Performance of Homebalance test in an assessment of standing balance in elderly adults

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Summary

Balance control is a critical task of daily life, the ability to maintain upright posture becomes of particular concern during aging when the sensory and motor system becomes deteriorated. Falls contribute to the most deaths caused by injury within the aged population, and the mortality rate following a fall is drastically elevated. Longitudinal and reliable assessment of balance control abilities is a critical point in the prediction of increased risk of falling in an elderly population. The primary aim of the study was to evaluate the efficiency of the Homebalance test in the identification of persons being at higher risk of falling. 135 subjects (82 women and 53 men) with geriatric syndrome have been recruited and the Homebalance and the Tinetti Balance test were performed. Results of both tests strongly correlated proving the good performance of the Homebalance test. Standing balance declines with increasing body mass index in both genders. Analysis of fluctuations of the center of pressure (COP) revealed higher frequency and magnitude in mediolateral direction COP movements when compared women to men. A strong negative correlation has been found between Tinetti static balance score and the total length of the COP trajectory during the examination on Homebalance ($r = -0.6$, $p<0.001$). Although both methods revealed good performance in detecting balance impairment, Homebalance test possesses higher precision due to the continuous nature of COP-derived parameters. In conclusion, our data proved that the Homebalance test is capable to identify persons with impaired balance control and thus are at higher risk of falling.

Keywords

Homebalance test, elderly adults, standing balance, Tinetti Balance Assessment Tool, BMI, fall risk prevention.

Introduction

Maintenance of upright posture is a complex physiological process requiring rapid integration and processing of information inputs from senses including vestibular, visual, and somatosensory systems, and full coordination of elements of the musculoskeletal system. Balance control is a critical task of daily life, the ability to maintain upright posture becomes, however, of particular concern during aging when the sensory and motor system becomes deteriorated. According to the Center for Disease Control and Prevention of the United States approximately one third of people older than 65 years reported at least one fall in the last 12 months **[1]**. Moreover, falls are the primary cause of injuries in the elderly **[2]** with many of those individuals incurring bone fractures and other injuries as a result **[3]**. Falls contribute to the most deaths caused by injury within the aged population, and the mortality rate following a fall is drastically higher than before falling **[4].** In addition to injury, the occurrence of falling is also negatively linked to the development of a fear which can lead to lifestyle changes that might additionally dramatically decline the quality of life **[5].** The maintenance of balance is thus of great interest in both healthcare professionals and daily assistants carrying of the aged individuals. Although age is a prominent factor affecting balance, an excessive weight also negatively influences balance control. We have recently shown that obesity, depression, mental and physical overload are predictors of disturbed balance in the elderly population **[6].** Also, other studies have shown that aged persons with high body mass index (BMI) are associated with an increased risk of falls**[7,8].**

Longitudinal reliable assessment of balance control abilities is a critical point in the prediction of increased risk of falling and its prevention. Moreover, an unbiased method for balance assessment is desired also for the evaluation of treatment strategies and last but not least in the decision-making process in institution of individual intensive care. The Tinetti Balance Assessment Tool (TMT) is broadly accepted, easy to perform, a clinical balance test used to measure static and dynamic balance in elderly persons **[9].** TMT shows good to excellent reliability, an intra-class correlation coefficient> 0.80, and moderate sensitivity and specificity for fall detection **[10,11].** Other studies suggest that the TMT score can identify older participants at high risk of falls due to muscle mass and strength alterations, in both one-dimensional and multidimensional analysis **[12,13].** However, TMT requires an experienced examiner, and its reproducibility is limited by the subjective manner of the test. Contrary, a posturography is the technique used to quantify postural control in upright stance in either static or dynamic conditions by computerized system. Static posturography test is performed in a standing posture of the patient on a force platform allowing to detect the oscillations of the body posture. These body oscillations are represented in posturography as excursions of the Centre of Pressure (COP) which is dynamically computed from force sensor signals of the platform. COP should be understood as an imaginary point at which the weight of the body will produce the same effect as the pressure of the body over the soles of the feet. Although sophisticated posturography tests can be performed in health facilities by healthcare proffesionals, a cheap posturographic platform-based systems have been introduced recently and due to their nature, they might be considered to be used by non-medical healthcare professionals or even in home self-test of the balance in elderly patients. The Homebalance posturography, also known as the Nintendo Wii Balance Board, is a personal computer-based modern diagnostic device offering possibility testing in a natural environment **[14,15].** The Homebalance posturographic platform has been also tested as a treatment device providing a training program based on feedback balance tasks. Dynamic detection of the COP by the Homebalance posturographic platform provides an opportunity for unbiased assessment of posturographic parameters.

