Aud Vestib Res (2020);29(1):10-25.

REVIEW ARTICLE

Motor development in deaf children based on Gallahue's model: a review study

Parvin Veiskarami[1], Mehdi Roozbahani[2*]

[1]- Department of Psychology, Borujerd Branch, Islamic Azad University, Borujerd, Iran
[2]- Department of Motor Behavior, Borujerd Branch, Islamic Azad University, Borujerd, Iran

Received: 9 Jul 2019, Revised: 24 Aug 2019, Accepted: 7 Sep 2019, Published: 15 Jan 2020

Abstract

Background and Aim: As deaf children grow up, they face difficulties that can affect their physical, emotional, motor, and cognitive development. This study reviews the recent studies conducted on motor development of deaf children based on Gallahue's model.

Recent Findings: Few studies have been conducted on deaf children's motor development stages; reflexive, rhythmic, rudimentary, and specialized movement. However, many studies investigated the fundamental movement stage with an emphasis on balance. They mostly reported the deaf children's delay in developing gait velocity (during walking), postural control, static balance, dynamic balance, spatial-temporal coordination, gross motor skills, fine motor skills, and motor skills learning, compared with their healthy peers.

Conclusion: Delay in motor development in deaf children is not necessarily the result of deafness or vestibular problems, but individual, environmental, and exercise factors are also involved. Providing appropriate educational opportunities for these children, training specialized teachers and parents, and holding training courses for hearing specialists can help promote motor development in these children.

* **Corresponding author:** Department of Motor Behavior, Borujerd Branch, Islamic Azad University, Imam Khomeini University Complex, Yadegar Imam Street, Navab Square, Borujerd, 6915136111, Iran. Tel: 009866-42518000, E-mail: Mehdi.roozbahani@Gmail.com

Keywords: Motor development; deaf children; fundamental motor skill; Gallahoe's motor development perspective

Citation: Veiskarami P, Roozbahani M. Motor development in deaf children based on Gallahue's model: a review study. Aud Vestib Res. 2020;29(1):10-25.

Introduction

The development can be studied from four different aspects: physical, emotional, motor, and cognitive development. These four development aspects have interaction with each other [1]. For example, a child who is physically impaired can also be affected by emotional, motor, and cognitive domains. Motor development based on Gallahue's model includes the following phases: a) reflexive movement, b) rhythmic movement, c) rudimentary movement, d) fundamental movement, and f) specialized movement. Reflexive movements (from four months before birth to one year after birth) are primarily controlled by genetics and less by the environment or learning. Rhythmic movements (from four months to one year) include repetitive movements of the head, trunk, legs, and hands. The activity at this phase is perceptual-motor; that is, the stimuli are perceived, processed, and responded [2]. Rudimentary movement phase (one to two years) includes gaining control of head and trunk and learning how to crawl, sit, and stand. Although these movements appear in a particular order in most children, the time of their appearance varies from one child to another. At this phase, the role of learning and environmental stimuli becomes more prominent than previous phase. The rapid development of cognitive and motor processes in this phase helps to learn fast rudimentary movements. The fundamental movement phase includes walking, running, jumping, hitting, kicking, throwing, catching, striking with one or two hands, and so on. This phase is more dependent on environmental stimuli, learning and training opportunities. Although most children may show these skills, they will not reach advanced or higher levels if they do not receive appropriate education and training [2]. Finally, in the specialized movement phase, fundamental movements are gradually evolving and combining to be used in daily life activities and sports. The phase includes three stages of transitional, application, and lifelong utilization [2].

Based on Gallahue's model, we can discuss the effect of hearing impairment on the development of motor skills in children. Different opinions are expressed on the importance of reflexes (first phase) during infancy. Some are necessary for the life of the child, and others are appropriate to prepare motor pathways until that the cortex controls voluntary movements [1,2]. Some reflexes are called through sound and stimulation of the labyrinthine system that are associated with the eighth cranial nerve. Since hearing impairment usually affects the labyrinthine system, those reflexes are also affected. Moro, startle, symmetrical tonic neck, parachuting, and labyrinthine righting reflex they are reflexes triggered by the sound and stimulation of the labyrinthine system.

Unfortunately, little information is available on the reflexes of deaf children to compare them with their healthy counterparts. Telen identified 47 rhythmic movements in children and divided them into four groups of lower limb movements (legs), trunk movements, upper limb movements (hands), and head and facial movements [2]. There is also little information about frequency of these movements (second phase) in deaf children, compare to healthy children. Limited studies have also been conducted on examining rudimentary movements (third phase) in deaf children and information regarding their control of head and trunk, crawling, sitting, and standing. It has been shown that children with hearing loss typically have developmental delays compared to their healthy counterparts in controlling head and walking independently [3]. Moreover, during walking, they do not adequately use the full range of motion of their feet and have impaired balance [4,5]. Congenital hearing loss, reduces gait velocity [6]. As with the previous phase, little research has been done at this phase, and it is unclear how much deaf children have motor developmental delays at this stage.

Fundamental movements (fourth phase) include stability, locomotor, and manipulative skills. Stability skills include standing on two legs with eyes open or close, walking on a balance beam, hand stand, body rolling, etc. Locomotor skills refer to walking, running, jumping, and hopping. Finally, manipulative skills are throwing, hitting, dribbling, kicking, striking, catching, and so on. Stability is the core of locomotor and manipulative skills. A person who cannot maintain his or her balance in a standing position cannot run. At this phase, both the quality and quantity of the skills are essential. Children who have not reached the advanced stages of fundamental development (a condition called “clumsy”) lose many opportunities to socialize through physical activity. As a result, specialized movements will also be affected, and they face many problems in the next phase. Complications such as overweight, diabetes, early onset of cardiovascular diseases can be the side effects of lack in fundamental skills developments [1,2].

