Feasibility of Static Posturography in Individuals with Residual Vision: A Pilot Study for a New Vision Re-education Protocol Targeting Postural Control

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HOW TO CITE:

Kristína Tománková (2026). Feasibility of Static Posturography in Individuals with Residual Vision: A Pilot Study for a New Vision Re-education Protocol Targeting Postural Control. International Journal of Special Education, 41(2s), 23-30.

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ABSTRACT:

University studies require high demands on the effectiveness of an individual's reactions to the environment and the ability to adapt to everyday activities while maintaining a certain quality of life. Disruption of multisensory integration in people with severe visual impairment, in terms of visual function with residual vision, can affect the learning process and social interaction. The research pilot study sample consists of 6 women and 6 men within average age 36.05 ± 6.02 years. All 12 participants were classified in the severe visual impairment (residual vision). The main aim of the pilot study is to demonstrate the feasibility of the study in terms of safety, clarity and technique; to demonstrate the sensitivity of the static posturography method for the purposes of entry and output diagnostics of a future study; to demonstrate the sensitivity of individuals to the ability of neuroplasticity through reactivity to visual input. Middle effect size of differences in postural parameters between open eyes (OE) and closed eyes (CE) stance was proved only in area (cm2) parameter. Differences in other parameters did not prove. Re-education of visual functions in people with severe visual impairment (residual vision), is a key element in preventing falls and improving postural stability.

Keywords: Proof of concept, visual input, low vision, postural stability, center of force.

1. Introduction

Bednarczuk et al. (2021) stated, that vision is one of the elements of the system responsible for maintaining static balance. Urbaniak-Olejnik et al. (2022) confirm that proper body balance is maintained by both sensory, i.e., vision, hearing, vestibular, and proprioception, and motor nervous systems. Visual control facilitates balance both in a static position, as well as during movement. Visual dysfunctions can adversely affect balance and stability control. Schwesig et al. (2011) found that vision impairment influenced postural control, especially if acquired and not congenital. Also, postural control depends on various condition, as stated Parreira et al. (2017), persons with visually impairment have poor postural control, which may interfere in their activities. Hojan-Jezierska et al. (2022) explain sense of sight. It may be essential for the maintenance of a stable posture. The presence of a sound stimulus improves the postural stability, although this improvement does not compensate for the disturbance caused by the optokinetic

stimulus. Hence, functioning of auditory and visual system can influence patients' posture. Baroncelli and Lunghi (2021) mention that brain plasticity refers to the ability of synaptic connections to adapt their function and structure in response to experience, including environmental changes, sensory deprivation and injuries. Plasticity is a distinctive, but not exclusive, property of the developing nervous system. The concept of neuroplasticity is described by classic paradigms to illustrate cellular and molecular mechanisms underlying synapse modifiability. Growing number of studies showing that the adult cerebral cortex retains a significant degree of plasticity highlighting how the identification of strategies to enhance the plastic potential of the adult brain could pave the way for the development of novel therapeutic approaches.

The main aim of this pilot study is to demonstrate the feasibility of the study in terms of safety, clarity and technique; to demonstrate the sensitivity of the static posturography method for the purposes of entry and output diagnostics of a future study; to demonstrate the sensitivity of individuals to the ability of neuroplasticity through reactivity to visual input. In addition, the study identifies the probability of fall risk, quantify visual dependence and assess the ability of sensory reweighting, i.e. the effectiveness of compensatory mechanisms, indirectly. It is assumed that these findings will be used as the basis for a methodological framework (proof of concept) for the design of a new future vision re-education protocol for enhancing postural stability.

2. Methodology

Design

This study is a quantitative pilot study with a quasi-experimental design. The study aimed on evaluating the feasibility of sensitivity static posturogrpahy method as a diagnostic tool by comparing postural stability under different sensory conditions (eyes open vs. closed). This is solved in context of future needs in development of a new re-education protocol.

Participants/Sample: The participants were current and former students of the Palacký University. The Research Ethics Committee of the Faculty of Education of Palacký University in Olomouc issued approval for the implementation of the study on August 26, 2024. Study is in in accordance with the current guidelines of the Declaration of Helsinki of 1975. Research was carried out between May and July of the year 2025. Participants signed informed consent. The research pilot study sample consists of 6 women and 6 men within average year 36.05 ± 6.02 years (Table 1.). All 12 participants were classified in the severe visual impairment category according to ICD-11 criteria (WHO, 2024), and all participants showing residual vision. Participants did not show hearing defects or diseases, defects or diseases of the musculoskeletal system. Also, were excluded persons with other diseases, with a negative history of accidents and injuries in the last year, and with somatic parameters (BMI, body weight, body height and waist circumference) out of normal healthy values. They stated that their physical activity does not exceed the physical demands of normal everyday life, without targeted sports physical activity. The inclusion in the age category of young adulthood (20 to 40 years) was intentional, to exclude the influence of a wide range of involutional changes, that could affect postural stability and especially hearing status.