The primary aim of the study was to evaluate the Homebalance test in identification persons at higher risk of falling, especially in an easy test designed to be performed by a non-medical healthcare professional. We thus performed a static stance test using Homebalance with eyes open and compared obtained COP parameters to TMT score in the elderly aged above 65 years. We have additionally used the known relationship between balance impairment and BMI value to verify the sensitivity of both methods.

Methods

Subjects and procedure

Ethics Committee of the Research Institution University of Physical Education and Sport PALESTRA Limited expressed full agreement with the goals and procedures of the GAČR research GA17-25710S character of the document a_217990. Written informed consent to participate in the study was obtained from all subjects after being introduced to the aims of the study, diagnostic methods, procedures, and data processing.

A standardized medical history protocol using a comprehensive geriatric assessment (CGA), which identifies the individual's medical, psychosocial, and functional limitations, was used to assess each participant's health status and diagnosed geriatric syndrome. Based on this, the physician made a medical recommendation and decision to include the individual in the study.

Subjects over the age of 65 with geriatric syndrome capable of underwent examination were enrolled in the study. The geriatric syndrome was diagnosed according to the presence of some of the following patterns: hypomobility, deconditioning and muscle weakness, instability with falls, anorexia or malnutrition, dehydration, incontinence, cognitive deficit, memory or behavioral disorders, or combined sensory deficit.

The exclusion criteria for participation in the study were established according to the White Book on Physical and Rehabilitation Medicine in Europe **[16]** and are as follows: acute infectious disease, all acute diseases and conditions in which destabilization of the state of health can reasonably be expected, cachexia, malignant tumor, non-compensated epilepsy, acute phase of psychosis, mental disorders with antisocial manifestations or with reduced communication, 2nd and 3rd-degree incontinence, and any present disease or medication preventing or influencing balance examination.

General examination

All subjects underwent general examination of body height, weight, and composition. The measurements were performed using common anthropometric procedures and an the weight device InBody 230 (year 2016). Body height, body weight, and BMI score according to Bláha et al. were achieved **[17].** The following categories were selected for the body mass index (BMI): normal BMI: 18.5–24.9 kg / m2; BMI_2 - overweight: 25.0–29.9 kg / m2, BMI_3 - obesity: ≥ 30.0 kg / m2 **[17].**

Examination of static balance

<u>Homebalance posturography method</u>

Homebalance posturography consists of Homebalance software and the Nintendo Wii Balance Board static platform. It is certified as a Class I medical device. The Homebalance software was developed at Charles University in Prague in cooperation with the Czech Technical University **[18]**. The examination of static balance was performed during resting stance on a Nintendo Wii platform for thirty seconds with the eyes open.

The coordinates of the centre of pressure (COP) were recorded (sampling frequency 98Hz) during the period into the personal computer for consequent offline analysis. To evaluate the static balance test a set of posturographic parameters were calculated, namely: the trajectory of COP (TF), the average position of COP (MD), the average position of COP in the mediolateral plane (APML), the average position of COP in an anterioposterior plane (APAP), an average quadratic distance of COP in the mediolateral plane (AQML) and the average quadratic distance of COP in the anteroposterior plane (AQAP) **[14,18].**

<u>Tinetti balance assessment tool</u>

The Tinetti Balance Assessment Tool is a clinical performance test used to measure static and dynamic balance in the elderly. In this study, we used only the static TMT balance test. The TMT static balance test is based on observations of the individual's performance while sitting and standing. Observer grades nine items (sitting balance, rises from a chair, attempts to rise from a chair, immediate standing balance, standing balance, nudged, eyes closed, turning 360 dg and sitting down) on a 2-point or a 3-point scale according to an original examination protocol **[19].** The maximum total score is 16 points for static balance. The higher the score, the better the performance **[19,11].**

Statistical analysis

Statistics were performed using standard methods by a professional statistician in MS Excel (Microsoft, USA), SigmaStat (Systat Software, San Jose, California, USA), or Matlab Software (Mathworks, Natick, USA). To find inter-variable dependency correlation and regression analyses were performed (Robust Kendall, O2PLS) **[20].** Graphs were created either by MS Excel or Matlab software.

