Research Article

Comparing Fine and Gross Motor Development in Normal Hearing Children, Rehabilitated, and Non-Rehabilitated Hearing-Impaired Children

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Highlights

- Hearing impairment in childhood may have major effects on motor development
- The development of fine motor skills requires precise synergy of small muscles
- Hearing rehabilitation seems to have an effect on the gross motor skills development

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ABSTRACT

Background and Aim: Motor development is a continuous process throughout life. Hearing impairment in childhood may have significant effects on motor development. This study compared the motor development of normal-hearing and hearing-impaired children at early developmental ages.

Methods: This research was a cross-sectional study. A total of 149 children aged six to eighteen months were selected and divided into three groups: normal-hearing children (NHC) (55 girls and 65 boys) selected by convenient sampling strategy, non-rehabilitated hearing impaired children group (NRHIC) (11 girls and 13 boys) selected by purposive method, and rehabilitated hearing-impaired children group (RHIC) (3 girls and 2 boys) selected by the census method. The Denver developmental screening test 2 (DDST-ll) was used to assess motor development. The obtained data were analyzed by Kruskal-Wallis, Mann-Whitney U tests, and curve drawing.

Results: The fine motor development of the NHC (9.63±28.83) was significantly greater than the RHIC (-18 ±26.83) and NRHIC (–21.25±30.26) groups, but there was no significant difference between the RHIC and NRHIC groups. In gross motor development, the NRHIC (–32.71±41.26) group had a more significant delay compared to the NHC (13.38±37.73) and RHIC (0±21.21) groups, but there was no significant difference between the NHC and RHIC groups.

Conclusion: Hearing rehabilitation can partially compensate for the developmental delay in gross skills, but this compensation has not occurred for fine motor skills. The development of fine motor skills requires a precise synergy of small muscles and the nervous system.

Keywords: Deafness; hearing impaired rehabilitation; motor skills

Introduction

One of the most important components of development is motor development. There are different perspectives on motor development; Gallahue's hourglass is one of the most popular perspectives. Motor development based on Gallahue's model includes the following phases: a) reflexive and rhythmic movement, b) rudimentary movement, c) fundamental movement, and d) specialized movement. Delay in each developmental stage will postpone the following stages [1]. Reflexes and rhythmic movements are essential for the children's survival and prepare them for voluntary movements. The rudimentary movement (developed at one to two years' age) phase includes gaining control of the head and trunk and learning how to crawl and sit. Although these movements appear in a particular order in most children, the time of their appearances varies from one child to another. At this phase, the role of learning and environmental stimuli becomes more prominent than in the previous phase [2]. One of the primary divisions for motor skills includes gross motor and fine motor skills. Gross motor skills are ones in which the body's large muscles, like the leg muscles, play a major role. These skills are involved in producing a set of movements such as walking or running and kicking. Fine motor movements are controlled mainly by small muscles, like the ones of the fingers and forearm that move hands and fingers. Therefore, movements such as grasping, receiving, and dropping objects are considered fine movements [3].

One of the most important physical aspects that affect other development components is the sense of hearing. Hearing loss in childhood is a common disease that may affect speech development and social and physical development [4]. Partial or complete inability to hear may occur in one or both ears, which can affect the learning of spoken language in children [5]. It is diagnosed when a person in a hearing test cannot hear a pure tone with an intensity of 25 dB in at least one ear. Hearing tests are recommended to diagnose hearing loss in all infants. Hearing loss can be classified as slight, mild, moderate, severe, and profound. Hearing problems can be divided into three categories: conductive hearing loss, sensorineural hearing loss, and central hearing loss [6]. The prevalence of bilateral, moderate to severe, and persistent sensory neural hearing loss in infants is 0.5 to 1 per 1000 live births, and since the onset of hearing loss can occur at any age, the prevalence in children under six years is 1.5 to 2 per 1000 [7].

