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REVIEW

Effect of exercise intervention on vestibular related impairments in hearing-impaired children

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KEYWORDS

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Abstract *Objective:* To analyze the methodological quality and compile the evidence from studies, which examined the efficacy of exercise interventions in the treatment of vestibular-related deficits in hearing-impaired children.
Sources: Extensive search of computerized bibliographic databases (MEDLINE, CINHAL, EMBASE, SCOPUS, ISI of web science, Cochrane Library, and AMED) was performed from earliest to February 7, 2011.
Data extraction: Potential articles were retained and analyzed by a single investigator to ensure the eligibility criteria. Methodological quality was analyzed using the PEDro scale.
Results: Our search yielded 8326 articles. Finally, two potential citations were retained for inclusion after removing duplicates, and excluding articles that do not fulfill the criteria.
Conclusion: Exercise programs that enhances the visual–motor and somatosensory abilities that enable substitution are more effective in improving the vestibular related deficits in children with hearing-impairment.

Contents

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1. Introduction

Hearing impairment is often defined in terms of communication deficit.[1] Despite this communication deficit a major impediment, hearing impairment is associated with other physical deficits such as vestibular related impairments.[2–4] Results of recent investigation have revealed that children with hearing loss may also present with balance and/or motor deficits.[5–7] Moreover, a recent systematic review confirms that balance and motor impairments were associated with hearing impairment.[8] Rine et al. reported progressive motor deficit in children with sensorineural hearing loss.[9] Wiegersma et al. confirmed that deaf children were inferior both in general dynamic coordination and visual-motor coordination.[10] Moreover, it is postulated that these deficits are related to damage to the vestibular system.[6,11,12] It is also reported that hearing impaired children with concomitant vestibular dysfunction have sensory organization deficit[13,14] and poor reading acuity.[15]

The typical treatment provided to the hearing impaired children is the cochlear implantation. Many researchers have questioned the impact of cochlear implantation in motor development and balance. Freja Gheysen et al. investigated the impact of a cochlear implant on the motor development of deaf children. The findings of their study showed that deaf children with a cochlear implant do not perform better on balance and motor skills than children without cochlear implant.[16]

Most children with vestibular deficits develop walking ability hence their deficits are un-noticed.[17] However, these children avoid outdoor games. Teachers of these children often complain of incoordination, clumsiness and balance deficits which may hinder the child's optimal performance.[18] Moreover, it is reported that the critical period of postural control development is between 4 and 6 years of age[19,20] and of motor development is 8 years.[21] Hence, intervention to address these deficits should be provided at the primary school age level. Remediation programs to address postural control as well as motor performances should focus on specific component deficiencies.[21,6] Interventional programs to address motor deficits in children with hearing impairments, must consider vestibular function and motor performance[12], as well as focus on improving visual and somatosensory effectiveness.[22]

Lewis et al. found that participation in a balance and body awareness program resulted in improved balance skills in children with hearing impairment[23], whereas Susan K. Effgen investigated the effect of a 10-day exercise program of static balance activities on the static balance ability of severely deaf children and found no significant difference in static balance ability.[24] The reports on interventions that address these deficits in children with hearing impairment are very minimal and inconclusive.[22,25] Thus, the question of whether exercise intervention is effective in the management of vestibular-related deficits in hearing impaired children remains unanswered. Therefore, the objective of this systematic review was to analyze the methodological quality and compile the evidence from studies, which examined the efficacy of exercise interventions in the treatment of vestibular-related deficits in hearing-impaired children.

2. Method

2.1. Search strategy

Relevant studies that focused on the effectiveness of exercise intervention on vestibular related impairments of children with hearing impairment were obtained through an extensive computerized search of Pubmed, MEDLINE, CINHAL (Cumulative Index to Nursing and Allied Health Literature), EMBASE, SCOPUS, ISI of web science, Cochrane Library, and AMED were searched from earliest to February 7, 2011 using the following key words: postural control, balance, motor skills, motor development, sensorineural hearing impairment/loss, hearing impairment/loss, deaf, and children or special children, exercise or rehabilitation or intervention or Physiotherapy were used in the search, including combination of these words. These data bases were chosen because they ensured access to health science journals. The search procedure was complemented by manually searching the bibliographies of the identified articles.

