Assessment of Motor Skills in Children With Visual Impairment: A Systematic and Integrative Review

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ABSTRACT: This study aimed to review and examine the tools used to assess psychomotor performance of children with visual impairment. Databases, such as SCOPUS, MEDLINE/PubMed, Medline/EBSCO, Web of Science, LILACS, CINAHL, and ScienceDirect, were searched using Mesh terms. Data from manuscripts fully available in these databases between 1994 and 2017 (except CINAHL—2014) concerning the evaluation, tool development, or intervention for the improvement of motor skills in children (age, 7-10 years) with visual impairment were collected. The Critical Review Form—Quantitative Studies was used to evaluate the quality of the articles. As a result, 1113 articles were found, but only 24 met the inclusion criteria; 66.7% of the articles had moderate quality, with unsatisfactory results regarding the validity and reliability of the tools used to assess these children, as well as the absence of clinical importance and practical application in such studies. Only the Test of Gross Motor Development-2 and Movement Assessment Battery for Children-2 described data on the validation and reliability in visually impaired children. To minimize systematic errors and improve the quality of the investigations, increasing the number of studies regarding the tools, functionality of their activities, and testing the adaptions is necessary.

KEYWORDS: Methods, data collection, psychomotor performance

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Introduction

Visual information serves as a stimulus for a child to move and as a feedback through which a child learns to correct and improve his or her movement. The perception of visual stimuli affects the organization of human motor actions, and its absence constrains the child to the space that his or her body occupies, restricting his or her exploration to the area closer to him or her and to the objects in which the child is in direct contact.[1]

Thus, motor development in children with visual impairment is expected to be different from that in typically developing peers.[2] All movements, especially those involving limb coordination-dexterity and visual motor control, may be modified by the reduced visual stimuli.[3] In addition, other factors can interfere in their development, such as intellectual and cognitive skills, presence of other disorders, and home and learning environments.[4]

Some motor skill difficulties found in children with visual impairment include difficulties in gait acquisition and postural problems; changes in spatial orientation and temporal structuring; difficulty in coordinating perceptual information and its adjustment to external reality; problems in the perception of the surroundings; delay in the construction of the corporal scheme and in the acquisition of functional habits, such as dressing and eating.[5] In addition, studies have discussed changes in the maintenance of orthostatic posture and the speed of postural adjustment,[6,7] postural control,[8] manual dexterity,[9,10] normal gait parameters,[11,12] and gross motor skills.[10,13] In some studies, poor motor performance in children with visual impairment is related to vision, but not to the severity of the disability. These studies showed that modifications in the environmental and task contexts are important to optimize motor performance.[14,15] Adaptations include extra time, stable environments, and use of sensory cues (visual and auditory).[15] However, there is no consensus regarding this association between the level of visual impairment and motor performance, and only some authors acknowledge the existence of this relationship.[10,12,16]

Studies have shown that the motor performance of children with visual impairment can be improved by engaging in specific activity programs.[3,17–20] Hence, early identification of motor problems is crucial because inadequate performance can result in long-term consequences.[21,22] Thus, reliable instruments are essential for professionals to identify children with motor deficits, to evaluate the development and effectiveness of interventions, and to help in mitigating the consequences of these problems. Nevertheless, the literature reviews by Skaggs and Hopper[16] and Houwen et al[15] on motor performance in children with visual impairment draw attention to the evaluation tools used in research. Some of the tests applied have undergone changes, such as the use of materials with vibrant colors, increased contrast of materials, permission for children to feel the test material before test conduction, or even the presentation of additional instructions before performing the task test.[14,15]

A literature review was conducted that aimed to assist the diagnosis and evaluation of intervention programs for children aged 7 to 10 years in a recognized institution of ophthalmic care in Brazil. This research aimed to describe the tools used in the literature to assess motor skills in children with visual impairment. The study assesses in detail the possible adaptations made and performed a critical analysis of the characteristics of these adaptations for assessing motor development in these children. Aspects of validation and reliability were also discussed.

Methods

A systematic literature review was conducted using the following electronic databases: SCOPUS, MEDLINE/PubMed, MEDLINE/EBSCO, Web of Science, LILACS, CINAHL, and ScienceDirect. The consultation included articles published between 1994 and 2017 (except CINAHL, that comprised articles until 2014) with the use of Mesh terms: "visually impaired persons" AND " child " AND "motor skills"; "visually impaired persons" AND "child" AND "postural balance"; "visually impaired persons" AND "child" AND "movement"; "low vision" AND "child" AND "motor skills"; "low vision" AND "child" AND "postural balance"; "low vision" AND "child" AND "movement." Only articles in English or Portuguese available in full text were included.

