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Postural stability in women in the eighth and ninth decades of life

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Purpose: The purpose of this paper was an attempt to evaluate changes in the level of static equilibrium and the impact of visual information on the effectiveness of postural reactions of women in geriatric age. *Methods*: 36 senior female residents of L.A. Helc Nursing Home in Cracow, Poland, were examined. Considering the age, 2 groups were distinguished: group I – women at the age 71–80 and group II – women aged 81–87. Their balance was assessed with stabilographic platform CQ Stab 2P. Measurements of the body stability were made in free standing position, with eyes open and eyes closed. Comparison of selected indicators of stability between the groups of the women was made with the Mann–Whitney U test. To assess the significance of differences between the results obtained in the test with eyes open and without visual control the Wilcoxon test was used. *Results*: Statistically significant differences between the results obtained in the groups concerned the length of the statokineziogram path on the X-axis, as well as the average speed of the COP movement on the X-axis. In the test without the visual control both groups showed statistically significant deterioration in most indicators of stability. *Conclusions*: Loss of postural control as a result of progressive involutional changes in the aging process is characterized by the intensity of the body instability in the frontal plane. These results indicate the need of applying in the rehabilitation programmes for elderly people adequate solutions, including the exercises directed at developing new or enhancing the decaying adjustment mechanisms.

Key words: *postural stability, stabilography, ageing*

1. Introduction

Aging is an inevitable process afflicting every human being. The result of aging is the decline in performance capacity of all functional and anatomical systems, deterioration or lowering of the analysers efficiency, inter alia, eyesight, hearing, touch. Delay, inadequacy or lack of reaction of a human occur in different situations. Muscle atrophy intensifies incapability of producing proper muscle tension, necessary in the reflex reaction. Siniaki et al. [22] claim that the intensity of isometric contraction of muscles between 30 and 80 years of age reduces by 50%. With age, gradual worsening of joint movement follows, which leads to increased stiffness of lower limbs and additionally influences the decay of muscle strength. Old age is connected with frequent occurrence of pathological changes resulting in pain and the necessity of immobilization and taking analgesic, antidepressant medicaments and tranquilizers. That is why, due to the bad overall medical condition, as a consequence of inactivity, we observed gradual handicap of motor postural system functionality affecting the postural stability. Deteriorating postural stability contributes to increasing of the risk of falls and, as a consequence, injuries of the musculoskeletal system. According to Błaszczyk and Czerwosz [4] the problem of losing balance concerns around 14% of population at the age of 50–60. Within the next ten years the risk of falls increases about 22% and in the group of 80 year olds the problem concerns more than 33%. Falls often cause anxiety affecting further life activity of elderly people, including the body posture and its stability.

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Melton [17] and Francis [10] emphasize that women, unlike men, are more prone to falls. They fall thrice more often and undergo fractures twice more often.

The facts presented were the direct reason for undertaking the study the aim of which was an attempt to evaluate changes in the level of static equilibrium and the impact of visual information on the effectiveness of postural reactions of women in the eighth and ninth decade of life.

2. Materials and methods

Examinations involved senior female residents of L.A. Helc Nursing Home in Cracow, Poland. Selection of the research groups was purposive. The inclusion criteria:

- age 70–90,
- dominating right hand and leg (determined on the basis of "Waterloo Handedness Questionnaire – Revised" [21],
- physical fitness that allowed for walking without orthopaedic equipment (walking canes, crutches, walkers),
- ability to take independently a standing position on the stabilographic platform,
- psychical status that allowed for participation in the study and following verbal instructions,
- a written consent to participate in the study.

The study excluded the persons after brain incidents, with hemiplegia and those who took medicines that might have affected balance.

Taking into account the above criteria, the study included 36 seniors divided into 2 groups. Group I consisted of 23 women at the age of 71–80 ($\bar{x}$ = 77.80 ± 2.54), and group II – 13 women aged 81–87 ($\bar{x}$ = 83.80 ± 2.30). The average body height of women in group I was $\bar{x}$ = 160.83 ± 4.28 cm and body weight $\bar{x}$ = 68.82 ± 14.73 kg and in group II, respectively $\bar{x}$ = 160.47 ± 4.79 cm and $\bar{x}$ = 58.19 ± 9.14 kg.

Stabilographic measurements were performed using the two-platform posturograph CQ Stab 2P (CQ Elektronik System, Poland). The device recorded the position of the center of pressure of the vertical forces with 6 sensors, 3 in each disk of the platform. Sampling rate was 200 Hz for each sensor. The disks of the platform were properly leveled, and their surfaces positioned to form a single plane. The study consisted of two successive tests. The first attempt was the measurement of the body stability in a relaxed standing position, with eyes open. The second test was conducted in the position as above, excluding the visual control of body position in space. In order to stabilize the load of the lower limbs, the 30-second intervals were recorded within one-minute tests [6]. The stance width of the lower limbs and the feet angle were natural, unforced. A fixation point was placed 1 meter away opposite the subject. After entering the platform, the subject stood still trying to keep her eyes on the point of reference. The proper test was preceded by a 20-second "training", after which we proceeded to recording the measurements. During the test the researcher was behind the person tested. Before attempting with eyes closed, the researcher made sure that the testee was able to maintain a free standing position without the visual control. In order to preserve the integrity of the research process, all the tests were carried out in the morning, using the same measuring instruments operated by the authors. The measurements were carried out in the gym, in conditions which ensure the isolation of acoustic stimuli that could interfere with postural reflexes during the study. The women were wearing gymnastic costumes without shoes.