Since most studies on the motor development of deaf children have been conducted on the fundamental phase, this study has focused on this phase and its different dimensions are presented in a separate section. A few studies are available regarding the specialized movements (the fourth phase) of deaf children. According to Hartman et al [7], the hearing impaired children with advanced motor skills are more likely to participate in sports activities than their deaf counterparts. Failure to achieve the proper level of motor development can force children to have a sedentary lifestyle, develop obesity, and related diseases. Deaf children are more overweight than their normal-hearing peers, 24.5% overweight rate in boys, and 20.4% in girls [8]. Boys' physical fitness is better than girls' and normal-hearing children are more physically fit than deaf children [9]. Overall, hearing loss in childhood can have significant effects on speech development, socialization process, and various psychological aspects [10,11]. Studies on deaf children have focused primarily on diagnosis, screening, auditory rehabilitation, and cochlear implantation, and related aspects have less considered. The studies related to motor movements are focused on balance and balance-related rehabilitation. Therefore, more attention should be paid to motor development in deaf children and its importance in audiology communities. In this regard, this study aimed to investigate the motor development in deaf children based on Gallahue's model.

Methods

In this review study, we attempted to examine the relationship between hearing loss and motor disorders in deaf children, the impact of exercise on the improvement of motor impairment in these children, and understanding the effect of motor development on cognitive, emotional, and physical developments. For this purpose, the related studies published in the past eight years, were collected from the Web of Science, Scopus, PubMed, CrossRef, and Google Scholar databases. The used keywords for searching were “motor development”, “gross motor skills”, “cognitive motor skills”, “balance”, “postural control”, and “hearing loss”. No studies were found from Iran before 2011. Overall, 16 studies conducted in Iran (Table 1) and 24 studies conducted in other countries (Table 2) were selected for the review.

Results

Most studies were performed and focused on the fundamental movement phase in deaf children and could be categorized as follows.

Balance and postural control

Most studies on the motor development of deaf children were about balance and postural control (stability skills) that results emphasized the weakness of postural control and balance in deaf children (static and dynamic) [12,13]. Studies show that deaf children have a weaker static and dynamic balance than healthy children [36-40]. The problem of balance control in deaf children can be attributed mainly to the vestibular system, as most children with congenital deafness have malfunctioning of the vestibular system. Some middle ear diseases, such as chronic otitis, may also affect the sensory nervous system and vestibular sensory system if left untreated [6].

Motor development tests

These tests are used for measuring stability, locomotor, and manipulative skills. Most studies used Scale of Intra-Gross Motor Assessment (SIGMA), Test of Gross Motor Development (TGMD), Movement Assessment Battery for Children (MABC), and Bruininks-Oseretsky Test of Motor Proficiency (BOTMP) for measuring motor development. A few studies used the SIGMA test and did not report a significant difference in motor development between deaf and normal-hearing children [14]. However, other studies indicated a significant difference between them. Dummer et al [15] considered some of the contradictions observed in various studies due to the use of measurement tools. For example, they believe that the SIGMA test, which was used to measure the maturity of motor skills, is not as accurate as of the TGMD test. Deaf children had 62%, 52%, and 45% development retardation compared to their healthy counterparts in finger agility, ball control, and balance skills, respectively [7] (Tables 1 and 2).

Age factor

Some scholars believe that as age increases,

Table 1. Summary of studies conducted in Iran on motor development of hearing-impaired or deaf children

Author(s)	Published year	Title/purpose	Study design/samples	Measures	Results
Hessari et al. [32]	2012	The effect of an 8-week core stability training program on the balance of deaf students	Twenty seven deaf students in two experimental (n = 14) and control (n = 13) groups	Balance Error Scoring System (BEES) test and Star Excursion Balance Test (SEBT)	Core stabilization exercises can improve static and dynamic balance in deaf children.
Shojaei [36]	2013	Evaluation of visual-motor skills in hearing-impaired children	Review study	-	One of the areas in which children with hearing loss may be impaired is visual-motor skills. Besides playing an essential role in the two critical functions of reading and writing, this skill is required for nonverbal communication. Deaf children have a developmental delay in visual-motor skills.
Amirsalari et al. [35]	2012	The effect of cochlear implantation (CI) on hearing perception and speech intelligibility in children with motor developmental delay	Two hundred and sixty-two children with profound hearing loss before language learning in two groups of with and without motor developmental delay	Categories of Auditory Performance (CAP) test, and Speech Intelligibility Rating (SIR) test	CI could improve hearing perception and speech intelligibility in both groups.
Valizadeh et al. [37]	2014	Comparison of static balance between blind and deaf children and their normal counterparts in different conditions	Seventeen congenital blind children (9 girls and 8 boys) and 30 deaf children (14 girls and 16 boys) aged 2-6 years	One leg stance test and Tandem stand test with eyes open/closed	Blind children had a weaker static balance compared with deaf and healthy children.
Majlesi et al. [43]	2014	The effect of proprioceptive exercise on static and dynamic balance of deaf children	Ten deaf children and 10 hearing children aged 9−12 years	Exercise with emphasis on the proprioceptive ability	Exercises that enhance the proprioceptive ability improve balance in deaf children.
Seyedi et al. [44]	2015	Effectiveness of sensory systems involved in postural control of deaf athletes and non-athletes	Thirty adolescents aged 15−20 years with profound and severe congenital hearing loss divided into athlete and non-athlete groups	The biodex balance system	Neuromuscular exercises that improve the function of the somatosensory system may have a more significant effect on improving the balance of deaf athletes.
Ahmadpour et al. [51]	2014	Comparison of the balance performance of hearing-impaired children using cochlear and hearing aid with healthy children	Sixty seven children with severe to profound hearing loss (21 using CI and 46 using a hearing aid) and 60 healthy children aged 7−8 years	Bruininks-Oseretsky Test of Motor Proficiency (BOTMP2)	Hearing-impaired children, especially those using CI, are at risk of balance defects. They should be screened for vestibular system deficiency.

