrahimi and Mohammad Salsali) utilized the Joanna Briggs Institute (JBI) critical appraisal tools [38] to assess the potential for bias, with the particular tool selected based on the design of each study included in the review (i.e. cross-sectional (n=3) [9, 20, 21] and case-control (n=10) [4, 7, 8, 32-35, 39-41].

Results

Study selection

The search strategy identified 897 studies. After the removal of duplicates, 430 studies remained. Title and abstract screening identified 27 potentially eligible studies. Seventeen of these studies were excluded due to not reporting sufficient data (n=2) or not meeting the inclusion criteria (n=15). Ten original studies met the inclusion criteria. However, 21 additional studies were included by searching Google Scholar, of which 18 were excluded for not meeting the inclusion criteria. As a result, 13 studies were included in the review. Figure 1 depicts the PRISMA flow diagram, showing the number of articles excluded at each stage of the systematic review and meta-analysis.

Study characteristics

Publication dates ranged from 2000 to 2022 (median, 2011), with 53% (7/13) of trials published after 2011. Of the eligible studies, ten were case-control, and three had a cross-sectional design. Among the selected articles, which included 1,145 participants in this systematic review, all conducted comparisons between the two genders, male and female. The ages of the participants ranged from 4 to 13 years. The included studies were conducted in Turkey [7, 33], Poland [35], Netherlands [4, 23, 34], US [9, 41]. Motor skills were measured in different ways, including the BOTMP [35], test of gross motor development-second/third edition [20, 41], Kinesthesia test [33], movement assessment battery for children [34], GT1M ActiGraph [23], Eurofit test battery [21], Jebsen hand function test [32], Lovett's manual muscle strength measurement [40].

Table 1. Characteristics of the included articles

Author	Participants	Sex	Variables	Tools	Study Design	Main Outcome
Bouchard et al. 2000 [8]	60 children (30 sighted-30 low vision) aged 8-13 years	Both gender	Gross motor skills, fine motor skills, and upper-limb coordination	BOTMP	Case-control	The motor skills of children with low vision were weaker than those of sighted children. In addition, the children with low vision had weaker motor skills, particularly in balance.
Houwen et al. 2007 [4]	20 visually impaired children and 100 sighted children	11 visually impaired boys and 9 visually impaired girls	Locomotor (run, gallop, hop, leap, jump and slide) and object control (catch, kick, overhand throw and underhand roll).	TGMD-2	Case-control	Children with visual impairments that participated in activities had dramatically stronger object control skill scores than those who did not.
Aki et al. 2008 [33]	20 students with low vision and 20 sighted children	9 girls and 11 boys	Accuracy of moving a finger from one point to another point	Kinesthesia test	Case-control	The students with low vision had a lower average score, taking more time to write the sentence than sighted students.
Houwen et al. 2008 [34]	25 children with VI and 25 children without VI	32 males and 16 females	Motor performance	Movement assessment battery for children	Case-control	Visually impaired children showed the weakest performance compared with sighted ones.
Houwen et al. 2008 [42]	48 children with V visual impairment I and 48 children without visual impairment	32 males and 16 females	Gross motor skills and physical activity	Test of gross motor development-2 and GT1M ActiGraph	Case-control	Children with visual impairment indicated lower gross motor skills. Performance than sighted peers.
Houwen et al. 2009 [21]	120 children (60 sighted and 60 visually impaired)	40 males and 20 females	Gross motor skills and physical fitness	TGMD-2 and eurofit test battery	Cross-sectional	Children who were visually impaired showed weaker gross motor skills than their peers.
Uysal et al. 2011 [7]	30 children with low vision, 30 totally blind children and 30 children with normal sight	Combination of girls and boys	Gross motor skills, balance and bilateral coordination	BOTMP and standing on one leg	Case-control	There was a growing gap between different visual acuity levels in the development of motor skills.
Uysal et al. 2012 [32]	42 students with low vision and 26 normal-sighted students	25 boys and 17 girls	Writing speed and legibility and Visual-motor ability	Jebsen hand function test and Bruininks-Oseretsky motor proficiency test	Case-control	Those with visual impairments have poorer handwriting performance, weaker legibility and weaker writing speed.
Wagner et al. 2013 [9]	23 children with visual impairment and 28 sighted children	9 girls and 14 boys with visual impairment	Motor skill performance (locomotor and object control)	TGMD-2	Cross-sectional	All the locomotor and object control skills assessed are significantly worse for blind children.
Haibach et al. 2014 [40]	100 children with visual impairments	61 boys and 39 girls	Motor skill performance (locomotor and object control)	TGMD-2	Case-control	There is no difference in the performance of children with different visual acuities, but those who are at the B1 level performed weakly.
Rutkowska et al. 2016 [35]	75 individuals	40 girls and 35 boys	Motor skills and bilateral coordination	BOTMP	Case-control	Serious visual impairment and a lack of sensation negatively affected participants' development in bilateral coordination.

