

# Movement and orthopedic problems based on postural instability in visually and hearing impaired people

(overview essay)

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**Abstract:** *This article proposes a literature review about the movement and orthopedic problems based on postural instability in visually and hearing impaired people. Visually and hearing impaired people are a potentially weakened target group with regard to the genesis of various orthopedic problems as well as morphological and structural foot deformities. The foot has an important functional relation within the lower limb and body. The paper clarifies the causes, mechanism of development and results of these problems. The article is supplemented by personal statements of the impaired on the occurrences and manifestations of specific pathologies in their daily lives.*

**Keywords:** *visual impairment, hearing impairment, posture, stability, balance, foot*

## 1 Introduction

Postural stability is the active holding of the body segment against the action of external forces to maintain an upright posture (Winter, 1995). It is actively managed and controlled by the internal forces, through the central nervous system (Vařeka, 2002). Posture can be affected by various factors. The neurophysiological effects belong among psychological factors and effects of the internal environment (different diseases) (Véle, 1995). Age affects postural stability; for example, a study shows that older footballers, aged 25 years and over, have a better postural control compared to younger footballers, aged under 25 years (Gosselin & Maltby, 2011). Holding the balance is achieved and maintained through a comprehensive set of sensorimotor system control that includes sensory input from the eyes, proprioception and the vestibular apparatus. These three sources of information to be sent to the brain as a nerve impulse from special nerve endings are called sensory receptors. The balance is the ability to maintain the center of gravity of the base. A properly functioning

system of balance allows people to determine the orientation with respect to gravity, determine the direction and speed of movement and perform automatic setup posture and stability in different activities and under different conditions (Shumway-Cook & Woollacott, 2001). The foot has an important functional relation within the lower limb and body. It constitutes an important supposition for maintaining the balance while standing, walking and in other derived movements (Votava, 2002). The function of the foot is static (bearing) and dynamic. The foot is illustrated as a “tripped model”, when the healthy foot with well-developed arches is supported only in 3 points (calcaneal protuberance, 1st metatarsal head and 5th metatarsal head). A healthy foot has a metatarsal head when laid on the mat and contributes roughly equally to transfer body weight. Plantar scrolling (unwinding) in healthy feet is the transfer of the pressure (center of pressure) through the lateral beam, from the 5th metatarsal head toward the 1st metatarsal head (Riegerová, Přidalová, & Ulbrichová, 2006). The primary function of the foot is to create a solid base and an equal distribution of excessive burdens of the lower limb while walking, and to reduce the energy intensity of walking while moving the body forward (Gross, 2002). The function of the foot is conditioned by its anatomical structure, which is contingent on the organization of the bones into two foot arches (longitudinal and transverse). Longitudinal vault is contingent on the higher medial arch which is created by three medial beams connecting talus, ossa cuneiformia, the 1st to 3rd metatarsus and phalanges of the first to third toes; it is employed during dynamic loading. Transverse vault is conditioned by the shape and organization of ossa cuneiformia (cuneiform bones) and proximal metatarsals. Its role is to provide protection to soft structures in the sole of the foot and partially absorb forces created when body weight is transferred. From the phylogenetic point of view, similarly to vertical pater, the vault is a young structure, and therefore labile and relatively easily vulnerable. Its disorders belong to the most common orthopedic defects in general. Static defects of the forefoot (hallux valgus, digitus quintus varus, hallux varus, hallux rigidus, digiti malei, digiti hamate, digiti Hippocratici) occur most frequently. Pain occurs frequently in the heel and in metatarsals. The typical defects of the foot vault are flat longitudinal vault (pes planovalgus), transverse flat foot (pes transversoplanus), and hollow foot (pes cavus; pes excavatus) (Riegerová, Přidalová, & Ulbrichová, 2006). The structure and function of the foot are adjusted to an appropriate distribution of body weight while standing and when moving in a gravitational field, the flexibility and shock absorption during movement, as well as a huge source of receptors necessary for the proper management of posture and motor on the principle of cybernetics (the principle of biological „locomotive computer“) (Müller, 2011). The causes of static deformities are long-term anomalous position of the foot, permanently applied tension, pressure on a certain part of the foot, or disproportion between the load and the resistance of the body (Matějovský, 2002). The foot is a shock absorber and sensory equipment.

