

Motor skills in children with hearing impairment

(overview essay)

Kristína Tománková

Abstract: *The overview essay presents a narrative literary review of the facts about the motor skills in association with hearing impairments in children from current studies in the period after 2010. This contribution presents various knowledge and selected research surveys in issue. Motor skills and motor development in children with hearing impairment is expected to be different from that in typically developing children in many ways. The aim of the contribution is to summarize appropriate and essential studies that show experiences with problem of motor skills, in a broader context, in child individuals with hearing impairment.*

Keywords: *hearing, impairment, deafness, hearing loss, movement, motor skills, motor function, motor development*

1 Introduction

Motor development is a continuous process throughout life. Hearing impairment in childhood may have significant effects on motor development (Veiskarami, Roozbahani, Saedi & Ghadampour, 2022). Many studies describe the relationship between hearing impairment and motor development and motor skills, while hearing impairment can affect their physical, emotional, motor, and cognitive development (Sahli, 2019; Veiskarami & Roozbahani, 2020; Masuda & Kaga, 2014). Vidranski & Farkaš (2015) present that hearing impairment is a major limitation in communication, and it can obstruct psychological development, development of social skills and motor development. Hearing impairment is the third most common contemporary chronic health condition, and it has become a public health problem. The effectiveness of problem solving in everyday life and in emergency situations depends greatly on the amount and quality of the motor programs. Therefore, it is evident that the normal

motor development in persons with hearing impairment is essential for everyday life. Singh, Raynor, Lee, et al. (2021) describe the impact of vestibular dysfunction on gross motor development in children with hearing loss. Developmental evaluation of deaf children before cochlear implantation has not been given enough attention (Li, Zhang, Yang, et al., 2021). Ganc, Kobosko, Jędrzejczak, & Skarżyński (2022) stated that due to the profound bilateral sensorineural hearing impairment, children with cochlear implant may experience delayed or discordant psychomotor development. Suaret et al. (2017) studied relationship between gait performance and hearing input during childhood assessed in pre-lingual cochlear implant deaf users.

Children with hearing impairments have a higher risk for deficits in balance and gross motor skills compared with children who are developing typically. As balance is a fundamental ability for the motor development of children, a valid and reliable assessment to identify weaknesses in balance is crucial (De Kegel et al., 2010). Children with hearing impairment have balance and motor deficits primarily due to concomitant damage to the vestibular structures. Although early intervention focused on the development of communication skills, investigations of intervention for the amelioration of balance deficits in children with hearing loss have been minimal and inconclusive (Majlesi, Farahpour, Azadian & Amini, 2014).

Selected studies to investigate the effect of motor training intervention on motors skills and balancing in hearing impaired children (Rajendran, Roy & Jeevanantham, 2013; Soori, Heyrani & Rafie, 2019), as well as Vongpaisal, Caruso & Yuan (2016) investigate the training tasks that engage active music listening through dance might enhance the song identification skills of deaf children.

Children with hearing impairment have balance and motor deficits primarily due to concomitant damage to the vestibular structures. Psycho-intellectual and social developmental disorders, as well as elimination of social activities and participation may diminish health-related quality of life in these children. Despite the documentation, assessment of balance, motor deficits, and health-related quality of life of these children are not included in the educational program, unless obvious neurological or orthopedic disorders are diagnosed (Rajendran, Roy & Jeevanantham, 2012). The review of Van Hecke et al. (2019) was performed to investigate the characteristics of vestibular dysfunctions in children with neurodevelopmental disorders. Many of the included studies reported central and/or peripheral vestibular aberrations in a subset of these children. These alterations may result in symptoms of distorted motor coordination or postural instability and might explain some of the balance problems observed in this population.

Balance is a critical component of daily living because it affects all movements and the ability to function independently (Haibach & Lieberman, 2013). Children with hearing impairment may have a potential risk for vestibular dysfunctions. They may undergo a sensory redistribution process whereby visual and somatosensory

information becomes more essential for postural control (Said, 2013). Kaga, Kimura & Minami (2019) investigated the developmental changes of vestibular ocular reflex and acquisition of postural control in infants with common cavity deformity. Also, children with CHARGE syndrome have sensory and motor impairments that could negatively affect their balance and postural control (Haibach & Lieberman, 2013). Early intervention after confirmation that a child is deaf or hard of hearing is necessary, as well as strict principles and guidelines for this intervention (Yoshinaga-Itano, 2014).