One of the components of development that is affected by hearing impairment is motor development. Children with severe, bilateral hearing loss, and vestibular disorder show gross motor developmental delay [8]. Typically, children with hearing problems cannot properly control their posture versus their normal-hearing peers [9] and have more imbalance [10]. Congenital hearing loss slows gait velocity [11]. Although approximately 6%-13% of school-age children have poor motor coordination, the underlying problems with fine and gross motor skills are often overlooked as growth problems [12]. Because different developmental components interact with each other, ignoring a delay in motor development may postpone another developmental component. In this regard, we can point to the strong connection between language and motor systems. Young children can discover new objects and practice language by acquiring motor skills that lead to their overall development. Congenital hearing loss and general loss of the vestibular system may lead to delayed development of speech and motor skills [13].

Fortunately, the global implementation of the neonatal hearing screening program has facilitated early detection and intervention for infants with hearing impairment. After the diagnosis of hearing loss in the baby, the process of intervention and rehabilitation begins. Once the auditory function has been optimized using the appropriate hearing aid selection process, the hearing-impaired child can enter the rehabilitation process. There are different approaches to hearing rehabilitation, all of which aim to restore the abilities, maintain the dignity of the hearing impaired person, and determine his or her legal and social status. Auditory verbal treatment (AVT) is one of the hearing rehabilitation methods for children with profound bilateral hearing loss [14]. The result of studies on the motor development of deaf children in the last three decades (1988-2020) indicates a delay in the development of gross and fine motor skills in deaf children; past research also confirms the effect of auditory rehabilitation and vestibular rehabilitation, and physical exercise on increasing vestibular adaptation and balance in these children [1, 15]. Nevertheless, the critical point is that most studies have been done in the age range of more than three years and usually at preschool age, and few studies are in the field of fine and gross motor development in children before language learning (under three years). Therefore, this study was performed to investigate the motor development of normal-hearing children aged six to eighteen months and compare it with rehabilitated and non-rehabilitated hearing-impaired children.

Methods

Study design and participants

The present research was a cross-sectional study from 2020 to 2021. A total of 120 normal-hearing children (NHC) with healthy physical conditions including 55 girls (45.8%) and 65 boys (54.2%) were selected by convenience sampling method and 24 non-rehabilitated deaf children (NRHIC) 11 girls (45.8%) and 13 boys (54.2%) and 5 deaf children with optimal rehabilitation status (RHIC) 3 girls (60%) and 2 boys (40%) were selected by census method and included in the study. The hearing threshold of deaf children participating in this project was 90 to 120 dB, and they had no physical problems other than hearing problems. Non-rehabilitated deaf children were identified in the hearing screening program but had not entered the appropriate rehabilitation intervention phase for any reason whatsoever during the follow-up of the project. The rehabilitated hearing-impaired children group in this project were those who, after being diagnosed with deafness, received rehabilitation services from special centers for the hearing-impaired children in Khorramabad. These services included the use of hearing aids, lip-reading, speech reading, and other skills for at least three months. The statistical population of this study was all children living in Khorramabad in the age range of six to eighteen months, identified through newborn hearing screening test sites in the city. The problems reported ranged from slight hearing loss in one ear to profound bilateral hearing loss. Therefore, according to the inclusion and exclusion criteria of this project, despite the identification of nearly one hundred hearing-impaired children in the study area, the number of samples of rehabilitated and non-rehabilitated hearing impaired children in this study was minimal.

Assessment tools

The tool for measuring development assignments in this project was the Denver development screening test 2 (DDST-ll). The test is a developmental screening test prepared in 1967 by Frankenberg et al. with 125 test items and revised and standardized in 1992. It tests children from birth to six years of age based on four different aspects of development: personal-social development, fine motor development, language development, and gross motor development. Developmental tasks and skills are scaled according to the order in which their natural development appears in children [16]. The Denver chart for each task shows the ages at which 25% -50%, 50%-75%, and finally, the age at which 75%-90% of Denver children could complete the task. In this study, the age range in which 50%-75% of children could do the task is considered the norm. The validity and reliability of the DDST-ll in Iran (the project site) have been confirmed [17]. According to the Denver test, children aged six to eighteen months were identified with gross movements and fine adaptive movements [18]. For all the children in the project, developmental tasks were done according to their age (Table 1). The climatic, cultural, and racial conditions can affect the results of a standard test. The gross and fine motor development of children with normal hearing in the age range of six to eighteen months in the study area was not much different from the Denver sample [19]. Therefore, rehabilitated and non-rehabilitated hearing-impaired children can be directly compared to the Denver sample (children with normal hearing).