Results

During the period of recruitment (from May to July 2018), 135 subjects with geriatric syndrome met the inclusion criteria. The experimental group consisted of 82 women (74±5years) and 53 men (73±5years). Detailed age characteristics of the experimental group are provided in Table 1.

	Female	*Male*
Count	82	53
Average age	74.0732	73.2264
Median	74.0	74.0
Standard deviation	5.04738	5.16513
Lower quartile	70.0	69.0
Upper quartile	77.0	77.0
Stnd. Skewness	0.132059	0.470304
Stnd. Kurtosis	-1.37179	-1.56767

Table 1 Age characteristic of the experimental groups (in total 135 subjects).

Although age and BMI did not significantly differ in between genders, a body composition by means of percentage of body fat has been found significantly lower in men than women (P=0.016). Interestingly, more women have been on psychoactive drug treatment during the examination period when compared to men (P=0.003). Psychoactive drugs were predominantly prescribed due to insomnia and thus were typically represented by short-acting benzodiazepines. Age influenced none of the factors. All results of statistic comparison and interactions of main factors between genders or age are provided in Table 2.

None of the subjects was excluded during the Homebalance test and all data were successfully recorded and were suitable for analysis. During the 30s recording of static stance with eyes open on Homebalance, a COP fluctuated typically with higher frequency and magnitude rather in anterioposterior than in mediolateral direction (Figure 1).

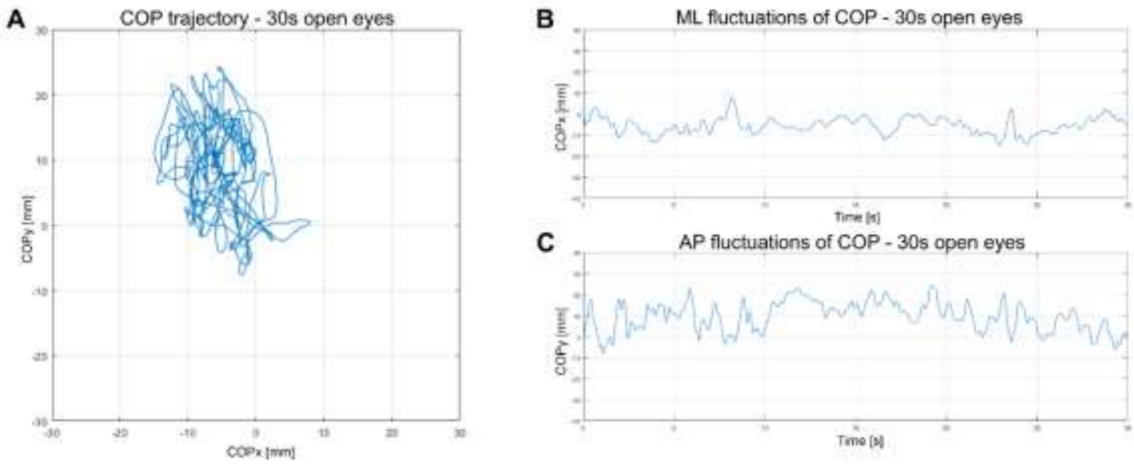

Figure 1 Representative trace of COP fluctuations during 30s examination interval recorded in a 78 years old woman, BMI 29, taking both analgetics and psychoactive drugs. Panel A represents native COP trace while panels B and C provide fluctuations of COP in mediolateral (ML) and anterioposterior (AP) direction respectively.

Although anterioposterior fluctuations of COP were prominent in both genders, we have found a significant difference in the total distance which COP traveled during the examination. Mathematical analysis of recordings revealed longer COP trajectory in women when compared to men (P=0.032). The consequent direction-specific analysis detected increased fluctuations in both parameters sensitive to mediolateral oscillations in women (P= 0.016 in both APML and AQML, Figure 2).

The score assessed by the static balance test of the Tinetti Balance Assessment Tool reached a median of score 24 (IQR = 5) in all 135 subjects. We have found no statistical difference between genders (men 24 IQR=5, woman 25 IQR =7, P=0.651, Table 2 and Figure 2).

To elucidate interactions between variables a set of correlation tests was performed. The analysis revealed a strong correlation between BMI and various parameters of static balance. Namely, higher BMI predicts worse performance in both TMT and Homebalance tests. Later revealed significant interaction in the mediolateral plane. Results of the set of correlations are provided in Table 3.