2.2. Criteria for considering studies for this review

After filtering the duplicates, a single investigator screened all the selected articles stage by stage. In the initial stage, titles and

abstracts of all retained articles were screened for eligibility. Studies were considered eligible for inclusion in this review if they met the following criteria: (1) RCTs comparing exercise intervention to a placebo intervention; (2) controlled comparison intervention, or standard care (treatment that is normally offered); (3) preliminary interventional studies; (4) age range 5–11 years; (5) results published as full reports before February 7, 2011 – abstracts were not included; (6) the study involved analysis of postural control and/or motor development and/or dizziness and/or vestibular hypo-function and/or vestibular related deficits in children with hearing impairment; (7) the study involved human children with hearing impairment/deaf/sensorineural hearing loss with or without cochlear implantation (CI); (8) the study had to be available in English; (9) studies in which the outcome of interest was balance or postural control, motor skills or motor development or vestibular function sensory organization or ENG. Exclusion criteria for this study were: (1) studies based on animal data; (2) studies published in languages other than English; (3) studies including subjects who were adults or elderly population; (4) children with hearing impairment who have associated neurological deficit; (5) non-interventional studies; (6) Case report/study. Finally, full-length articles of selected citations were reviewed in detail.

2.3. Data extraction and quality assessment

All potential articles were retained and reviewed by a single investigator to ensure that they fulfilled the eligibility criteria. Eligible studies for inclusion were analyzed for methodological quality using the PEDro scale. PEDro scale[26] is specifically designed for physiotherapy literature and it considers blinding at three different levels (subject, evaluator and the therapist). It demonstrates moderate to high reliability and allows high internal validity to be rewarded in studies that cannot be double blinded. Heterogeneity among the study interventions and the outcome measures prevented us from performing Meta-analysis.

2.4. Critical appraisal

The potential studies included were also critiqued using a rating system originally developed by Henrica CW de Vet et al.[27] in 1997 which facilitates more detailed evaluation of the study methods. This rating system examines criteria such as participant characteristics, sample size, description of interventions, and the validity and reliability of the chosen outcome measures. Henrica CW de Vet et al. rating system provides a detailed evaluation of the study methods and it has been used in systematic reviews in physiotherapy.[28–31] Each criterion was graded on 3 rating categories: (1) pass-met criterion; (2) moderate-incomplete/partially met criterion; and (3) fail-did not meet criterion/no information available. Summary scores were not used as there are no clear decision rules for establishing cut-off scores for high and low quality trails using this tool.[32]

3. Results

The results of our search through eight databases are presented herein. Our search yielded 8326 articles. The first screening consisted of reading the titles and the abstracts and eliminating the duplicates. 3453 articles were retrieved after removing 4873 duplicates, of which 3386 articles were excluded on the basis of title or abstract and 67 full text articles were assessed for eligibility. Finally, a total of 2 potential citations were retained for inclusion in the systematic review. Each article was read thoroughly by the reviewers and is summarized below. The two studies included in this review assess the effectiveness of the exercise program on vestibular related deficits in children with hearing impairment.

3.1. Quality assessment and critical appraisal

Table 1 presents PEDro scores for the two included studies on a scale of 1–11 with higher scores demonstrating higher quality. Rine et al. study[22] achieved a PEDro score of 11/11 repre-

Table 1 Methodological quality assessment of included studies.[a]

Study	1	2	3	4	5	6	7	8	9	10	11	Total score
Rine et al.[22]	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Susan K Effgen[24]	Y	Y	N	Y	N	N	N	Y	N	Y	N	5

[a] 1. Eligibility criteria. 2. Random allocation. 3. Concealed allocation. 4. Baseline comparability. 5. Blind subjects. 6. Blinding of clinician. 7. Blinding of assessor. 8. More than one measure on 85% of subjects. 9. All subject included or intention to treat analysis. 10. Statistical comparison of groups. 11. Point estimate and variability.

Table 2 Critical appraisal of included studies.[a]

Study	1	2	3	4	5	6	7	8	9	10	Main concerns
Rine et al.[22]	P	P	P	P	P	P	P	P	P	P	–
Susan K Effgen[24]	P	P	F	P	M	P	F	P	P	P	Agreement to participate Sample size Blinding

[a] 1. Study design. 2. Baseline characteristics. 3. Agreement to participate. 4. Intervention. 5. Sample size. 6. Data collection methods. 7. Blinding. 8. Participants starting/finishing. 9. External validity. 10. Statistical tests. P: Pass, met criterion; M: Moderate, incomplete/partially met criterion; F: Fail, did not meet criterion (the fail rating was also assigned if no information was provided in the publication on a specific criterion).

