# Postural stability and postural control in visually and hearing impaired persons

(overviewed essay)

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***Abstract:*** *This article proposes a basic knowledge and selected research surveys in issue of the postural stability and postural control in visually and hearing impaired people. Postural stability is influenced by integration and evaluation of visual, vestibular and somatosensory information. Visually and hearing impaired people are a potentially weakened target group with regard to the disturbed keeping of the postural stability, posture and balance. Postural Feedback Training would allow increasing the neural adaptability. Biofeedback method is based on the biomechanical measurement and physiological body system mechanisms.*

***Keywords:*** *postural stability, postural control, feedback, balance, visual impairment, hearing impairment*

## 1 Introduction

There are many terminological and factual discrepancies in the issue of postural stability, balance and postural control. Definitions and opinions vary across a variety of specialists – biomechanics, medics, physiotherapists and others (Bizovská, Janura, Míková & Svoboda, 2017).

In biomechanical studies, the basic concept of "postural control" is testing of the process of maintaining a vertical posture in fall protection, most often in various modifications, when is a quantified the postural deviations (so-called titubation). In a broader sense, "postural control" is perceived not only as a control of position, but also as a control of the movement of the entire system (human body) in the external environment, in solving various movement tasks and situations. From the kinesiological point of view, this is a function of postural and locomotive motor skills, declaratively (Véle, 2006).

"Postural stabilization" (used term "balance") is a functional complex motor ability that is related to the processes of so-called "postural control" (Figure 1). "Postural control" is understood as a neural mechanism that is responsible for maintaining the position and allowing for a purposeful movement in the gravitational field. Nervous system plays key role, while stability detects (feedback) and instability predicts (feedforward) (Bizovská, Janura, Míková & Svoboda, 2017).

## 2 Selected research surveys in the issue

**Biofeedback** (BF) is known to improve postural control and reduce postural sway. However, the effects that different BF modes (coding for more or less complex movement information) may have on postural control improvement are still poorly investigated. In addition, most studies do not take into account the effects of spontaneous motor learning from repetition of a task when investigating biofeedback-induced improvement in postural control. In study of Dozza et al. (2011), they compared the effects of four different modes of audio-biofeedback (ABF), including direction and/or magnitude of sway information or just a non-specific-direction alarm, on the postural sway of 13 young healthy adults standing on a continuously rotating surface. Compared to the non-specific-direction alarm, ABF of continuous postural sway direction and/or amplitude resulted in larger postural sway reduction in the beginning of the experiment. However, over time, spontaneous postural motor learning flattened the effects of the different modes of ABF so that the alarm was as effective as more complex information about body sway. Nevertheless, motor learning did not make ABF useless, since all modes of ABF further reduced postural sway, even after subjects learned the task. All modes of ABF resulted in improved multi-segmental control of posture and stabilized the trunk-in-space. Spontaneous motor learning also improved multisegmental control of posture but not trunk-in-space stabilization as much as ABF. In conclusion, although practice standing on a perturbing surface improved postural stability, the more body sway information provided to subjects using ABF, the greater the additional improvement in postural stability (Dozza et al., 2011).

ABF for postural control is widely used to improve postural stability. However, the effective sensory information in BF systems of motor learning for postural control is still unknown. The purpose of study of the Hasegawa et al. (2017) was to investigate the learning effects of **visual versus auditory BF** training in dynamic postural control. Eighteen healthy young adults were randomly divided into two groups (visual BF and auditory BF). In test sessions, participants were asked to bring the real-time center of pressure (COP) in line with a hidden target by body sway in the sagittal plane. The target moved in seven cycles of sine curves at 0.23Hz in the vertical direction on a monitor. In training sessions, the visual and auditory BF groups were required to change the magnitude of a visual circle and a sound, respectively, according to the distance between the COP and target in order to reach the target. The perceptual magnitudes of visual and auditory BF were equalized according to Stevens' power law. At the retention test, the auditory but not visual BF group demonstrated decreased postural performance errors in both the spatial and temporal parameters under feedback condition. These findings suggest that visual BF increases the dependence on visual information to control postural performance, while auditory BF may enhance the integration of the proprioreceptive sensory system, which contributes to motor learning without BF. These results suggest that auditory BF training improves motor learning of dynamic postural control (Hasegawa et al., 2017).

