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Review

Does the practice of sports or recreational activities improve the balance and gait of children and adolescents with sensorineural hearing loss? A systematic review

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ABSTRACT

Background: Balance and gait disorders have been observed in children and adolescents with sensorineural hearing loss (SNHL), justified by vestibular dysfunctions that these children may present, due to the injury to the inner ear. Therefore, some investigations have suggested that the practice of sports or recreational activities can improve the balance and gait of this population.
Objective: Assess the evidence quality from randomized or quasi-randomized controlled trials that used sports or recreational activities as an intervention to improve the balance and /or gait of children and/or adolescents with SNHL.
Methods: Systematic review that surveyed articles in nine databases, published up to January 10, 2019, in any language, using the following inclusion criteria: (1) Randomized or quasi-randomized controlled trials. (2) Participants from both groups with the clinical diagnosis of SNHL, aged 6–19 years old, without physical problems, cognitive or neurological deficits, except the vestibular dysfunction. (3) Using the practice of sports or recreational activities as an intervention, to improve the balance and/or gait outcomes.
Results: 4732 articles were identified in the searches, after the removal of the duplicates articles and the reading of the titles and their abstracts, remained 16 articles for reading in full, being 5 trials eligible for this systematic review. Of the five eligible trials, three used sports activities and two recreational activities as intervention and presented very low-quality evidence for balance and gait outcomes.
Significance: Sports and recreational practices seem to represent promising modalities to improve the balance and gait of children and adolescents with SNHL. However, due to the methodological limitations of the trials and the low quality of the current evidence on the topic, the results of the trials should be interpreted with caution. Due to the low quality of evidence observed, we suggest that new trials be proposed on this topic, with greater methodological rigor, to provide high-quality evidence on the effectiveness of sports and recreational practices to improve the balance and gait of children and adolescents with SNHL.

1. Introduction

Balance is an essential prerequisite for most daily life activities in children. It is the complex ability to maintain, achieve, or restore the state of balance of the body while a child stands still, prepares to move, in movement, or prepares to stop moving [1]. The regulation of this body balance occurs through afferent sensory processing of three sensory systems: visual, somatosensory and vestibular, integrated to the central nervous system, aiming at generating motor responses and keeping the body in balance [2]. However, changes in some of these sensory systems can trigger disturbances in the body balance.

Peripheral vestibular dysfunctions are outcomes often observed in children with SNHL. Some investigations have found disorders in the vestibular system in about 41–85 % of their samples, composed by

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children or adolescents with SNHL [3–7]. Besides, some other studies suggest that there is a parallelism between the extension of the inner ear lesion and the presence of vestibular dysfunctions in children with SNHL, so that the greater the degree of hearing loss presented by the child, the greater the chances to occur lesions in the vestibular system [7–12].

Peripheral vestibular dysfunctions can occur in children with SNHL due to injury to the inner ear, which causes lesions to the cochlea, and may also affect the vestibular system. As the cochlea and vestibule share the continuous membranous labyrinth of the inner ear and, therefore, lesions or pre, peri or postnatal trauma can cause damage to one or both systems [13]. This occurs also because the vestibular apparatus and the cochlea are organs that are anatomically very close and functionally related in terms of innervation and vascularization [14]. The peripheral vestibular dysfunctions observed in children with SNHL may result in balance disorders in this population.

Disturbances in the balance (static or dynamic) in children with SNHL have been reported frequently in the literature [15–19]. Changes in gait are also mentioned, which is a body balance-dependent motor skill to be performed adequately. Changes in gait in children with SNHL are related to a slower speed [19,20], greater ground reaction force [21] and worse performance in gait-related functional tasks [22], compared to the normal-hearing children, occurring the same with other motor skills [23–26]. This low motor performance of the children with SNHL, concerning balance, gait and other motor skills, has been associated with the vestibular dysfunctions that these children may present due to the injury to the inner ear.

Children with SNHL and associated vestibular dysfunction have shown worse balance performances compared to the normal-hearing ones [27–30]. There is also evidence that children without vestibular dysfunctions have worse balance than normal-hearing children suggesting that SNHL alone could contribute to disturbances in balance in the childhood [28,29]. When comparing the balance of children with SNHL, with and without vestibular dysfunctions, it is observed that those with disorders in the vestibular system demonstrate the greatest balance deficits [27–30]. This suggests that when the two inner ear organs are injured, greater the child body balance impairment is.

These limitations in the balance may negatively affect motor control, impairing the functionality, typical childhood play, and sports and recreational practices of children with SNHL, making them not comparable to other children in terms of motor performance. This can affect their social relations, cause emotional disturbances and the isolation of these children [31], which have already shown more depressive symptoms than the normal-hearing children [32].

Besides, some authors have reported that children with SNHL have shown less participation in sports and school practices [33,34] when compared to normal-hearing children. The greatest motor limitations were identified in the manual skills, with the use of balls and balancing activities. The authors emphasize that improving such motor skills, even in childhood, could positively contribute to a better social context and inclusion of these children. Other studies also observed that children with SNHL who used to practice sports and/or recreational activities obtained better balance and motor efficiency when compared to those who did not practice these activities [35–37]. Raising the hypothesis that the practice of sports or recreational activities could be associated to improve balance and motor skills in children with SNHL, which justifies this review.

Therefore, this systematic review aimed to assess the quality of evidence from randomized or quasi-randomized controlled trials that used the practice of sports or recreational activities to improve the balance and gait of children and adolescents with SNHL, using the best evidence level: the GRADE system (Grading of Recommendations, Assessment and Evaluation), to answer the following question:

Does the practice of sports or recreational activities improve the balance and gait of children and adolescents with SNHL?

2. Methods

This systematic review was conducted according to the guidelines of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement [38], and its protocol was registered at PROSPERO under number (CRD42018096309) [39].

2.1. Identification and selection of the trials

Nine electronic databases were used to perform the searches of the trials in this systematic review: MEDLINE/PubMed, EMBASE, SCOPUS, LILACS, CINAHL, CENTRAL (Cochrane Central Register of Controlled Trials), Web of Science, PEDro and Google Scholar. The last search occurred on January 10, 2019, and there was no restriction of the publication time of the articles or languages, and a manual search was performed on the list of included trial references to ensure that all relevant trials on this topic were included.