Author	Participants	Sex	Variables	Tools	Study Design	Main Outcome
Brian et al. 2019 [20]	15 sighted children and 10 children with visual impairment	12 boys and 13 girls	Locomotor skills and ball skills	TGMD-3	Cross-sectional	Children without visual impairment appeared to have the most elevated fundamental motor skills levels compared with those with visual impairment. Children with visual impairment showed significant formative delays.
Kurtoğlu et al. 2022 [39]	250 participants aged 10-19 years	161 females and 89 males	Balance, sitting reach, standing long jump, vertical jump, and hand-grip strength	Lovett's manual muscle strength measurement and eurofit test battery	Case-control	The degree of vision has a significant influence on both physical and motor development. As far as physical and motor characteristics are concerned, individuals with total visual impairment develop slower than learners with visual impairments.

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Abbreviations: BOTMP: Bruininks-Oseretsky test of motor proficiency; TGMD-2: Test of gross motor development-second edition; TGMD-3: Test of gross motor development-third edition.

Risk of bias

The specific JBI tool was applied according to study design (i.e. cross-sectional (n=3) [9, 20, 21] and case-control (n=10) [4, 7, 8, 23, 32-35, 40]. It is worth noting that all of the cross-sectional studies could not find any confounding factors in their analysis and, therefore, did not apply strategies to deal with these factors. However, inclusion and exclusion criteria were clearly defined in their works. In addition, exposure and outcome measurement were assessed in a valid and reliable way. For the 70% of case-control studies, exposure measurement was not evaluated reliably or consistently. Furthermore, only one study had an exposure period of interest that was long enough to be meaningful; other studies did not report any information regarding this issue. More-