The weight of the body is borne mainly by the inner half of the foot, while the outer half maintains stability (Riegerová, Přidalová, & Ulbrichová, 2006). Balance disorders often manifest themselves as uncertainty when walking. Uncertainty is expressed by a wide step, uncertain feelings while walking, rigidity and clumping. The symptoms are enhanced by finger paresthesia, sensory disturbance of lower limbs, and atactic movement due to the increased muscle tone of lower limb (Mumenthaler, 2008).

## **2 Visual impairment**

Visual impairment has been described in a variety of contexts, in the concepts of functional blindness, partial blindness, low vision, and expressions such as visually defective, visually handicapped, visually impaired (visually disabled), or visually limited. In recent decades, the diversity of terminological expressions has reflected a tendency to use the term impairment (Florian and McLaughlin, 2013). Definitions of visual impairment may vary across agencies and programs. Some definitions focus on the measures of acuity, while others focus on more functional descriptions (Randall et al., 2000). There is no unified consensus concerning the terminology of visual impairment, it is practically defined by the experts who use it (Sardegna et al., 2002).

### **2.1 Categorization of visual impairments**

World Health Organization (WHO) defines 4 levels of visual function, according to the International Classification of Diseases – 10: normal vision, moderate visual impairment, severe visual impairment and blindness. But in fact, moderate visual impairment combined with severe visual impairment are grouped under the term “low vision” (WHO, 2017). Thus, we can define the following categories: Normal vision: is defined as a decimal acuity equal to or better than 1.0 (Valberg, 2008). Low vision (moderate visual impairment, severe visual impairment): Alberta (1998) specifies low vision as the visual functioning of someone for whom eyeglasses, contact lenses, medical treatment, or surgery cannot correct vision to the normal range. The person with low vision may experience more types of vision problems as overall blurred vision (diabetic retinopathy), loss of central or center vision (macular degeneration), loss of peripheral or side vision (glaucoma, stroke). Blindness: refers to total blindness (in which there is a total loss of vision), to no light perception, or to particular visual limitations (Jones, 2013). In addition to the classification of WHO, we mention the following categories used in Czech and central European literature: low vision, partial sightedness, blindness and binocular vision impairment. The category of partial sightedness is located on the boundary between low vision and blindness. Binocular vision impairments often mean partial or total loss of stereoscopic vision and binocular depth perception (Kosikowski & Czyzewski, 2010).

The following text will continue with orientation and mobility in the context of visual impairment. We will also focus on the structural, morphological and pressure foot changes based on postural instability in visually impaired persons.

## **2.2 Contemporary research on movement and orthopedic problems**

Orientation can be understood as the ability to use one's remaining senses to understand location in the environment at any given time, and mobility is the facility of movement. Orientation and mobility may be defined as the teaching of concepts, skills, and techniques necessary for a person with a visual impairment to travel safely and efficiently through any environment and under all environmental conditions and situations (Jacobson, 1993). For a blind person, every movement which demands spatial orientation, and every inadvertent movement, is a targeted and conscious motion. The transfer in space requires constant concentration on and confrontation with the forms imagined with the perceived experience. Many activities in the training of spatial orientation and independent movement are necessary to fix at the level of perfectly mastered skills, or even habits. When an individual loses their eyesight, they experience feelings of fear, usually in the space of the unknown. An impaired person is trying to overcome the fear of space during the training by conducting an independent movement. Some learned movement patterns may not be desirable (incorrect posture, tilting forward, etc.) (Wiener, 1986).

A person with a visual impairment uses the entire body to receive information of various kinds (compensation factors: tactility, hearing, smell, echolocation ability). In subjects, the sense during the touch of the foot allows them to check the quality of the surface, changes in the terrain, and other effects (Jesenský, 2007). The use of neuromuscular mechanisms of memory then continues with multisensory connections between the senses, the ability to form an idea of their body in a movement in space, and the already mentioned role of the touch of the foot. An exhaustive constant focus on any activity is connected with a separate independent motion. The loss of vision and the response to changes in perception are also an integral part of the human brain plasticity. An ability to respond to the state of transformation, it is associated with a number of other areas, and affects the overall perception of individuals with visual impairment in the context of the specifics of the imagination (Majerová, 2016).

