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Original Article

Postural instability in cognitively impaired elderly during forward and backward body leans

Błażej Cieślik, MSc, PT[1)*], Dagmara Chamela-Bilińska, PhD, PT[2)], Bożena Ostrowska, PhD, DSc, PT[2)], Joanna Szczepańska-Gieracha, PhD, DSc, PT[2)]

[1)] *Faculty of Pedagogy, Jan Długosz University: Armii Krajowej 13/15, 42-200 Częstochowa, Poland*
[2)] *Faculty of Physiotherapy, The University School of Physical Education, Poland*

Abstract. [Purpose] The aim of this study was to determine whether there are differences in postural stability control while leaning forward and backward between healthy elderly participants and elderly participants with cognitive impairment. [Participants and Methods] Postural stability was analyzed in 36 participants. According to the Mini-Mental State Examination results, participants were divided into the cognitive impairment group and the control group. A force plate was used to register the center of pressure in the sagittal and frontal plane, during two trials of maximum forward and backward body leaning. [Results] Significant differences were shown in both forward and backward leaning between the control and cognitive impairment groups. [Conclusion] The control of stability in the sagittal plane during maximum forward and backward lean of the body in cognitively impaired patients is similar to the results obtained by their healthy peers. However, individuals with cognitive impairment demonstrated larger lateral oscillations, which may be the reason for postural instability in this group, leading to an increased occurrence of falls.
Key words: Balance, Cognitive impairment, Postural stability

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INTRODUCTION

Maintaining the stability of the upright position is an important process used both in locomotion and during the activities of daily life. In accordance with the stability model, in order to maintain balance, a person should keep his or her center of mass (CoM) within a specific area. Whenever this state is disrupted, the risk of a fall increases. The maximum excursion of the CoM beyond the safe zone that an individual can make without the need for an additional step is called the limits of stability (LoS). Crossing the LoS boundary requires a correction strategy to be applied, such as bending the knees or taking a step[1)]. The further the range of the limits of stability, the greater the error margin when on the verge of falling[2, 3)].

The process of maintaining balance requires the appropriate integration of several sensory systems, i.e. vision, proprioception, and the vestibular system[4)]. These systems may be disrupted in dementia patients, among others, due to the disease in the small cerebral vessels. The impact of dysfunction of small cerebral vessels on gait stability and balance was demonstrated in 2017[5)]. These observations were confirmed by a number of publications in which the findings indicate worse postural stability, assessed under various conditions, in cognitively impaired patients[6–9)]. As a consequence, falls are a more frequent and more dangerous occurrence in this group of people[10)].

It is believed that the maximum body lean test may provide valuable information on dynamic balance in the frequently falling elderly participants[11)]. A clinical counterpart of the body lean tests is the functional reach test (FRT) used by clinicians, e.g. during the Balance Evaluation Systems Test (BESTest)[12)]. The test involves reaching to a point indicated by the therapist without taking a step, which causes the CoM to travel beyond the quadrilateral base of support. It has been established that,

*Corresponding author. Błażej Cieślik (E-mail: b.cieslik@ajd.czest.pl)

Table 1. Participant characteristic

Characteristic	CI	CON	p
Age (years)	71.9 ± 6.9	74.9 ± 4.6	0.17
Body mass (kg)	70.0 ± 13.4	65.1 ± 10.3	0.34
Body height (cm)	165.6 ± 9.7	158.3 ± 7.6	0.06
Gender (females/males)	10/8	13/5	0.12
MMSE scores	16.4 ± 3.6	27.0 ± 1.9	0.00

CI: cognitive impairment; CON: control. Mean values ± standard deviation.

in healthy individuals, there are no differences in the maximum values of the functional reach test between older adults and young adults[13]. Also, no differences have been demonstrated in the FRT between elderly non-fallers and elderly fallers[14]. There is a lack of scientific findings that would evaluate postural stability while leaning forward and backward in cognitively impaired individuals.

In 2017, Tylor et al. demonstrated that poorer FRT scores may be a strong predictor of falls[15]. The parameter of body lean test which is evaluated most frequently is their range. However, from the biomechanical viewpoint, during such tests an important role may also be played by certain additional parameters, such as mean velocity or sway variation[16]. These parameters supplement the main result of balance tests, providing additional information on postural stability. It seems relevant to verify the behavior of postural stability parameters during the maximum body lean tests. Therefore, the aim of this study was to determine whether there are differences in postural stability control while leaning forward and backward between healthy elderly individuals and elderly participants with cognitive impairment. Study hypothesis assumes that elderly with cognitive impairment demonstrate higher differentiation in stabilographic parameters while leaning forward and backward than healthy elderly.