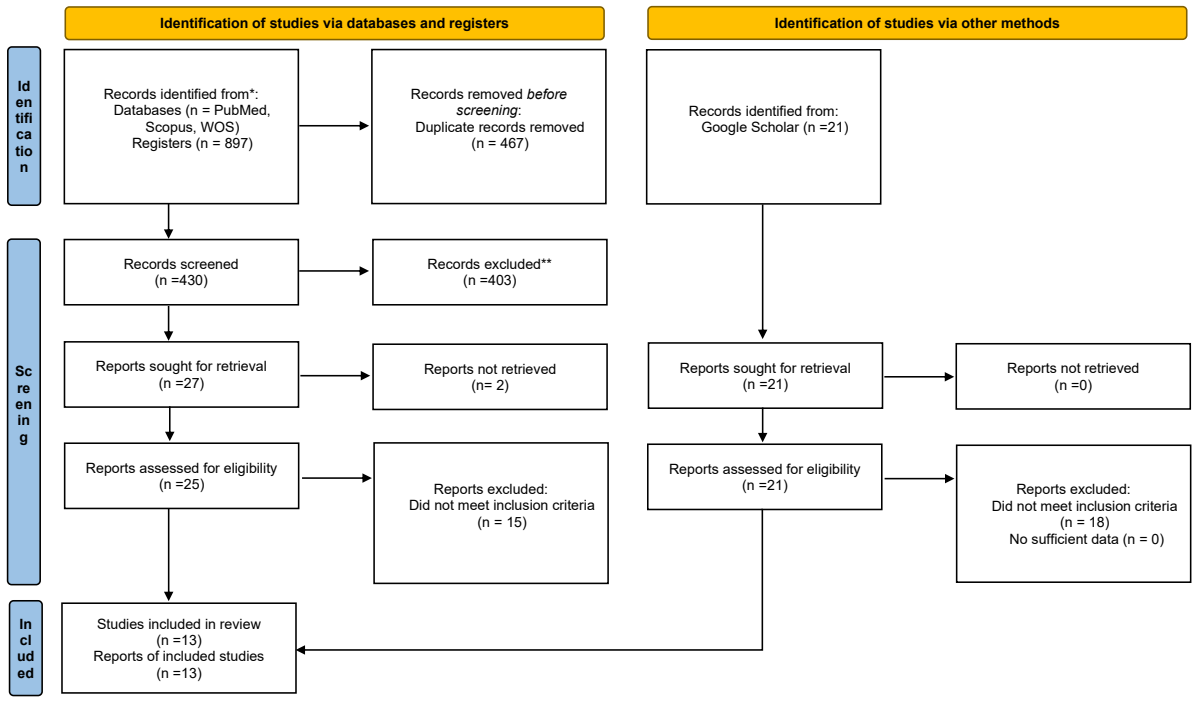

Figure 1. Flow diagram for eligible studies

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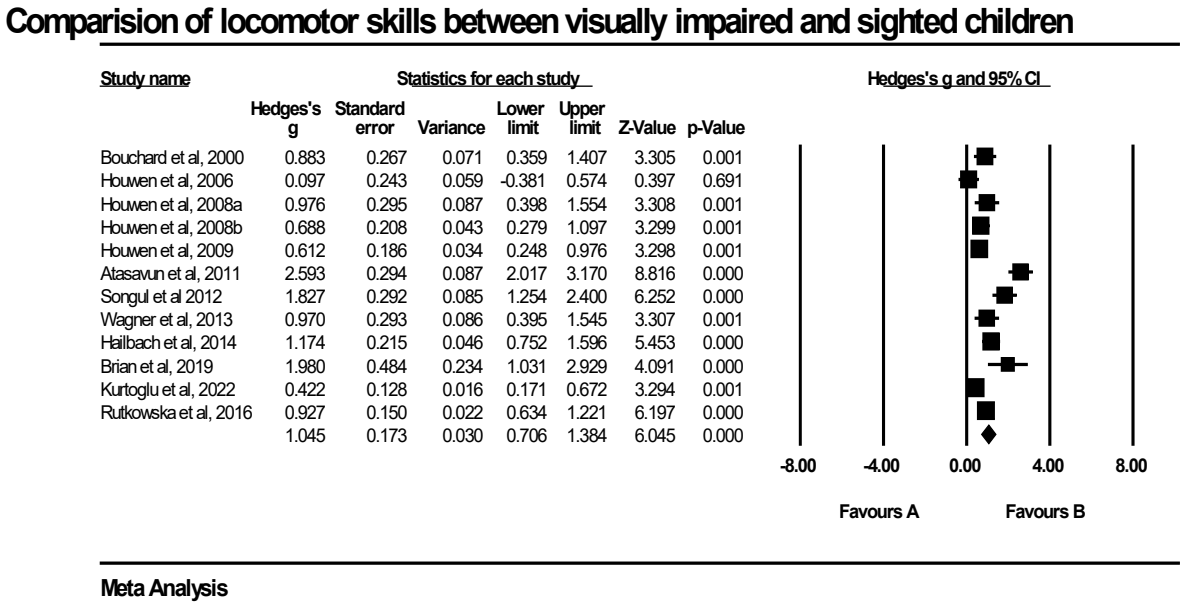

Figure 2. Forest plot comparing locomotor skills between visually impaired and sighted children *Journal of Pediatrics Review*

over, 60% of the studies did not find any confounding factors or strategies to address them. Online supplemental tables contain detailed information on the risk of bias in each study (Supplementary Tables 1 and 2).