We have further correlated the subject's performance on both Tinetti and Homebalance tests to compare performance of both methods. To attain symmetric data distribution and constant variance in both variables, power transformations were applied in both dimensions. Then the correlation was calculated and the obtained reduced principal axis and confidence ellipsoid were retransformed to the original scale for better comprehension. A strong negative correlation has been found between Tinetti's static balance score and the total distance which COP traveled during the examination on Homebalance (r = -0.6, p<0.001, Figure 3). Although, both methods revealed good performance in detecting balance impairment, a Homebalance test possesses higher precision due to the continuous nature of COP-derived parameters.

X-Variable	Gender (female=0; male=1)			Age		
	Kendall's τ correlation			Kendall's τ correlation		
Y-Variable	coefficient (95% CI)	Z-value	p-value	coefficient (95% CI)	Z-value	p-value
Gender				-0.068 (-0.179, 0.045)	-0.93	0.353
Age	-0.068 (-0.179, 0.045)	-0.93	0.353			
BMI	-0.041 (-0.153, 0.073)	-0.55	0.583	0.022 (-0.091, 0.135)	0.36	0.72
FAT	-0.175 (-0.282, -0.064)*	-2.41	0.016	-0.044 (-0.156, 0.069)	-0.72	0.472
Tinetti	-0.033 (-0.146, 0.08)	-0.45	0.651	-0.018 (-0.13, 0.096)	-0.28	0.78
Analgetics	-0.15 (-0.259, -0.038)	-1.74	0.082	0.019 (-0.094, 0.132)	0.26	0.793
Psychopharm	-0.259 (-0.362, -0.151)**	-3	0.003	-0.005 (-0.118, 0.108)	-0.06	0.95
TF	-0.152 (-0.26, -0.04)*	-2.15	0.032	0.103 (-0.01, 0.214)	1.73	0.084
MD	-0.135 (-0.244, -0.022)	-1.9	0.058	0.034 (-0.079, 0.146)	0.56	0.575
APML	-0.171 (-0.279, -0.06)*	-2.42	0.016	0.002 (-0.111, 0.115)	0.04	0.971
APAP	-0.068 (-0.18, 0.045)	-0.96	0.337	0.053 (-0.06, 0.165)	0.89	0.372
AQML	-0.172 (-0.279, -0.06)*	-2.42	0.016	0.008 (-0.105, 0.12)	0.12	0.901
AQAP	-0.074 (-0.185, 0.039)	-1.04	0.298	0.059 (-0.054, 0.171)	0.99	0.321

Table 2 Gender and Age interactions, BMI – body mass index, TF - the trajectory of COP, MD - the average position of COP, APML - the average position of COP in the mediolateral plane, APAP - the average position of COP in an anterioposterior plane, AQML - an average quadratic distance of COP in the mediolateral plane, AQAP - the average quadratic distance of COP in the anteroposterior plane.

X-Variable	Y-Variable	Correlation coefficient	p-value	
BMI	Tinetti	-0.362	<0.001	**
	MD	0.210	0.014	*
	MDML	0.220	0.011	*
	MDAP	0.152	0.079	
	AQML	0.253	0.003	*
	AQAP	0.158	0.068	
FAT	BMI	0.509	<0.001	**
	Tinetti	-0.208	0.016	*
	MD	0.084	0.331	
	MDML	0.127	0.142	
	MDAP	0.002	0.986	
	AQML	0.133	0.124	
	AQAP	-0.002	0.982	

Table 3 Pearson's correlation revealed an interaction between static balance tests and BMI or FAT. BMI – body mass index, TF - the trajectory of COP, MD - the average position of COP, APML - the average position of COP in the mediolateral plane, APAP - the average position of COP in an anterioposterior plane, AQML - an average quadratic distance of COP in the mediolateral plane, AQAP - the average quadratic distance of COP in the anteroposterior plane.