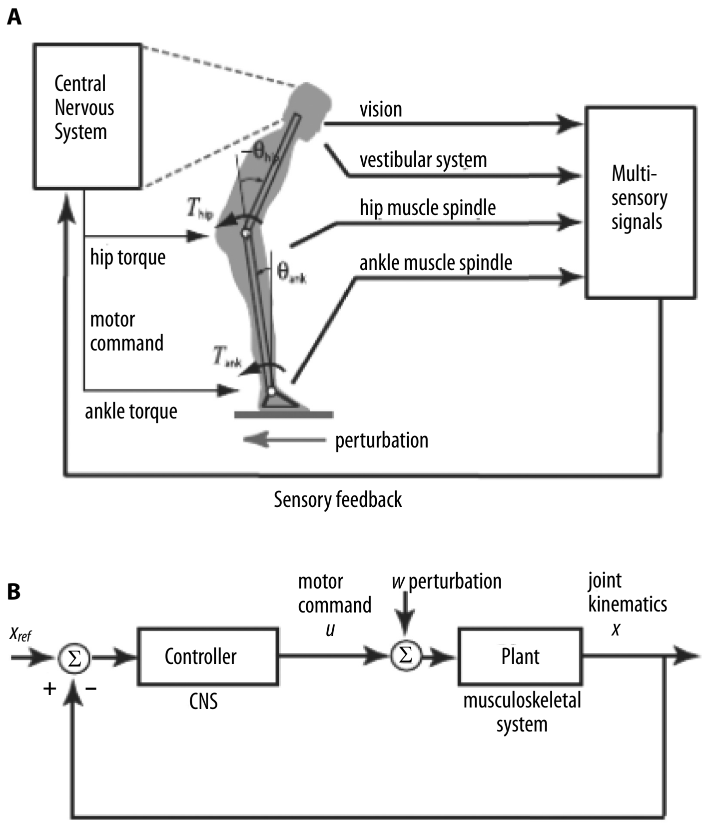


**Figure 1:** *Postural control. A: schematic model of long-loop human postural control by the CNS. Sensory information of body states are measured by vision, the vestibular organ and muscle spindles, and then sent to the CNS to be processed. Based on an estimate of body kinematics, appropriate control plans are selected and then corresponding motor commands are produced as joint torques. B: the feedback control of the body posture can be modeled by a feedback control system. Plant represents the musculoskeletal system, sensor describes the multisensory system, and the controller represents the CNS (Kim et al., 2009).*

**Vision and touch** rapidly lead to postural stabilization in sighted subjects. Is touch-induced stabilization more rapid in blind than in sighted subjects, owing to cross-modal reorganization of function in the blind? Schieppati et al. (2014) estimated the time-period elapsing from onset of availability of haptic support to onset of lateral stabilization in a group of early- and late-onset blinds. Eleven blind (age 39.4 years ± 11.7 SD) and eleven sighted subjects (age 30.0 years ± 10.0 SD), standing eyes closed with feet in tandem position, touched a pad with their index finger and withdrew the finger from the pad in sequence. EMG of postural muscles and displacement of centre of foot pressure were recorded. The task was repeated fifty times, to allow statistical evaluation of the latency of EMG and sway changes following the haptic shift. Steady-state sway (with or without contact with pad, no haptic shift) did not differ between blind and sighted. On adding the haptic stimulus, EMG and sway diminished in both groups, but at an earlier latency (by about 0.5 s) in the blinds ($p < 0.01$). Latencies were still shorter in the early-than late-blinds. When the haptic stimulus was withdrawn, both groups increased EMG and sway at equally short delays. Blinds are rapid in implementing adaptive postural modifications when granted an external haptic reference. Fast processing of the stabilizing haptic spatial-orientation cues may be favored by cortical plasticity in blinds. These findings add new information to the field of sensory-guided dynamic control of equilibrium in man (Schieppati et al., 2014).