The search strategies used in each database are available in Appendix 1.

The articles found in each database were independently analyzed by each of the two reviewers (Melo RS and Tavares-Netto AR), who judged their relevance by reading the titles and abstracts in front of a computer, according to the following inclusion criteria: The studies should be randomized or quasi-randomized controlled trials, that using the practice of sports or recreational activities as intervention, involving children with ages between 6–19 years old, with clinical diagnosis of SNHL, without physical problems, cognitive or neurological deficits, except the vestibular dysfunction and who evaluated balance and/or gait outcomes.

In this first analysis, the articles were divided into eligible or discarded for this review. Those doubtful articles, or those with potential abstracts to be included in this systematic review were retained for further analysis by reading the full text of the paper. The disagreements between the inclusion of one of the trials for this systematic review were solved by both reviewers; in the cases where no common sense was obtained, the opinion of a third reviewer (Ferraz KM) was requested.

For those cases in which there was a lack of information on the articles, the authors of this review sent an e-mail to the corresponding authors of the essays, to obtain the necessary information. We emphasize that we obtained answers from all the authors of the trials that had doubts about their inclusion or not in this review.

2.2. Assessment of the studies characteristics

2.2.1. Quality of evidence

Quality of evidence was evaluated using the approach proposed by the GRADE system [40]. According to this proposal, five factors can interfere in evidence quality from a trial: design, risk of bias, inconsistency, indirectness and imprecision. For each of these items, evidence was considered according to the following classification: not serious (no decrease in points), serious (decrease of 1 point) or very serious (decrease of 2 points), scored according to the risk of study bias. For the specific item 'risk of bias' of GRADE, the Cochrane instrument was used to evaluate the risk of bias of the trials, which evaluates the following items: randomization, anonymous allocation, blinding of the participants and of the outcome assessors, losses or incomplete data, selective description of outcome and others (if applicable). Each item of the risk of bias instrument was assessed as follows: low risk of bias (green), unclear risk of bias (yellow) or high risk of bias (red), according to the risk of bias presented by the trial.

2.3. Participants

The studies were included if the participants were children or adolescents with age between 6–19 years, included in both groups

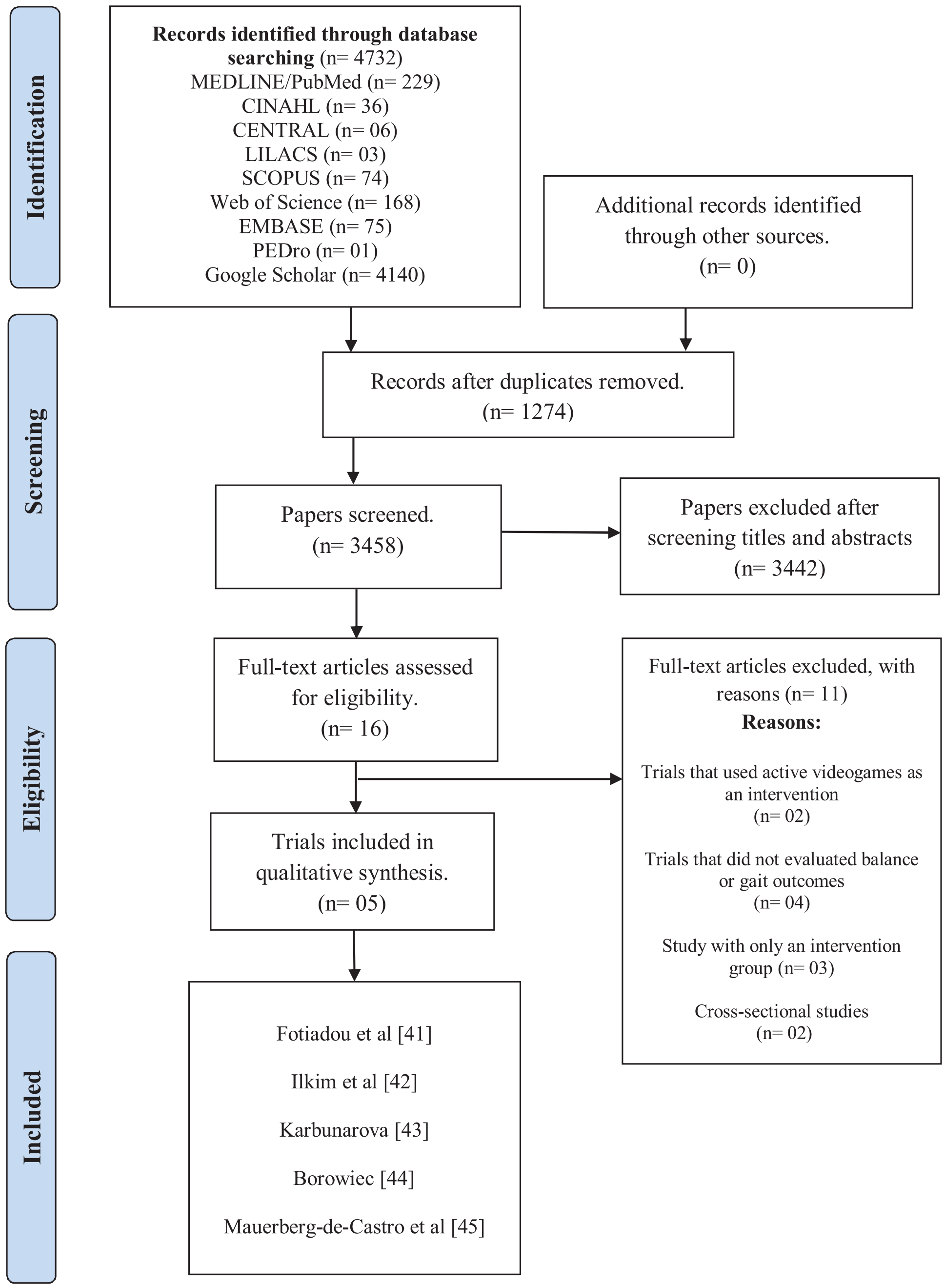

Fig. 1. Flow of studies through the review, according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA).