To be included articles should deal with the assessment or the development of tools, or motor skill interventions in children with visual impairment; evaluate children aged 7 to 10 years; and use standardized assessment procedures. The age range was defined based on a project with the main objective of following up the intervention programs in children with visual impairments aged 7 to 10 years. Researches evaluating children with neurological, attention and hyperactivity disorders, and orthopedic injury, or assessing cognitive or speech skills, or that did not clarify the information for inclusion were excluded.

The query was conducted in each database, using the keywords and evaluating the search results with respect to the inclusion criteria. When the title and abstract were not conclusive regarding the fulfillment of the inclusion criteria, the full-text article was assessed. For those articles meeting the inclusion criteria, data regarding the sample, country of study, objectives, method, and instruments were used, and the main conclusions of the study were collected with an individual form.

Motor skill was defined as a complex, voluntary, and guided movement of one or more body parts performed to achieve a particular goal.[23] This review included those articles dealing with the functional categories of motor skills: stability, locomotion, and object control. Stability skills were those involving the maintenance of balance in the individual against gravity; locomotion skills, those tasks dealing with the change of position of the individual, considering a fixed point; and object control skills, tasks including the act of applying force to an object, or receiving it.[23] Likewise, gross and fine motor skills were defined as actions using large and small muscle groups, respectively.[24]

For this study, the World Health Organization[25] criterion was used, which establishes that moderate (visual acuity $< 6/18 \geqslant 6/60$) and severe visual impairments (visual acuity $< 6/60 \geqslant 30/60$), together, comprise the group of individuals with low vision. Low vision along with blindness represents all visual impairments.

The quality of the articles meeting inclusion criteria was evaluated with Critical Review Form—Quantitative Studies,[26] adapted by Houwen et al.[18] The items of the study that were evaluated included study objective, literature review, suitability of the study design, sample, outcomes, intervention, results, conclusions, and clinical implications, with 16 items (15 when no interventions were involved). If the article met the criterion of the question, it was scored 1; 0, when the criterion was not fulfilled; NA when the criterion was not applied to the research; ?, in cases where the item was not clearly described. Those articles with scores $\geqslant 12$ and $\leqslant 7$ were considered as having low and high risk of bias, respectively.[18]

Results

The search in the databases resulted in 1113 files, of which only 24 met the inclusion criteria. The files were sometimes indexed by more than one database, causing a redundancy in the results (Figure 1). Despite the number of files in the various databases, most of them were excluded because they did not discuss the motor skills and/or did not include the age group of interest and/or included children with multiple disabilities and/or without visual impairment.

Data extraction from 24 articles regarding the study objectives, participants, instruments, and results, and the qualitative evaluation can be found in Chart 1 and Table 1, respectively. In 10 studies, the authors claimed to have assessed the children applying modifications in the tools that included changes in materials and their colors and in procedures, such as allowing children to feel the objects to be manipulated.

Most of the studies presented a moderate risk of bias (n=16; 66.7%), with satisfactory results regarding the definition of the study objectives, review on the subject, sample described in detail with their ethical rights ensured, and results expressed in terms of statistical significance (Table 1). However, few articles reported having conducted studies on the validity and reliability of the tools in visually impaired children or demonstrated the clinical importance and practical application of the final study conclusion.

Table 2 shows that the most frequently used tools were Bruininks-Oseretsky Test of Motor Proficiency (BOTMP), Test of Gross Motor Development-2 (TGMD-2), and walkways/platforms. However, only TGMD-2[14] and Movement Assessment Battery for Children 2 (MABC-2)[27] were considered valid and reliable in children with visual impairment.