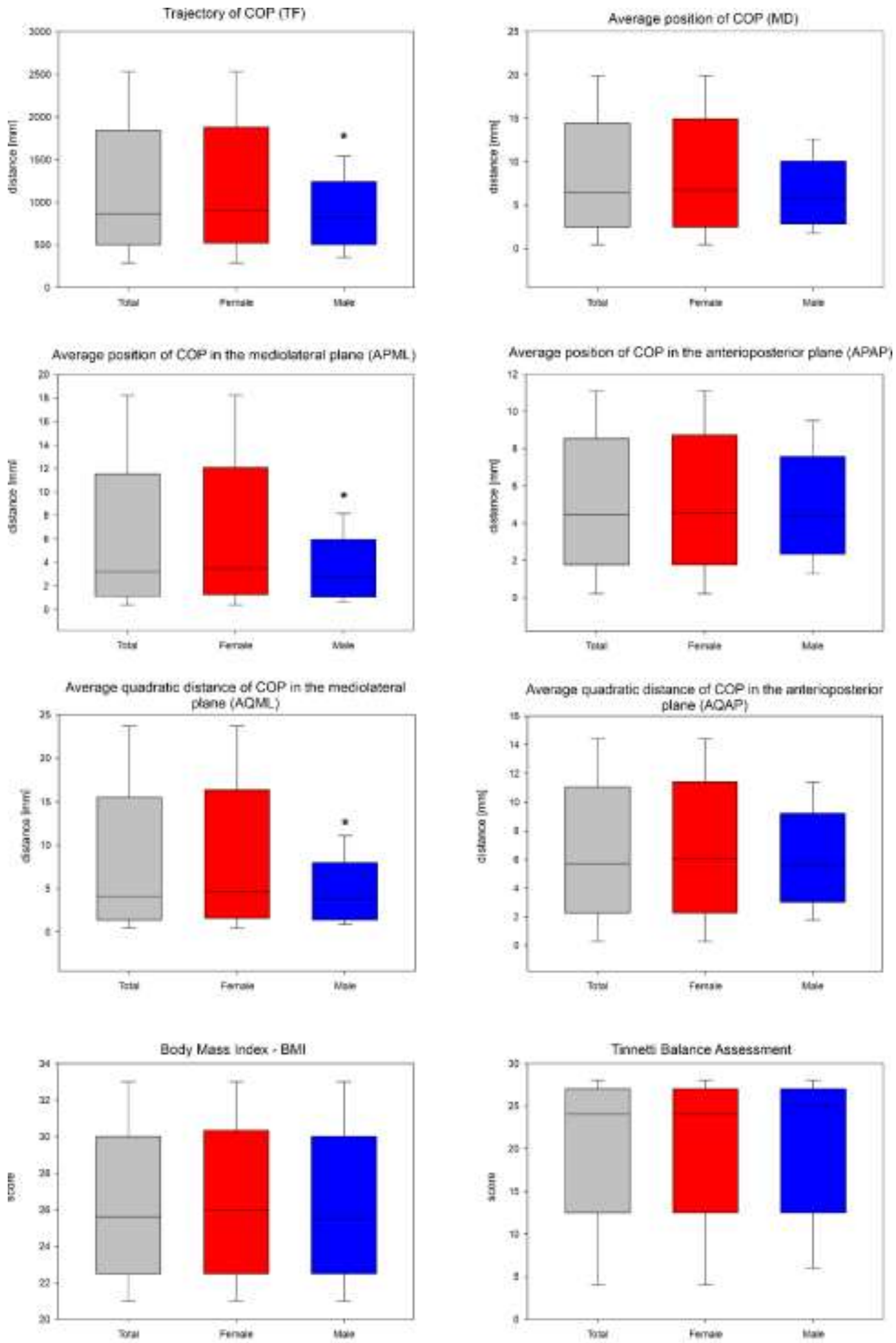

Figure 2 COP parameters revealed longer COP trajectory (TF) in women specifically in mediolateral direction (APML, AQML). Gray box belongs to all 135 subjects, red to women and blue to men. Tinetti and BMI did not differ between genders. Data are presented as box plots with median, IQR, and minimum and maximum as error bars.