Description of the selected variables

Six studies examined the locomotor and object control skills of visually impaired and sighted children. Five studies used the TGMD-2 [4, 9, 21, 23, 41] and one study used TGMD-3 [20] to assess the locomotor and fine motor skills. Furthermore, four studies evaluated gross and fine motor skills using the BOTMP [7, 8, 32, 35]. Also, one study evaluated motor performance using the movement assessment battery for children [34], one study used the Kinesthesia Test for the accuracy of moving a finger from one point to another [33] and finally, one study assessed balance, sitting reach, standing long jump, vertical jump, and handgrip strength using Lovett's manual muscle strength measurement and Eurofit test battery [40]. We reported the findings from the JBI tool used to evaluate the validity and reliability of gross motor and fine motor assessments.

Data analysis

Locomotor skills were evaluated in three studies in several ways [8, 23, 40]. They conducted an analysis of different aspects of locomotion within the same population. Thus, we were able to perform a fixed model meta-analysis for these studies, which was then incorporated into the main analysis. Also, two studies [7, 41] compared motor skills among three groups: Vision, low vision, and blind. However, since we intended to conduct a meta-analysis between the sighted and low-vision groups, we performed another fixed model meta-analysis for these studies to inform our main analysis.

Locomotor

Twelve studies [4, 7-9, 20, 21, 23, 32-35, 40] compared locomotor (gross) motor skills between low vision and sighted groups. The total number of participants in these studies was 1244. Before conducting the main analysis, we used fixed model meta-analysis to aggregate the data from a study that examined several aspects of locomotor motor skills separately. We obtained an overall comparison from these data. The forest plot (Figure 2) shows a significant difference between low vision and sighted groups ($P<0.001$, 95% CI, 0.706%, 1.384%). The majority of these studies reported a significant difference between the groups considered. However, in some studies, this difference was not observed. The results revealed that heterogeneity was significant after accounting for it ($P<0.001$; $I^2=85.837$). Egger's regression test found significant evidence of publication bias ($P=0.040$). This implies that the tendency for studies with significant results to be more likely published may impact the findings of the meta-analysis. The trim and fill method was used to assess the possible effect of future studies on the research results. The results indicated that adding five randomly hypothetical studies to

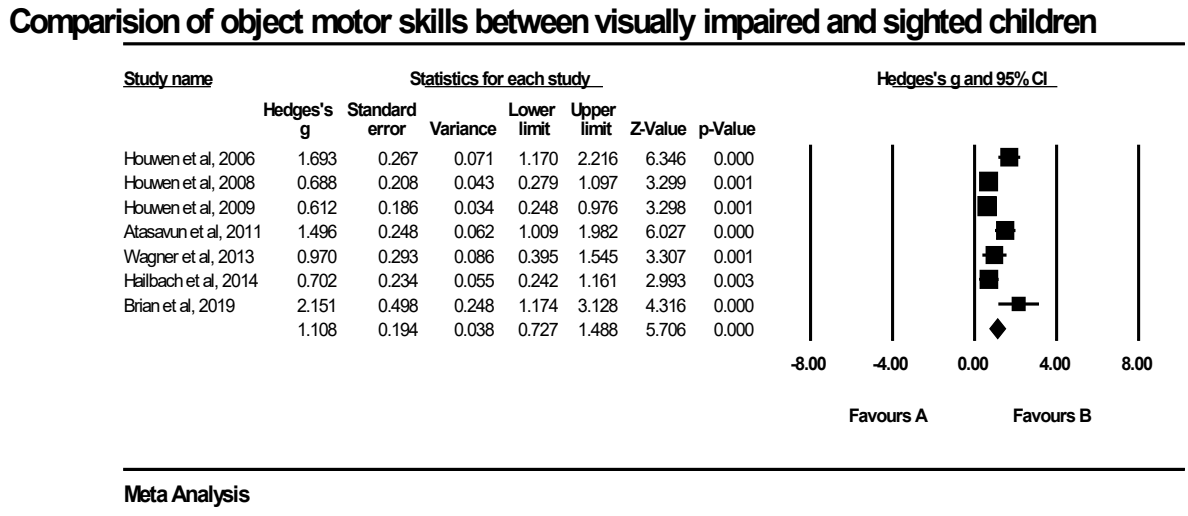

Figure 4. Forest plot comparing object skills between visually impaired and sighted children

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the left side of the graph could change the meta-analysis results. Therefore, it seems that the publication bias affected the results of these studies (Figure 3).