2 Overview of research findings to the solved topic

Veiskarami, Roozbahani, Saedi & Ghadampour (2022) researched a total of 149 children aged six to eighteen months. Children were selected and divided into three groups: normal-hearing children (55 girls and 65 boys) selected by convenient sampling strategy, non-rehabilitated hearing-impaired children group (11 girls and 13 boys) selected by purposive method, and rehabilitated hearing-impaired children group (3 girls and 2 boys) selected by the census method in cross-sectional study. The Denver developmental screening test 2 (DDST-II) was used to assess motor development. The fine motor development of the normal hearing children (9.63 ± 28.83) was significantly greater than the rehabilitated hearing-impaired children (-18 ± 26.83) and non-rehabilitated hearing-impaired children (-21.25 ± 30.26) groups, but there was no significant difference between the rehabilitated hearing-impaired children and non-rehabilitated hearing-impaired children's groups. In gross motor development, the non-rehabilitated hearing-impaired children (-32.71 ± 41.26) group had a more significant delay compared to the normal-hearing children (13.38 ± 37.73) and rehabilitated hearing-impaired children (0 ± 21.21) groups, but there was no significant difference between normal-hearing children and rehabilitated hearing-impaired children's groups. 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. In the study of Sahli (2019) a total of 169 children with bilateral sensorineural hearing loss, who have the chronological average age of 26.4 months, have been examined. All children are unilateral cochlear implant users and have no known additional impairments and/or diseases other than their hearing loss. The development of children with hearing loss, divided into three groups according to age of diagnosis, amplification, and training has been identified using the DDST-II, and then, general development and sub-development results of these age characteristics have been compared accordingly. As a result of the study, 105 (62.1%) out of 169 children identified with DDST-II have been found to be normal, 48 (28.4%) of them suspicious, and 16 (9.5%) children are found to be abnormal. It appears that

the children who have been diagnosed before age of 6 months, instrumented between 3 and 6 months, and started to auditory-verbal training are revealed to have normal skills in their personal–social, language, fine, and gross motor field capabilities. As the age of diagnosis and intervention is delayed, the rate of delay in the development domains seems to be increasing, which is statistically significant ($p < 0.001$). Children with hearing loss develop similar outcomes in comparison with their normal auditory peers once they are diagnosed before age of 6 months and benefit from early intervention services. The study of Veiskarami & Roozbahani (2020) reviews the recent studies conducted on motor development of deaf children based on Gallahue's model. 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. 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. Singh, Raynor, Lee, et al. (2021) described the impact of vestibular dysfunction on gross motor development in children with hearing loss. A systematic review was reported that the articles on children with hearing loss who underwent at least 1 instrumented measure of vestibular function and had gross motor milestones assessed were included. Eleven articles were included in the systematic review. Three articles stratified quantitative results of gross motor milestone acquisition by severity of vestibular impairment. Over half of studies were case series published within the last 5 years. This systematic review showed that children with hearing loss and severe, bilateral vestibular dysfunction demonstrate delayed gross motor milestones. However, it was difficult to draw conclusions on whether milder forms of vestibular dysfunction significantly affect gross motor milestone acquisition in children with hearing loss. The reason is that most studies were of low to moderate quality, used different assessment methods, and contained results that were descriptive in nature. This emerging area would benefit from future research, such as higher-quality studies to assess vestibular function and gross motor milestones. This would allow for better characterization of the impacts of vestibular impairment, especially milder forms, in children with hearing loss. Masuda & Kaga (2014) examined the relationship between acquisition of motor function and vestibular function in children with bilateral severe hearing loss. A total of 97 children under 4 years old with hearing loss defined as a hearing threshold of both ears greater than 80 dB were included in this study. For