Assessment

At first demographic information was recorded for each child referred to the Central Audiology Clinic of Khorramabad by observing all health protocols for COVID-19 disease. If the inclusion criteria were met, diagnostic hearing tests of otoacoustic emissions (OAE), auditory brainstem response (ABR), auditory steady-state response (ASSR), and behavioral audiometry were performed as needed. Then, the gross and fine motor development of the child was assessed with DDST-II appropriate to the child's age. OAE was one of the tests used in this project. Passing this test confirms the child's hearing health, and failing the test leads to other diagnostic hearing tests. ABR was another test used in this project. The presence of wave V at an intensity of 25-30 dB confirms the child's hearing health. The absence of ABR waves at higher intensities refers the child to other diagnostic hearing tests. The ASSR was performed on children referred for ABR testing for the final diagnosis of hearing loss. Behavioral audiometry was based on observing the child's reactions to the sound presented by sound makers.

To evaluate motor development with the DDST-II, first, a vertical line was drawn on the Denver chart sheet according to the child's calendar age, and the date of the test was written above it. In fact, drawing a line determines what tasks the child should do in each aspect of development (gross and fine motor development) So if the child passed an item, the letter "P" was placed on the column, and if not, the letter "F" was placed. After showing the task by the examiner, the child performs the skill and is either given a P score of one or an F score of zero. In this study, if 50% to 75% of Denver's normal

children could complete this assignment, it was considered the benchmark for what a child should also be able to do (All three groups participating in the project) (Tables 1 and 2). Finally, the Denver test provided two sets of data for analysis. First the number of tasks that the participant is expected to pass at each age according to the participant's age (task data). Second is the delay, non-delay, or advanced development of the participant, which is based on the day unit (developmental data). A positive sign next to the number of days means that the participant's development is advanced, and a negative sign means a development delay. The zero also means that the participant's development is expected.

Data analysis

Data analysis was performed based on both the number of gross and fine motor skills tasks and the number of days of delay or advance of gross and fine motor development of children compared to the Denver scale. Tasks data information was shown with graphs (Figures 1 and 2), and non-parametric Kruskal-Wallis and Mann-Whitney U tests were used to analyze developmental data by day because they did not have a normal distribution (Figures 3 and 4).

Results

The average scores based on task data of gross and fine motor development of children with normal hearing (NHC) and deaf children with and without hearing rehabilitation (NRHIC and RHIC) are listed in Table 2. As shown in this Table, the rehabilitated children enumerated in this scheme are in the age range of 15 to 18 months.

As shown in Figures 1 and 2, delays in fine motor skills can be seen in deaf groups. In gross motor skills, developmental delay is compensated in rehabilitated children.

The delay, non-delay, or advance development of the participant, based on the day (developmental data), are shown in Figures 3 and 4. NHC children are above (positive score) or on the midline (score 0), and a small number of them are below the midline (negative score). In other words, the difference between gross and fine motor development in NHC and Denver sample was not significant [19]. It can also be seen in Figure 3 that the gross motor development scores in NRHIC are below the midline (negative score), but in the RHIC group, the scores are often higher or on the midline. Regarding the NRHIC group, the scores of fine motor development are often below the midline (negative score), and in the RHIC group, the scores are often lower or close to the midline (Figure 4).