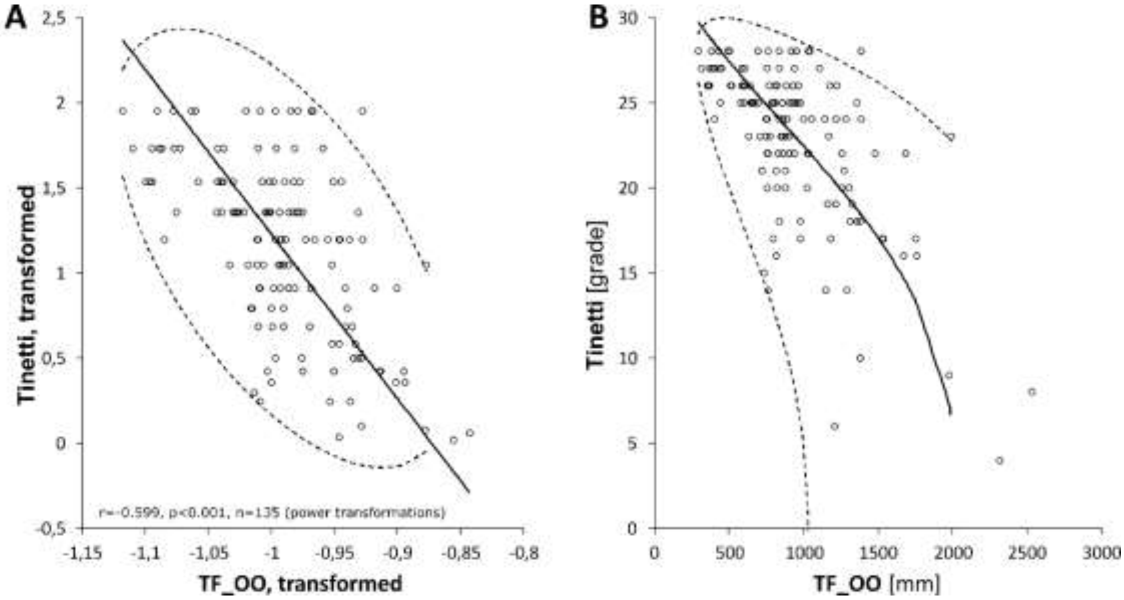

Figure 3 Correlation between results of both static balance tests – Tinetti and length of of COP trajectory during Homebalace test with eyes open (TF_OO). Panel A represents power transformed data in both dimensions while panel B shows the correlation of raw data. Tinetti tightly correlates with the total distance COP traveled in the Homebalance test. Data suggests higher sensitivity of the Homebalance test than Tinetti.

Discussion

We performed a static stance test using Homebalance with eyes open and compared obtained COP parameters to TMT score in 135 recruited persons aged above 65 years. Additionally, we have correlated results to BMI intending to compare the sensitivity of both methods for balance assessment. In agreement with previous studies, our data show that balance is significantly impaired independently of the evaluation method used **[20].** Impaired control of both static and dynamic balance leads to increased risk of falls during daily activities resulting in severe injuries and decline of quality of life in the elderly people. Posture imbalance during aging is likely a result of a combination of various pathophysiological processes and the cause should be assessed individually. However, in general, a typical mosaic of patterns is observed. The presence of neurological, metabolic, musculoskeletal, cardiovascular, or vision disorders influences the ability to sense upright posture and thus negatively and often progressively influence control of balance **[21]**. Important parts of proprioception also deteriorate with age and result in a diminished information flow to central nervous system (CNS) **[22]** and have been linked to poorer balance control **[23,24]**. Reduction in numbers of intrafusal and nuclear chain fibers has been observed in brachial biceps muscle with aging **[25,26]**. Skeletal muscles as the main effector of the balance control system decline with age in their abilities to generate force and other biomechanical properties. The loss of muscle mass is likely responsible for the age-dependent decline in maximal force during voluntary contraction **[27]** although also other factors such as a decline in maximal firing rate of muscle fibers **[28]** or decrease in a number of motor units of skeletal muscle **[29,30]** might facilitate and accelerate age-related muscle weakening. Alterations in the vestibular and vision system and connecting central pathways occur with aging. Specifically, between 40 and 70 years of age a reduction of approximately 40% in hair and neurons has been reported **[22,31]**. The minimum light needed to see an object increases with age due to specific structural changes such as a loss in the visual field, a decline in visual acuity, and visual contrast sensitivity, altogether leading to impaired contour and depth perception **[22,32]**. It should be noted that the above-mentioned factors besides static balance also negatively influence overall motor abilities and thus demanding daily activities such as walking on stairs represents a high risk of falls and consequent injuries **[33]**.

The evaluation of COP fluctuations detected by force platforms has been used to quantify postural stability in quiet standing in elderly people **[34,35]** and to identify those with increased risk of falls and mobility limitations **[36,37,38]**. We observed that COP traveled significantly longer distances during the static balance test in women in contrast to men. Bryant et al. **[34]** found opposite gender effect in raw posturography data, however, when the COP fluctuations were normalized to a body height, no gender differences were observed in their study. Our data thus suggest higher risk of falls in women due to impaired static balance. Although most reports indicate in agreement with our observations a higher incidence of falls in women in comparison to men **[39]**, others describe the opposite **[40]** or no difference in risk of falls in elderly people of both genders **[41].** Further well-controlled longitudinal studies are needed to elucidate this issue.