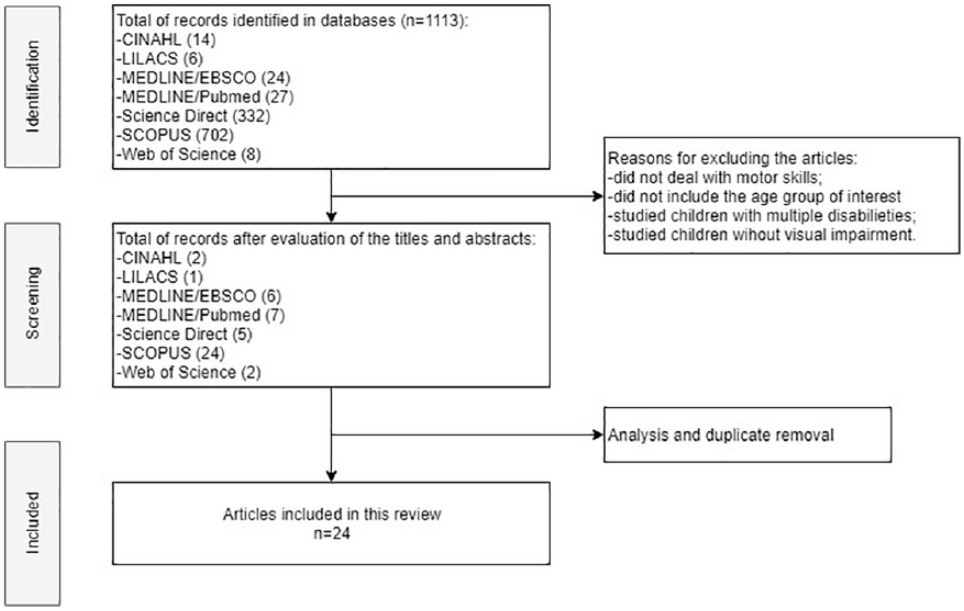

Figure 1. Steps in database search process.

Discussion

This study found that the researches evaluating motor skills in children with visual impairment have important limitations, such as methodological aspects were less frequent to fulfill the evaluation criteria according to the Critical Review Form (adapted from Houwen et al[28]). Some problems detected included not using valid and reliable measures, and the absence of justification of the sample size (Table 1). The instruments used with visually impaired children are generally valid and reliable in children without disability,[16,18] but there is no specific evaluation material for these children according to some authors.[3,10]

Among the tools surveyed, some evaluated manual dexterity (ManuVis and Jebsen-Taylor Hand Function Test), gross motor skills (TGMD-2), balance (stabilography-static equilibrium, and Pediatric Balance Scale (PBS)-static and dynamic), and those that evaluated a combination of skills (MABC-manual dexterity, ball skills and balance; BOTMP-fine and gross motor function; Ayres Southern California Sensory Integration Tests-sensory integration with tests of sensorial discrimination, sensory responsiveness, fine and gross motor function and praxis). The only tests that presented validity and reliability of data in children with visual impairment were the TGMD-2[14] and MABC-2.[27] The reproducibility of other evaluation methods, such as the first version of MABC[14,15] and the wooden walkway,[29] had been evaluated in these children, but there was a lack of studies on the validity of the applied methods.

The lack of instruments for children with visual impairment resulted in the need for adaptations of the tests, which indicates the inadequacy of the original test. The modifications included the use of colors providing high contrast,[13–15,19,27,30] permission to feel the material before the task was performed,[13–15,27,30] the use of additional information and/or instructions,[14,30,31] increasing the size of objects,[13,14,29] using other senses (hearing, touching),[10,27,30,31] and performing/feeling the movement before performing the task.[13,14,27,30,31] However, the authors suggested that the adaptations did not influence the skills required to perform the activities.[14,15]

According to Topor,[32] the visual function of people with visual impairment can be maximized by adjusting color, contrast, lighting, space or distance, and time. The use of primary colors with a high degree of contrast between the work area and manipulated object, stimulation of several senses (touch, smell, hearing), and the simplification of the environment eliminating the excess of information are encouraged. According to the authors, the accuracy and speed of performing an activity generally decrease when the child has low vision, which suggests the possibility of increasing the time allocated to the task.

Adjustments in the environmental and task contexts are also important to optimize the motor performance.[14] Children with low vision usually have difficulty perceiving objects when the tasks are conducted in poorly lit environments (very dark or very light) with little use of contrast, the representation of complex, three-dimensional shapes that have depth, or use of figures that do not correspond to their potential of vision. Thus, the use of the remaining senses in addition to their residual vision should be stimulated.[14]

Furthermore, the validity and reliability observed for a tool are only applicable when the instrument is used as established in the protocol. Modifications to these instruments may require, in addition to the authors' permission, the study of validation as if it was a new tool.[32] That is, the changes used in the assessment tools may have compromised the validity and reliability of the results. Thus, studies on the standardization of

Chart 1. Data on the literature search for articles on motor skills assessment in children with visual impairment.