Table 3 Baseline characteristics of study populations of trials included in this review.

Author	Study design	Population	Sample size		Mean age		Gender	
			Treatment group	Control group	Treatment group	Control group	M	F
RM Rine et al.[22]	Placebo-controlled wait listed design	25 children with SNHL and vestibular impairment	10	11	67.54	68.4 (in months)	9	12
Susan K. Effgen[24]	Pretest-Post test control group design	Severely deaf children	25	24	7–11 (yrs)	7–11 (yrs)	29	20

Table 4 Design characteristics of studies included in this review.

Study	Intervention	Dosage	Outcome measure	Results	Follow up	PEDro score/11
RM Rine et al.[22]	Exercise intervention compared with placebo intervention	30 min session, 3 times/ week for 12 weeks	Posturography sensory conditions testing using SMART balance master system, gross motor scale of the Peabody developmental motor scales	Significant difference between groups for all the outcomes	12 weeks	11
Susan K. Effgen[24]	Static balance exercise program	15 min session, daily for 10 consecutive school days	Force platform (four different stance)	No significant difference in static balance ability as measured by degree of sway. Significant improvement in the length of time that children in the experimental group could stand on one leg	Not clear	5

senting a higher quality and that of Effgen[24] study was awarded a score of 5/11representing a moderate quality. Table 2 presents critical appraisal of the included studies. Rine et al. study fulfilled all the criteria on Henrica CW de Vet et al. critical appraisal scale, whereas the Effgen study lacked details on few components.

3.2. Baseline characteristics of the included studies

Both the studies included in this review examined the effectiveness of exercise program on vestibular related deficits. Tables 3 and 4 summarize the characteristics of the included studies. Both the included articles were true experimental studies: Rine et al. used a Placebo-controlled wait listed design and the other one by Effgen was a pretest–posttest control group design.

In terms of hearing impaired children sampled, Rine et al. study[22] included children with SNHL and vestibular impairment, and the Effgen[24] study included severely deaf children. Rine et al. assigned the children into groups using a random block design in which groups were matched for age and age equivalent score on motor development testing and Effgen assigned subjects to group by stratified, random sampling according to sex and age. The sample size of Rine et al. study was 25, and of Effgen was 49.

3.3. Instrumentation

With regard to the outcome measures, Rine et al. measured sensory integrative postural control abilities using Posturography and motor development using gross motor scale of the Peabody Developmental Motor Scales (PDMS).[22] They tested Posturography sensory conditions using SMART balance master system which includes an enclosure and a force platform that facilitates computerized measurement of postural stability used to maintain vertical orientation. They obtained postural sway measures under six sensory conditions: (1) eyes open, fixed support; (2) eyes closed, fixed support; (3) sway-referenced vision, fixed support; (4) eyes open, sway-referenced support; (5) eyes closed, sway-referenced support; (6) sway-referenced vision, sway-referenced support. Scores were compared to the normative data. Rine et al. tested motor development using the gross motor scale of the Peabody developmental motor scales (PDMS) which is a norm referenced standardized test that provides standardized "z" and age equivalent scores for the scale and each sub test. It is composed of six subtests that assess related motor abilities that develop early in life: Reflexes, Stationary (body control and equilibrium), Locomotion, Object Manipulation, Grasping, and Visual-Motor Integration.

Effgen measured static balance by having the subject standing on the force platform.[24] The subject was made to stand on the force platform for 30 s in each of the following test positions: (1) stand, feet together, medial borders touching, eyes open, (2) stand, feet together, medial borders touching, eyes closed and covered, (3) stand on right leg, unsupported, eyes open, (4) stand on left leg, unsupported, eyes open.

3.4. Intervention

The exercise intervention in Rine et al. study was designed to enhance the visual–motor and somatosensory abilities which enable substitution and was similar to those described by Krebs et al. The exercise session included eye hand coordination, general coordination activities, visual motor training and balance training and the exercise program was carried out for 30 min session/3 times per week for 12 weeks.[22].

The exercise intervention provided by Effgen[24] was based on the program outlined by Armheim and Pestolesi and each session included standing on toes with feet apart and feet together, standing on right foot unsupported with the left foot behind the right knee, standing on left foot unsupported with the right foot behind the left knee and standing with right heel touching left toe, feet in a straight line. The children in the experimental group participated in a 15 min session exercise program for 10 consecutive school days.