By direction-specific analysis of COP fluctuations, we further revealed significant differences in the directionality of the COP fluctuations between genders. Although the typical pattern of COP movement is anterioposterior fluctuations, we found that women swayed with higher frequency and magnitude in mediolateral direction when compared to men. It has been shown that the stance width for balance tasks has a significant effect on the direction and magnitude of the COP fluctuations. Using a narrow stance to assess balance likely produces greater fluctuations of COP in the mediolateral direction, than those using a wider stance **[42,43]**. In our study **[33]** subjects stood on the force plate which has fixed dimensions and thus were forced to stand in a predetermined stance position. However, whether this is the reason for gender difference in mediolateral COP fluctuations remains to be elucidated by further studies. Recent studies by Kovačíková and Abrahamová and Hlavacka **[35]** using the same hardware as we did, has also revealed a difference in the balance control of older women and men. In agreement with our data, the conclusion of the study suggests that women have more severe impairment of balance control in the ML plane (mediolateral) and at the same time in the AP (anterioposterior) plane during the downstairs step. Although dynamic nature of the downstairs step test represents different balance control tasks, these results further support our finding on gender and direction-specific COP fluctuation pattern in elders.

We have correlated the subject's performance in balance tests with all available variables. We have observed significant dependency of both the Tinetti and Homebalance test on body weight as expressed by BMI and fat percentage. The effect of obesity on postural control has been studied earlier in various age groups. Rossi-Izquierdo et al. pointed out that obesity had a negative effect on postural control **[7]**. In a study published by Hue et al. **[44]** a strong correlation between body weight with impaired postural balance has been observed in the adult population (age range 24–61 years). Joon et al. **[45]** have further analyzed reasons for impaired stability control in obese subjects and revealed a higher occurrence of joints of the lower extremity and other musculoskeletal disorders which likely participate in overall worse balance performance **[46].**

In our study, we have observed that more women have been on psychoactive drug treatment during the examination period when compared to men. Orlando et al. **[47]** have systematically reviewed medication in ~3.9 million people treated with at least one drug. The number of prescriptions was significantly higher in females than males in all types of drugs including psychoactive drugs. The only higher prevalence identified in males were antidiabetics. Conversely, treatment duration was longer among males. The higher number of females on psychoactive drug medication well corresponds with the finding of a higher prevalence of mental health issues in females recently published in a systematic review by Otten et al. **[48]**. They identified and further analyzed a variety of protective and risk factors including social factors, lifestyle, physical health, body mass index (BMI), diabetes, genetic and biological factors. The most evident were the gender-specific risk profiles for depression with mostly external risk factors for men and internal risk factors for women. However, whether psychoactive medication affects our findings remains unresolved.

We aimed to compare Homebalance and Tinetti balance tests in our study. We have observed good compliance of subjects to the Homebalance test with eyes open which can be thus used also for self-test. Moreover, our correlation analysis indicates that Homebalance is more sensitive than Tinetti which by its nature has to be performed and assessed by an experienced examiner. Homebalance test is based on the Nintendo Wii force platform and can be used also for biofeedback training which might improve balance performance in elderly people and thus improve their quality of life. Nintendo Wii force platform has been used also in other studies with similar conclusions **[15]**. However, it should be noted that the Nintendo Wii force platform balance tests do possess limitations such as worse signal to noise ratio or inconsistent sampling rate when compared to certified posturography platforms. Thus it is important that appropriate data acquisition protocol and digital filtering are properly chosen and outcome variables which do not inherit the error from this device are used for evaluating balance performance.

In conclusion, our data has shown that the Homebalance test is able to identify people with impaired balance control and are at higher risk of falling. Capability of Homabalance test to reliably assess main posturographic parameters of static balance by non-medical healthcare proffesionals in home environment opens new opportunities to help suffering elders. Early detection of balance impairment in elderly persons might finally lead to earlier prescribtion of relevant preventive and treatment strategies with aim to decrease risk of falls and improve a quality of their lifes.

Conflict of interests

There is no conflict of interest.

Acknowledgments

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