Table 1. Summary of studies conducted in Iran on motor development of hearing-impaired or deaf children-continue

Author(s)	Published year	Title/purpose	Study design/samples	Measures	Results
Ahmadpour et al. [45]	2015	The effect of a selected rhythmic exercise on the balance control of hearing-impaired children with vestibular system deficiency	Twenty four children with neurosensory hearing loss (in two intervention and control groups)	BOTMP2	A period of organized physical activity with emphasis on sensory stimulation could reduce the dependence on visual inputs in hearing-impaired children with vestibular system deficiency and increase the sensitivity of the vestibular system.
Khodashenas et al. [46]	2017	The effect of a selected exercise program on the static and dynamic balance of deaf children	Twenty deaf boys aged 8−14 years	Stork balance test and BOTMP2	A selected exercise program could improve the static and dynamic stability of deaf children. They recommended that these training programs should be included in the rehabilitation program for these children.
Ebrahimi et al. [52]	2016	Assessment of balance in deaf children with and without CI	Sixty healthy children, 50 deaf children without CI, 35 deaf children with CI	BOTMP2	Deaf children performed more poorly in all areas than normal-hearing children, whereas CI children performed poorer than children without CI.
Rashidi et al. [40]	2017	Comparison of fine motor skills between children with profound hearing loss and a group with normal hearing	Sixteen students aged 7−13 years with profound hearing loss as a test group and 41 age-matched normal hearing students	Purdue pegboard test	Children with profound hearing loss may have weaker skills in complex and delicate movements compared to the group with normal hearing.
Ebrahimi et al. [47]	2017	The effect of the vestibular rehabilitation program on sensory balance function in children with profound and severe hearing loss with bilateral vestibular deficiency	Twenty four children with profound and severe hearing loss aged 4−7 years (12 experimental and 12 control)	BOTMP2 and vestibular function tests	Vestibular rehabilitation focused on surrogacy strategies improves vestibular function and postural control in children with bilateral vestibular deficiency.
Taheri et al. [48]	2017	The effect of the combined core and neuromuscular stability exercises on postural control in students with congenital hearing loss	Twenty four students with congenital hearing loss, 12 controls and 12 experimental	Postural control test	Combined core and neuromuscular stability exercises can improve the postural balance in hearing-impaired students and can be used along with other exercise programs.

Table 1. Summary of studies conducted in Iran on motor development of hearing-impaired or deaf children-continue

Author(s)	Published year	Title/purpose	Study design/samples	Measures	Results
Zarei et al. [49]	2017	Effect of a combined exercise program on the physical fitness factors of deaf students	A preliminary randomized clinical trial study. 24 deaf male students, 12 controls and 12 experimental	Y balance test, Sorensen test (a timed measure to assess the endurance of the trunk extensor muscles), sit-up test and stair test	A combination of endurance and core stability exercises improve physical fitness in deaf students.
Nadertabar et al. [27]	2017	The effect of computer games on visual-motor skills in deaf students	Thirty deaf students aged 7−10 years	Visual-motor assessment test and its subscales (20 private sessions each for 50 minutes twice a week by specialized computer games)	Specialized computer games can positively impact the development of visual-motor skills in deaf students if carefully selected and used at appropriate levels.
Mazaheryazdi et al. [33]	2017	The interaction of hearing and dual-task oriented training on postural control of deaf children	Twenty five children 8−10 years old with CI (11 boys, 14 girls)	Force plate in three different conditions: 1) creating a challenge in the sense of sight, 2) performing cognitive tasks, and 3) causing somatosensory disruption, both on and off CI.	Benefiting from the rest of the auditory sense resulted in better postural stability and a decrease in fluctuations in cognitive task performance. The interactive effect of auditory sense and cognitive balance exercises showed that auditory sense plays an important and active role in controlling the status of hearing-impaired children.

Table 2. Summary of studies conducted in other countries on motor development of hearing-impaired/deaf children

Author(s)	Published year	Country	Title/purpose	Study design/samples	Measures	Results
Crowe et al. [12]	1988	USA	Motor skills related to balance deficiency in deaf children aged 7-13 years	Twenty nine deaf children and 13 with normal hearing	Balance test, muscle contraction, coordination	Motor skills in children with hearing loss depend on their balance performance. In interventions for movement impairment in deaf children, their balance and motor efficiency should be evaluated. The balance performance of deaf children is poorer.
Butterfield [14]	1993	USA	Motor skills in deaf and hearing children	Fifty four deaf children and 56 with normal hearing aged 3−8 years	SIGMA	Motor development speed in deaf and hearing children
Magnusson et al. [19]	1995	USA	Vestibular function and postural control in deaf children candidate for cochlear implantation	Seven deaf children and 21 controls	Galvanic electrical stimulation of the vestibular nerve	Those who are sensitive to galvanic electrical stimulation had less motor control, which may be the cause of dizziness in patients received CI.
Dummer et al. [15]	1996	USA	Motor performance of deaf children	Ninety one deaf girls and 110 deaf boys aged 4−18 years	TGMD	Deaf children had lower TGMD scores, but in case of providing sport activities and motor skill training, deaf and hearing children could obtain equal TGMD scores.
Tan Sing et al. [31]	2017	Singapore	Motor skills of hearing-impaired male adolescents in an educational setting	Seven deaf boys and 17 hearing boys aged 13−17 years	McCarron Assessment of Neuromuscular Development (MAND)	There was no considerable difference between fine and gross motor skills, but the balance power score of deaf subjects was lower than that of controls. Hence, they need specific physical training for balance improvement.
Lieberman [17]	2004	USA	Comparing motor development between deaf children with and without deaf parents	Eleven girls and 18 boys aged 4−9 years	TGMD	There was no significant difference in motor development between deaf children with and without deaf parents
Dair [8]	2006		The prevalence of overweight among deaf children	One hundred and fifty one deaf children aged 6−11 years	BMI	About 24.7% of boys and 20.4% of girls had overweight. From the age of 8 years onward, the BMI of girls tended to decrease compared to that of boys

Table 2. Summary of studies conducted in other countries on motor development of hearing-impaired/deaf children-continue

