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Postural Stability of Women Over 60 Years: Physically Active and Physically Inactive

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Abstract

Introduction and objective: Maintaining an upright posture requires the human nervous system to integrate information from visual, vestibular, proprioceptive and exteroceptive systems in order to determine the appropriate neuromuscular strategy. All elements of postural control are affected by involutional changes which, consequently, lead to loss of balance and falls. Taking up physical activity is an important preventive measure. The purpose of this study is: (1) To assess the impact of physical activity on postural stability of women between 60 and 84 years of age and (2) To evaluate the participation of visual feedback in compensation for balance disorders.

Materials and methods: The study group consisted of 56 female, between 60 and 84 years of age. They were divided into two groups: the first consisted of 26 women who were physically active and the second comprised of 30 women not involved in any organized forms of physical activity. Postural stability was measured using Biodex Balance System (BBS) in combined conditions of visual feedback (eyes open and eyes closed) and on different platform stability (static and unstable surface).

Results: There were no statistically significant differences between the study groups in the tests conducted with visual feedback. The tests performed without visual feedback showed substantial differences in each of the presented indicators (OSI, APSI, MLSI) in favour of women who were regularly involved in organized forms of physical activity.

Conclusion: The results confirm the positive impact of physical activity on the postural stability of women over 60 years of age. The most significant differences between the studied groups were observed in tests performed without visual feedback. The results show how important the organ of vision is in controlling a stable posture, and how important it is to train other sensory inputs which affect postural stability.

Keywords: Postural stability; Physical activity; Women over 60 years of age

Introduction

Postural control is achieved through constant maintenance of the center of gravity (COG) over the base of support (BOS), both in static and dynamic conditions [1]. Maintaining an upright posture requires the human nervous system to integrate information from visual, vestibular, proprioceptive (mainly from muscle spindles) and exteroceptive (in particular from cutaneous receptors in the soles of the feet) systems in order to determine the appropriate neuromuscular strategy and it is possible to shift back the center of gravity (COG) to its position prior to the loss of balance [2-5]. This ability of the body is necessary to maintain a stable posture, which is essential for almost all life activities, ranging from simple bodily movements, through locomotion to complex physical activities.

All elements of postural control undergo changes over the years. Involutional changes include weakening of all functional and anatomical systems. This is the result of a systemic and local ageing of tissues and the slowing of biological and metabolic processes, as well as slower regeneration and reparation. Consequently, we can observe age-conditioned functional disorders of musculoskeletal and nervous systems responsible for maintaining a stable posture [6].

Usually deficiencies in one element of postural control do not lead to instability, because compensation mechanisms from other sensory inputs are automatically triggered. However, deficiencies in several elements can result in loss of balance and falls [7,8]. Early detection of balance impairments is crucial to identify older adults at risk of falls and further impairments. Therefore, sensitivity to subtle changes in balance is imperative for assessment tools [9,10]. Although researchers emphasize the fact that falls may occur in each ontogenesis phase, they appear more frequently in the elderly and lead to more serious health consequences [11]. It has been proved that the reduced ability to maintain balance is the major factor leading to falls among older people [12-14]. It is estimated that during one year 30% of people over 65 years of age experience a fall. In a group of people over 80 as many as 40% experience a fall in a year, and among elderly with chronic diseases and disabilities falls are even more common [15].

An important contribution to successful aging and prevention of falls is taking up physical activity. Exercise interventions can reduce the risk and rate of falls in the elderly by between 15-32% [16-18]. Many authors emphasize the positive link between the increased and properly selected physical activity of the elderly and the sense of balance and the decreasing risk of falls [19-21]. Introduction to physical activity is at the core of health and well-being. The benefits of physical activity, including reduced risk of non-communicable diseases and lower levels of stress, anxiety, and depression, are well known [22].

The aim of the study was twofold:

1. To define the effect of physical activity on balance in women aged between 60-84 years.

2. To determine the role of visual feedback in the compensation for balance disorders.

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Materials and Methods

Participants

A total of 56 women aged 60 - 84 years took part in the study. The first group comprised 26 physically active women who had been practicing regularly 3 times a week for at least 2 years, in compliance with the recommendations of the World Health Organization (WHO) [23]. WHO recommends that adults (including the elderly) engage in at least 150 minutes of moderate-intensity physical activity each week. Among disciplines practiced in the test group were gymnastics, dancing, 'healthy spine' classes, tai-chi, nordic walking, swimming and yoga. The configuration of disciplines and exercises done during the week was personally selected by each woman. The control group comprised 30 women who defined themselves in the interview as physically inactive and did not participate in any form of physical activity. The exclusion criterion was testing positive in one or more of the following tests: cerebellar testing (finger-to-nose test, diadochokinesis) and static and dynamic tests which assess the correctness of posture and gait (Romberg test, Unterberger test, the Babinski-Weil test). Both groups were homogeneous in terms of age, height, weight, and BMI. General characteristics of the studied groups are presented in Table 1.