Table 1. Descriptive statistics of basic somatic parameters of the study sample

Characteristics (N=12)	M	±	SD	Mdn	Var
Age	36.05	±	6.02	36.24	33.22
Body height (cm)	169.09	±	7.21	170.9	47.76
Body weight (kg)	76.55	±	13.83	76.30	175.40
BMI index	26.66	±	3.88	26.41	13.83
Waist circumference (cm)	88.79	±	15.25	87.00	213.39

Note. M = mean; SD = standard deviation; Mdn = median; Var = variance. BMI = Body Mass Index.

Instruments

Postural stability measurements were performed using the VersaTek Cuff Based Pressure Measurement System – MatScan - model 3150 (Tekscan Inc., 307 West First Street, South Boston, MA 02127, USA). Basic anthropometric parameters were measured by anthropometer (model A-213), digital personal scale, and tape measure.

Procedure

It was measured stance phase with OE and CE in length of 30 seconds, with feet in a normal position (shoulder-width apart). So that the subject could assume a natural stance during most common daily activities. Frankfurt horizontal (Linea horizontalis auriculoorbitalis) is a key reference plane in head anatomy, which defines the standard position of the skull for measurement and diagnostics, connecting the lower edge of the orbit (orbitale) with the upper edge of the external auditory meatus (porion). Data analysis was performed using FootMat Clinical 7.1 software (Table 2.). Basic anthropometric parameters were measured by anthropometer (model A-213), digital personal scale, and tape measure. Personal anamnesis was collected by interview. The measurements were carried out under standard conditions, always in the same room, under the same lighting, sound, temperature and time conditions (until 12:00 p.m.). The measurements were conducted in accordance with ethical principles, regarding the vulnerability of the participants due to their disabilities. The risk of falling or injury during the measurements was eliminated, by the researcher constantly standing diagonally behind the participants, in the blind spot of the visual field. The real measurement process was reported by the parameters of feasibility parameters (Table 3.).

Table 2. Descriptive statistics of postural parameters of the study sample

N = 12 Average age (36,05 ± 6,02 years)						
	OE			CE		
	M ± SD	Mdn	Var	M + SD	Mdn	Var
Area (cm2)	0.94 ± 1.09	0.38	1.09	1.31 ± 1.36	0.89	1.71
Distance (cm)	32.80 ± 12.37	25.90	140.27	33.99 ± 13.11	27.05	157.61
A–P excursions (cm)	1.59 ± 0.53	1.42	0.26	1.66 ± 0.83	1.34	0.84
L–R excursions (cm)	1.04 ± 0.80	0.79	0.59	1.15 ± 0.82	0.84	0.61

Note. M = mean; SD = standard deviation; Mdn = median; Var = variance; A–P = anterior – posterior; L–R = left – right; OE = open eyes; CE = closed eyes.

Data Analysis

Given that this is a pilot study, descriptive statistics methods were used primarily, focusing on calculating the effect size. It was calculating Cohen D for effect size differences between OE and CE stance in postural parameters. Selected parameters were calculated in statistical program Excel (Microsoft Windows). Our goal was to determine raw image (factual basis) about of the size of the differences (the magnitude of the effect size), whether these differences are practically important in intention study aims.

3. Results

Highlight significant results without interpretation Table 3 shows report of observed parameters of feasibility of the study. Overall, it can be assessed that the study was conducted without problems. Modifications were proposed in terms of using a safety rack and enhancing the participants' sense of psychological well-being. Also, results in table 3 shows that the sensitivity of the static posturography method, for the purposes of entry and output diagnostics, for a future study is accurate.

Table 3. Report of observed parameters of feasibility of the study

parameters	aims of observations / report of the study
recruitment success	ratio of addressed persons and included persons
	mass addressing of people within institutions / 12 persons was included in the study and met every conditions, disability category especially
adherence to protocol	number of people who completed the measurement without intermission
	12 persons completed the measurement without intermission
time consumption	average time required for instructions, personal interview and one measurement block
	10 minutes for instructions; 20 minutes for personal interview; 15 minutes for one measurement block
clarity of the instructions	subjective assessment of the clarity of instructions on a Likert scale from 1 to 5 (1 - best, 5 - worst)
	Subjective assessment of clarity of instructions for participants in the sample by level is 1- 2.
adverse evens (safety)	occurrence of dizziness, nausea, anxiety, fear, uncertainty, loss of balance
	no occurrence
technical reliability	number of measurements that had to be repeated due to general measurement error
	two persons / in one measurement block

Differences in postural parameters between OE and CE stance (Table 4.) demonstrate the suitable sensitivity of individuals to the neuroplasticity ability through reactivity to visual input. Differences are expected, which verify still quite high visual dependency. Results showed the fact that residual vision can have still stabilized effects. In parameter area (cm2) participants show difference with middle effects. It means that participants still rely on their residual vision. Impaired visibility in dark spaces or at dusk and darkness can become a problem in everyday life, but participants adaptation ability is quite good, generally. In parameter distance are obtained difference with small effect. The differences in A-P and L-R excursions between OE and CE stance are small. This indicates that studied participants are accustomed to compensating for fluctuations after the complete elimination of visual input.