Author(s)	Published year	Country	Title/purpose	Study design/samples	Measures	Results
De Kegel et al. [22]	2015	Japan	Motor development of deaf children with and without CI	Forty eight children with a hearing loss were included in this controlled prospective follow-up study and were subdivided into a CI group (n = 23) receiving a CI during the follow-up period and a control group (n = 25) receiving no CI during the follow-up period All children were assessed around the ages of 6 (T1), 12 (T2), 18 (T3), and 24 (T4) months	Developmental Motor Scales-2 (PDMS-2), Alberta Infant Motor Scales (AIMS) (only at T1 and T2), and Ghent Developmental Balance Test (GDBT) (only at T3 and T4). In addition, collic vestibular-evoked myogenic potential testing was performed in all children	This study shows that the trajectory of gross motor development can be changed in children with a hearing loss after a cochlear implantation. Implanted children show a drop in their gross motor performance within the age range of 6 to 18 months, at which period the majority of the implantations took place, with a tendency of recovery toward the age of 2 years
Gheysen et al. [38]	2008		motor development of deaf children with and without CI	Thirty six deaf children (15 boys and 21 girls, 20 of whom had CI) and 43 hearing children as controls	MABC, Kinder test, and one leg stance test	Motor development of hearing children was significantly better than that of deaf children (with or without CI). Although there was significant between two deaf groups, the performance of those with CI was worse
Gkouvatzi Mantis and Kambas [16]	2010		Comparing reaction time, visual-motor control and speed/agility of hands in deaf and hard of hearing children	Seventeen deaf and 17 hard of hearing children aged 6−14 years	Some factors of BOTMP2	There was no significant difference between deaf and hard of hearing children, but visual-motor control and speed/agility of hands were improved with the increase of age.
Livingstone and McPhillips [56]	2011		Comparing gross motor skills development in hearing-impaired children received CI	Twenty-five deaf children (14 boys and 11 girls), 27 IQ-matched deaf children (15 boys and 12 girls) and 26 age-matched deaf children (8 boys and 18 girls) aged 8−9 years	MABC	Hearing-impaired children had poorer gross motor skills compared to IQ- and age-matched deaf children

Table 2. Summary of studies conducted in other countries on motor development of hearing-impaired/deaf children-continue

Author(s)	Published year	Country	Title/purpose	Study design/samples	Measures	Results
Rajandran [10]	2011	Italy	A review of motor skills and balance function in children with hearing loss	Children with hearing loss	-	Children with hearing loss have several problems due to their sensory system impairment. The focus in the treatment of these children is on their language development.
Tan sing et al. [34]	2011	Singapore	Balance control of hearing-impaired children and healthy children and the effect of exercises on their balance	Two children	Static and dynamic balance tests	The combined sensory training and exercise approach can be useful for both normal and deaf children.
Schwab et al. [13]	2011		Factors affecting the balance function of deaf children and adolescents	Eighty subjects (40 deaf as test group and 40 healthy as controls) aged 4−20 years	Equi test	In deaf children, the latency and balance scores were significantly lower than the control group. There was a positive linear relationship between their age and balance scores. Gender, the extent of hearing loss, and the cause of deafness did not significantly affect the balance function. Deaf participants with normal caloric responses had significantly higher balance scores than those with balance deficits
Hartman et al. [7]	2011	Netherlands	Motor skill performance and sports participation in deaf elementary schools	Forty two deaf children	MABC and a questionnaire measuring sports activity	The deaf children had motor problems in manual dexterity, ball skills, and balance skills as 62%, 52%, and 45%, respectively. Those who showed better motor skill performance had higher participation in sports activities
Shah et al. [39]	2013	India	The effect of the motor control program on improvement of gross motor skills and postural control in children with neurosensory hearing loss (a pilot study)	Ten subjects aged 6−12 years	TGMD and Pediatric Balance Scale (PBS)	eye-hand coordination and visual-motor training, balance training, activities to improve general co-ordination, eye-hand coordination and visual-motor training, balance training, activities to improve general co-ordination, eye-hand coordination and visual-motor training, balance training, activities to improve general coordination can help develop gross motor skills in deaf children.
Al-Rahamneh et al. [9]	2013	Jordan	Comparison of physical fitness levels of deaf and hearing children	Seventy five boys and 73 girls (hearing group); 49 boys and 31 girls (deaf group) all aged 10−13 years	Push-up, sit-up, sit and reach, 4×10 m shuttle-run and 1-mile run	Boys had better physical fitness than girls. Hearing children performance was better in the push-up, sit-up, and 1-mile run tests than deaf children. Hearing girls performance was better in 4×10 m shuttle-run than deaf girls.

Table 2. Summary of studies conducted in other countries on motor development of hearing-impaired/deaf children-continue

Author(s)	Published year	Country	Title/purpose	Study design/samples	Measures	Results
Zawi et al. [55]	2014	Malaysia	Gross motor skills development in male pre- and early school-aged children with hearing loss	Three hundred and fifteen pre- and early-school male children	TGMD	There was a significant difference between pre- and early-school male children in terms of TGMD score (locomotor and object manipulation skills), which indicates the effect of age on motor development. However, no significant difference was found between them in terms of the gross motor development quotient score.
Demanze et al. [41]	2014	France	Static and dynamic postural control in post-lingual cochlear implanted children: the impact of dual-tasking, visual and auditory inputs suppression	Thirteen normal (6 males and 7 females), and 16 cochlear implanted (10 males and 6 females)	Postural tests in eyes open and closed	Deaf children with CI had lower postural control scores than the control group in dynamic and static conditions, especially with closed eyes, and require visual inputs to control posture and balance.
Vidranski et al. [23]	2015		Motor skills in deaf children with and without CI	Review of 22 studies related to motor skills of deaf children with and without CI	-	Deaf children show suboptimal levels of motor skills, especially balance. There is very few studies on comparison of deaf children with and without CI.in addition, their results are contradictory. Many studies have demonstrated that regular and appropriate physical exercise improve the motor skills of hearing-impaired children, especially balance. The importance of motor skills development for hearing-impaired children has been emphasized by the fact that the development of motor skills has a vital role for the child's interaction with the outside world, action, perception and acquisition of academic skills and other skills necessary for life.
Leigh et al. [42]	2015		Determining the factors that influence the motor and psychosocial development of 3-year-old deaf and hard of hearing children	Three hundred and one deaf and hard of hearing children (160 boys and 141 girls)	Child Development Inventory	There was a positive correlation between social skills and motor development and also between language skills and motor development. Girls performed better on gross motor subscales. Children with hearing aids had better performance than those with CI on the gross motor subscales.