AUTHORS	COUNTRY	OBJECTIVE/CONDUCTIVE QUESTION	PARTICIPANTS	INSTRUMENT	RESULTS/CONCLUSION
Aki et al[3]	Turkey	To study the effectiveness of a training program for children with visual impairment	Forty children with low vision, aged from 8 to 10 years old, were divided into two groups: 20 children each in the training and home training program groups	Bruininks-Oseretsky Test of Motor Proficiency—Short Form (BOTMP-SF). The authors did not comment on adaptions made on the test	Significant differences were found in all abilities after the training program. No differences were found in the home training program, except for the visuo-motor control. Children with visual impairment have residual vision, and learning to use it depends on an adequate rehabilitation
Aki et al[33]	Turkey	To assess the effect of upper extremity kinesthetic sense on writing performance on students with low vision	Twenty students with low vision (mean age, 9.4 years) and 20 sighted peers (mean age, 10.1 years old)	The Kinesthesia Test, part of Ayres Southern California Sensory Integration Tests and the Jebsen Hand Function Test-Writing subtest	Students with low vision scored lower on kinesthetic perception and writing performance than sighted peers. Kinesthetic sense of the upper extremities seems to be important for writing performance. The low visual input in the students with low vision can restrain the kinesthetic sense when compared with that in sighted peers. This impairment can interfere with learning to write
Alexandre et al[39]	Portugal	To assess the influence of visual information, degree of slope, and external acoustical, and tactile cues on children's locomotion modes, gait patterns, gait deviation, and time to ascend or descend different slopes	Ten children aged between 5.8 and 7.7 years: 5 were blind, 5 were sighted	Sloping walkway that allows the inclination variation. Children wore socks that were ink painted to mark their steps. All locomotion modes were recorded	Some gait parameters can be improved by auditory and tactile cues in children with visual impairment. The stimuli were more efficient among blind children than in normal-sighted ones when blindfolded
Bakke et al[27]	Brazil	To adapt Movement Assessment Battery for Children 2 (MABC-2) (age band 2) for children with low vision and test the validity and reliability of the new protocol The paper also discusses the protocol used to adapt the tool	All children had aged from 7 to 10 years. Forty children with low vision participated in the study: 10 in the pilot study (to bring up the difficulties faced by these children in the test); 30 to test the validity and reliability of the new protocol	MABC-2 with adaptations	Substantial to almost perfect inter-rater reliability was found between the component standard scores and a reasonable to excellent concordance rate in the classification of movement difficulty. The adapted tool has moderate internal consistency. The adapted MABC-2 Test improved the assessment of motor performance in children with low vision
Bouchard and Tétreault[34]	Canada	To describe motor development in children with visual impairment aged 8 to 13 years; to compare their motor development to that in a group of normal-sighted children of the same age and sex; and to identify factors that significantly influence motor development	60 children (30 with low vision and 30 normal-sighted matched by age and sex) aged 8 to 13 years	BOTMP with no adaptations	The results demonstrated that children with low vision had lower scores than normal-sighted peers in all motor abilities, particularly in balance. Gross motor skills in these children develop slower than fine motor skills
Gazzellini et al[35]	Italy	To compare three hypotheses concerning the gait of blind persons: balance deficit, lack of an anticipatory mechanism, and foot probing the ground	12 children with congenital blindness (age range, 3.5-13.2 years; mean age, 7.9 years) and 11 normally developing children (age range, 3.5-12.8 years; mean age, 8.3 years)	Walkway of 10 m free from obstacles; optoelectronic system (ViconMX) and two force platforms; Plug-in-Gait full body marker setup; posturography	Results support the hypothesis of lack of dynamic anticipatory control strategies. The atypical gait progression can be described by pelvis anteversion, ankle maximum plantar flexion in late stance and early swing, ankle maximum power in late stance, maximum vertical component of ground reaction force, and maximum anterior-posterior component of ground reaction force, with the last two occurring during late stance
Haibach et al[30]	United States of America	To evaluate the influence of age, sex, and severity of visual impairment in locomotor and object control skills in children with visual impairment	100 children with visual impairment (age range, 6-12 years) without other impairments	Test of Gross Motor Development 2 (TGMD-2)—with adaptations	The degree of visual impairment influenced children with the smallest visual function most severely. Older children performed better in dribbling than younger children. Boys scored better than girls only in some object control abilities