evaluation of vestibular function, a damped-rotational chair test was performed, and the horizontal nystagmus was recorded using electronystagmography. Head control and independent walking were delayed in 28 of 97 children with severe hearing loss. Reduced response to the rotational chair test was observed in 16 of 97 children (16.5%), with 11 of these children having inner ear anomalies and reduced vestibular function. Of the 10 children who were followed up by the rotational chair test, 2 children with idiopathic congenital hearing loss without inner ear anomalies (100%) and 6 of 8 children with bilateral inner ear anomalies (75%) showed more obvious nystagmus during rotation compared with the initial examination. When vestibular function is reduced in the rotational chair test in children with severe hearing loss, the vestibular function may be acquired later due to maturing vestibular sensory cells and vestibular nerve of the inner ear along with physical growth. Rajendran, Roy & Jeevanantham (2012) in objective review systematically analyzed the available information in the literatures regarding the postural control, motor skills, and health-related quality of life in children with hearing impairment. The results of this review suggest that children with hearing impairment exhibit suboptimal levels of function in postural control, motor skill performance, and health-related quality of life. Said (2013) assessed the balance ability in children with sensorineural hearing loss compared with normal-hearing controls using clinical balance subset tests. Next, they determined the prognostic value of some etiological, audiological, and demographic (age and sex) factors in predicting a possibility for vestibular impairment for the early identification of children with vestibular deficits. Thirty children with normal hearing (17 girls and 13 boys) and 50 children with bilateral sensorineural hearing loss of varying degree, aged between 5 and 15 years. All of them were subjected to the following: basic audiological evaluation (pure tone, speech audiometry), immittancemetry and auditory brainstem responses, clinical balance subset tests of the standardized Bruininks-Oseretsky Test of motor proficiency (BOT-2), modified Clinical Test of Sensory Interaction for Balance (mCTSIB), one-leg stand (OLS), and tandem stand. Hearing-impaired children showed bilateral sensorineural hearing loss of varying degree, ranging from moderate to profound hearing loss (moderately severe 32%, severe 18%, and profound 50%) and of different etiologies (heredofamilial 46%, acquired 38%, not known 16%). Balance abilities as measured in this study were significantly poorer in hearing-impaired children compared with normal-hearing children. Hearing-impaired children with acquired cause and profound degree of sensorineural hearing loss had the highest abnormal score in these clinical tests compared children with other etiologies and degrees of sensorineural hearing loss (although this difference did not reach statistical significance). In most clinical balance tests that were done in this study, the youngest children in the hearing-impaired group achieved scores that were almost lower than the scores obtained by the older age groups; the most significant difference was observed for

tests performed with eyes closed. Balance dysfunction occurs in a significant percentage of hearing-impaired children and may have significant detrimental effects on motor development mainly in very young children. Therefore, information on the identification and treatment of these balance dysfunctions is crucial. Kaga, Kimura & Minami (2019) investigated the developmental changes of vestibular ocular reflex and acquisition of postural control in infants with common cavity deformity. Eight infants who were congenitally deaf complicated by common cavity deformity were studied. The damped rotational chair test was carried out to evaluate vestibular ocular reflex. Acquisition of head control and independent walking in these infants was compared with that in normal infant's milestones of gross motor development. All the eight infants with common cavity deformity did not show per-rotatory nystagmus in the damped rotational chair test around the first year of life. However, a normal number of beats and a longer duration of per-rotatory nystagmus for their age were recorded at around three or four years of age. In the eight infants with common cavity deformity, vestibular ocular reflex was not present around the first year of life but appeared after three or four years probably because of some vestibular sensory cells. Head control and independent walking were delayed but eventually acquired by the central vestibular compensation. Based on this study, we present two hypotheses regarding appearance of vestibular ocular reflex and acquisition of gross motor development in infants with common cavity deformity with development and growth: (1) the vestibular ocular reflex may develop after the maturity of some vestibular sensory cells stimulated by endolymphatic flow in the common cavity deformity, (2) the central vestibular compensating mechanism could accelerate gross motor development and balance function (3). This study suggests that some vestibular sensory cells may be present in the common cavity deformity because the vestibular ocular reflex begins to function after three or four years of age and gross motor function is acquired when the vestibular ocular reflex appears and by the central vestibular compensating mechanism in the brain.