(control and intervention) and presented no physical problems and associated cognitive or neurological deficits, except the vestibular dysfunction.

2.4. *Interventions*

The intervention group should have been treated with interventions that used the practice of sports or recreational activities, which stimulate the vestibular system. The control intervention could have occurred with activities of daily living, recreation, leisure, any intervention or without any intervention.

For sports interventions, we consider sports used in a professional or amateur way, and as a reference, we used sports practiced in the last Olympic games of summer (Rio de Janeiro, Brazil - 2016) or winter (Pyeongchang, South Korea - 2018), described below:

2.4.1. *Sporting activities*

Sports modalities of the Summer Olympic Games (Rio de Janeiro, Brazil - 2016):

Athletics, Badminton, Basketball, Boxing, Canoeing, Cycling, Fencing, Football, Gymnastics: Artistic, Rhythmic and Trampoline, Golf, Handball, Horsemanship, Grass Hockey, Judo, Weightlifting, Olympic Fighting, Aquatic Marathon, Water polo, Modern pentathlon, Rowing, Rugby, Taekwondo, Archery, Shooting, Tennis, Table tennis, Triathlon, Sailing, Volleyball and Beach volleyball.

Sports modalities of the Olympic Winter Games (Pyeongchang, South Korea - 2018):

Biathlon, Bobsled, Curling, Downhill skiing, Cross-country skiing, Freestyle skiing, Combined Nordic skiing, Ice hockey, Luge, Figure skating, Speed skating, Short skating, Speed skating, Ski jumping, Skeleton and Snowboarding.

Table 1
Summary of the included trials.

Author	Country	Motor Skill	Design	Characteristics of volunteers	Number of volunteers		Characteristics of Interventions	
					CG	IG	CG	IG
Fotiadou et al. [41]	Greece	Balance	Quasi-randomized trial	Children with SNHL (hearing loss degrees > 70 dB), both sexes and age range between 7–9 years.	12	17	40 minutes sessions, three times/week of physical education activities, for 16 weeks.	40 minutes sessions, three times/week of rhythmic gymnastics activities, for 16 weeks.
Ilkim et al. [42]	Turkey	Balance	Quasi-randomized trial	Children with SNHL (hearing loss degrees between 90 – 110 dB) and age range between 12–14 years.	30	30	Sessions using the gymnastic exercises, three times/week, for 14 weeks.	Sessions using the athletic exercises, three times/week, for 14 weeks.
Karbunarova [43]	Ukraine	Balance and Gait	Quasi-randomized trial	Children with SNHL, both sexes and age range between 6-10 years old.	10	10	Soccer, volleyball and basketball classes, two times/week, for 10 weeks.	Swimming classes, two times/week, for 10 weeks.
Borowiec [44]	Poland	Balance	Randomized controlled trial	Children with SNHL, both sexes and age range between 10–13 years.	11	14	45 minutes sessions, four times/weeks of physical education classes, for 16 weeks.	45 minutes sessions, four times/week: two of physical education classes and two of dance program, for 16 weeks.
Mauerberg-de-Castro et al. [45]	Brazil	Balance	Quasi-randomized trial	Children with bilateral profound SNHL (hearing loss degrees > 70 dB), both sexes and age range between 10–15 years.	10	10	Regular physical education classes.	90 minutes sessions, two times/weeks of dance activities, for 26 weeks.

SNHL: Sensorineural hearing loss; dB: decibels; CG: control group; IG: intervention group.

2.4.2. Recreational activities

Regarding recreational activities, we used as reference the most practiced activities by the children in the typical games of childhood, in leisure or recreation, which could stimulate the vestibular system and thus improve the balance and gait, which could have been used by the trials and which are listed below.

Ballet, Dance, Use of slackline, Cycling, Skates, Skateboard or Scooter, Playing Capoeira, Skipping rope, Ice skating and Surfing.

2.5. Outcomes evaluated

The outcomes evaluated in this systematic review were balance and gait.

We included the trials that evaluated the balance outcome, according to the parameters of anteroposterior and medial-lateral pressure center oscillation, measured in cm/s, or by the oscillation area of the center of pressure, measured in cm^2, evaluated by the instruments: force platform, or by computerized dynamic posturography.

Also included were studies that assessed balance using the following instruments: Pediatric Balance Scale, Pediatric Reach test (front or side), Test of Gross Motor Development, Motor Proficiency test, One Leg Standing test, Peabody Developmental Motor Scales and Movement Assessment Battery for Children (MABC), or others. All of these are clinical tests or scales often used in clinical practice and by studies that evaluated the balance outcome in children.

Included were studies that evaluated gait with any condition related to walking, such as gait speed, the distance between feet, stride length, running or any other means of locomotion. Also included were investigations that assessed gait using the following instruments: Dynamic Gait Index, Timed Up and Go test, by accelerometry, camcorders, photos, and material such as dye to mark the footsteps of children on the floor or paper, or those that used sand for this purpose.

2.6. Data extraction and analysis

The studies data included in this review were extracted and recorded on a standardized form created by the authors. These data were filed independently by both reviewers in Review Manager (RevMan) software, version 5.1.6, for subsequent analysis of the information and discussion of the possible discrepancies. The risk of bias was qualitatively described.

3. Results

3.1. Flow of the trials through the review

A total of 4732 articles were identified according to search strategies in the nine databases. After the removal of the duplicated articles, 3458 articles remained which were evaluated, one by one, by titles and abstracts, and 16 articles were selected for reading in full. After reading the articles, 5 trials were considered eligible for this systematic review, one randomized [44] and four quasi-randomized [41–43,45], as shown in Fig. 1, which brings the extraction flowchart from the articles of this systematic review, according to PRISMA's recommendation.

Out of the five trials included, three used interventions with sports activities: Fotiadou et al. [41], Ilkim et al. [42] and Karbunarova [43] and the other trials used the recreational activities: Borowiec [44] and Mauerberg-de-Castro et al. [45].