Table 4. Effect size of differences in postural parameters between OE and CE stance

N (12) age (36,05 ± 6,02 years)		
	OE - CE differences M ± SD	d

Area (cm2)	-0.27 ± 0.49	-0.55**
Distance (cm)	-1.64 ± 4.36	-0.37*
A -P excursion (cm)	-0.05 ± 0.42	-0.12*
L - R excursion (cm)	- 0.09 ± 0.35	-0.27*

Note. A – P = anterior – posterior; L – R = left – right.

OE = open eyes; CE = closed eyes; d – Cohen's D

(*- small effect; **- middle effect; ***- strong effect)

4. Discussion

Urbaniak-Olejnik et al. (2022) obtained that persons with visually impairment does not show significant difference between parameter area (1.1 ± 0.7 cm2 vs. 1.2 ± 0.9 cm2) in stances with OE and CE on the stable surface. These results are in agree with our findings. Persons with visual impairment, in comparation with healthy participants showed in stance with CE statistically significant differences (<0.05) for area (1.9 ± 1.0 cm2) (Urbaniak-Olejnik et al., 2022). Becker et al. (2025) measured these data of healthy participants aged 18 – 30 years and we are mentioning this for comparation with our findings (sway path length in CE stance = 250 ± 116 mm and in OE stance = 337 ± 151 mm; area of ellipse in OE stance = 125 ± 82 mm2 and area of ellipse in CE stance = 175 ± 125 mm2. Ohlendorf et al. (2020) measured these data of healthy female adults aged between 31 and 40 years and found, that body sway in sagittal plane has 12.00 mm, body sway in frontal plane has 8.17 mm and ellipse area has 0.72 cm2.

The results (mean COG velocity) of this study confirm that subjects with visual impairment, regardless of eyes opening or closure, behave in the same manner as sighted subjects with eyes closed (Alghadir et al., 2019). The study of Tomomitsu et al. (2013) aimed to evaluate the influence of reduced visual information on postural control by comparing low-vision and normal-vision adults in static and dynamic conditions. The findings suggest that visual feedback is crucial for determining balance, especially for dynamic tasks and on foam surfaces. Low-vision individuals had worse postural stability than normal-vision adults in terms of dynamic tests and balance on foam surfaces. Bednarczuk et al., (2021) stated that differences were noted in balance of persons without visual impairments in single-leg stance tests with OE and CE, as well as when standing on both feet with EO and CE. In persons with visual impairment, significant differences were observed in the single left-leg stance test with EO and CE only. Testing conditions and disability levels exerted a significant influence on static balance in single-leg tests. The findings of the study confirm the role of vision in maintaining balance in the context of factors that may affect it, i.e. conditions (EO or CE) and possibilities of receiving visual stimuli disability level.

Visual deprivation led to a decrease in dynamic stability parameters in the anteroposterior and vertical axes. Even the movement of sighted people in unchallenged conditions is dependent on visual information (Kahaki et al., 2024). The symptoms of visual dependence can be generated by the actual compensation process (i.e., a conscious increase in reliance on visual stimuli can elicit symptoms) (Maire et al., 2017). Cataract-reversal participants who experienced a transient phase of blindness and gained sight through cataract removal surgery showed worse balance performance compared with sighted controls even when tested with CE. Individuals with reversed congenital cataracts performed worse than individuals with reversed developmental (late emerging) cataracts. Balance performance in congenitally cataract-reversal participants when tested with CE was not significantly different from that in permanently blind participants. In contrast, their gait parameters did not differ significantly from those of sighted controls. The present findings highlight both the need for visual calibration of proprioceptive and vestibular systems and the cross-modal adaptability of locomotor functions (Hötting et al., 2024).