Object

Seven studies [4, 7, 9, 20, 21, 40, 41] compared low vision and sighted groups in object (fine) motor skills. The total number of participants in these studies was 602. Before conducting the main analysis, we used fixed model meta-analysis to aggregate the data from a study that examined several aspects of object motor skills separately. Eventually, as Figure 4 indicates, the pooled analysis of studies was one (P<0.001, 95% CI, 0.727%, 1.488%) Analysis of the data from these stud-

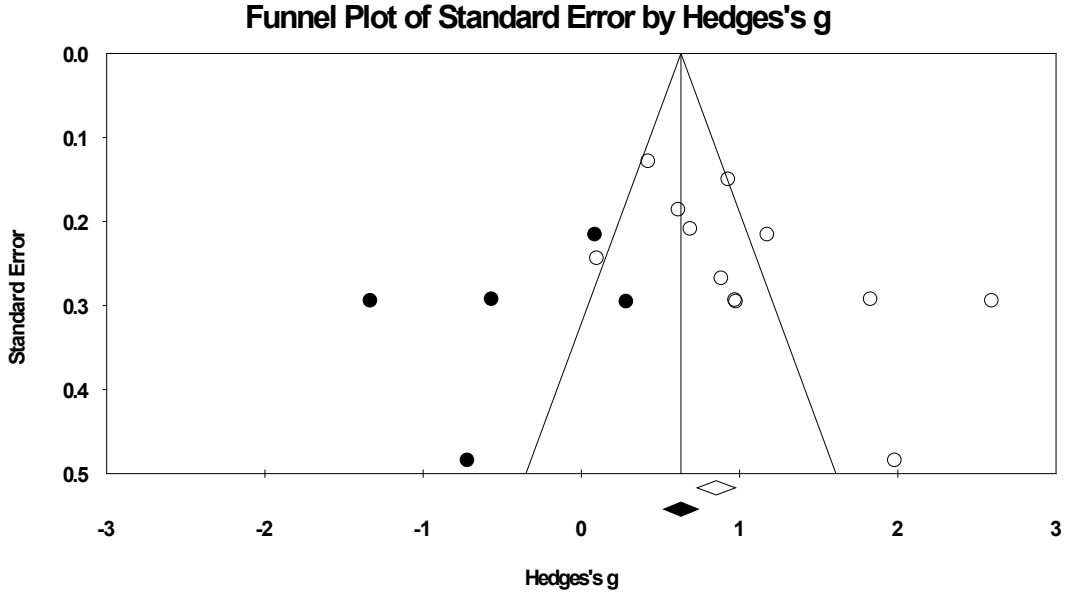

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Figure 3. Funnel plot of comparison between visually impaired and sighted children for locomotor skills

Notes: Funnel plot assessing the presence of publication bias in a meta-analysis comparing locomotor skills between visually impaired and sighted children. The white circles represent the studies that were actually observed, while the grey circles represent the studies that were imputed.