The foot changes and the postural instability in visually impaired persons can be seen from the contexts of orientation and mobility, the receiving information, the role of the touch of the foot, the plasticity of the brain, etc. Let us continue with current research. Due to the theoretical-critical resource analysis, we found various studies aimed at our topic. The objective of the study of Hallemans, Ortibus, Meire, & Aerts (2010) was to demonstrate specific differences in gait patterns between those with and without a visual impairment. They performed a biomechanical analysis of the

gait pattern of young adults ( $27 \pm 13$  years old) with a visual impairment ( $n = 10$ ) in an uncluttered environment and compared it to the gait pattern of age matched controls ( $n = 20$ ). The results showed that even in an uncluttered environment, vision is important for locomotion control. The differences between those with and without a visual impairment, and between the full vision and no vision conditions, may reflect a more cautious walking strategy and adaptive changes employed to use the foot to probe the ground for haptic exploration. The development of normal postural reactions that oppose the force of gravity and maintain the body's balance during exercise and rest is possible due to stimulation of the labyrinth and the labyrinth's cooperation with proprioception, vision, touch, and hearing (Nakajima, Kaga, Takekoshi, & Sakuraba, 2012). Vestibular receptors receive impulses related to the position of the head in space and generate reflexes that play a key role in basic motor responses; for example, maintaining head and body posture. Due to this complex process, we have, *inter alia*, a sense of control over the moving body and its orientation in space (Greenwald and Gurley, 2013).

### **2.3 Personal statement of the visually impaired**

A 21-year-old respondent with congenital visual impairment (practically blind) reports suffering from vertigo sporadically. She was diagnosed with glaucoma and aphakia and she also undergoes treatment at allergology, cardiology and endocrinology (thyroid gland). When describing her lifestyle, she mentions not using coffee and nicotine at all and using alcohol occasionally. She regularly uses immunosuppressive drugs and eye drops, other types of medicine rather occasionally. She does not perform any sport activity of a more intensive nature; she performs only common everyday movements (e.g. walking from work, walking up the stairs, housework, and physical activity up to 30 minutes per day). The respondent subjectively evaluates her motor coordination as normal. Overcoming differences in elevation represents a problem for her, for example, when walking down the stairs or on an uneven surface, as she experiences instability and even a guide's assistance does not improve the situation. With respect to the sense of direction, she mentions being able to move on her own (with a stick) in a familiar environment; in an unfamiliar environment, with a guide's assistance or a classmate's help. Spatial vision (stereoscopy) is not involved, due to residual vision considerably out of focus, and compensated by the processing of hearing stimuli. She feels that her posture is getting worse, she starts feeling discomfort as well as muscle tension and stiffness, which is accompanied by tiredness and occasional pain. Among orthopaedic defects, she suffers from scoliosis.

### **3 Personal statement of the hearing impaired**

A hearing impairment is very variable. Hearing impairments can be divided according to the time of the beginning of hearing loss, the level of spoken speech or the degree of hearing loss. People with a hearing impairment can be called the deaf, persons with residual hearing and hard of hearing.

#### **3.1 The classification of hearing loss according to the time of beginning of hearing loss**

Hearing loss may be congenital or acquired. Congenital hearing loss is a hearing loss which develops in the time of pregnancy. The child is born deaf or hard of hearing. Most children with hearing loss are hard of hearing. Children who are hard of hearing communicate by spoken speech and use hearing aids. Some children with severe hearing loss have a cochlear implant. Deaf children communicate in sign language because they do not hear spoken speech (America Speech-Language-Hearing Association, online). The causes of congenital hearing loss can be genetic and non-genetic. Non-genetic factors are, for example, infectious diseases, low birth weight or maternal intoxication during pregnancy (America Speech-Language-Hearing Association, online).