Approval was obtained from the Research Ethics Commission of the Józef Piłsudski University of Physical Education in Warsaw in accordance with the ethical standards laid down in the Declaration of Helsinki. All participants were informed of the experimental procedures and signed informed consent prior to the experiment.

Measurements

Postural stability was measured using a Biodex Balance System SD (BBS), an instrument designed to measure and train postural stability on static or unstable surfaces. The BBS consists of a circular platform that is free to move in the anterior-posterior and medial lateral axes simultaneously, offering the ability to control the movement degree of the platform on 12 levels. The BSS device is interfaced with dedicated software (Biodex Medical Systems, Inc. version 1.3.4), allowing the BBS to measure the degree of tilt in each axis, providing an average sway score. Eight springs located underneath the outer edge of the platform provide resistance to movement (stability level of the platform), with resistance levels ranging from 12 (most stable) is 1 (least stable). The BBS has a display to give feedback in real time about the posture and is calibrated before use. The participants stood on the BBS supported on their two legs, facing towards the display, for all time trials. All trials were conducted without shoes and foot position was recorded using the coordinates on the platform's grid to ensure the same stance and, therefore, consistency with future tests. In this research five measurement protocols were used: the Postural Stability Test (PST) in a variety of conditions – stable platform with eyes open and with eyes closed and the Fall Risk Test (FRT) with open and closed eyes. In the PST the platform is static in the anterior-posterior and medial-lateral axes and can measure the Overall Stability Index (OSI). This test consisted of three trials, each 20 second long, with 10 seconds between trials. These indexes represent fluctuations around a zero-point established prior to testing when the platform was stable. In the FRT, the platform is unstable and thus permits investigators to obtain the Fall Risk Index (FRI). This test was conducted using the standard software configuration: three trials of 20 seconds each, with 10 seconds rest between tests, and platform levels varying from 12 to 6 for open eyes and from 6 to 1 for closed eyes [24].

The role of visual feedback in maintenance of balance was assessed with Visual Inspection Indicator (VII) for OSI, APSI and MLSI. VII was calculated on the basis of the modified equation described by Mraz et al. [25].

$$VII = \frac{\text{stability index without visual control} - \text{stability index with visual control}}{\text{stability index without visual control} + \text{stability index with visual control}} \times 100$$

Using the obtained mean values and standard deviations so called 'effect size' was calculated, which can be presented as a quantitative measure of the strength of the phenomenon calculated on the basis of the data [26]. It is a supplement to statistical inference, next to p-significance.

Safety of the participants during the tests was ensured by the side rails and the assistance of the study director. For all participants, basic somatic measurements were taken – body weight and height using a standard electronic scale and anthropometer. On the basis of these anthropometric measurements the Body Mass Index (BMI) was calculated. The recorded data were analyzed statistically using the STATISTICA software (v. 12). Shapiro-Wolf test was used to verify if the distribution of the examined features is consistent with the normal distribution.

A2 (group) × 2 analysis of variance (ANOVA) with repeated measurements on OSI (Overall Stability Index), APSI (Anterior-Posterior Stability Index), MLSI (Medial-Lateral Stability Index) and FRI tests ($p<0.05$). When statistically significant differences appeared multiple repetition, tests were conducted (post hoc Least Significant Difference test NIR).

Results

Parameters defining the balance on a static and unstable surface were recorded on the BBS platform. Results of the tests carried out with visual feedback are presented in Table 2, without visual feedback in Table 3.

The values of the Overall Stability Index (OSI), the indicator of stability towards the anterior-posterior (APSI) and medial-lateral (MLSI) directions and the risk of falls (FRT) were lower in physically active women, but not statistically significant. Physically active women as well as physically inactive women fall within normal limits in the risk of falls test (FRT) (manufacturer data in the BBS software: 1.9-3.5).

Stability indexes in tests performed without visual feedback show lower values of all the indicators in the physically active women. The same tendency was observed in tests performed with visual feedback. The differences in values of all tested parameters were statistically significant, most evidently in the case of Overall Stability Index (OSI), which was additionally confirmed by a large 'effect size'. The table above shows that, according to the scale of effect size developed by Cohen [27], the effect is large in the indexes recorded in eyes-closed conditions. The biggest effect is in OSI with eyes closed, while the effect in tests with eyes open in OSI and APSI is average. FRT measurement was excluded

Group	n	Age (years)	Body Height (cm)	Body Mass (kg)	BMI
Female (Group 1)	26	68.42 ± 6.18	157.3 ± 0.05	65.69 ± 8.24	26.6 ± 3.75
Female (Group 2)	30	68.27 ± 7.46	160.6 ± 6.95	69.19 ± 12.23	26.84 ± 4.59

Table 1: Participant demographics (mean ± SD).