Subjects with **low vision** often use a cane when standing and walking autonomously in everyday life. One aim of study of the Sozzi et al. (2018) was to assess differences in the body stabilizing effect produced by the contact of the cane with the ground or by the fingertip touch of a firm surface. Another aim was to estimate the promptness of balance stabilization (or destabilization) on adding (or withdrawing) the **haptic input** from cane or fingertip. Twelve blind subjects and two subjects with severe visual impairment participated in two experimental protocols while maintaining the tandem Romberg posture on a force platform. In one protocol, subjects lowered the cane to a second platform on the ground and lifted it in sequence at their own pace. In the other protocol, they touched an instrumented pad with the index finger and withdrew the finger from the pad in sequence. In both protocols, subjects were asked to exert a force not granting mechanical stabilization. Under steady-state condition, the finger touch or the contact of the cane with the ground significantly reduced (to 78% and 86%, respectively) the amplitude of medio-lateral oscillation of the centre of foot pressure (CoP). Oscillation then increased when haptic information was removed. The delay to the change in body oscillation after the haptic shift was longer for addition than withdrawal of the haptic information (1.4 s and 0.7 s, respectively; $p < 0.001$), but was not different between the two haptic conditions (finger and cane). Similar stabilizing effects of input from cane on the ground and from fingertip touch, and similar latencies to integrate haptic cue from both sources, suggest that the process of integration of the input for balance control is initiated by the haptic stimulus at the interface cane-hand. Use of a tool is as helpful as the fingertip input, and does not produce different stabilization. Further, the latencies to haptic cue integration (from fingertip or cane) are similar to those previously found in a group of sighted subjects, suggesting that integration delays for automatic balance stabilization are not modified by visual impairment. Haptic input from a tool is easily exploited by the neural circuits subserving automatic balance stabilization in blind people, and its use should be enforced by sensory-enhancing devices and appropriate training (Sozzi et al., 2018).

Walking is an important component of daily life requiring sensory motor integration to be successful. Adding haptic input via light touch or anchors has been shown to improve standing balance; however, the effect of **adding haptic input** on walking is not clear. The scoping review of Oates (2014) systematically summarizes the current evidence regarding the addition of haptic input on walking in adults. Following an established protocol, relevant studies were identified using indexed data bases (Medline, EMBASE, PsychINFO, and Google Scholar) and hand searches of published review articles on related topics. 644 references were identified and screened by a minimum of two independent researchers before data was extracted from 17 studies. A modified TREND tool was used to assess quality of the references which showed that the majority of studies were of moderate or high quality. Results show that adding haptic input changes walking behavior. In particular, there is an immediate reduction in variability of gait step parameters and whole body stability, as well as a decrease in lower limb muscle activity. The effect of added haptic input on reflex modulation may depend on the limb of interest (i.e., upper or lower limb). Many studies did not clearly describe the amount and/or direction of haptic input applied. This information is needed to replicate and/or advance their results. More investigations into the use and design of the haptic tools, the attentional demands of adding haptic input, and clarity on short-term effects are needed. In addition, more research is needed to determine whether adding haptic input has significant, lasting benefits that may translate to fall prevention efforts (Oates, 2014).

Good balance, an important ability in controlling body movement, declines with age. Also, balance appears to decrease when **visual input** is restricted, while this has been poorly investigated among visually impaired very old adults. The objective of study of the Chen et al. (2012) is thus to explore whether the **balance control** of the very old differs with varying degrees of visual impairment. This cross-sectional study was conducted in community centers and residential care homes. Thirty-three visually impaired (17 = low vision; 16 = blind) and 15 sighted elderly aged 70 years participated in the study. All participants were assessed: 1. concentric isokinetic strength of the knee extensors and flexors; 2. a sensory organization test to measure their ability to use somatosensory, visual, and vestibular information to control standing balance; 3. a perturbed double-leg stance test to assess the ability of the automatic motor system to quickly recover following an unexpected external disturbance; 4. the five times sit to stand test. Compared with low-vision subjects, the sighted elderly achieved higher peak torque to body weight ratios in concentric knee extension. The sighted elderly showed less body sway than the low vision and blind subjects in sensory conditions where they benefited from visual inputs to help them maintain standing balance. The sighted and low-vision subjects achieved smaller average body sway angles during forward and backward platform translations compared to the blind subjects. Low vision and blindness decrease balance control in elderly (Chen et al., 2012).