#### **3.2 The classification of hearing loss according to the level of spoken speech**

According to the level of spoken speech, hearing loss can be prelingual, perilingual and postlingual. Prelingual hearing loss begins during pregnancy or in the first months of the child's life. Children with prelingual hearing loss do not hear spoken speech and they cannot learn spoken speech naturally. These children do not have psychical problems that may be caused by hearing impairment. Perilingual hearing loss begins in the time of learning spoken speech. This is a period between 3 and 5 years of life. Postlingual hearing loss occurs at the time when the child can use spoken language. This child does not have any problems with communication by spoken speech (Tarciová, 2010).

#### **3.3 The classification of hearing loss according to the degree of hearing loss**

When we search degrees of hearing loss we can find medical terms such as normacusis, hypacusis and surditas. Lejska describes normacusis as a degree when a person does not have any problems with communication and their auditory threshold at an audiometric examination does not exceed the intensity level 20 dB (Lejska, 1994). Hypacusis (hard of hearing) can be divided into hypacusis conductive, hypacusis sensorineuralis, hypacusis mixta and hypacusis centralis (Lejska, 1994). Hypacusis conductiva means a hearing loss when the outer and middle ear are damaged. Potential causes of conductiva hearing loss are wax buildup, ear infection, a foreign object

lodged in the ear, ruptured eardrum, and structural malformation of parts of the ear (Betterhearing, online). Hypacusis sensorineuralis means a hearing loss when the inner ear is damaged (Lejska, 1994). Sensorineural hearing loss includes trauma to the head, ototoxicity, genetics, illness and aging (Betterhearing, online). Surditas (deafness) is the most severe case of hearing loss. Surditas means that the person cannot hear voices and cannot learn spoken speech naturally (Lejska, 1994).

### **3.4 The classification of hearing loss according to the type of hearing impairment**

In special education results, we can find a description of people with different cases of hearing loss. We can term these people as deaf, hard of hearing, those with residual hearing and those with profound hearing loss. A deaf person cannot hear and understand spoken speech (Potměšil, 2011). Hearing loss begins in the pre-, peri-, or postnatal period. The child either cannot use spoken language or spoken language is very difficult for them. They communicate in sign language (Tarciová, 2010). People who are hard of hearing have substantial difficulties with hearing spoken language. These people use hearing aids or cochlear implants (Tarciová, 2010). We can classify those hard of hearing by using the categories of mild, moderate, severe and profound hearing loss. People with mild hearing loss can hear sounds louder than 40 dB: "Someone with mild hearing loss may have minimal or no issues communicating in quiet, in one-on-one settings, or with only a couple of people. But they tend to have difficulty hearing softer environmental sounds as well as some conversations, especially in noisier environments, at a distance, in larger-group settings, or over the phone." (Betterhearing, online). People with moderate and severe hearing loss have substantial difficulties with hearing spoken language. These people may use hearing aids or listening devices (Betterhearing, online). People with profound hearing loss probably cannot hear any speech or some loud sounds. They often use hearing aids or cochlear implants. They communicate in sign language (Betterhearing, online).

### **3.5 Contemporary research on movement and orthopedic problems**

The development of normal postural reactions that oppose the force of gravity and maintain the body's balance during exercise and rest is possible due to stimulation of the labyrinth and the labyrinth's cooperation with proprioception, vision, touch, and hearing (Nakajima, Kaga, Takekoshi & Sakuraba, 2012). Vestibular receptors receive impulses related to the position of the head in space and generate reflexes that play a key role in basic motor responses; for example, maintaining head and body posture. Due to this complex process, we have, inter alia, a sense of control over the moving body and its orientation in space (Greenwald & Gurley, 2013). Research results between normally hearing children and severely to profoundly hearing impaired