Of the excluded trials, two used games-based virtual reality as an intervention [46,47], four [48–51] used sports or recreational practices as intervention, however, balance and gait outcomes were not analyzed. Three studies [52–54] contained only the intervention group and two other studies [55,56], these were cross-sectional studies.

Table 2
Methodological aspects and conclusions of the trials that used the practice of sports and recreational activities to improve the balance performance and gait of children and adolescents with SNHL.

Author	Country	Motor Skill	Outcome measures	Instruments used for the assessment	Control group		Intervention group		Conclusion
					Pre	Post	Pre	Post	
Fotiadou et al. [41]	Greece	Balance	Dynamic Balance	Force Platform	30s: 5.70 ± 1.58 45s: 9.05 ± 3.33 60s: 11.8 ± 3.28	30s: 5.95 ± 1.52 45s: 9.54 ± 2.84 60s: 12.1 ± 3.39	30s: 5.41 ± 1.50 45s: 9.80 ± 2.89 60s: 13.5 ± 4.10	30s: 10.0 ± 2.95 45s: 15.6 ± 4.83 60s: 22.2 ± 6.40	The findings of this study provide evidence that the specific rhythmic gymnastics program facilitates significant improvement in the dynamic balance ability of children with deafness.
Ilkim et al. [42]	Turkey	Balance	Static Balance	Flamingo Balance Test	Gymnastics: 11.1 ± 2.49	Gymnastics: 8.85 ± 1.12	Athletics: 6.30 ± 3.08	Athletics: 4.50 ± 1.01	At the end of the training, the positive improving of these parameters has shown that the athletics in hearing impaired develops balance, reaction time and muscle strength more than gymnastic. Hearing impaired individuals can be directed to the sport of athletics to increase daily living activity levels and quality of life.
		Balance	Static Balance	Romberg Test	RL: 2.0 ± 1.1 LL: 1.4 ± 0.8	RL: 2.6 ± 0.8 LL: 2.1 ± 0.7	RL: 1.3 ± 1.25 LL: 1.0 ± 0.8	RL: 4.5 ± 1.26 LL: 3.3 ± 1.5	The swimming program had a positive effect concerning on the ability to preserve the static balance according to Romberg's test and on the coordination skills by the result of the test walking on the gymnastic balance beam.
Karbunarova [43]	Ukraine	Balance	Dynamic Balance	Bondarevsky Test	RLEO: 4.4 ± 2.3 LLEO: 3.5 ± 1.9 RLEC: 1.9 ± 1.2 LLEC: 1.1 ± 0.9	RLEO: 5.2 ± 1.7 LLEO: 5.2 ± 1.7 RLEC: 2.9 ± 1.1 LLEC: 2.2 ± 0.7	RLEO: 4.5 ± 2.5 LLEO: 3.4 ± 2.3 RLEC: 1.4 ± 1.7 LLEC: 1.0 ± 1.2	RLEO: 6.8 ± 2.1 LLEO: 5.6 ± 1.7 RLEC: 4.1 ± 1.4 LLEC: 3.0 ± 1.0	
		Gait	Gait	Walking on Balance Beam Test	02 Falls[b]	02 Falls[b]	03 Falls[b]	00 Falls[b]	
Borowiec [44]	Poland	Balance	Dynamic Balance	Balancing Backward Test	50.1	52.7	50.5	55.6	The use of exercises performed to the music with enhanced high pitch tones and the vibrations showed a positive impact on the level of coordination abilities of the deaf.
Mauerberg-de-Castro et al [45]	Brazil	Balance	Balance-Related Tasks	Psychomotor Battery of Ozeretski-Guilmain	8[a]	9[a]	9[a]	11[a]	Findings suggested that dance activities can change deaf individuals' auditory perception of rhythmic structures. Participation in such a program can also positively affect psychomotor development.

S: Seconds; a: psychomotor age (in years old); b: Falls from Balance beam; RL: Right leg; LL: Left leg; RLEO: Right leg with eyes open; RLEC: Right leg with eyes closed; LLEO: Left leg with eyes open; LLEC: Left leg with eyes closed.

3.2. Characteristics of the included trials

All trials included in this review compared the practice of sports or recreational activities, with physical education classes, or other intervention. The characteristics of the included trials, on the characterization of the children, the methodological aspects and their conclusions are described in Tables 1 and 2.

3.2.1. Risk of bias

Regarding the randomization of the sample, only Borowiec [44] mentioned that has performed, however, did not clearly describe how randomization was conducted in your trial. The other four trials [41–43,45] did not even mention the randomization, only reported that the children were divided into control or intervention groups, presenting a high risk of bias, for those trials that did not randomize the sample.

Regarding the secrecy of the children's allocation, no trials mentioned that they have done so, which indicates a high risk of bias for all of them.

None of the trials reported on the blinding of the children and the outcome assessors, that is, the evaluators were probably aware to which group the assessed children belonged (control or intervention), representing a high risk of bias for the trials that did not control the blinding of examiners of the outcomes.

There were sample losses in the Karbunarova trial [43], the author reported that some children were unable to perform the tasks of the evaluation tests. The same occurred in the Mauerberg-de-Castro et al. [45] trial, in which some children in the control group did not perform the post-test, indicating a high risk of bias for both trials.

There was no selective description of outcomes in any of the trials included in this review.

Another bias not controlled by the trials was vestibular dysfunction of the children and this should have been controlled because it directly influences the results of the trials. The fact of the child with SNHL has disturbances in balance and gait has been largely associated with the peripheral vestibular dysfunctions that these children may present, due to the injury to the inner ear.

Also, children with SNHL and associated vestibular dysfunction have the worst performances in balance and motor skills and this could underestimate the effect size of the interventions. Resulting thus, in a high risk of bias for all the trials included in this review and that did not control the presence of vestibular dysfunction in their samples. Which can be observed in Figs. 2 and 3 and in Table 3, which bring the critical analysis of the risk of bias of the trials and the GRADE evidence quality table, respectively.

3.2.2. Participants

The five trials included in this review presented 154 volunteers and investigated whether the practice of sports or recreational activities improves the balance and/or gait of children and adolescents with SNHL. Three trials [41–43] on balance (n = 109), used sports practices as intervention and two trials, also pertaining to balance (n = 75), recreational activities [44,45]. One of the trials that used sports practices as intervention also evaluated the gait outcome [43].