Chart 1. (Continued)

AUTHORS	COUNTRY	OBJECTIVE/CONDUCTIVE QUESTION	PARTICIPANTS	INSTRUMENT	RESULTS/CONCLUSION
Hallemans et al[12]	Belgium	To describe the changes in gait related to age in individuals with low vision and blindness	31 individuals with visual impairment (15 girls/women; 16 boys/men; age range, 1 year and 3 months to 44 years); and 60 normal-sighted individuals (30 girls/women and 30 boys/men; age range, 3 years and 3 months to 46 years)	Instrumented walkway, free of obstacles. Gait was recorded using an infrared camera system—Vicon	Individuals with congenital disorders of the peripheral visual system showed good performance in locomotion. However, adaptation in gait pattern, such as shorter stride and longer double support phase were present. These modifications were more evident in blind individuals than in those with low vision
Houwen et al[13]	Netherlands	To assess the qualitative performance in gross motor abilities in children with visual impairment and their association with the degree of impairment and participation in sports	20 children with visual impairment (age range, 6-11 years; 11 boys and 9 girls) and 100 normal-sighted children (age range, 6-11 years; 49 boys and 51 girls)	TGMD-2—with adaptations	Children with visual impairment had lower scores in object control skills than normal-sighted children. Nonetheless, the degree of impairment was not associated with a worse motor performance. The study suggested an association between object control abilities and sport practice
Houwen et al[15]	Netherlands	To assess the performance in children with visual impairment (age range, 7-10 years) in different motor abilities	48 children with visual impairment (25 aged 7-8 years; and 23 aged 9-10 years); 48 normal-sighted children (25 aged 7-8 years; 23 aged 9-10 years)	MABC—with adaptations	In children with visual impairment, the performance is related to the nature of the activity: if they require less visual function, they may not be sensitive to the effects of less visual impairment during the motor activities. The severity of visual impairment does not seem to be related to motor performance, except when associated to bimanual and hand-eye coordination
Houwen et al[18]	Netherlands	To study the variables that are related to motor performance in children and teenagers with visual impairment by a literature review	The review included 26 articles with individuals with visual impairment aged 4-18 years	The review identified articles that used assessment tools: BOTMP, MABC, stabilometer, TGMD-2 Test for Manual Dexterity in Visually Impaired Children; Pictorial scale of Perceived Competence; Sports Camp Evaluation Instrument; Bender Visual-Motor Gestalt Test, Halstead-Reitan Neuropsychological Battery, Wechsler Adult Intelligence Scale for children; arm positioning task, dart-throwing task, Minnesota Functional Vision Assessment; balance board and balance beam, talking pedometer, Leonard balance test; Movement in Space Recording form; Kinaesthetic Sensitivity Test e Manual Placement Task; Stork Stand; Accelerometer Triaxial; Actometer; Academic Learning Time in Physical Education (ALT-PE) sheet and observation system; Children's Activity Form (CPAF); Functional assessment based on a method by Hyvärinen; Athletic Identity Measurement Scale, Physical Self-Perception Profile; Visual-motor control and upper limb speed; handedness test, sorting test, finger dexterity test, among others	Limited evidence was found in three associations: (1) severity of visual impairment and the performance in dynamic balance and manual dexterity tasks; (2) amblyopia/strabismus and fine motor skills; (3) movement intervention and motor performance. Weak evidence was found to refute a relationship between sex and static balance

(Continued)

Chart 1. (Continued)