The results of the Kruskal-Wallis test in fine ($\chi2=29.82$, $p\leq0.001$) and gross ($\chi2=27.84$, $p\leq0.001$) motor skills showed significant differences between the three groups based on developmental days. The results of the Mann-Whitney U test showed that the RHIC ($U=158.5$, $p=0.032$) and NRHIC ($U=600$, $p=0.001$) groups had a significant developmental delay in fine skills compared to the NHC group. Regarding the development of gross motor skills, the NRHIC group had a significant developmental delay compared to the RHIC group ($U=3.9$, $p=0.048$) and the NHC group ($U=512$, $p=0.001$) (Table 3 and Figures 3 and 4).

Discussion

According to the study results, the difference between fine motor development in hearing-impaired children (RHIC and NRHIC) and their normal-hearing counterparts in the early stages of development is significant. In other words, despite auditory rehabilitation in the RHIC group, fine motor development has not been improved. While gross motor development is significantly different between NHC and NRHIC children, there is no sig-

Table 1. Motor skills based on Denver scale

Age (Months)	Gross motor development tasks	Fine motor development tasks
6–8	Sit no support	Look for yarn/rake raisin/pass cube/take 2 cubes/bang 2 cubes held in hands/thump-finger grasp
8–10	Stand holding on/pull to stand/get to sitting	Put block in cup
10–12	Stand to 2 seconds	Scribbles
12–14	Stand/alone/stoop and recover/walk well	Dump raisin demonstrated/tower of cubes 2
14–16	Walk backwards	Tower of cubes 4
16–18	Runs/walk up steps/kick ball forward	Tower of cubes 6

Table 2. Mean (standard deviation) scores of gross motor development and fine motor development skills normal hearing children, rehabilitated hearing impaired children and non-rehabilitated hearing impaired children groups

Age (Month)	Mean (SD)					
	Gross Motor Development			Fine Motor Development		
	RHIC	NRHIC	NHC	RHIC	NRHIC	NHC
6.00		9.25 (2.11)	10.80 (0.52)		8.50 (1.20)	9.77 (0.98)
7.00		8.00 (2.95)	9.40 (0.48)		9.50 (1.41)	10.33 (0.47)
8.00		10.00 (0.00)	12.00 (0.68)		9.50 (0.00)	13.20 (0.56)
9.00		9.00 (0.00)	13.14 (0.89)		10.00 (0.00)	12.88 (0.78)
10.00		13.00 (3.10)	13.90 (0.98)		12.50 (1.78)	13.33 (0.53)
11.00		13.00 (2.57)	14.20 (1.20)		10.00 (2.58)	12.00 (0.89)
12.00		13. 50 (23.12)	15.60 (0.94)		12.50 (2.67)	14.50 (0.78)
13.00		15.75 (3.56)	17.45 (0.89)		14.25 (3.10)	15.18 (0.89)
14.00		18.00 (2.97)	19.30 (0.68)		14.50 (1.98)	17.30 (0.96)
15.00	15.00 (0.00)	18.00 (0.00)	18.55 (0.96)	15.00 (0.00)	16.00 (0.00)	17.50 (0.74)
16.00	19.00 (0.00)	15.00 (0.00)	18.50 (0.98)	15.00 (0.00)	17.00 (0.00)	16.94 (0.87)
17.00	21.00 (0.00)	18.00 (0.00)	21.30 (0.84)	15.00 (0.00)	17.00 (0.00)	16.00 (0.73)
18.00	20.50 (1.89)	21.00 (4.87)	21.00 (0.78)	17.00 (0.45)	17.00 (4.12)	16.66 (0.82)

RHIC; rehabilitated hearing impaired children, NRHIC; non-rehabilitated hearing impaired children, NHC; normal hearing children

nificant difference between NHC and RHIC children in gross motor development because gross motor scores were found to be positively related to chronological age, whereas the opposite trend was observed for fine motor scores. A disassociation between fine and gross motor development in prelingually hearing-impaired children, i.e. fine motor skills versus gross motor skills, tends to be delayed as the prelingually hearing-impaired children get older. Auditory deprivation may lead to the atypical development of specific motor skills that share common cortical processing resources [20]. On the other hand, fine skills require precise synergy between the agonist, antagonist, and nervous system muscles, and learning this coordination takes time [2]. It should be noted that the rehabilitated children in this study have been under rehabilitation services for a short time (three months), so the results may change over time. Therefore, timely rehabilitation should be emphasized, so hearing rehabilitation must be updated to develop fine motor skills.