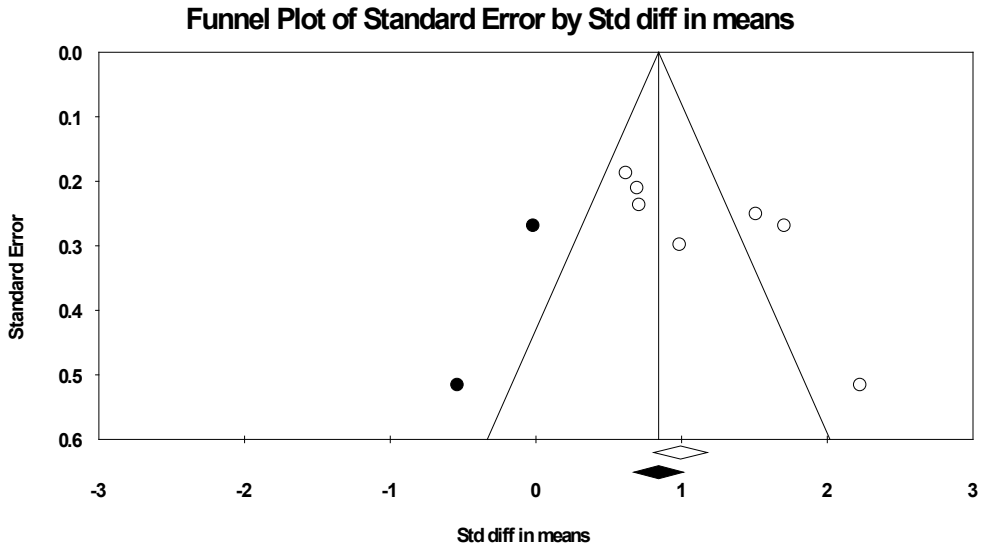

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Figure 5. Funnel plot of comparison between visually impaired and sighted children for object skills

Note: Funnel plot assessing the presence of publication bias in a meta-analysis comparing object skills between visually impaired and sighted children. The white circles represent the studies that were actually observed, while the grey circles represent the studies that were imputed.

ies, as shown in the forest plot, revealed a significant difference between the low vision and sighted groups in object motor skills. After examining the heterogeneity, the results showed that it was significant (P<0.001; I^2=75.287). Egger's regression test indicated no publication bias among the eligible studies (P=0.056). This suggests that the results of this meta-analysis may be influenced by the tendency for smaller studies with larger effects to be published more frequently. The trim and fill method was used to check the possible effect of future studies on the research results. The results showed that adding two randomly hypothetical studies to the left side of the graph may not change the meta-analysis results. Therefore, it seems that the publication bias had no effect on the results of these studies (Figure 5).

Discussion

This is the first study to review and analyze the motor skills of children with visual impairment and their sighted peers. The results of the meta-analyses demonstrated significant differences in locomotor (gross) and object (fine) control skills between sighted children and those with visual impairments. According to our results, some studies have indicated that the development of motor skills in children with visual impairment should be effectively monitored from early childhood [21, 39]. These studies suggest that delays in the motor characteristics of visually impaired children may primarily be attributed to a lack of sufficient support for their motor development [23]. One study declared that participation in sports can significantly support the development of motor skills in children with visual impairment, demonstrating that those who participated in sports achieved significantly higher scores in object and locomotor skills compared to those who did not participate [4]. Since people primarily interact with their environment through their sense of sight, any early deficiencies in inter-sensory coordination can potentially hinder the development of their fundamental skills [42]. Children with visual impairment experience delays in the development of their motor skills; for instance, visually impaired children achieved crawling or creeping skills approximately two months later than their sighted peers [8]. In addition, a child's level of motor skills indirectly reflects his/her development of neuromuscular coordination, as elaborated in a study showing that vision loss negatively affects the development of participants' bilateral coordination [35]. Fundamental motor skills, which are divided into locomotor and object control skills, are affected by visual impairment [20]. Some studies have shown that children with visual impairments experience notable challenges in their locomotor and object control skills, especially compared to their sighted peers [7, 41]. In a study that compared locomotor and object control skills in children with and without visual impairment, it was found that children with visual

impairment showed significantly lower locomotor and object control skills than children without visual impairment. Additionally, children without VI did not demonstrate a developmental delay, while children with VI did show developmental delays [20]. Also, it was found that visual severity significantly affected the performance of all assessed motor skills, such as locomotor and object control skills [9, 43]. For instance, some studies have declared that children at the B1 level demonstrated noticeably lower proficiency in motor skills compared to the children at the B2 or B3 levels. Across almost all motor skills examined, the B1 group's performance was significantly inferior to that of the other groups. [4, 40, 44].

Children with low vision often experience difficulties with sensory integration due to their limited sensory input [45]. This lack of kinesthetic information or sensory input hinders their development, resulting in inadequate object skills, such as writing [17]. Some research has demonstrated that students with low vision have poorer handwriting performance compared to their peers without visual impairment, particularly because their legibility is lower and their writing speeds are slower [32, 33]. This issue is interpreted as arising from sensorimotor, perceptual, and cognitive problems encountered by children with low vision.