The study of the Haibach & Lieberman (2013) was to assess the balance and self-efficacy of balance of children with CHARGE syndrome. Twenty-one children with CHARGE syndrome aged 6–12 and 31 age- and gender-matched sighted control participants without CHARGE syndrome completed the study. The Pediatric Balance Scale results revealed that the participants in the control group performed significantly better than did those with CHARGE syndrome ($p = 0.05$), with 57% of those with CHARGE syndrome at a medium to high risk of falls but all those in the control group at a low risk. Most children with CHARGE syndrome also had low Activities-Specific Balance Confidence Scale scores, and these scores were moderately correlated with the Pediatric Balance Scale scores ($r = 0.56$) but were not significantly associated with gender ($r = 0.065$) or age ($r = -0.169$). Relationship was found between the balance self-efficacy of the children with CHARGE syndrome

and their objectively measured balance. Self-efficacy of balance has been correlated with an increased risk of falls and with decreased participation in physical activities. Increased physical activity with a focus on balance and movement would likely improve these children's balance and self-efficacy of balance. Practitioners should understand that children with CHARGE syndrome will likely have poorer balance and lower confidence in their balance. Balance confidence and capabilities have implications for the development of motor milestones, such as walking, and the ability to perform functional activities. Future research should examine interventions to improve both balance and confidence in balance in these children. Van Hecke et al. (2019) was performed to investigate the characteristics of vestibular dysfunctions in children with neurodevelopmental disorders. Normal functioning vestibular system is thought to be critical in a child's development on many levels. In case of a vestibular dysfunction motor, cognitive, psychosocial, and educational symptoms may occur which tend to overlap with those found in patients with neurodevelopmental disorders. Moreover, in nearly all neurodevelopmental disorders it is known that postural instability, balance, gross and fine motor disturbances are frequently occurring in a subset of patients, which may assume a possible association between vestibular function and neurodevelopmental disorders. Although one cannot assume that a vestibular dysfunction is solely responsible for the wide range of symptoms observed in these children, the hypothesis of the possible connection has been supported by most of the included studies. To get a representative overview and to better understand the potential association and characteristics (i.e., the cause, origin, symptoms, whether there is a partial/complete, bi-/unilateral, or central/peripheral problem) of a (concomitant) vestibular dysfunction in children with various neurodevelopmental disorders, more research with more scientific rigor and an extensive vestibular test battery is required. Nevertheless, since comparable symptoms may occur in both children with neurodevelopmental disorders and vestibular-impaired patients, the authors of this systematic review would like to encourage clinicians to be aware of these similarities when determining the vestibular or neurodevelopmental disorder diagnosis.

The aim of the research of Vidranski & Farkaš (2015) is to analyze the available information pertaining to motor skills of hearing-impaired children both with and without a cochlear implant and to analyze possibilities of influencing their motor skills. The relevant studies on motor skills of hearing-impaired children both with and without a cochlear implant were obtained by an extensive computer search of various databases using special keywords and extraction with respect to certain criteria, resulting in 22 studies. The overall results of this systematic review indicate that the children with hearing impairment exhibit suboptimal levels of motor skills especially balance. Very few studies compared children with hearing impairment with a cochlear implant unit and without a cochlear implant unit and the results