Table 3. Mean (standard deviation) of selected developmental aspects compared to the norm of Denver test by day in normal hearing children (n=120), non-rehabilitated hearing impaired children (n=24), and rehabilitated hearing impaired children (n=5)

Group	Mean (SD)	
	Fine Motor	Gross Motor
NHC	9.63 (28.83)	13.38 (37.73)
NRHIC	–21.25 (30.26)	–32.71 (41.26)
RHIC	–1800 (26.83)	0.00 (21.21)

NHC; normal hearing children, NRHIC; non-rehabilitated hearing impaired children, RHIC; rehabilitated hearing impaired children

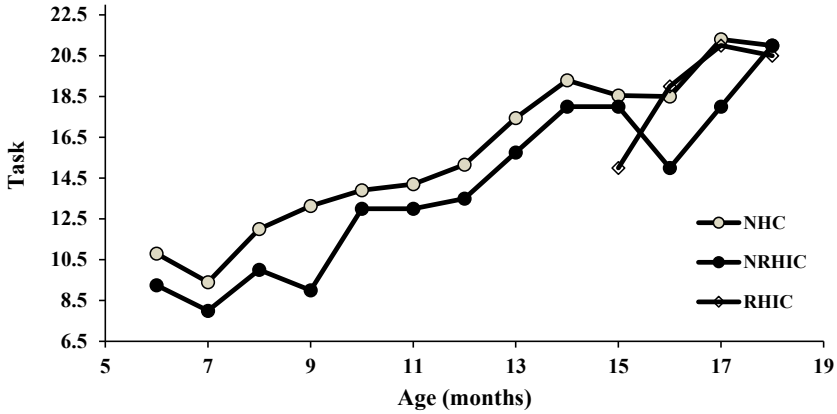

Figure 1. Gross motor development based on tasks. NHC; normal hearing children, NRHIC; non-rehabilitated hearing impaired children, RHIC; rehabilitated hearing impaired children

The age range of the children studied in this study was six to eighteen months. At this age, the reflex movement would have been completed, and the children are in the rudimentary movement stage because some of their reflections are related to the auditory system or labyrinth system both are related to the eighth nerve [1]. Since hearing impairment also affects the labyrinth system, the reflexes triggered by them are also affected [21]. Moro, symmetrical tonic neck, parachuting, and labyrinthine righting are some of the reflexes that can be stimulated by the hearing or labyrinth system [22]. According to reflex theory, an advanced reflex is not a new reflex but is created by completing or combining lower-level reflexes. In other words, a higher-level reflex develops when a child is exposed to new stimuli that require complex movement. More than the previous reflex, and with changes in reflex, the child's involuntary movements become voluntary [23]. On the other hand, in the stage of preliminary voluntary movements, the role of learning and environmental stimuli is more potent than in the previous developmental stages [1].

As we know, environmental stimuli and training opportunities for hearing-impaired children are less than their hearing counterparts. Normal hearing children respond to surrounding sounds such as rattles, toys, pleasant and rhythmic songs, and TV sounds, but deaf children lack these opportunities. Therefore, the delay in developing gross and fine motor skills in hearing-impaired children can be related to the lack of peripheral vocal stimuli and the consequent lack of progress in reflex movements to the preliminary movements [24]. Environmental constraints (family, friends, community, etc.) also contribute to delayed motor development in deaf children. Because of hearing loss, many learning opportunities can be lost. For example, the family of a deaf child may prefer their child not to participate in various social events, like playing with their normal-hearing counterparts, etc. which