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Stability Index (SI)	Group 1 (n=26)	Group 2 (n=30)	Effect Size	P-value
AXIS-static	0.42 ± 0.15	0.57 ± 0.42	0.53	0.104
APSI-static	0.32 ± 0.12	0.44 ± 0.35	0.51	0.094
MLSI-static	0.21 ± 0.02	0.25 ± 0.20	0.36	0.377
FRT (6-2)	1.87 ± 0.94	2.18 ± 0.85	0.35	0.207

OSI: Overall Stability Index, APSI: Anterior-Posterior Stability Index, MLSI: Medial-Lateral Stability Index, FRT: Fall Risk Test.
Effect Size=Mean of group 2 - Mean of group 1/Standard deviation of/in both groups.

Table 2: Measurements of stability index with eyes open in female participants (mean ± SD) Group 1 and Group 2.

Stability Index (SI)	Group 1 (n=26)	Group 2 (n=30)	Effect Size	P-value
AXIS-static	1.2 ± 0.53	2.56 ± 0.21	3.78	0.000001
APSI-static	0.94 ± 0.45	1.92 ± 1.14	1.23	0.00013
MLSI-static	0.54 ± 0.39	1.34 ± 0.85	1.29	0.00005

OSI: Overall Stability Index, APSI: Anterior-Posterior Stability Index, MLSI: Medial-Lateral Stability Index, Static - stable platforms.
Effect Size=Mean of group 2 - Mean of group 1/Standard deviation of/in both groups.

Table 3: Measurements of stability index with eyes closed in female participants (mean ± SD) Group 1 and Group 2.

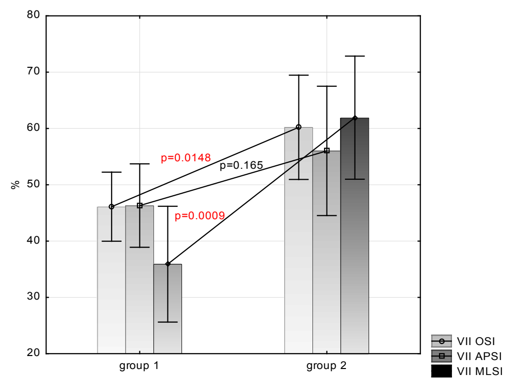

Figure 1: Visual inspection indicator (VII) (mean and SD) studied groups.

from the analysis because with their eyes closed participants were not able to stay unsupported on the platform.

The obtained indexes (OSI, MLSI, APSI) were used to calculate the Visual Inspection Indicator (VII), which is the difference of results between tests performed with and without visual feedback. The values of VII in the group of active women are significantly lower and fall within: 35.9 ± 25.5 – ML and 46.1 ± 15.2 - OSI. In the group of inactive women, the values of this indicator are much higher and reach: 49.8 ± 29.3 - ML and 60.2 ± 24.8 - OSI.

It should be noted that the biggest difference between the groups appeared in the indicator for lateral oscillations (Figure 1). The maximum value of the indicator may reach 100%. The indicator is increased with size of the difference between the index in the test with eyes closed and the size of this index with eyes open.

Another area of analysis involved the configurations of physical activities selected by the women in the first group. Analysis of variance showed no statistically significant differences between participants grouped according to the characteristics of the activities they undertook. Neither was any dependency discovered between the results of postural stability and the features of their trainings.

Discussion

It is predicted that more than 15% of the population worldwide will be over 65 years old by 2050 [15]. Involutional changes, which undoubtedly reduce the ability to maintain balance and increase the risk of falls, are an integral part of the aging process [2-6]. It poses a major health problem for the aging societies. One of the assumptions of this study was to present the results confirming the positive impact of physical activity on the improvement of balance and prevention of falls. The tests carried out with visual feedback show no significant differences between the groups. However, it should be noted that all the results were more favorable for the group of women who were physically active. Small differences between the groups may stem from the fact that the assessment of postural stability was carried out on a stable platform, which does not demand high physical fitness.

What we have shown, however, is that an important factor in maintaining stability was the possibility to control the deflection of the centre of gravity (COG) by using the sight. The center of pressure (COP) of the feet is presented as a point which the person undergoing the test should observe on the screen synchronized with the BBS platform, on which the measurements are recorded. In maintaining a stable upright posture the sight performs a very important role. It supports the vestibular system and complements the information submitted by proprioceptors. Its function can be defined as compensatory for other senses, so losses in their functions can be effectively compensated [27,28]. Failure of the oculomotor apparatus, the visual acuity and angle may cause deterioration of the ability to adjust the body posture to maintain the balance [29].