Table 2. Summary of studies conducted in other countries on motor development of hearing-impaired/deaf children-continue

Author(s)	Published year	Country	Title/purpose	Study design/samples	Measures	Results
Suarez et al. [6]	2017		Evaluation of gait velocity performance in CI children	Ten pre-lingual CI children and 14 hearing children aged 10−16 years	Gait velocity (GV) using a 10-m test in three conditions: (A) cochlear implant turned on with environmental noise (EN), (B) cochlear implant turned on with EN and with a cognitive dual-task (DT), and (C) CI turned off	GV in the control group was lower in B condition than in A condition; GV was faster in the control group in A condition compared with the three conditions; pre-lingual CI children had slower GV during walking compared to those had CI after the age 3. It can be concluded that hearing inputs are not neutral in motor skills and that the complicated interactions between them occur in the early stages of child development.
Penenory et al. [50]	2018	Colombia	Targeted review of compilations and classification of educational aids and enhancement of psychomotor skills in hearing-impaired children	Literature review	-	There are underlying psychomotor problems in the deaf that impede their normal developmental process. It was also found that different technologies can be useful in their psychomotor rehabilitation.
Metgud and Topkar [57]	2019		Comparing the balance and agility of deaf children with those of healthy children	Sixty five deaf children and 130 hearing children aged 9−14 years	PBS and agility t-test	Deaf children had lower PBS and agility t-test scores compared with the normal-hearing children scores.

motor development in the deaf improves [14,16]. The difference in deaf children's motor development is related to factors such as the type of school, physical education programs, parenting style, and opportunities to play fun games [7,9,14,31,34,39].

Parental role

Motor development in deaf children with deaf parents does not differ significantly from those with normal-hearing parents [17]. Parents' stress and anxiety about possible harm to their deaf child, prevent them from engaging in routine activities and leads them to a sedentary lifestyle [11].

Cochlear implantation

The cochlear and vestibular systems have many similarities in cellular and neuronal microstructure and function in addition to the anatomical proximity to the origin and growth of the embryo. Thus, patients with cochlear dysfunction and sensorineural hearing loss are also at risk for vestibular dysfunction. In children with severe to profound sensorineural hearing loss, cochlear implantation (CI) provides an opportunity for regaining auditory sensation. Improved access to auditory information for development of speech and language in children and improved speech understanding in adults have prevented the side effects of cochlear implants on other inner ear organs to be studied. CI can also lead to secondary damage to the vestibular end organs, especially saccule and post-implantation vestibular dysfunction, which may be accompanied by some degree of vestibular dysfunction [12,18]. It was shown that children who were sensitive to galvanic electrical stimulation of the vestibular nerve after implantation had less motor control, which may be the cause of dizziness in patients received CI [19].

In recent decades, the number of children with CI has increased, but the question is whether they still have movement problems after CI. Children with deafness suffering from damage to the eighth nerve, and those received CI have balance problems. Deaf children with a balance disorder tend to focus more on visual information to maintain their balance, especially when their sensory information conflicts with vision and when the risk of falling increases (e.g. standing on uneven surfaces). Hearing and vestibular rehabilitation, as well as physical training, increase the balance and vestibular adaptation in these children after CI [20,21]. These children generally have developmental delays in balancing and sequencing complex movements compared with their normal counterparts [7]. Some studies report that balance and motor development in children without CI is better than in those who received CI [6,22,41,42,51,52], while some show no significant difference between them [36]. CI by itself seems to have little effect on motor development [22]. Deaf children with CI compared to the controls and those without CI have lower performance and require visual inputs to control movement and balance in dynamic and static position, especially with closed eyes [10,28,33]. Gait velocity in children with CI is significantly slower than in normal-hearing peers, especially in children who had CI before the age of 3 years [6]. CI improves hearing perception and speech intelligibility of deaf children with motor developmental delay similar to deaf children with normal motor development [23].

Motor coordination

Motor coordination is defined as the goal directed performance a group of muscles in a particular time sequence to do a motor activity. Coordination is present in all aspects of motor activity (e.g. visual-motor, two-limb or multi-limb activity, etc.). Gross motor skills coordination, is delayed in deaf children, for example quality of running in deaf children is low [22]. Therefore, motor skills, such as catching the ball, which requires visual-motor, temporal, and spatial coordination, are delayed in deaf children [24].

Fine motor skills

Fine motor skills (such as manipulation, dexterity, hand-eye coordination) in preschool hearing-impaired children are developmentally delayed [25,26]. The development of visual-motor coordination is influenced by hearing and auditory-verbal experiences that can effect on cognitive development [26]. Development of fine motor skills (eye-hand coordination, i.e. using scissors to cut out a specific shape) compared with the gross motor skills (balance, postural control, walking, or throwing) is more delayed in deaf children [7,26].

Intervention and education

Studies have shown that core stability exercises, proprioceptive and strengthening exercises, selective rhythmic exercises, balance exercises, vestibular rehabilitation, combined exercises, endurance exercises, general coordination exercises, hearing availability, and participation in sports activities affect balance and postural ability of deaf children [32,33,39]. Selected computer games are also useful for the development of visual-motor skills of hearing-impaired children [27].