PARTICIPANTS AND METHODS

Postural stability was analyzed in 36 participants (23 females and 13 males). The mean age of the participants was 73.4 years (±5.7), mean body height 162 cm (±8.1), and mean body mass 67.5 kg (±11.8). The Mini-Mental State Examination (MMSE) was used to assess cognitive status[17].

The study included individuals over 65 years of age with no accompanying diseases that could affect the results of the study. The exclusion criteria included orthopedic injuries impeding independent movement as well as neurological disorders (stroke patients, Parkinson's patients), two and more falls a past year. An additional differentiating criterion for the study groups was the MMSE score: below 24 (study group, CI) and 24 or more (control group, CON). The study group comprised 18 persons with mean age 71.9 (±6.9) years, mean MMSE score of 16.4 (±3.6) and MMSE range of 11–23. In the control group, where 18 individuals were also examined, the mean age was 74.9 (±4.6) years, the mean MMSE score was 27.0 (±1.9) and MMSE range of 24–30. The two groups did not differ significantly with respect to age (Table 1).

The study was approved by the Scientific Research Ethics Committee at the University of Physical Education in Wroclaw (1/2016). All participants gave their written consent to perform both the cognitive screening tests and stabilographic tests.

In order to perform the postural stability test, a Kistlers force plate (Type 9286B, Switzerland) with BioWare software was used to register the center of pressure (CoP) of the feet in the sagittal (A/P) and frontal (M/L) plane, during two trials of maximum body leaning with eyes open on a hard surface. The first trial consisted of the participant leaning his or her body forward as far as possible, without bending in hip joints and maintaining the position for 4 seconds. The second trial followed a similar protocol, but the participant leaned the farthest possible backward. The parameters of CoP movement were analyzed both without a division by planes (mean radius [mm], total surface area [mm^2]) and with the breakdown into the sagittal plane and frontal plane (mean velocity [mm/s] and path length [mm]).

Statistical calculations were performed using Statistica 10 software. The results were presented using descriptive statistics, including the mean and standard deviation. Due to the nature of the data obtained, which met the criteria for normal distribution, the statistical significance of results of the groups being compared was examined using Student's t-test for independent groups and set at a level of $\alpha<0.05$.

RESULTS

The analysis of stabilographic parameters during the forward lean shows a significant difference in the mean values between the groups. The total surface area marked by CoP was 32% larger for people with cognitive impairment. No significant differences were observed regarding the total mean CoP radius. Statistically significant differences were visible in results for parameters obtained in the frontal plane. In the cognitive impairment (CI) group, the values were higher by about 30%. The main parameters studied in this trial, i.e. the sagittal plane parameters did not show statistically significant differences within the studied groups (Table 2).

Table 2. Mean values ± standard deviation of stabilographic parameters during maximum forward lean

	Mean radius (mm)	Sway area (mm^2)	Total path way (mm)		Mean velocity (mm/s)	
	Total	Total	M/L	A/P	M/L	A/P
CI	15.2 ± 4.9	2,046 ± 340	232 ± 85	353 ± 74	7.5 ± 2.6	13.2 ± 3.6
CON	12.9 ± 3.8	1,388 ± 353	165 ± 30	419 ± 88	5.1 ± 0.9	11.1 ± 2.2
Difference (%)	−15	−32	−29	19	−32	−16
p	0.17	0.004	0.008	0.08	0.002	0.07

M/L: frontal plane; A/P: sagittal plane.

Table 3. Mean values ± standard deviation of stabilographic parameters during maximum backward lean

	Mean radius (mm)	Sway area (mm^2)	Total path way (mm)		Mean velocity (mm/s)	
	Total	Total	M/L	A/P	M/L	A/P
CI	12.1 ± 5.0	1,970 ± 754	263 ± 165	367 ± 87	8.2 ± 5.2	13.0 ± 3.9
CON	11.2 ± 3.9	1,349 ± 638	162 ± 46	416 ± 125	5.2 ± 1.5	11.6 ± 2.7
Difference (%)	−7	−32	−38	13	−37	−11
p	0.6	0.04	0.03	0.27	0.04	0.2

M/L: frontal plane; A/P: sagittal plane.

A similar situation occurred during the backward lean trial. A statistically significant difference in stabilographic parameters between the groups was visible with regard to the same indicators as in the forward lean trial. The total surface area differed between the studied groups by over 30%, while parameters obtained in the frontal plane differed by over 35%. Mean velocity and CoP path length in the sagittal plane did not show a statistically significant difference (Table 3).