of those studies are quite contradictory. Numerous studies have confirmed that the regular and appropriate physical exercise can improve motor skills of children with hearing impairment, especially balance. The fact that the development of motor skills is crucial for the child's interaction with the outside world, action, perception and acquisition of academic skills and other skills necessary for life shows the importance of motor skills development for children with hearing impairment. Li, Zhang, Yang, et al. (2021) in study was designed to evaluate the comprehensive developmental performance of deaf children who are cochlear implant candidates. The medical records of pediatric candidates for cochlear implant were reviewed. Five hundred children (287 boys; median age: 21.00 months; range: 6–72 months) with a diagnosis of severe-to profound hearing loss were included. Preoperative developmental evaluation, including gross motor, fine motor, adaptability, language, and social skill were retrieved. Comprehensive developmental performances including verbal and nonverbal skill were assessed. Compared with normal developmental metrics, deaf children had developmental delay ($p < 0.001$), which occurred in not only the verbal but also nonverbal skill (all $p < 0.05$). Of the 500 deaf children, 50 (10%) had normal performance; the majority (51.6%) had mild neurological dysfunction. Of all the sub-developments, language developed worst (normal rate: 4.2%) and gross motor developed best (normal rate: 42%). Age of intervention was a risk factor for the developmental level of deaf children ($b = 0.340$, $p < 0.05$). Pediatric candidates for cochlear implantation had both verbal and nonverbal developmental delay. Age of intervention was a risk factor for the developmental level. Comprehensive developmental evaluation of deaf children before cochlear implantation should be paid enough attention. Early intervention for improving hearing was of significance. The aim of the study of Ganc, Kobosko, Jędrzejczak, & Skarżyński (2022) was to assess the psychomotor development of children after 2 to 3 years from the time of acquiring a cochlear implant. 24 children with bilateral profound sensorineural hearing loss aged 36 to 52 months who received a cochlear implant between 8 and 30 months of age participated in the study. Psychomotor Development Assessment Cards (KORP) were used in the study, which are a tool providing the assessment of psychomotor development in the areas of: motor, fine motor and lateralization, visual perception and visual-motor coordination, communication and speech, emotions and social relations, behavioral functions and pre-school or school skills (depending on the child's age). The testing using KORP was carried out between 23 and 33 months after a cochlear implant activation. Approximately 75% of the children from the study group had the level of development in the field of motor sphere and fine motor and lateralization similar when compared to a group of hearing peers from the normative group. In the field of visual perception and eye-hand coordination it was around 70%. Half of the surveyed group of children showed a low level of functioning in the sphere of communication and speech, and about 60% of the

diagnosed children achieved a low level in the field of emotional and social development, behavioral functions as well as knowledge and learning skills. The obtained results indicated that deaf children who are a cochlear implant users show discordant development. Suaret et al. (2017) studied sensorimotor interaction in deaf children. Relationship between gait performance and hearing input during childhood were assessed in pre-lingual cochlear implant users. Gait velocity, using a 10-meter test, was measured by means of three inertial sensors in 10 pre-lingual cochlear implant users (10–16 years old) in three sensory conditions: (1) cochlear implant turned on with environmental noise, (2) cochlear implant turned on with environmental noise and with cognitive dual task, and (3) cochlear implant turned off. Gait velocity with environmental noise and dual task was assessed in a normal hearing control group ($n = 14$). In results, gait velocity in control group was lower in dual task than with environmental noise ($p = 0.019$); gait velocity was faster in control group with environmental noise compared with the three conditions in cochlear implant users (environmental noise, $p = 0.006$; dual task, $p = 0.0001$; cochlear implant turned off, $p = 0.03$); and cochlear implant users had slower gait velocity walking with environmental noise ($p = 0.037$). The results suggest that auditory input is not neutral in motor skills and the complex interaction between them is generated in the earlier stages of childhood development. The assessment of gait performance in pre-lingual deaf children with cochlear implant and with dual task ($p = 0.022$). Dividing the cochlear implant users' sample by age, the acoustic information generates a slower gait for those implanted after 3 years old.

De Kegel et al. (2010) compared children with hearing impairments with children who are developing typically. The purpose of this study was to investigate the construct validity of posturography and clinical balance tests in children with hearing impairments and in children who are developing typically. The study involved 53 children with typical development and 23 children with hearing impairments who were between 6 and 12 years of age and without neuromotor or orthopedic disorders. All participants completed 3 posturography tests (modified Clinical Test of Sensory Interaction of Balance [mCTSIB], unilateral stance, and tandem stance) and 4 clinical balance tests (one-leg stance with eyes open and with eyes closed, balance beam walking, and one-leg hopping). Three conditions of the mCTSIB, unilateral stance, and 2 clinical balance tests were able to distinguish significantly between the 2 groups. Children with hearing impairments showed more difficulties in balance tasks compared with children who were developing typically when 1 or 2 types of sensory information were eliminated or disturbed. The study showed only low to moderate correlations among the different methods of evaluating balance. The study of Majlesi, Farahpour, Azadian & Amini (2014) investigated the effect of a 12-session exercise balance program based on proprioception training on balance and gait in deaf as compared with hearing schoolchildren. The subjects, 10 deaf and 10 typically