Recent experiments have shown that the **visual channel of balance control** is susceptible to cognitive influence. When a subject is aware that an upcoming visual disturbance is likely to arise from an external agent, that is, movement of the visual environment, rather than from self-motion, the whole-body response is suppressed. Guerraz & Day (2005) ask whether this is a principle that generalizes to the vestibular channel of balance control. They studied the whole-body response to a pure vestibular perturbation produced by galvanic vestibular stimulation (GVS; 0.5 mA for 3 sec). In the first experiment, subjects stood with vision occluded while stimuli were delivered either by the subject himself (self-triggered) or by the experimenter. For the latter, the stimulus was delivered either without warning (unpredictable) or at a fixed interval following an auditory cue (predictable). Results showed that GVS evoked a whole-body response that was not affected by whether the stimulus was self-triggered, predictable, or unpredictable. The same results were obtained in a second experiment in which subjects had access to visual information during vestibular stimulation. We conclude that the vestibular-evoked balance response is automatic and immune to knowledge of the source of the perturbation and its timing. We suggest the reason for this difference between visual and vestibular channels stems from a difference in their natural abilities to signal self-motion. The vestibular system responds to acceleration of the head in space and therefore always signals self-motion. Visual flow, on the other hand, is ambiguous in that it signals object motion and eye motion, as well as self-motion (Guerraz & Day, 2005).

Studies in visually deprived animals, in blind humans, in cataract patients and cochlear implanted children have provided converging evidence for the hypothesis that a large number of **multisensory processes** are not innate but depend on multisensory experience during early life. Research in congenitally blind humans has suggested that **vision** might play a special or even essential role for the emergence of multisensory functions. Studying blind humans is an excellent opportunity to investigate how experience might shape **auditory processing**. In everyday life, blind humans rely more on auditory information than sighted humans to recognize people, localize events, or process language. A growing number of studies have provided evidence that the increased use of the auditory system results in compensatory behavior in the blind. Blind humans perform better in perceptual auditory tasks, like pitch or duration discrimination, and in auditory language and memory tasks. Neural plasticity at different levels of the auditory processing stream has been linked to these behavioral benefits. In everyday life, many events stimulate more than one sensory system. Multisensory research has cumulated evidence that the integration of information across modalities facilitates perception and action control. Neurophysiological correlates of multisensory interactions have been described for various subcortical and cortical areas. There is evidence that vision plays a pivotal role in setting up multisensory functions during ontogeny (Hötting & Röder, 2009).

### Conclusion

Vision loss and blindness are almost always accompanied with feelings of imbalance and disturbed gait. Similarly, with congenital visual impairment can be recorded in some individuals fear of movement or worry while walking in an unknown space, accompanied by an unsteady walk. The body posture and walking quality are subsequently connected with complex lifestyle, as well as with question of different visual perception of body in space. Increased incidence of balance between people with hearing impairment is primarily on deaf who have sensory-neural hearing loss. Fault accuracy of kinetic features of foot, static (standing upright stance) and dynamic (movement, walking) leads to significant changes of gait stereotype and individual modifications of the motor assumptions. Throughout the life of impaired persons is required to take care of the spatial orientation and movement in space, upright body posture training. Also stability problems of people with hearing impairment are not rare because adequate postural stability requires the integration and evaluation of visual, vestibular and somatosensory information. Healthy body posture and gait has unimaginable importance in terms of quality of life and social integration of the individuals.

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(reviewed twice)

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