children at the age of 6 to 10 years showed a significant difference in two static balance skills. There was a significant difference in static balance skills of standing on one leg on a line and standing on one leg on a balance beam with eyes closed (Jafari, Malayeri & Rezazadeh, 2011). The static and dynamic balance performance of deaf children with and without cochlear implants was studied by Ebrahim, Movallali & Jamshidi (2016). They studied 85 children with congenital and early acquired bilateral profound sensorineural hearing loss and normally hearing children at the age of 7–12 years. They used the balance subtest of Bruininks-Oseretsky Test of Motor Proficiency. The results showed the total score, especially the total score of children with cochlear implant, was significantly lower than that of the control group. The control group had a better balance performance than the implant group in all of the items. The findings suggested that deaf children, especially those with cochlear implants, are at risk from motor and balance deficits. Livingstone and McPhillips (2011) conducted a similar survey, which examined motor skill deficits in children with partial hearing. They studied three groups of children: 1) a partially hearing group; 2) a non-verbal IQ-matched group; 3) an age-matched group. Children with hearing impairment had a bilateral hearing loss > 60 dB. The results showed that the MABC score (Movement Assessment Battery for Children Score) of the first group was significantly lower than those of both comparison groups; the children in the first group had particular difficulties with balance. Kegel, Maes & Baetens (2012) dealt with the influence of vestibular dysfunction on the motor development of hearing-impaired children. They tested children with unilateral or bilateral hearing impairment >40 dB at the age of 3–12 years. They used MABC – second edition and VEMP (vestibular evoked myogenic potential). The results showed that “balance performance on MABC-2, clinical balance tests, as well as the sway velocity assessed by posturography in bipedal stance on a cushion with eyes closed and in unilateral stance differed significantly between both groups. Wilson, Garner & Loprinzi (2016) pointed out the relationship between hearing impairment and balance. They used the data from the 2003–2004 National Health and Nutrition Examination Survey and detected that sensory impairment was associated with perceived difficulty of falls and functional balance, because participants with a single sensory impairment had 29 % reduced odds of having functional balance and their reported difficulty with falls increased by 61 %. Wolter, Cushing & Madrigal (2016) implemented a pilot study about relationships between hearing impairment and balance. Their research group included children with unilateral sensorineural hearing loss and children with normal hearing. They were tested by Bruininks–Oseretsky (BOT-2). The BOT-2 test score showed that balance ability was significantly worse in children with unilateral sensorineural hearing loss.

### 3.6 Personal witness of hearing impairment

A 30-year-old respondent with congenital hearing impairment of perceptual type (residual hearing) reports suffering from vertigo several times a day. When describing her lifestyle, she mentions not using coffee and nicotine at all, using alcohol occasionally in small amount, and using medicine irregularly, rather occasionally. Twice a week, she performs a rather intensive (maximum heart rate of 65-80 %) active sport activity for more than 30 minutes. In her case, vertigo occurs in relation to a specific situation, namely the change of body position. The respondent also mentions suffering from feelings of uncertainty and deviating from her body's balance several times a day. The respondent has difficulty with overcoming differences in elevation; in particular, she suffers from vertigo when rising up. In spite of that, she considers her motor coordination normal and problem-free. However, she describes her postural habits as bad, and further specifies her everyday problems as a feeling of discomfort, muscle tension and stiffness, often even muscle fever, overall tiredness and pain. Among orthopedic defects, she suffers from cervical kyphosis and lumbar lordosis related to a mild pelvic deviation.

## 4 Conclusion

Visually and hearing impaired people are a potentially weakened target group with regard to the genesis of light, medium or hard morphological and structural foot deformities. The foot has an important functional relation within the lower limb and body. The function of the foot is static and dynamic. In addition, stability problems in people with hearing impairments are not rare, as adequate postural stability requires the integration and evaluation of visual, vestibular and somatosensory information. Research shows that 30%-70% of people with hearing impairment have problems with balance. The foot requires increased attention not only as the final link in affect mechanism chain of daily load, but especially as the executive body apparatus and an important input feedback factor. This feedback should perform a support function, not a limit function, for all-purpose and optimal development of the impaired person. The genesis of deformities is supposed on the base of postural instability, which is subsequently reflected in the change of the center of pressure. The movement of the center is reflected in plantar pressure redistribution and consequently, depending on the duration, causes the genesis of foot deformities. Surprisingly, this problem is not thoroughly examined and processed in Czech or foreign literature. Healthy body posture and gait have unimaginable importance in the terms of quality of life and social integration of the individuals. Throughout the lives of impaired persons, spatial orientation and movement in space as well as upright body posture training

require to be taken care of. The effect of health restrictions extends to all spheres of human existence, making it rather difficult, especially in the education process.

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