DISCUSSION

The aim of this study was to determine whether differences occur in postural stability control while leaning forward and backward between healthy elderly individuals and the elderly with cognitive impairment. Elderly people suffering from CI tend to fall three times more often than their healthy peers[18–20]. One of the reasons for the increased frequency of falls may be anatomical differences hampering movement in joints of the spine and lower extremities. In CI patients, this could be caused by their functional limitations and reduced daily physical activity. The study consisted of holding a maximum lean of the body in one direction. In other words, the mean radius makes it possible to determine whether there are any anatomical differences that restrict the participant's movements. Comparing the mean radius of CoP sway, we have demonstrated in our study that there were no significant differences between the studied groups. This means that, during this movement, the groups did not differ in biomechanical terms and were able to perform a similar maximum body lean.

Moreover, it turns out that among healthy elderly people the increased frequency of falls is not related to stability in the sagittal plane. In 2016, Faraldo-García et al. demonstrated a lack of differences in the obtained anteroposterior stability limits between the healthy and the frequently falling elderly[21]. Research shows that the quadriceps femoris muscle and the hamstring muscles play important roles in the process of maintaining static and dynamic balance. Their strength is positively correlated with results obtained in the LoS trials among young people[22]. In other words, the greater the muscle strength, the larger the range of LoS. The studies cited above, and the results of our own research may be indicative of a similar joint mobility range and muscle strength in the studied groups. Therefore, reasons for increased occurrence of falls in elderly patients with cognitive impairment should not be seen in terms of anatomical limitations of maximum movement in the sagittal plane.

However, there was a significant difference in medio-lateral (M/L) control during the maximum forward and backward lean. Both the parameters for mean velocity and the length of the total CoP path were significantly different between the studied groups. In the CI group, in both the forward and backward lean, strong lateral oscillating movements were observed, which were significantly smaller in the control group. What is more, when analyzing the mean velocity of CoP sways, we could observe that the movements were much more chaotic. These observations were confirmed in the parameter of the total surface area plotted by the path traveled by the CoP. For CI patients, the result of this parameter was about one-third higher in both trials. Bearing in mind that the groups were not significantly different in terms of the mean radius of the CoP sways, a larger surface area obtained by the CI group is a sign of high instability of the performed movement. While the instability in leaning forward may be easily compensated for by a step forward, when leaning back, each additional lateral component of the movement may increase the risk of a fall. In our study, the CI group obtained over 30% higher stabilographic scores in the frontal plane in both forward and backward lean, which proves that the study group was more unstable.

In 2009, it was determined that an unsafe gait is a significant risk factor for falls in elderly people with cognitive impairment[23]. It is the additional lateral oscillations resulting in instability that cause unsafe gait. In 2015, Doi et al. demonstrated a relationship between white matter loss (WML) with trunk stability during dual-task gait trail[24]. Loss of white matter volume could be a predictor of cognitive impairment[25]. Our study group contains participants with MCI. Therefore, the poorer result obtained by a study group in the frontal plane could be related to trunk stability during specific tasks, such as leaning forward or backward. Other studies have found a correlation between activation of abdominal muscles (the external oblique muscle and the quadratus lumborum muscle) and the limits of stability in elderly people. It has been found that weaker activation of those muscles is associated with the lower scores in trials on the limits of stability[26].

Research shows that although exercise programs preventing falls in elderly people with cognitive impairment show a certain degree of effectiveness, they still need to be further developed[27]. It seems that, in order to prevent falls in this group, these additional movements in the frontal plane must be reduced. Thus, improving trunk stability could be beneficial for fall prevention in cognitively impaired elderly. Simultaneously, improving reaction time and quadriceps muscles strength could reduce fall risk in the elderly with CI[28]. It may be worthwhile to consider dance therapy. In 2016, research showed that dance therapy improved the results obtained in LoS tests among healthy elderly women[29]. Other study demonstrated a beneficial influence of dance therapy on reaction time and fall risk in elderly woman[30].

The limitations of the research project have been contemplated. The main limitation of this study is the small number of participants in the studied groups, which makes it difficult to transpose the results into the population of people with cognitive impairment. Another limitation is the use of the MMSE as a criterion to determine the severity of cognitive impairment. The MMSE is a screening tool with a large margin of error. Just a single point might have determined whether a person would be assigned to the control group or the study group. Therefore, it would be worthwhile to repeat the study with a larger study group, using more precise diagnostic tools. It would also be appropriate to additionally specify the impact of activation of abdominal muscles on the limits of stability in this group. The muscles stabilize the body in the frontal plane, which may be significant for the improvement of stability. The above remarks will surely contribute to a better understanding of postural instability in elderly people with cognitive impairment, which, in turn, will lead to creating valuable fall prevention programs.

In conclusion, the control of stability in the sagittal plane during the maximum forward and backward lean of the body in cognitively impaired patients is similar to results obtained by their healthy peers. There are, however, significant differences in lateral stability during the performance of these movements. Individuals with cognitive impairment demonstrate larger lateral oscillations, which may be the reason for postural instability in this group, leading to an increased occurrence of falls.

Conflict of interest

The authors declare no conflicts of interest.

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