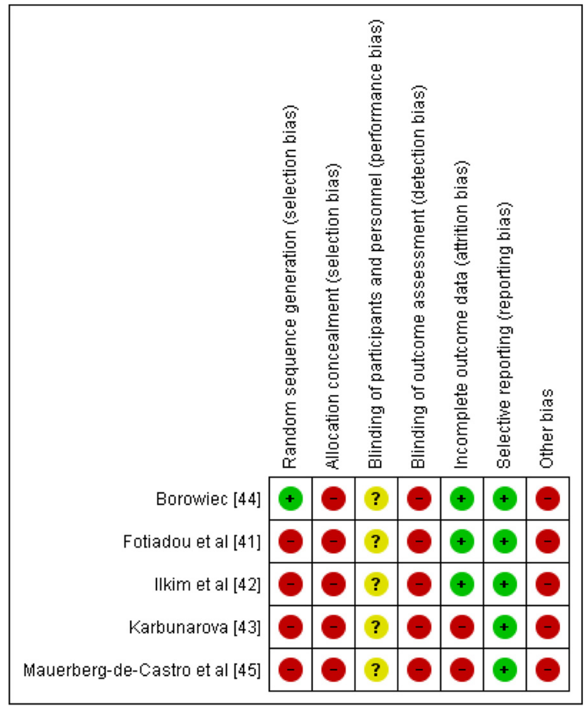

Fig. 3. Risk of bias of each included trial assessed using the Cochrane Risk of Bias Tool.

3.2.3. Intervention

Two out of the three trials that used sports practices as an intervention, opted for rhythmic gymnastics. Fotiadou et al. [41] opted for gymnastics in the intervention group and, for the control group, physical education classes were offered. On the other hand, Ilkim et al. [42] selected gymnastics for the control group and the intervention group practiced athletics activities. In the Karbunarova trial [43], swimming was used in the intervention group, and the control group practiced sports games (Soccer, Volleyball and Basketball).

These interventions presented similar characteristics, Fotiadou et al. [41] performed their experiment at 16 weeks, performing three sessions during the week, lasting forty minutes each. Ilkim et al. [42] conducted their trial at 14 weeks, also performing three sessions weekly and the authors did not make clear the duration of the sessions. The Karbunarova trial [43] was completed at 10 weeks, with two sessions performed on the week and the duration of the sessions was also not reported. We have sent several emails to the authors to obtain such information, but we have not received any responses.

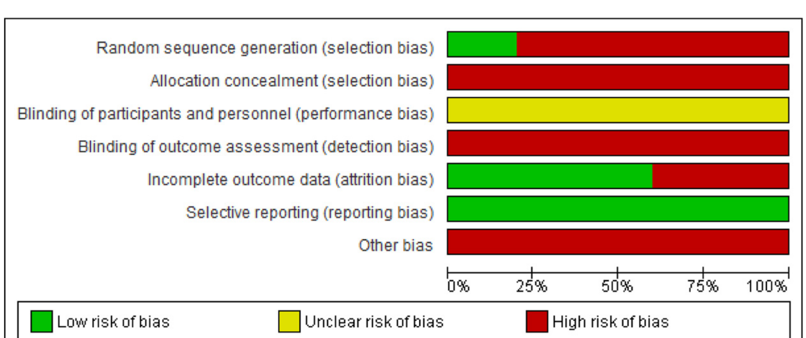

Fig. 2. Risk of bias summary of the included trials.

Table 3
Quality of evidence of the trials that used the practice of sports or recreational activities to improve the balance performance and gait of children and adolescents with SNHL.

Quality assessment							№ of patients		Quality of evidence	Importance
№ of studies	Study design	Risk of bias	Inconsistency	Indirectness	Imprecision	Other considerations	Sports or recreational activities	Control		
Balance – Practice of sports activities (follow up: mean 14 weeks; assessed with: Force Platform, Flamingo Balance Test, Bondarevsky Test and Romberg Test)										
03 [41,42,43]	Quasi-randomized trials	very serious [a,b,c,d,e,f]	not serious	serious [g,h]	not serious	all plausible residual confounding would reduce or improve the demonstrated effect [f]	57	52	⊕◯◯◯ VERY LOW	CRITICAL
Balance – Practice of recreational activities (follow up: mean 21 weeks; assessed with: Balancing Backward and Psychomotor Battery of Ozeretski-Guilmain)										
02 [44,45]	Randomized and quasi-randomized trials	very serious [a,b,c,d,e,f]	not serious	serious [h]	not serious	all plausible residual confounding would reduce or improve the demonstrated effect [f]	39	36	⊕◯◯◯ VERY LOW	CRITICAL
Gait – Practice of sports activities (follow up: 10 weeks; assessed with: Walking on Balance Beam Test)										
01 [43]	Quasi-randomized trial	very serious [a,b,c,d,e,f]	not serious	serious [g]	not serious	all plausible residual confounding would reduce or improve the demonstrated effect [f]	10	10	⊕◯◯◯ VERY LOW	CRITICAL

[a] There was no random sequence generation.
[b] No allocation secrecy.
[c] There was no blinding of the children.
[d] There was no blinding of the evaluator of outcome.
[e] Loss or incomplete data.
[f] There was no evaluation of children's vestibular function.
[g] Inclusion of very young children (under seven years old).
[h] Children using hearing aids during the intervention programs.

In the three trials, significant improvements were observed in the children's balance after interventions with sports activities practices (Table 2).

The other two trials, based on recreational activities, used dance as an intervention and presented very heterogeneous programs. Borowiec [44] concluded his experiment in 16 weeks, with two weekly sessions lasting 45 min for both groups. The intervention group practiced the dance program and physical education classes, and the control group participated only in physical education classes. In the Mauerberg-de-Castro et al. trial [45], 90-minute sessions were performed twice weekly and a total duration of 26 weeks. The intervention group practiced only the dance activities and the control received only physical education classes. In both trials, improvements in the balance of children after intervention using dance programs were observed.