Discussion

According to the Newell's theory, the three constraints of individual, environmental, and task can interact with one another to explain human motor development. In other words, motor developmental delay in deaf children is not merely due to hearing loss [14,28]. Delay in motor development in deaf children can result from their deprivation from some sensory information (e.g. hearing) and impaired vestibular performance [12,13,38-40,47]. 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 may deprive the child of opportunities for participation and movement [8,11]. Appropriate sports opportunities, motor skills training, and vestibular rehabilitation improve motor control and balance in the deaf [7,9,27, 48-50,53,54]. Another constraint is task-related. Choosing inappropriate tasks for these children can result in their failure in doing motor activities and discourage them from pursuing fun activities. That is why a branch of physical education called "adaptive physical education" has been created for children with physical and motor disabilities to provide motor tasks appropriate to their developmental level.

In our opinion, we should not expect emergence, disappearance, number, and frequency of reflexes, and rhythmical stereotypies (first phase of Gallahue's model) in deaf and hearing children to be similar, because some reflexes are triggered by the presence of auditory and vestibular stimuli. To evaluate the reflexes, we recommend the use of the Milani-Comparetti Motor Development Screening Test and Primitive Reflex Profile so that the reflexes of deaf children and their natural counterparts can be compared. Some studies have been conducted to evaluate reflexes in healthy children and their impact on motor development [29].

Based on the rudimentary movement phase of Gallahue's model, the role of environmental stimuli and sports opportunities in deaf children is less than those in their hearing counterparts. For example, normal-hearing children show a motor response to their surrounding sounds (e.g. rattles, toys, pleasant and harmonious songs), but deaf children do not respond because of no auditory stimulation; hence, deaf children may show a delay in acquiring rudimentary movement skills compared with their peers. There are few studies on this phase that can provide definitive information on the time delay of rudimentary movement in deaf children, but independent walking in these children has been reported to be delayed [3]. For this phase, Bayley Scales of Infant and Toddler Development-Third Edition (appropriate test for an age range from 1 to 42 months) and Peabody Developmental Motor Scales, Second Edition (appropriate test for age range from birth through 5 years, it also examines eight reflexes in children aged 11 months and less) are recommended.

During the fundamental movement phase, parents of deaf children may also restrict and prevent them from social and sports participation because of possible dangers in sports and social situations [11]. In addition, the delay in previous phases is added to this phase. The results of studies on fundamental skills, gross and fine motor skills, motor coordination, spatial and temporal perception, etc. show that these skills are delayed in deaf children [27,30,37,45, 46,57]. In countries with advanced adaptive physical education, fundamental skills in deaf and hearing children are not different with healthy children [11,14-16]. This finding indicates that education is a crucial factor in learning these skills [33,46,49]. Motor developmental delay in the rudimentary and fundamental movement phases affects the phase of specialized movement [31].

Motor development is essential for understanding and interacting with the outside world, including schools. The importance of fingers dexterity (fine motor skills) in students with hearing loss can be significant from another view, such as the use of computers in the education system. Multimedia technology is a modern and diverse way of conveying concepts and information across different contexts (images, sounds, animations, and videos) that ensure diversity and continuity of learning in students. Although it mainly involves visual comprehension and does not require significant auditory skills, but fingers dexterity is essential for to use a computer, mouse, keyboard, etc. [27].

Most of the studies in the field of deaf rehabilitation have focused on their balance and few on the rehabilitation of fundamental skills. In this regard, providing appropriate educational opportunities, using trained teachers, educating parents, training adaptive physical education, and holding training courses for hearing specialists can be helpful. Other useful strategies for encouraging and giving opportunities to the deaf children are participate in sports activities and rhythmic movement [44,45] such as roping, skipping, rhythmic movements, hops, aerobics (especially with stick), using training videos [27] that show how to walk, run, jump, leap, kick, etc. [37,46,48], and doing fun games with equipment (e.g. ball games) [7,32] or without equipment (e.g. swimming) [9], which can improve postural control and balance [14,31,49].

Conclusion

Few studies have conducted in the field of motor development for deaf children in terms of reflexive, rhythmic, rudimentary, and specialized movements. Moreover, most rehabilitation studies have emphasized hearing loss and balance rehabilitation and paid less attention to motor development. Because of the national infant screening plan in Iran, it is now possible to identify deaf infants at reflexive and rhythmic stages by a suitable platform for studying motor development of deaf children and comparing them with healthy counterparts. We hope that future studies can provide strategies for promoting motor development in deaf children.

References

1. Payne VG, Isaacs LD. Human motor development a lifespan approach. Khalaji H, Ashtari MR, Kashani V, Heydarian S, Mokabarian M, translators. 8th ed. Tehran: Aeezh; 2014.
2. Gallahue DL, Ozmun JC, Goodway JD. Understanding motor development. Hemayettalab R, Movahedi AR, Farsi AR, Foladian J, translators. 6th ed. Tehran: Elmoharekat; 2019.
3. Masuda T, Kaga K. Relationship between acquisition of motor function and vestibular function in children with bilateral severe hearing loss. Acta Otolaryngol. 2014; 134(7):672-8. doi: 10.3109/00016489.2014.890290
4. Jafarnezhadgero AA, Shad MM, Majlesi M, Granacher U. A comparison of running kinetics in children with and without genu varus: A cross sectional study. PLoS One. 2017;12(9):e0185057. doi: 10.1371/journal.pone.0185057
5. Melo RS, Marinho SEDS, Freire MEA, Souza RA, Damasceno HAM, Raposo MCF. Static and dynamic balance of children and adolescents with sensorineural hearing loss. Einstein (Sao Paulo). 2017;15(3):262-8. doi: 10.1590/S1679-45082017AO3976
6. Suarez H, Alonso R, Arocena S, Ferreira E, Roman CS, Suarez A, et al. Sensorimotor interaction in deaf children. Relationship between gait performance and hearing input during childhood assessed in pre-lingual cochlear implant users. Acta Otolaryngol. 2017;137(4): 346-51. doi: 10.1080/00016489.2016.1247496
7. Hartman E, Houwen S, Visscher C. Motor skill performance and sports participation in deaf elementary school children. Adapt Phys Activ Q. 2011;28(2):132-45.
8. Dair J, Ellis MK, Lieberman LJ. Prevalence of overweight among deaf children. Am Ann Deaf. 2006; 151(3):318-26. doi: 10.1353/aad.2006.0034
9. Al-Rahamneh H, Dababseh M, Eston R. Fitness level of deaf students compared to hearing students in Jordan. Journal of Physical Education and Sport. 2013;13(4): 528-32. doi: 10.7752/jpes.2013.04083
10. Rajendran V, Roy FG. An overview of motor skill