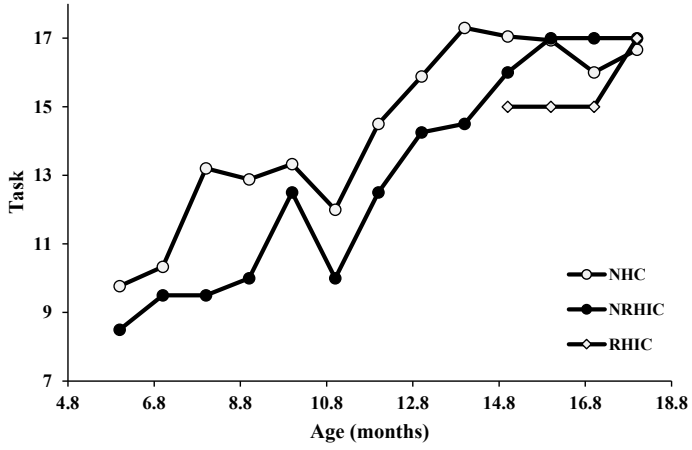

Figure 2. Fine motor development based on tasks. NHC; normal hearing children, NRHIC; non-rehabilitated hearing impaired children, RHIC; rehabilitated hearing impaired children

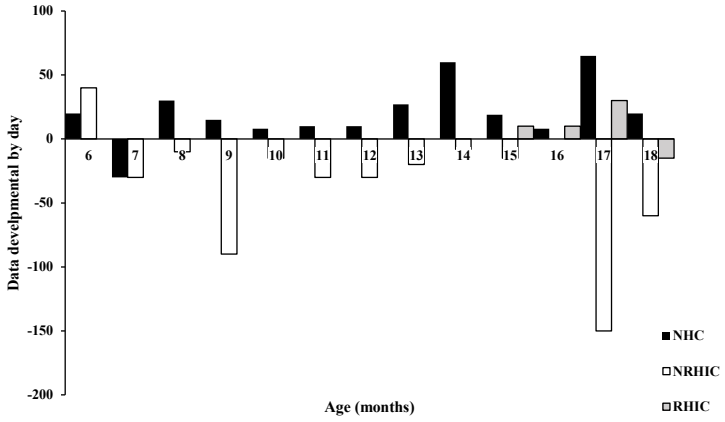

Figure 3. Gross motor development based on data developmental by day. NHC; normal hearing children, NRHIC; non-rehabilitated hearing impaired children, RHIC; rehabilitated hearing impaired children

may deprive the child of opportunities for participation and movement [25].

Some researchers believe that motor development improves in hearing-impaired children with increasing age [26, 27]. Also, the development of fine skills is more delayed than the development of gross skills in hearing-impaired children [28, 29]. Therefore, considering that the rehabilitated children in this project were in the age range of 15 to 18 months, both age and rehabilitation factors can improve gross motor development.

According to the American Speech and Hearing Association, hearing rehabilitation after a hearing loss is an essential step for hearing-impaired children. Hearing loss, regardless of its cause (acquired or congenital), impairs language and speech development [30]. The age of children undergoing hearing rehabilitation is a crucial factor that can affect rehabilitation outcomes, including various factors such as emotional, social, linguistic, and speech development [31].

At present, according to the guidelines of the Joint Committee on Neonatal Hearing (2007) (which provides principles and guidelines for early hearing detection and intervention), the recommended age for hearing rehabilitation is less than six months of age, and late participation in a hearing rehabilitation program can affect outcomes [14].

In Iran (project area), despite increasing knowledge about the importance of early intervention and rehabilitation in hearing care professionals, many children begin a hearing rehabilitation program or use a hearing aid too late. Out of 29 deaf children participating in the study, 19 were diagnosed with hearing problems before the age of three months, eight between the ages of three and six months, and only one after six months; this finding indicates the success of the global hearing screening pro-