AUTHORS	COUNTRY	OBJECTIVE/CONDUCTIVE QUESTION	PARTICIPANTS	INSTRUMENT	RESULTS/CONCLUSION
Houwen et al[14]	Netherlands	To investigate psychometric properties of TGMD-2 in children with low vision	75 children with visual impairment (age range, 6-12 years)	TGMD-2 and MABC—both with adaptations. Validity data only on TGMD-2	TGMD-2 showed high internal consistency and satisfactory inter- and intra-rater and test-retest reliabilities. The factorial analysis supported the internal structure of TGMD-2. A correlation was found between TGMD-2 object control tests and MABC ball activities, indicating that they assess similar constructs. TGMD-2 demonstrated to be a valid and reliable tool to assess gross motor skills in children with visual impairment
Houwen et al[36]	Netherlands	To compare motor skills and physical fitness in primary school children with and without visual impairment	60 children (40 boys and 20 girls) with visual impairment (age range, 6-2 years); a group of 60 matched normal-sighted children	TGMD-2—with adaptations—and Eurofit	The degree of visual impairment did not influence the results. Children with visual impairment had lower scores in locomotor and object control skills (TGMD-2), as well as plate tapping, standing broad jump, 5 × 10 m shuttle run, and 20-Multistage Shuttle Test (MST) (Eurofit). A high proportion of overweight/obese children was found among those with visual impairment; hence, health-related activities should be promoted to help enhance motor skills in this population
Jazi et al[19]	Iran	To asses if balance-improving exercises influences dynamic balance in children with visual impairment	19 children with visual impairment (age range, 8-14 years). The study did not include blind children	Modified Bass Test of Dynamic Balance marked with halogenic light (for better visibility)	The dynamic balance between the experimental and control groups was not different, but dynamic balance improved in both groups after the exercises
Liebrand-Schurink et al[37]	Netherlands	To examine the controllability of cylinder- and dome-shaped magnifiers in young children with visual impairment	56 children with visual impairment and 66 children with normal sight (age range, 4-8 years)	Goal-directed arm movements with an object over the surface of a digitizer	Children with visual impairment performed slower but not less accurate movements than children with normal sight with both magnifier-like objects Nevertheless, the dome magnifier seems to be the better choice for young children with visual impairment Improvement of fine motor skills, especially when referring to Low Vision Aid (LVA) use, is as high priority in low-vision rehabilitation
Liebrand-Schurink et al[38]	Netherlands	To analyze the effectiveness and efficiency of magnifier used in a task in children with visual impairment	29 children with visual impairment and 47 children with normal sight (age range, 4-8 years)	Children moved the stand magnifier over the surface of a digitizer as quickly as possible toward a small target symbol. Performance was measured in terms of accuracy, response time, identification time, and movement time	The success rate, mean reaction time, and mean movement time of first and second movement parts were not significantly different between children with and without visual impairment Children with visual impairment were able to handle the stand magnifier just as fast as normal-sighted children and were even more efficient in identifying small symbols
Reimer et al[9]	Netherlands	To describe the development of the Test for Manual Dexterity in Visually Impaired Children	133 children (65 boys and 68 girls), 66 of which had visual impairment (26 were blind and 40 had low vision) and 67 had normal sight (age range, 6-11 years and 11 months)	Test for Manual Dexterity in Visually Impaired Children (ManuVis)	Manual dexterity skills develop differently in children with low vision than in normal-sighted individuals in all tested items. The test may be applied to compare data from a child with visual impairment with the data from a normal group
Rutkowska et al[39]	Poland	To evaluate the bilateral coordination in children and adolescents with visual impairments compared with their sighted peers To identify the influence of sex and age on bilateral coordination	75 individuals with congenital severe visual impairment (40 girls and 35 boys); 139 youth without visual impairment	Subtest 4 “Bilateral Coordination” of the BOMPT-2	Severe visual impairment and lack of visual sensation influence the development of bilateral coordination of youth aged 7 to 18 years negatively Age and sex were not associated with bilateral coordination Coordination abilities improved with age in youth with visual impairment, but they still showed difficulties in the ability to use the left and right sides of the body

Chart 1. (Continued)