performance and balance in hearing impaired children. Ital J Pediatr. 2011;37:33. doi: 10.1186/1824-7288-37-33
11. Veiskarami P, Roozbahani M. [Investigate the effectiveness of auditory rehabilitation on the stress, anxiety, depression and life expectancy of parents of deaf children]. Yafte. 2018;20(2):11-9. Persian.
12. Crowe TK, Horak FB. Motor proficiency associated with vestibular deficits in children with hearing impairments. Phys Ther. 1988;68(10):1493-9.
13. Schwab B, Kontorinis G. Influencing factors on the vestibular function of deaf children and adolescents - evaluation by means of dynamic posturography. Open Otorhinolaryngol J. 2011;5:1-9.
14. Butterfield SA, Mars Hans V, Chase J. Fundamental motor skill performances of deaf and hearing children ages 3 to 8. Clinical Kinesiology. 1993;47(1):2-6.
15. Dummer GM, Haubenstricker JL, Stewart DA. Motor skill performances of children who are deaf. Adapt Phys Activ Q. 1996;13(4):400-14. doi: 10.1123/apaq.13.4.400
16. Gkouvatzi AN, Mantis K, Kambas A. Comparative study of motor performance of deaf and hard of hearing students in reaction time, visual-motor control and upper limb speed and dexterity abilities. Int J Spec Educ. 2010;25(2):15-25.
17. Lieberman LJ, Volding L, Winnick JP. Comparing motor development of deaf children of deaf parents and deaf children of hearing parents. Am Ann Deaf. 2004; 149(3):281-9. doi: 10.1353/aad.2004.0027
18. Motasaddi Zarandy M, Khorsandi MT, Rezazadeh N, Yazdani N, Mokhtarinejad F, Bayat A, et al. [Vestibular dysfunctions in cochlear implant patients; A vestibular evoked myogenic potential study]. Audiol. 2010;19(2): 18-24. Persian.
19. Magnusson M, Petersen H, Harris S, Johansson R. Postural control and vestibulospinal function in patients selected for cochlear implantation. Br J Audiol. 1995; 29(4):231-6.
20. Vitkovic J, Le C, Lee SL, Clark RA. The contribution of hearing and hearing loss to balance control. Audiol Neurootol. 2016;21(4):195-202. doi: 10.1159/000445100
21. Zur O, Ben-Rubi Shimron H, Leisman G, Carmeli E. Balance versus hearing after cochlear implant in an adult. BMJ Case Rep. 2017;2017. pii: bcr-2017-220391. doi: 10.1136/bcr-2017-220391
22. De Kegel A, Maes L, Van Waelvelde H, Dhooge I. Examining the impact of cochlear implantation on the early gross motor development of children with a hearing loss. Ear Hear. 2015;36(3):e113-21. doi: 10.1097/AUD.0000000000000133
23. Vidranski T, Farkaš D. Motor skills in hearing impaired children with or without cochlear implant--a systematic review. Coll Antropol. 2015;39 Suppl 1:173-9.
24. Savelsbergh GJ, Netelenbos JB, Whiting HT. Auditory perception and the control of spatially coordinated action of deaf and hearing children. J Child Psychol Psychiatry. 1991;32(3):489-500. doi: 10.1111/j.1469-7610.1991.tb00326.x
25. Lévesque J, Théoret H, Champoux F. Reduced procedural motor learning in deaf individuals. Front Hum Neurosci. 2014;8:343. doi: 10.3389/fnhum.2014.00343
26. Horn DL, Fagan MK, Dillon CM, Pisoni DB, Miyamoto RT. Visual-motor integration skills of prelingually deaf children: implications for pediatric cochlear implantation. Laryngoscope. 2007;117(11):2017-25. doi: 10.1097/MLG.0b013e3181271401
27. Nadertabar M, Sharifi Daramadi P, Pezeshk S, Farrokhi N. [The influence of computer games on visual-motor skills in deaf students]. MEJDS. 2017;7:101. Persian.
28. Newell KM. Constraints on the development of coordination. In: Wade MG, Whiting HTA, editors. Motor development in children: aspects of coordination and control. The Netherlands: Martinus Nijhoff, Dordrecht; 1986. p. 341-60.
29. Akhast A, Riyahi A. [Remaining of initial reflection and movement disorders in children]. Journal of Exceptional Education. 2009;92:3-11. Persian.
30. Farsi A, Entezari Z. [Human motor development tests]. Tehran: Shahid Beheshti University; 2018. Persian.
31. Jernice TSY, Nonis K. The motor skills of adolescents with hearing impairment in a regular physical education environment. Int J Spec Educ. 2017;32(3):596-607.
32. Farzaneh Hessari A, Daneshmandi H, Mahdavi S. [The effect of 8 weeks of core stabilization training program on balance in hearing impaired students]. Juornal of Sport Medicine. 2012;3(2):67-83. Persian.
33. Mazaheryazdi M, Moossavi A, Sarrafzadah J, Talebian S, Jalaie S. Study of the effects of hearing on static and dynamic postural function in children using cochlear implants. Int J Pediatr Otorhinolaryngol. 2017;100:18-22. doi: 10.1016/j.ijporl.2017.06.002
34. Jernice TSY, Nonis KP, Yi CJ. The balance control of children with and without hearing impairment in singapore--a case study. Int J Spec Educ. 2011;26(3): 260-75.
35. Amirsalari S, Yousefi J, Radfar S, Saburi A, Tavallaie SA, Hosseini MJ, et al. Cochlear implant outcomes in children with motor developmental delay. Int J Pediatr Otorhinolaryngol. 2012;76(1):100-3. doi: 10.1016/j.ijporl.2011.10.011
36. Shojaei R, Hasanzadeh S, Farahbod M. [Visual- motor skills in school-aged students with and without profound hearing loss]. Journal of Exceptional Children. 2013; 13(3):23-6. Persian.
37. Vali-Zadeh A, Rezazadeh F, A'ali S, Mostafa-Zadeh A. [Comparison of static balance among blind, deaf and normal children in different conditions]. Archives of rehabilitation. 2014;14(4):106-12. Persian.
38. Gheysen F, Loots G, Van Waelvelde H. Motor development of deaf children with and without cochlear implants. J Deaf Stud Deaf Educ. 2008;13(2):215-24. doi: 10.1093/deafed/enm053
39. Shah J, Rao K, Malawade M, Khatri S. Effect of motor control program in improving gross motor function and postural control in children with sensorineural hearing loss-a pilot study. Pediat Ther. 2013;3:1-4. doi: 10.4172/2161-0665.1000141
40. Rashidi Z, Rasouli F, Mohammadi H, Heidari A. [Comparison of fine motor function between children with profound hearing loss and those with normal hearing]. Journal of North Khorasan University of Medical Sciences. 2017;8(3):417-25. Persian. doi: 10.18869/acadpub.jnkums.8.3.417
41. Bernard-Demanze L, Léonard J, Dumitrescu M, Meller R, Magnan J, Lacour M. Static and dynamic posture control in postlingual cochlear implanted patients: effects of dual-tasking, visual and auditory inputs