3.2.4. Outcome measures

Trials of the interventions with sports practices have chosen different instruments for assessing the balance of children. Fotiadou et al. [41] were the only ones who used a more rigorous instrument to assess balance, a force platform. Ilkim et al. [42] evaluated the balance of the children by the Flamingo Balance test and Karbunarova [43] by the Romberg and Bondarevsky tests.

In the trials with recreational activities (the dance), the balance was measured through clinical tests, Borowiec [44] used the Balancing Backward test and Mauerberg-de-Castro et al. [45] to Psychomotor Battery of Ozeretski-Guilmain.

The gait was evaluated only by the Karbunarova trial [43] measured by Walking on the gymnastic balance beam test.

The variability of the instruments used by the trials to evaluate the outcomes, the heterogeneity of the interventions modalities and the age groups of the samples, made it impossible to perform the meta-analysis in this systematic review.

4. Discussion

This is the first systematic review that evaluated the quality of the evidence from the trials that used the practice of sports or recreational activities to improve the balance and/or gait of children and adolescents with SNHL.

Five trials were analyzed in this review, three of them related to sports activities and two to recreational ones. Although trials have found that balance and gait improved after interventions, the quality of this evidence is very low due to the methodological bias in the trials, which can be observed in the critical analysis of the bias risk of this review.

Of the main bias observed in the analyzed trials, it can be pointed out the lack of randomization and the confidentiality of the sample allocation, the non-blinding of the outcome assessors, the sample losses and the uncertainty about the presence or absence of vestibular dysfunction in the samples.

Faced with this bias, we decided to punctuate them and discuss them in isolation, in detail, below.

Randomization is one of the steps that should be prioritized in a clinical trial, as it ensures homogeneity between groups, controlling the selection bias. Another absent aspect of the analyzed trials was the secrecy of children's allocation, a process adopted to prevent the knowledge of the group's prior allocation by the researcher. The trials analyzed by this review did not present a greater rigor in these two methodological steps of a clinical trial, demonstrating that these steps need greater control in the next trials on the topic, since trials with the absence of the secrecy of allocation, overestimate the effect of the intervention by up to 30 % [57].

Another very important methodological step of a clinical trial is the blinding of the outcome assessors, which was not performed in any of the trials analyzed. This step demonstrates a strong idea of the reliability of the findings presented by the trial, avoiding that the possibility of prior knowledge about the children's allocation interferes with their response to the treatment (conduction bias) or the evaluation of outcomes (detection bias). Lack of control at this step renders the quality of evidence presented by the reduced trial and its questionable findings as seen in the trials reviewed in this review, and therefore, there should be greater control of the blinding of outcome assessors in future trials on this topic.

Karbunarova [43] and Mauerberg-de-Castro et al. [45] reported sample losses in their trials; however, they did not mention *intention-to-treat analysis*. The *intention-to-treat analysis* allows all participants to be followed until the end of the trial, regardless of what happens to some of them, thus controlling for loss bias. The exclusion of participants who did not remain until the end of the statistical analysis study may overestimate the effect size of intervention and the *intention-to-treat analysis* aims to control this deviation [58]. The sample losses observed in the trials added to the absences of the *intention-to-treat analysis* implied a bias for both trials.

Another important bias observed in all the trials included in this review was the lack of control of the vestibular dysfunction in the sample, since the fact that children with SNHL present disturbances in balance and gait have been widely associated with vestibular dysfunctions, reported frequently in this population. However, children with SNHL with and without vestibular dysfunctions present different balance performances compared to the normal-hearing children. Those with vestibular dysfunctions are those that present the worse balance performances compared to normal-hearing children [28–30] and also compared to those with SNHL without vestibular dysfunctions [29,30].

This discrepancy between the motor performance of children with SNHL with and without vestibular dysfunctions should be considered for the performance of a clinical trial whose objective is to improve the motor performance of these children. This must occur because children without vestibular dysfunctions can be stimulated by the intervention and present positive effects more quickly. On the other hand, children with vestibular dysfunctions can demonstrate satisfactory results later because of their greater motor and balance impairments.

Thus, the fact that the child with SNHL had or not vestibular dysfunction could influence in the results of the trials, overestimating the effect size of the interventions with the presence of many children without vestibular dysfunctions or underestimating the effect size of those trials containing a large number of children with vestibular dysfunctions.

That is, future trials on the topic should consider the above information’s for dividing the sample into groups (control and intervention) at the time of randomization. Making the groups homogeneous about the number of children with SNHL with and without vestibular dysfunctions and thus, to observe the effects of the interventions in more homogeneous samples and with these controlled biases.

The control of vestibular dysfunction is also important, since it may influence the choice of duration of the intervention. This information is important for future trials, since trials with longer duration may have positive effects on the children with SNHL (with and without vestibular dysfunctions). On the other hand, interventions with a shorter duration may only reach children without vestibular dysfunctions, with a lower compromise in the balance and thus, have satisfactory results in a smaller number of children. Because the sample could contain many children with vestibular dysfunctions, who might need a longer intervention time, than what was proposed by the trial for the rehabilitation of the balance and gait of these children.

However, the above hypotheses can only be confirmed or rejected by future trials that presented control of the vestibular dysfunction of the sample and that include children with SNHL with and without vestibular dysfunctions, which could not be observed here, because none of the trials analyzed by this systematic review evaluated the function of the vestibular system of the sample.

The control of the vestibular dysfunction in the sample is essential to ensure that the intervention proposed by the trial is benefiting children with SNHL and associated vestibular dysfunctions, which present greater balance deficits. The absence of this control would be another confounding effect of the trial.

Therefore, we suggest that the future trials, besides evaluating the function of the vestibular system of the sample, also present their isolated results, dividing the children according to the diagnosis of the function of their vestibular system. Demonstrating the results of the effect of the interventions in children with and without vestibular dysfunctions. In this way, one can contribute to elucidate if the proposed treatment is effective for all the children with SNHL (with and without vestibular dysfunctions) and be useful for help guide clinical practice, and the recommendation of sports and recreation activities for these children.