Limited access to physical movement and a lack of opportunities for physical activity have been proven to hinder children's ability to perform motor skills effectively [18]. In another study, it was found that children with visual impairments engage in sedentary activities for the majority of their waking hours, and their overall physical activity levels are significantly lower compared to peers without visual impairments, which is associated with lower levels of locomotor and object control skills [41]. In contrast, it has been suggested that children with visual impairments do not necessarily have poor motor performance overall; rather, the specific task at hand influences their performance. Research has demonstrated that children with visual impairments exhibit the lowest performance compared to their peers without visual impairments in different locomotor and object control skills [34].

Conclusion

The results of the meta-analyses showed significant differences in locomotor (gross) and object (fine) control skills between sighted and visually impaired children. A possible explanation for these findings is that children with visual impairments, such as blindness or low vision, are more likely to experience difficulties in motor skills performance, such as locomotor and object control skills. Future studies should examine variables affecting the motor skills of children with visual impairments, such as different medical conditions, interventions, and various social and psychological factors.

Strengths and limitations

A strength of the current investigation is that it included a wide range of representative variables from various original and peer-reviewed articles. Additionally, to our knowledge, this is the first comprehensive review with a meta-analysis summarizing the comparison of gross (locomotor) and fine (object) motor skills in children with visual impairment and their sighted peers. We conducted a meta-analysis and compiled the pooled comparison of gross and fine motor skills in the included outcomes, despite the fact that some outcomes were not consistently assessed across the studies. We adhered to a protocol registered on PROSPERO and conducted this systematic review in accordance with PRISMA recommendations. We performed thorough searches across seven reliable databases.

There are several limitations to our study. First, we only considered original publications in English-language peer-reviewed journals and did not include other scientific literature, like books, conference proceedings, and textbook chapters. Expanding the range of academic sources and including publications in different languages would be beneficial in future research. Additionally, there were not enough studies to compare the disorders between sighted and visually impaired children, and there was insufficient research to evaluate how the level of blindness can affect fundamental skills such as locomotor and object control. Furthermore, the use of different tools and methodologies across studies may have contributed to data heterogeneity. Lastly, there was evidence of publication bias, indicating a need for more precise studies in future research.

Ethical Considerations

Compliance with ethical guidelines

There were no ethical considerations to be considered in this research.

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Authors contributions

Study design and data collection: Ebrahim Ebrahimi, Mohammad Salsali and Rahman Sheikhhoseini; Writing and final approval: All authors.

Conflicts of interest

The authors declared no conflicts of interests.

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Supplementary Table 1. Risk of bias included case control study

Study	1	2	3	4	5	6	7	8	9	10	Overall Score
Bouchard et al. 2000 [8]	Y	Y	N	N	N	N	N	Y	N	Y	4
Kurtoğlu et al. 2022 [39]	Y	Y	N	N	N	Y	N	Y	N	Y	5
Houwen et al. 2007 [4]	Y	Y	N	N	N	N	N	Y	N	Y	5
Rutkowska et al. 2016 [35]	Y	Y	Y	N	N	Y	Y	Y	N	Y	7
Uysal et al. 2011 [7]	Y	Y	N	Y	Y	N	N	Y	Y	Y	7
Haibach et al. 2014) [40]	Y	Y	N	Y	Y	Y	Y	Y	N	Y	8
Aki et al. 2008 [33]	Y	Y	Y	N	N	N	N	Y	N	Y	5
Uysal et al. 2012 [32]	Y	Y	Y	Y	Y	N	N	Y	N	Y	7
Houwen et al. 2008 [34]	Y	Y	Y	N	N	Y	Y	Y	N	Y	7
Houwen et al. 2007 [4]			Y	N	N	N	N	Y	N	Y	5

Supplementary Table 2. Risk of bias included cross-sectional studies

Study	1	2	3	4	5	6	7	8	Overall Score
Houwen et al. 2009 [21]	Y	Y	Y	NA	N	N	Y	Y	5
Wagner et al. 2013 [9]	Y	Y	Y	NA	N	N	Y	Y	4
Brian et al. 2019 [20]	Y	Y	Y	NA	N	N	Y	Y	5