The postural stability results of our study, in terms of reactivity to vision loss, are better than we expected, or not much worse than in the healthy population. Our participants are sensitive to the potential of neuroplasticity; it seems according to the average values and their differences. When comparing the average values, I noticed that the differences in area according to OE and CE confirm the sensitivity. L-R excursions in both stances (OE and CE) enhanced lower values in comparison with A-P excursions in both stances (OE and CE). This is good indicator of low risk of falling. Higher A-P excursion values are normal in healthy people and in people with visual impairments, where is the even typical. However, the distance parameter does not change much when participants close their eyes. The relationship between these two situations (area vs. distance) is a postural strategy, where the body's center of gravity moves widely in the dark, but the movements are smooth and slow, suggesting hip and muscle involvement, also function of inner ear. Balance requires less effort with low accuracy which may slightly increase the risk of falling. This indicates the need for balance training, for better and faster joint and tendon correction, for purpose training with center-of-gravity movement in a smaller area. The condition of the foot can also be a question which opens possibilities for further research. Various training methods for improving postural flexibility are described in the studies. Jeter et al. (2015) detect that the persons with visual impairment are at greater risk for falls due to irreparable damage to visual sensory input contributing to balance. Targeted training may significantly improve postural stability by strengthening the remaining sensory systems. Here, we evaluate the Ashtanga-based Yoga Therapy (AYT) program as a multi-sensory behavioural intervention to develop postural stability in visual impaired. These preliminary results establish the potential for AYT training to develop the remaining somatosensory and vestibular responses used to optimize postural stability in a visual impaired (Jeter et al., 2015). Danna-dos-Santos et al. (2015) found that the coordination of postural muscles likely involves the distribution of common neural inputs to distinct muscles to form modal units that can be manipulated by the CNS. These results indicate a key role of visual information in the generation of common input to muscles involved in postural control. Waer et al. (2023) describe that listening to music has been found to influence postural balance in both healthy participants and certain patients, whereas no study investigates such effects among healthy middle-aged women. Thus, this study aimed to investigate the effect of music on postural balance in middle-aged women. We concluded that listening to Mozart's symphony improved postural performance in middle-aged women, even in challenged postural conditions. These enhancements could offer great potential for everyday functioning. Reactive postural control essential for maintaining balance during daily activities, relies on a complex sensory system integrating visual, vestibular, and proprioceptive inputs. Deficits in reactive postural control can lead to falls, especially in unpredictable environments where sensory inputs are challenged. Traditional rehabilitation often fails to prepare patients adequately for real-world conditions. These findings underscore the significant role of combined platform instability and reduced sensory input on postural control. Study presents a novel method for challenging balance and suggests that sensory integration with variable instability could be valuable in training and rehabilitation, even for healthy individuals (Gudžiūnas et al., 2024).

As a pilot study, its primary limitation is the low number of participants. The statistical analysis reflects this small sample size and is therefore not designed to achieve statistical significance, formulate generalizations, or confirm hypotheses. The measurement was realised in stance with feet in a normal position (shoulder-width apart), not in typical stance of Romberg test, therefore the subject could assume a natural stance during most common daily activities. Other detailed foot characteristics and weight bearing, which may be key to the explanation, were not assessed. Only the proof of concept was the aim of the study, including the standardization of measurements, as well as the verification of the sensitivity of the method for achieving the result. Standardization of measurements will focus on eliminating distraction and fatigue, supporting eye fixation, and new

features such as a safety rack. A new vision re-education protocol focused on postural control should aimed at improving contrast sensitivity to light, shapes and colours; dual tasks consisting of movement tasks and specific visual and auditory stimuli to improve posture and stability; and for technological support for balance training with audio or vibrotactile signals in situations of balance loss. The new protocol should also result in recommendations for modifying the school environment and ergonomics of students.

5. Conclusion

University studies require high demands on the effectiveness of an individual's reactions to the environment and the ability to adapt to everyday activities while maintaining a certain quality of life. Disruption of multisensory integration in people with severe visual impairment (in terms of visual function with residual vision), can affect the learning process and social interaction. Re-education of visual functions in people with severe visual impairment (in terms of visual function with residual vision), is a key element in preventing falls and improving postural stability. Within this category of visual impairment, it should be key to maximizing the remaining visual functions and maintaining them. Static posturography offers objective data for the evaluation of these interventions, but its use in this specific population requires verification of the methodology. We demonstrated the feasibility of posturographic study in people with residual vision in terms of safety, clarity and technique. We have found that the method of static posturography appears to be suitable for demonstrating a relatively low level of visual dependence, as this may in certain contexts indicate a sufficient capacity for neuroplasticity. We would like to use this sensitivity to the brain plasticity in a future study that will propose a new vision re-education protocol.

6. Acknowledgements

The author would like to thank the visually impaired participants for their participation in the study, the members of leadership in Faculty of Education of Palacký University in Olomouc, and members of Proteching B team for their support and providing professional training, which was crucial for the implementation of the study. The study was funded by the Dean's Grant Fund of the Faculty of Education, Palacký University in Olomouc (Czech Republic), solved in period 2022-2025, under project number: VaV_PdF_2022_04 and project title: "Structural, morphological and pressure changes on the foot in the context of postural stability in students with visual and hearing impairment".

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