Regarding the evaluation of the vestibular function, De Kegel et al. [28] found that the asymmetry of VEMP (vestibular evoked myogenic potential) could be a good predictor of balance disorders in children with SNHL. Thus, this method of assess of the vestibular function could be one of those chosen by future trials on this topic to evaluate the function of the vestibular system of their samples.

In addition to the bias mentioned above, it is worth mentioning that other aspects of SNHL and individual characteristics of the children may also represent biases to the trials and, therefore should be better controlled in future trials on the topic.

One of them is the degree of hearing loss. Of the five trials analyzed, three [41,42,45] reported that their samples had the highest degrees of hearing loss (severe and profound). This data is relevant because pieces of evidence already correlate the extent of hearing loss to the presence of vestibular dysfunctions in children, which may have occurred in the trials analyzed in this review.

Another characteristic of the children with SNHL that would justify the examination of vestibular function in the trials sample is the etiology of hearing loss, which is not very detailed by the trials. Only one trial detailed the SNHL etiology of the sample, whereas other studies did not even mention this outcome, and of the 27 children in the Fotiadou et al. sample [41], 15 presented meningitis as an etiological factor, which has been associated with vestibular dysfunctions in children with SNHL [59–62].

The meningitis is capable of resecting the endolymph present in the semicircular canals of the vestibular apparatus, which may lead to abrupt ossification of the inner ear and increase the density of the cochlea and posterior labyrinth, characteristics that can be observed on computed tomography in children with suspected ossification [63–65]. This could also justify the fact that children with SNHL with meningitis as an etiological factor presented low performances in the balance [61,66].

The age of the sample is another very relevant aspect that should be planned in a clinical trial, and two trials [44,45] of the five analyzed in this review used children and adolescents in the same sample, and did not categorize their results according to the age range, not allowing the analysis of their results obtained in children and adolescents. In addition to the physical and motor discrepancies between the children and adolescents, some studies have reported that there is an improvement of the balance in children with SNHL with advancing age, that is, in the adolescence, the balance is more stable than in the childhood in individuals with SNHL [66–69]. Thus, grouping children and adolescents in the same trial and not exposing their results, alone, for each age group, may represent a selection bias for both trials.

In addition, Shumway-Cook & Woollacott [70] analyzed the development of postural stability in groups of subjects of different ages and reported that postural stability in children is not fully developed before age seven. However, the Karbunarova trial sample [43] consisted of children aged 6–10 years and the trial did not report the number of children by age groups, which may configure a selection bias for this trial.

Thus, the future trials that intend to observe the effects of interventions in children with SNHL with balance stability under development (less than seven years old) need to categorize their findings, presenting the results of the interventions for children with mature balance stability or in development to avoid possible bias and help guiding clinical practice of these children.

Another questionable aspect of the trials [42,44] was the use of individual sound amplification devices by the children with SNHL, and that could influence the results since some studies have observed that cochlear implants and sound amplification devices have improved balance stability of adults and the elderly [71–76]. Similar findings have also been reported in the children with SNHL and users of cochlear implants, who have shown improvement in the balance stability [77–80], possibly due to the auditory opportunities provided by these devices, suggesting that auditory input is not neutral in the motor skills [81].

This motor enhancement of children's balance with cochlear implants can be justified suggesting that sound signals serve as fixed points of environmental reference [82–84], providing spatial maps of the environment to the children and thus a better space-temporal orientation and balance for these children [84,85]. Thus, the children who used hearing devices may have benefited from this mechanism, presenting a better spatial orientation and balance stability, demonstrating more favorable results to the intervention, which could represent a bias for the trials in which children used sound amplifiers.

Cochlear implants have shown satisfactory results on auditory and communication outcomes in children [86–89], which could characterize a bias if the trials included these children, as mentioned above. Besides that, children using cochlear implants also have a high frequency of vestibular dysfunctions and balance changes [90–93], which would represent another bias for the trials that included such children in their samples.

As discussed above, including children with and without cochlear implants in the same trial may influence the results of the trial and to underestimate the effect size of the interventions because of the possibility of vestibular dysfunction in the sample or to overestimate the effect size of the interventions by the auditory capacity that these children now present. Thus, trials conducted with children with SNHL with and without cochlear implants in the same sample need to expose the results of these children in isolation to reduce the biases, demonstrating the effectiveness of the interventions for children with SNHL, users or non-users of cochlear implants.

We also highlight that in this extensive search in the literature, we found several pieces of evidence that children with cochlear implants present vestibular dysfunctions and balance changes [90–97], however, there are still no proposed trials for the motor skills rehabilitation of this population. Thus, we suggest that trials on this theme be performed for children with cochlear implants, aiming to improve balance, gait, motor skills, quality of life and well-being of these children.

Finally, three shortcomings present in the trials analyzed need to be pointed, one of them being the choice of the instruments for the evaluation of the outcomes. Four of the five trials opted for clinical tests to measure outcomes, and one trial used a force platform. The use of different and unvalidated instruments for children, such as the Romberg test, for example, which was proposed for the evaluation of the elderly balance, reduces the reliability of the evidence and, in this systematic review made it impossible to perform the meta-analysis. We suggest that the next trials use more rigorous and already validated methods to children for evaluating the outcomes, to allow the achievement of a meta-analysis of the results of the trial and thus, to help in guiding the decision-making process of the use of the sports and recreational practices in this population.

Other important gap in the trials analyzed, which should be mentioned in the future trials on this topic, concerns the adverse effects of interventions. Only the Fotiadou et al. trial [41] mentioned that its intervention did not produce adverse effects in children and this information is very relevant, since it guides the recommendation of sports and recreational activities in the children with SNHL, allowing to analyze the relationship between the benefits of the intervention and their adverse effects.

The last aspect should be punctuated, given the increasing number of recently published trials on this topic, using other interventions [98–101]. The interventions in the groups (intervention and control) of the trials analyzed in this systematic review have similarities in terms of session duration, number of sessions performed per week, and the total duration of the intervention program. However, the main difference lies in the characteristics of the movements performed by the children in each group. The control groups activities were more focused on physical education classes (three trials), while the intervention groups performed rhythmic gymnastics, dance, athletics and swimming activities.