suppression. Front Integr Neurosci. 2014;7:111. doi: 10.3389/fnint.2013.00111
42. Leigh G, Ching TY, Crowe K, Cupples L, Marnane V, Seeto M. Factors affecting psychosocial and motor development in 3-year-old children who are deaf or hard of hearing. J Deaf Stud Deaf Educ. 2015;20(4):331-42. doi: 10.1093/deafed/env028
43. Majlesi M, Farahpour N, Azadian E, Amini M. The effect of interventional proprioceptive training on static balance and gait in deaf children. Res Dev Disabil. 2014;35(12):3562-7. doi: 10.1016/j.ridd.2014.09.001
44. Seyedi M, Seidi F, Rahimi A, Minoonejad H. An investigation of the efficiency of sensory systems involved in postural control in deaf athletes and non-athletes. Juornal of Sport Medicine. 2015;7(1):111-27. doi: 10.13140/RG.2.1.4785.0328
45. Ahmadpour A, Aslankhani MA, Ashayeri H, Jafari Z. [Effects of a selected rhythmic exercise program on the balance control in hearing-impaired children with vestibular dysfunction]. Journal of Motor Behavior. 2015; 7(21):47-64. Persian.
46. Khodashenas E, Moradi H, Asadi Ghalen M, Heidari E, Shams A, Enayati ghasbeh A, et al. [The effect of selective training program on the static and dynamic balance of deaf children]. Journal of Mashhad University of Medical Sciences. 2017;60(1):383-91. Persian.
47. Ebrahimi AA, Jamshidi AA, Movallali G, Rahgozar M, Haghgoo HA. The effect of vestibular rehabilitation therapy program on sensory organization of deaf children with bilateral vestibular dysfunction. Acta Med Iran. 2017;55(11):683-9.
48. Taheri M, Irandoust K, Norasteh AA, Shavikloo J. [The effect of combined core stability and neuromuscular training on postural control in students with congenital hearing loss]. J Res Rehabil Sci. 2017;13(2):80-6. Persian. doi: 10.22122/jrrs.v13i2.2846
49. Zarei H, Norasteh AA, Hajihosseini E. [The effect of a combined training program on physical fitness factors among deaf boy students: a randomized clinical trial study]. J Res Rehabil Sci. 2017;13(3):153-61. Persian. doi: 10.22122/jrrs.v13i3.2914
50. Peñeñory VM, Manresa-Yee C, Riquelme I, Collazos CA, Fardoun HM. Scoping review of systems to train psychomotor skills in hearing impaired children. Sensors (Basel). 2018;18(8). pii: E2546. doi: 10.3390/s18082546
51. Ahmadpour A, Aslankhani MA, Ashayeri H, Jafari Z. [The comparison of balance performance among children with cochlear implantation, post-aural aid and normal children]. Journal of Kermanshah University of Medical Sciences. 2014;18(8):479-90. Persian.
52. Ebrahimi AA, Movallali G, Jamshidi AA, Haghgoo HA, Rahgozar M. [Balance performance of deaf children with and without cochlear implants]. Acta Med Iran. 2016;54(11):737-42. Persian.
53. An M, Yi C, Jeon H, Park S. Age-related changes of single-limb standing balance in children with and without deafness. Int J Pediatr Otorhinolaryngol. 2009; 73(11):1539-44. doi: 10.1016/j.ijporl.2009.07.020
54. Mortazavi SS, Mortazavi Z, Mirbagheri SS. Evaluation of the relationship between fine motor skills and demographic indices in students with hearing impairment. Specific physical therapy Journal. 2016;6(2):93-102. doi; 10.18869/nrip.ptj.6.2.93
55. Zawi K, Denise Koh Choon L, Rozlina Tan A. Gross motor development of Malaysian hearing impaired male pre- and early school children. International Education Studies. 2014;7(13):242-52.
56. Livingstone N, McPhillips M. Motor skill deficits in children with partial hearing. Dev Med Child Neurol. 2011;53(9):836-42. doi: 10.1111/j.1469-8749.2011.04001.x
57. Metgud DC, Topkar P. Balance and agility testing in normal and hearing-impaired children: A Case–Control study. Indian J Phys Ther Res. 2019;1(1):42-6.