developing children were assigned to an experimental and a control group respectively. Taking up the initial differences between the groups through a pretest under different conditions, the participants in the experimental group went through a 12-session intervention program including static and dynamic training with emphasis on proprioceptive system. After this, the participants were tested again. The data obtained was analyzed using repeated measure. A comparison between the control and experimental groups revealed that the intervention program had not significantly increased gait velocity while it had significantly decreased the amount of sway. Thus, it was concluded that an exercise program that enhances somatosensory ability can result in improved balance in deaf children. Rajendran, Roy & Jeevanantham (2013) in study determined the effectiveness of vestibular-specific neuromuscular training on motor skills, balance, and health-related quality of life in hearing impaired children. The results revealed that 6 weeks of vestibular-specific neuromuscular training improved the postural control, motor skills and quality of life in hearing impaired children. This indicates that this 6-week intervention can bring about a statistically significant difference. Soori, Heyrani & Rafie (2019) aimed to investigate the effect of 8 weeks of perceptual-motor training on bimanual coordination performance and static and dynamic balancing in students with hearing impairment aged 8–11 years in Kermanshah. 20 girls with hearing impairment with a mean age of 9.35 ± 1.42 were randomly selected and divided into control and experimental groups. The used tools in this study were continuous bimanual coordination test device, stork balance test, and Y dynamic balance test. First, all participants performed bimanual coordination task, and static and dynamic balance tests as pretest. Then, the experimental group performed the exercise training (such as static and dynamic balancing, throwing, and catching a ball, running between obstacles) for 8 weeks, 3 sessions per week, and 60 min per session and finally posttest was applied for both groups. According to the obtained results, it can be concluded that exercise training was effective in improving motor skills, as well as the use of these trainings is recommended to increase the level of motor performance. Vongpaisal, Caruso & Yuan (2016) examined whether training tasks that engage active music listening through dance might enhance the song identification skills of deaf children with cochlear implants. Nine cochlear implants children learned new songs in two training conditions: (a) listening only (auditory learning), and (2) listening and dancing (auditory-motor learning). They examined children's ability to identify original song excerpts, as well as mistuned, and piano versions from a closed-set task. While cochlear implant children were less accurate than their normal hearing peers, they showed greater song identification accuracies in versions that preserved the original instrumental beats following learning that engaged active listening with dance. The observed performance advantage is further qualified by a medium effect size, indicating that the gains afforded by auditory-motor learning are practically meaningful. Furthermore, kinematic analyses of body movements

showed that cochlear implants children synchronized to temporal structures in music in a manner that was comparable to normal hearing age-matched peers. Our findings are the first to indicate that input from cochlear implants devices enables good auditory-motor integration of timing cues in child cochlear implants users for the purposes of listening and dancing to music. Beyond the heightened arousal from active engagement with music, our findings indicate that a more robust representation or memory of musical timing features was made possible by multimodal processing. Methods that encourage cochlear implants children to entrain, or track musical timing with body movements, may be particularly effective in consolidating musical knowledge than methods that engage listening only.

Yoshinaga-Itano (2014) in document called: "Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing". This document is a supplement to the year 2007 position statement of the Joint Committee on Infant Hearing and provides comprehensive guidelines for establishing strong early intervention systems with appropriate expertise to meet the needs of children who are deaf or hard of hearing. Optimal outcomes can only be achieved when there is high quality to the universal newborn hearing screening programs, the audiologic diagnostic process of confirmation that a child is deaf or hard of hearing and fitting of amplification, and the provision of appropriate, individualized, targeted, and high-quality early intervention services. There are 12 best practice guidelines for early intervention programs that include the provision of timely referral to early intervention services with providers who have knowledge and skills in early childhood deafness and hearing loss, infusion within the system of partnerships with parents as well as professionals who are deaf or hard of hearing, longitudinal developmental assessments for monitoring the child's development, data management systems that include developmental outcomes, a process to monitor the fidelity of the intervention, and appropriate services for children with additional disabilities, those from non-English speaking families, and those from special populations, including unilateral hearing loss and auditory neuropathy/ dysynchrony.