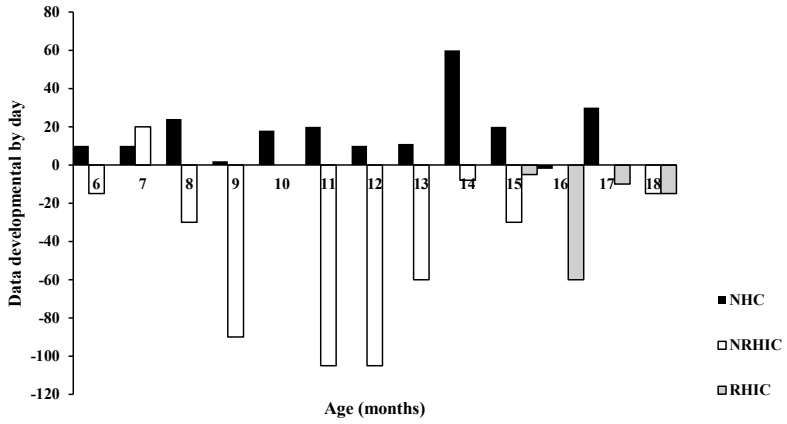

Figure 4. Fine motor development based on data developmental by day. NHC; normal hearing children, NRHIC; non-rehabilitated hearing impaired children, RHIC; rehabilitated hearing impaired children

gram in the city of Khorramabad. If the assessment after the diagnosis of hearing loss is done correctly and on time, hearing loss will not occur as a disability in the future life of the hearing impaired children. However, only five had received rehabilitation services. There are many delays and shortcomings in hearing rehabilitation that undermine the success of the neonatal hearing screening program. Of 29 deaf children in this study, eight had a deaf person in their family (first- and second-degree relatives), and 21 of them lived in families who had not experienced the existence of a hearing-impaired person before and usually had a high resistance to accepting their child's hearing loss. This situation causes them to miss a great opportunity to start treatment and rehabilitation of the child on time.

It should be noted that auditory training is a subset of hearing rehabilitation. However, the particular focus of the rehabilitation team on it has led to the neglect of other aspects of auditory rehabilitation, including motor development and individual social skills. Numerous studies have been conducted that, while reporting the shortcomings of social skills in hearing-impaired people, have emphasized the importance of education, acquisition, and application of social skills and the promotion and development of these skills [32]. Unfortunately, parents' level of education in all three groups of participants was intermediate, and the level of postgraduate education was low. Also, in terms of employment, most parents had unsustainable jobs, such as labor gardening, color work, and seasonal work. It is a season in which these two cases indicate the unfavorable economic situation of the households in the city under study. Given the high cost of hearing aids and the treatment and hearing rehabilitation classes, perhaps this was one of the few reasons for the small number of rehabilitated children in this study. The economic sanction in Iran has led to an increase in the cost of hearing aids and cochlear implants. The COVID-19 epidemic has further led to fewer available resources for children due to the closure of hearing training centers, which has caused only online education to be available. The best procedure is recommended by the global neonatal hearing screening program, which is after the diagnosis of hearing loss, the evaluation is completed in the first few months after birth for hearing rehabilitation.

Conclusion

The Denver-II screening test is recommended to assess motor skills development in health and special centers for the hearing-impaired children aged six to eighteen months. Also, the difference between fine and gross motor development in hearing-impaired children and hearing counterparts at the same early developmental ages is evident. Hearing rehabilitation seems to affect the gross motor skills development of hearing-impaired children. Because the global implementation of the neonatal hearing screening program has facilitated early diagnosis for infants with hearing impairment, it is essential to start intervention and appropriate and optimal rehabilitation as soon as possible for various aspects of pediatric development, including motor development.

Ethical Considerations

Compliance with ethical guidelines

This study has an ethical approval (IR.IAU.B.REC.1400.007) conducted in Khorramabad City, Lorestan Province, Iran.

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Authors' contributions

PV: Study design, acquisition of data, assessment of hearing, evaluation Denver test, interpretation of the results, statistical analysis, drafting the manuscript; MR: Study design, supervision, interpretation of the results, statistical analysis, drafting the manuscript; SS: Study design, interpretation the results; EG: Study design, interpretation the results

Conflict of interest

The authors declared no conflicts of interest.

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