AUTHORS	COUNTRY	OBJECTIVE/CONDUCTIVE QUESTION	PARTICIPANTS	INSTRUMENT	RESULTS/CONCLUSION
Uysal et al[40]	Turkey	To assess the effect of loss of hearing and vision on balance and gait.	60 children: 20 with hearing loss, 20 with blindness, and 20 healthy controls. The mean age of the hearing-impaired group was 9.3 years (*SD* = 0.9), the mean age of the blind group was 12.2 years (*SD* = 2.5), and the mean age of the controls was 9.3 years (*SD* = 0.6)	Standing Balance subtests of the Southern California Sensory Integration Tests. Gait was assessed by powdering the children' feet and having them walk on a dark platform. All the children's footprints were measured to calculate time-distance measures of gait	Children with hearing loss had similar results as those in the control group rather than the vision loss group. Blind children had more problems with balance and gait than the control group
Uysal and Aki[41]	Turkey	To investigate the relationship between writing skills and visual motor control in children with low vision and compare their results to those of normal-sighted peers	42 students with low vision (mean age, 9.7 years); and 26 normal-sighted students (mean age, 9.9 years)	BOTMP-SF and the Jebsen Taylor Hand Function Test's writing subtest, and a legibility assessment. Illumination and contrast were increased to enable objects to be seen more easily	Significant differences were found between the group in terms of writing speed, legibility, and visual motor control. Students with low vision had lower scores in writing, less legibility, and speed. Visual motor control was correlated with writing speed in children with low vision
Uysal and Düger[10]	Turkey	To compare motor performance of school children with different visual acuities (low vision, total or near total blind, normal-sighted children) The incidence and degree of visual impairment in association with consanguinity was also investigated	30 children with low vision; 30 children almost or totally blind; 30 normal-sighted children (age range of all children, 7-14 years)	BOTMP with adaptations	Differences in the development of motor skills were detected among children with different visual acuity; children with visual impairment had lower scores Higher percentage of consanguineous marriage was detected in the families of children with visual impairment
Uysal and Düger[42]	Turkey	To verify the effect of writing and reading training on preferred font type and size in students with low vision	35 children with low vision with a mean age of 10.9 years	Writing subtest of the Jebsen-Taylor Hand Function Test, read in 1 min, and legibility	Students gained speed in writing and reading after training, but the legibility did not improve significantly. Training may affect the preference for font size and style in children with low vision
Wagner et al[31]	United States of America	To provide an empirical basis for teaching gross motor skills in children with visual impairment	23 blind children (age range, 6-12 years); and 28 normal-sighted children (control group) with comparable ages and sex	TGMD-2—with adaptations	Children with visual impairment showed significantly worse performance in all locomotion and object control skills. The research discusses the need for a specific curriculum for children with visual impairment to diminish this difference
Zyłka et al[43]	Poland	To assess functional balance in girls with visual impairment and to investigate the correlation between stabilography and clinical balance assessment using Pediatric Balance Scale	26 girls with visual impairment (age range, 10-15 years)	Pediatric Balance Scale (with adaptations) and stabilography	Girls with visual impairment demonstrated difficulties when the base was narrowed when standing, as well as in situations where the center of gravity was closer to the extremity of the base of support. The correlation between stabilography and the scale showed some evidence of its concurrent validity for assessment in girls with visual impairment

Table 1. Qualitative evaluation of articles that assessed motor skills in visually impaired children with the Critical Review Form—Quantitative Studies.

AUTHORS	QUESTIONS																	RISK OF BIAS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	TOTAL	
Aki et al[3]	1	0	1	0	1	0	1	0	0	1	1	?	0	0	0	0	6	High
Aki et al[33]	1	0	0	0	0	0	1	0	0	NA	1	?	0	1	0	0	4	High
Alexandre et al[29]	1	1	1	0	1	0	1	1	0	NA	1	1	0	1	0	0	9	Moderate
Bakke et al[27]	1	1	1	0	1	0	1	1	1	NA	1	1	1	1	1	1	13	Low
Bouchard and Tétreault[34]	1	1	1	0	1	1	1	0	0	NA	1	?	1	1	1	1	11	Moderate
Gazzellini et al[35]	1	1	1	0	1	0	1	0	0	NA	1	1	0	1	0	0	8	Moderate
Haibach et al[30]	1	1	1	0	1	0	1	1	1	NA	1	1	1	1	1	1	13	Low
Hallemans et al[12]	1	1	1	0	1	1	1	0	0	NA	1	?	0	1	0	1	9	Moderate
Houwen et al[13]	1	1	1	0	1	0	1	1	0	NA	1	1	0	1	0	0	9	Moderate
Houwen et al[15]	1	1	1	0	1	0	1	1	0	NA	1	?	0	1	1	1	10	Moderate
Houwen et al[14]	1	1	1	0	1	0	1	1	1	NA	1	1	0	1	0	1	11	Moderate
Houwen et al[36]	1	1	1	0	1	1	1	1	0	NA	1	1	1	1	1	1	13	Low
Jazi et al[19]	1	1	1	0	1	0	1	0	0	1	1	?	0	1	0	0	8	Moderate
Liebrand-Schurink et al[37]	1	1	1	0	1	0	1	0	0	NA	1	1	1	1	1	0	10	Moderate
Liebrand-Schurink et al[38]	1	1	1	0	1	0	1	1	0	NA	1	1	0	1	0	0	9	Moderate
Reimer et al[9]	1	1	1	0	1	0	0	0	0	NA	1	?	0	1	1	1	8	Moderate
Rutkowska et al[39]	1	1	1	0	1	0	1	1	1	NA	1	1	0	1	1	1	12	Low
Uysal et al[40]	1	1	1	0	1	0	1	0	0	NA	1	1	1	1	1	1	11	Moderate
Uysal and Aki[41]	1	0	0	0	1	0	1	0	0	NA	1	?	0	0	0	1	5	High
Uysal and Düger[10]	1	0	1	0	1	0	1	0	0	NA	1	?	1	0	1	1	8	Moderate
Uysal and Düger[42]	1	1	1	0	1	0	1	0	0	1	1	?	0	1	0	1	9	Moderate
Wagner et al[31]	1	1	1	0	1	0	1	0	1	NA	1	?	1	1	1	1	11	Moderate
Zyłka et al[43]	1	1	1	0	1	0	1	0	0	NA	1	?	0	1	0	1	8	Moderate