The differences between the modalities proposed by the trials in the intervention and control groups could justify the better balance and gait performances obtained by the intervention group, since dance and athletics, interventions of three trials, are modalities that present wide displacements of the gravity center. In addition to the need to organize and plan the movements during the dual tasks, when there is a need to overcome an obstacle in the case of athletics or to coordinate the movements with the vibration of the music or the stage, in the interventions with dance. The other interventions of the trials used rhythmic gymnastics and swimming, which can also influence the balance of children who practicing these modalities.

Swimming is one of the sports that could influence the rehabilitation of balance in children with SNHL and associated vestibular dysfunction, not only by the exercises themselves, but also because of the movements of head performed by their practitioners, as they turn their heads sideways, or to a the sides of the shoulder to breathe, during the freestyle swim, for example. Besides, the sports with rapid eye movement to accompany ball movements, such as table tennis, for example, could also influence the vestibular system and balance of these children, since exercises with head and eye movements have been called key exercises for the vestibular rehabilitation in children with vestibular dysfunctions [102].

This makes it difficult to know what are the real effects of swimming on balance rehabilitation in children with SNHL. However, the future trials could look at the effects of the four types of swimming on the balance of these children, as not all of them have head rotations in their practice. In addition, there is evidence that children with SNHL present a reduction in their range of movements and changes in head postural alignment compared to normal-hearing children [103–105] and this information should be considered by the next trials on this topic, who used the swimming as intervention, because it can influence children's motor performance and impact on the results of the trials.

The presence of the head and eye movements in the practice of some specific sports seems to be an advantage, but children with SNHL and associated vestibular dysfunction may feel dizziness or vertigo due to the rapid and constant movements of the head and eyes during these sports practices. This could negatively affect the motor performance of these children and influence trials results. The same can occur in those sports that have turns or pirouettes, such as artistic gymnastics, rhythmic and trampoline, ornamental jumps, taekwondo, or ice skating and in recreational activities as well, such as ballet and capoeira, demonstrating thus, the importance of choice of the modalities of the intervention and control groups and of reporting the adverse effects of interventions in the next trials on the topic.

Despite the biases above, the experiments analyzed by this review have positive characteristics, which should be highlighted and maintained in the next trials on the topic. Three trials contained relatively robust samples, two of them above twenty-five children [41,44] and another trial with a total of sixty children [42]. Studies with representative samples favor the generalization of their findings; however, it was not mentioned by any of the trials if there was any calculation for the definition of the sample size, which should be done in the next trials.

Another very relevant aspect of the trials that may help to indicate the sports or recreational activities for children with SNHL was the detailed exercises performed by the children during the interventions. Four trials [41,42,44,45] reported in detail what movements (exercises) the children performed in the intervention program, making these exercises replicable for future trials and guiding rehabilitation or recreation professionals, such as physical therapists, occupational therapists and physical educators in their therapeutic or professional practice.

This systematic review observed that the positive effects of the experiments with sports or recreational activities on the balance and gait of children with SNHL were observed in the trials in which the intervention program presented session time equal to or greater than 40 min, performed twice weekly or more, with total duration of the intervention equal to or greater than sixteen weeks [41,42,45]. This information can help guide new trials on the topic and the recommendation of sports and recreational activities in children with SNHL.

This systematic review presented as a limitation not to have searched the thesis databases and dissertations on the proposed theme.

Lastly, we believe that possibly the low motor performance of the child with SNHL concerning balance and gait may be a reflection of an inadequate perceptual-motor stimulation in early childhood and insufficient or not directed to the specific needs of the child in the school environment. This scenario can be reversed with specific motor interventions, using different approaches, giving motor experiences to these children, aiming to improve their motor skills.

Sports and recreational opportunities should be better planned and offered to the children with SNHL and this updated review provides evidence not previously discussed in the literature that will assist future trials on this topic. The professionals who work in the area of child motor behavior and in the school environment can use the information's discussed in this systematic review to stimulate the postural and motor system of children with SNHL, because sports and recreational practices are motivational, playful modalities that can be used to improve balance and gait of children and adolescents with SNHL, with preference to those interventions based on high-quality of evidence, thus justifying the realization of future trials on this topic.

5. Conclusions and suggestions for future trials

Sports and recreational practices seem to represent promising modalities to improve the balance and gait of children and adolescents with SNHL. However, due to the methodological limitations of the trials and the low quality of the current evidence on the topic, the results of the trials analyzed in this systematic review should be interpreted with caution.

Moreover, only one of the trials reported the adverse effects of the interventions, this makes it difficult to evaluate the relationship between benefits and adverse effects of the interventions. Thus, the result of conductive question of this systematic review, if the practice of sports or recreational activities is effective to improve the balance and gait of children and adolescents with SNHL was inconclusive. Any estimation presented by this systematic review would be uncertain, inconclusive or insufficient to support a recommendation involving sports and/or recreational practices to improve the balance and gait of children and adolescents with SNHL.

Given the low quality of evidence observed in this review, we suggest that new trials may be proposed on the topic, with better methodological quality, to provide high-quality evidence on the effectiveness of sports or recreational practices to improve the balance and gait of children and adolescents with SNHL. The next trials should control selection bias, the blinding of the outcomes assessors, the sample losses, and assess the function of children's vestibular system.

We also suggest that the next trials should consider the effects of other sports or recreational modalities on the balance and gait and that others functional and clinical outcomes can also be included, such as running, functionality, frequency of falls, quality of life of the children, and if the performance of the children on sports and/or recreational practices has improved, aspects so far ignored by the literature trials.

The future trials on this topic could still analyze the satisfaction of the parents and of the child on the interventions, identifying the domains and functional or daily life skills that have been improved in the children after the interventions and also the positive and negative points of these interventions, from the perspective of the parents and of the child. Making the intervention centered on the child's participation, involving the parents in therapy and providing evidence for future therapeutic decision-making on this issue.

In addition, the next trials could also investigate the values related to the costs of the interventions, and how long their effects remain. Such data are extremely important, as they will provide theoretical and scientific support to guide the sports or recreational practices recommendations and motor rehabilitation in children with SNHL.

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Declaration of Competing Interest

The authors declare that they have no conflict of interest.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.gaitpost.2020.02.001.

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