Further analysis of the study results show that in both groups there was a significant deterioration of indicators in tests with eyes closed. When the participants did not observe the COP, so they could not use their eyes to control their posture, PST results worsened significantly. The biggest difference was visible in the Overall Stability Indicator (OSI).

When the participants were placed on the unstable platform (FRT) with their eyes closed, both active and inactive women were not able to complete the tests and kept falling from the platform. Wiszomirska et al. [30] carried out similar tests involving young women (about 20 years old), older women (about 68 years old) and women with vision loss (about 19 years old). During the test on the unstable platform without visual feedback older women were not able to achieve a positive result and fell from the platform. The visually impaired women achieved significantly worse results than the young women with good sight. These studies indicate that the ability to control the balance decreases with age, and that it is particularly difficult on unstable ground, and the incentives provided by the organ of vision are of key importance for maintaining stability. Visual stimuli ensure creation of a surrounding reference system [31]. It is emphasized by the values calculated by the 'effect size' equation. Following the classification proposed by Cohen [27] the values of all the indicators with eyes closed can be classified as medium effects. The value of 'effect size' is lower in the tests with eyes open, where there were no statistically significant differences, which is why most of the indicators fall within the range of small effects (only the OSI indicator slightly exceeds the upper limit of the range). These data allow to observe the tendency of increased strength of effect size in eyes-closed conditions.

To define the role of visual feedback in maintaining postural stability the Visual Inspection Indicator (VII) was calculated. Significantly lower values of this indicator were recorded in the group of physically active women. In our interpretation visual feedback plays a significant role in maintaining postural stability, which is suggested by the participation of visual feedback in the compensation for balance disorders. The biggest differences between the groups were observed in lateral oscillations. This indicator is of particular interest, since it is more affected by ageing and disease and since its deterioration has been associated with an increased risk of falling [32-34].

This thesis is compatible with the observations made by some researchers who studied stability of the elderly [9,35], who claim that the measurements in the coronal plane are a better indicator of body balance disorders in these people than those taken in the sagittal plane. However, these results are in contrast to Aydog et al. [36], who also studied the repeatability of the measurements on the BBS platform. They evaluated the three indicators of stability and made a claim that APSI and OSI are the reliable indexes, while MLSI is the least reliable. Similar results were obtained by Ocetkiewicz et al. [37], who made a suggestion that the measurement of the lateral oscillation is not repeatable and the APSI is more repetitive than all the other indicators. Low repeatability MLSI index may be associated with physiological limitation in the ability to make postural corrections in ML direction regardless of age. For the younger group this frequency of postural corrections may be in the ML direction, whereas for the older population this was not the case, as claimed by Baltich et al. [38]. The authors suggest that in the older group the musculoskeletal system is not sufficient to reduce the amount of movement and get the body back to an equilibrium position, which may predispose to falls. It has previously been proved that the largest postural sway is observed in the AP direction [39,40], which is in agreement with our results, it is easier to make postural corrections in this direction [38].

It can be assumed that the significantly higher values of the tested indicators in the eyes -closed conditions in the physically inactive women in comparison to the active participants stem from the fact that physical activity, containing elements of stretching and cardiovascular and strength training, has a positive impact not only on the muscle system, but also on all the systems of the human body. Physical activity has also a positive effect on the nervous system, on the development of motor memory and on the speed and ease of response to external stimuli, thanks to which people can effectively build the schema of their own body and kinesthesia, which allows to 'feel your body'. Better results achieved by the active women indicate higher efficiency of the vestibular system and proprioception in comparison to women physically inactive. When the visual stimuli are cut off the other sensory inputs may compensate for the absence of vision and maintain a stable posture.

In the light of the conducted study it can be considered a valid claim that multidisciplinary physical activity, which consists of muscle strength training, motor coordination training, training of proprioception, motor efficiency and other, has a positive impact on the balance of older women. Shaping these elements is necessary in the fall prevention strategy [41]. Weakening of postural stability is closely related to a development of disability, difficulty with performing activities of daily living, as well as a reduction in the quality of life of older people. Physical activity can significantly improve these elements [42-45].

The authors of this study make an additional indication for trainings, which should be extended by safe exercises without visual feedback (with eyes closed), which ensure greater stimulation of other sensory inputs (vestibular system or proprioceptive sensation) responsible for the balance.

Conclusions

1. The results confirm the positive effect of physical activity on postural stability without visual feedback in women over 60.
2. Visual feedback is crucial in maintaining postural stability in older people.
3. It is advisable to carry out further research on posture control mechanisms in the elderly in order to implement appropriate interventions aimed at improving balance and preventing falls.

Limitations

Study participants were women over 60 years of age who intensively participate in social life and live in a large metropolitan area. Therefore, the results of this research cannot be applied to all elderly people. They are an objective which can be reached by people over 60 and an indication that appropriate lifestyle can slow down involutional changes.

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