Questions: 1=Was the purpose stated clear? 2=Was relevant background literature reviewed? 3=Was the design appropriate for the study question? 4=Were there any biases present? 5=Was the sample described in detail? 6=Was the sample size justified? 7=Was informed consent obtained? (if not described, assume no); 8=Were the outcome measures reliable? (if not described for children with visual impairment, assume no); 9=Were the outcome measures valid? (if not described for children with visual impairment, assume no); 10=Was intervention described in detail? 11=Were results reported in terms of statistical significance? 12=Were the analysis methods appropriate? 13=Clinical importance was reported? 14=Conclusions were appropriate given the study methods? 15=Are there implications for clinical practice given the results of the study? 16=Were limitations of the study acknowledged and described by the authors? Scores of items: 0=does not meet criterion; 1=satisfies criterion; ?=not clearly described; NA=not applicable.
The article by Houwen et al[18] has not been evaluated because it is a review article.

Table 2. Absolute and relative frequency of the use of tools to assess motor skills in visually impaired children in this systematic review.

TOOLS	N
Bruininks-Oseretsky Test of Motor Proficiency (BOTMP)	5
Test of Gross Motor Development 2 (TGMD-2)	5
Walkway/platform	4
Movement Assessment Battery for Children (MABC)	3
Jebsen-Taylor Hand Function Test	3
Southern California Sensory Integration Test	2
Pediatric Balance Scale (PBS)	1
Stabilography	1
Manual Dexterity in Visually Impaired Children (ManuVis)	1
Posturography	1
Modified Bass Tess	1

n denotes number of studies using the instruments.

changes in the tests for children with visual impairment can help minimize systematic errors in research and enhance the possibility of making more accurate comparisons between data from different studies.

The functionality of some activities evaluated in the tests is another important point worth raising; some may not be part of the daily routine of children with visual impairment. Therefore, this study underlines the importance of the development of instruments with better ecological validity for children with visual impairment,[18] along with reinforcing the need for studies in these children, as well as adequate tools for them.

Conclusions

Research on motor skills in children with visual impairment is limited because of a shortage of instruments for assessing motor function in these children. In the past 23 years (1994-2017), only 24 articles were found in seven databases (SCOPUS, MEDLINE/PubMed, MEDLINE/EBSCO, Web of Science, LILACS, CINAHL, and ScienceDirect) investigating motor skills in children with visual impairment. Although this review detected the use of varied tools that evaluate fine, to gross motor and locomotor, functions, as well as batteries of tests that examine a combination of these, only TGMD-2 (gross motor development) and MABC-2 (manual dexterity, balance and object control) demonstrated validity and reliability in this population.

Data from this review suggest the need to expand the studies on the tools, as well as on the functionality of the activities for application in children with visual impairment. The discussion on the changes made in the activities will result in systematic error minimization and better research quality.

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Author Contributions

HAB (corresponding author—hannebakke@gmail.com)—conceptualized and designed the study, designed the data collection instruments, and coordinated data collection, drafted the initial manuscript, critically reviewed the manuscript, and approved the final manuscript as submitted; WAC—conceptualized and designed the study, drafted the manuscript, and approved the final manuscript as submitted; ISDO—conceptualized and designed the study, drafted the manuscript, and approved the final manuscript as submitted; SWS—conceptualized and designed the study, drafted the initial manuscript, and approved the final manuscript as submitted; MTC—conceptualized and designed the study, drafted the initial manuscript, and approved the final manuscript as submitted.

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