3 Conclusion

The development of motor skills requires a precise cooperation of the muscles and the nervous system. The adequate motor development is key for the child's interaction with environment and people, for everyday full life and successful future. Early diagnosis of hearing impairment, especial before age of 6 months, is very important. Delay in motor development in children with hearing impairment is not always from due of deafness or vestibular problems, but individual factors are considered. Is not excluded that, vestibular function may be acquired later in maturation of vestibular sensory cells and vestibular nerve of the inner ear along with physical

growth. Symptoms of vestibular dysfunction may be very similar with symptoms of neurodevelopmental disorders (postural instability, balance, gross and fine motor disturbances) and some researchers encourage clinicians to be aware of these similarities when determining the vestibular or neurodevelopmental disorder diagnosis. Current studies indicate that children with hearing impairment show lower level of motor skills, especially balance. A few studies researched effect of the cochlear implantation on motor skills, but results are ambiguous. Evaluation of the development of hearing-impaired children before cochlear implantation has not been given enough attention, concurrently some results indicated that cochlear implant users show discordant development. Numerous studies have confirmed that the regular and appropriate physical exercise can improve motor skills of children with hearing impairment, especially balance. Exercise intervention program, often in the usual length of 6 weeks, enhances somatosensory ability can result in improved balance in deaf children. Age of intervention is a risk factor for next motor developmental level. There are 12 best practice guidelines (“Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing” as a statement of the Joint Committee on Infant Hearing) for early intervention programs that include the provision of timely referral to early intervention services with providers who have knowledge and skills in early childhood deafness and hearing loss, infusion within the system of partnerships with parents as well as professionals who are deaf or hard of hearing, longitudinal developmental assessments for monitoring the child’s development, data management systems that include developmental outcomes, a process to monitor the fidelity of the intervention, and appropriate services for children with additional disabilities, those from non-English speaking families, and those from special populations, including unilateral hearing loss and auditory neuropathy/dyssynchrony.

References

- [1] Ganc, M., J. Kobosko, W. W. Jędrzejczak, & Skarżyński, H. (2022). Psychomotor development of children with bilateral profound sensorineural hearing loss using cochlear implant for at least 2 years. *Journal of Hearing Science*, 12(1), 182–182.
- [2] Haibach, P. S. & Lieberman, L. J. (2013). Balance, and Self-efficacy of Balance in Children with CHARGE Syndrome. *Journal of Visual Impairment*, 107(4), 297–309, doi:10.1177/0145482X1310700406.
- [3] Van Hecke, R., Danneels, M., Dhooge, I., Van Waelvelde, H., Wiersema, J. R., Deconinck, F. J. A., & Maes, L. (2019). Vestibular Function in Children with Neurodevelopmental Disorders: A Systematic Review. *Journal of Autism*, 49(8), 3328–3350, doi:10.1007/s10803-019-04059-0.
- [4] Kaga, K., Kimura, Y., & Minami, S. (2019). Development of vestibular ocular reflex and gross motor function in infants with common cavity deformity as a type of inner ear malformation. *Acta Oto-Laryngologica*, 139(4), 361–366, doi:10.1080/00016489.2018.1548777.