In both the studies, make-up sessions were provided for the missed sessions. Both the studies compared exercise program with control groups. The placebo group in Rine et al. study participated in 30 min sessions of language development training program for three days per week. Furthermore, exercise intervention was provided to the participants in the placebo group following the post test. In Effgen study the subjects of the control group were engaged in their normal classroom activity (free play).

4. Discussion

The findings of this review indicate that the exercise program that enhances the visual–motor and somatosensory abilities that enable substitution is more effective in improving the motor development and the postural control. Despite these findings, the results must be interpreted with caution as we were able to identify only two experimental studies that address our field of interest and they provide contrasting results. Furthermore to the authors' knowledge no comprehensive systematic review of studies investigating the effectiveness of exercise intervention on vestibular related impairments in hearing impaired children has been published.

Lewis et al. found that participation in balance and body awareness program resulted in improved balance skills. The results of this study could not be included in this review as we were able to trace only the abstract.[23].

Rine et al. study[22] showed that pre intervention, the children with SNHL along with bilateral vestibular impairment demonstrated motor development deficit and postural control deficit compared with the normative sample and following exercise intervention, no placebo intervention, motor development and postural control improved. The post test PDMS raw scores as well as merged scores on SCT-3 and the vision and somatosensory ratios of the exercise group improved significantly. The placebo group which participated in the exercise intervention following the post-test also showed similar improvements at the second post-test. They also noted that following exercise intervention, the scores of the children with SNHL with concurrent vestibular impairment were similar to the normative sample. The results of the Effgen study[24] are not consistent with Rine et al. study. Effgen found no significant difference in static balance ability as measured by degree of sway, however he found a significant improvement in the length of time that children in the experimental group could stand on one leg.

An important factor to be considered is the different set of exercises provided and the follow up period. Rine et al. provided exercise intervention that enables substitution and the exercise was provided for a total of 30 sessions within the four month period whereas, Effgen[24] provided the traditional exercises for a total of 10 sessions. Thus the traditional exercise and the insufficient duration of the exercise program might have lead to the lack of improvement in the degree of sway. However Effgen noted a significant improvement in the length of time stood on one leg which reflects a quantitative improvement. Furthermore Rine et al. study was considered strong by the PEDro scale as well as by the Critical appraisal rating system. Effgen study was considered moderate by the PEDro scale and was deficient in certain criteria on the critical appraisal: there was inadequate information on the sample size, blinding and agreement to participate.

When taking into account the quantitative improvement in the Effgen study and the significant improvement in the motor ability and the postural control in the Rine et al. study, it would be reasonable that the exercise that enabled substitution rather than the traditional set of exercises would be more effective in improving the vestibular related impairments in children with hearing loss.

5. Limitations

The findings of this systematic review have to be considered in the light of limitations. A single reviewer selected the reviewed articles independently, adhering to the inclusion/exclusion criteria. Although these criteria were followed by the reviewer, this was still a subjective process which potentially introduced selection bias. In addition conference proceedings, unpublished studies and the articles in the foreign languages were not retrieved, which creates a potential for publication bias. However, as no additional papers emerged from bibliographic checking of the retained studies, it can be assumed that a comprehensive search was conducted.

6. Clinical implications

Exercise program that enhances the visual-motor and somatosensory abilities that enables substitution seems to be effective in improving the motor development and the postural control deficits in children with hearing impairment compared to placebo intervention and traditional exercises. The substitution exercise program also halt the progressive motor development delay in children with sensorineural hearing loss and concurrent vestibular impairment. However Rine et al. warrant their findings only to the pre-school aged children. In addition the long term effect of the improvements noted in Rine et al. study also remains unanswered.

7. Research implications

Because only two studies that investigated the effectiveness of the exercise program on vestibular related deficits in hearing impaired children were identified, and their results were not consistent, further research examining this issue is needed. Further research that examines this issue in primary school children is also needed, since most children with vestibular deficits do develop walking ability, and their problems are not noted at earlier stages. Testing of the persistence of the achieved improvements may also provide useful information. Such a study is currently under way.

8. Conclusion

The findings of this review suggest that exercise program that enhance the visual-motor and somatosensory abilities that enable substitution are more effective in improving the vestibular related deficits in children with hearing impairment. Further research is crucial because if these interventions can improve the vestibular related deficits in hearing impaired children, the findings can be generalized to a larger population of hearing impaired children with vestibular deficits which would facilitate them to receive appropriate treatment that minimize the negative impacts of these impairments.

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