- [5] De Kegel, A., Dhooge, I., Peersman, W., Rijckaert, J., Baetens, T., Cambier, D., & Van Waelvelde, H. (2010). Construct Validity of the Assessment of Balance in Children Who Are Developing Typically and in Children with Hearing Impairments. *Physical Therapy*, 90(12), 1783–1794.
- [6] Li, Y., Zhang, W., Yang, Y., et al. (2021). Developmental performance among pediatric candidates for cochlear implantation. *Acta Oto-Laryngologica*, 141(1), 66–72, doi:10.1080/00016489.2020.1821914.
- [7] Majlesi, M., Farahpour, N., Azadian, E., & Amini, M. (2014). The effect of interventional proprioceptive training on static balance and gait in deaf children. *Research in Developmental Disabilities*, 35(12), 3562–3567, doi: 10.1016/j.ridd.2014.09.001.
- [8] Masuda, T., & Kaga, K. (2014). Relationship between acquisition of motor function and vestibular function in children with bilateral severe hearing loss. *Acta Oto-Laryngologica*, 134(7), 672–678, doi:10.3109/00016489.2014.890290.
- [9] Rajendran, V., Roy, F & Jeevanantham, D. (2012). Postural control, motor skills, and health-related quality of life in children with hearing impairment: a systematic review. *European Archives of Oto-Rhino-Laryngology*, 269(4), 1063–1071, doi:10.1007/s00405-011-1815-4.
- [10] Rajendran, V., Roy, F., & Jeevanantham, D. (2013). A preliminary randomized controlled study on the effectiveness of vestibular-specific neuromuscular training in children with hearing impairment. *Clinical Rehabilitation*, 27(5), 459–467, doi:10.1177/0269215512462909.
- [11] Sahli, A. S. (2019). Developments of children with hearing loss according to the age of diagnosis, amplification, and training in the early childhood period. *European Archives of Oto-Rhino-Laryngology*, 276(9), 2457–2463, doi:10.1007/s00405-019-05501-w.
- [12] Said, E. (2013). Clinical balance tests for evaluation of balance dysfunction in children with sensorineural hearing loss. *The Egyptian Journal of Otolaryngology*, 29(3), 189.
- [13] Singh, A., Raynor, E. M., Lee, J. W. et al. (2021). Vestibular Dysfunction and Gross Motor Milestone Acquisition in Children with Hearing Loss: A Systematic Review. *Otolaryngology-Head*, 165(4), 493–506, doi:10.1177/0194599820983726.
- [14] Soori, Z., Heyrani, A. & Rafie, F. (2019). Exercise effects on motor skills in hearing-impaired children. *Sport Sciences for Health*, 15(3), 635–639, doi:10.1007/s11332-019-00564-y.
- [15] Suarez, H., Alonso, R., Arocena, S., Ferreira, E., Roman, C. S., Suarez, A. & Lapilover, V. (2017). Sensorimotor interaction in deaf children. Relationship between gait performance and hearing input during childhood assessed in pre-lingual cochlear implant users. *Acta Oto-Laryngologica*, 137(4), 346–351, doi:10.1080/00016489.2016.1247496.
- [16] Veiskarami, P. & Roozbahani, M. (2020). Motor development in deaf children based on Gallahue's model: a review study. *Auditory*, 29(1), 10–25.
- [17] Veiskarami, P., Roozbahani, M. Saeedi, S. & Ghadampour, E. (2022). Comparing Fine and Gross Motor Development in Normal Hearing Children, Rehabilitated, and Non-Rehabilitated Hearing-Impaired Children. *Auditory*, 31(3), 208–217, doi:10.18502/avr.v31i3.9871.
- [18] Vidranski, T. & Farkaš, D. (2015). Motor Skills in Hearing Impaired Children with or without Cochlear Implant – A Systematic Review. *Collegium Antropologicum*, 39, 173–179.
- [19] Vongpaisal, T., Caruso, D. & Yuan, Z. (2016). Dance Movements Enhance Song Learning in Deaf Children with Cochlear Implants. *Frontiers in Psychology*, 1(11), 1078, doi:10.3389/fpsyg.2016.00835.
- [20] Yoshinaga-Itano, Ch. (2014). Principles and Guidelines for Early Intervention After Confirmation That a Child Is Deaf or Hard of Hearing. *Journal of Deaf Studies*, 19(2), 143–175, doi:10.1093/deafed/ent043.

(reviewed twice)

Kristína Tománková, PhD.

Palacký University

Žižkovo nám. 5

771 40 Olomouc

Czech Republic

e-mail: kristina.tomankova@upol.cz