The following indicators of stability were analysed:

- SP – total path length, on both axes (2D), in mm,
- SPAP – statokinesiogram path length on the *OY* axis (the sagittal plane), in mm,
- SPML – statokinesiogram path length on the *OX* axis (the coronal plane), in mm,
- MA – the mean amplitude (radius) of the COP, in mm,
- MAAP – average COP displacement from 0 point on the Y axis, in mm,
- MAML – average COP displacement from 0 point on the X axis, in mm,
- MaxAP – antero-posterior stability range: maximum displacement of the COP from 0 point along the Y axis, in mm,
- MaxML – lateral stability range: maximum displacement of the COP from 0 point along the *X* axis, in mm,
- MV – mean velocity of COP movement, on both axes (X-Y), in mm/s,
- MVAP – mean velocity of COP movement on the OY axis, in mm/s,
- MVML – mean velocity of COP movement on the OX axis, in mm/s,
- SA – sway area of the COP point, in mm^2,
- MF – mean frequency of COP, in Hz,
- LWAP – number of COP displacements on the *Y* axis,
- LWML – number of COP displacements on the *X* axis,

– RQSP – Romberg quotient for the path length: SP-EO/SP-EC,
– RQSA – Romberg quotient for the size of the surface area: SA-EO/SA-EC,
– RQMV – Romberg quotient for the COP average velocity along the X and Y axis: MVEO/MV-EC.

The examinations were approved by the directors of the Nursing Home and the acceptance of the Bioethics Committee at the Medical Department of Rzeszów University was obtained. All the women received detailed information concerning the aim and methodology used in the study.

On the basis of the data gathered the following descriptive statistics parameters were calculated: arithmetical mean values ($\bar{x}$) and standard deviation (SD), medians (Me), quartile ranges (QR). The normalcy of distribution of particular characteristics was verified by means of the Shapiro–Wilk test. In order to compare the selected indicators of stability between the two groups of women we used the non-parametric Mann–Whitney U test. To assess the significance of differences between the results obtained in the test with eyes open and without visual control, the non-parametric Wilcoxon matched pairs test was used. Results were considered statistically significant if the probability level of the test was lower than the predetermined level $\alpha = 0.05$. In this paper, the Statistica StatSoft 10.0 was used to process the statistical test results.

3. Results

Table 1 contains the descriptive statistics of stability indicators recorded in the test with eyes open in each group and the level of statistical significance of differences between the values achieved by the subjects enrolled in the two categories. This data shows that with age most of the indicators have the rising tendency. This is particularly true for the stabilogram amplitude parameters, as well as the path length of the statokineziogram. Statistically significant differences between the groups were found in the statokineziogram path length and average velocity of the center of foot pressure (COP) in the ML direction. The indicators describing the maximum displacement of the center of gravity in both directions and the associated surface area delineated by the COP were subject to minor decrease with age or remained unchanged. High standard deviations for statokineziogram path length and size of the surface delineated by COP indicate the presence of big individual differences indicating the differentiation in the locomotive potential of the subjects (Table 1).

Analysis of the stability indicators recorded in the test with eyes closed did not show statistically significant differences between the two groups of women. However, the earlier described trend of deterioration with age of most of the analyzed indicators stays,

Table 1. Descriptive statistics for the stability indicators recorded in the test with eyes open and Mann–Whitney U test between the study groups of women

Indicator	Group I (*n* = 23)				Group II (*n* = 13)				U	*p*
	$\bar{x}$	SD	Me	RQ	$\bar{x}$	SD	Me	RQ		
SP-EO	330.48	121.44	303.00	128.00	396.08	132.64	398.00	96.00	98.00	0.093
SPAP-EO	252.43	116.65	198.00	106.00	297.08	134.12	270.00	102.00	108.50	0.182
SPML-EO	160.09	40.42	156.00	53.00	199.15	55.20	190.00	42.00	75.50	0.015*
MA-EO	3.26	1.68	2.70	3.20	2.88	0.85	2.70	1.10	144.00	0.869
MAAP-EO	2.67	1.39	2.40	2.50	2.11	0.60	2.00	0.70	128.00	0.489
MAML-EO	1.39	0.97	1.20	1.40	1.48	0.80	1.10	1.20	127.00	0.469
MaxAP-EO	9.76	5.14	8.10	7.30	8.88	3.81	8.20	3.40	145.00	0.895
MaxML-EO	5.36	4.65	3.80	5.00	4.78	2.01	4.70	1.80	135.00	0.645
MV-EO	11.02	4.05	10.10	4.30	13.21	4.42	13.30	3.20	98.00	0.093
MVAP-EO	8.42	3.88	6.60	3.60	9.90	4.47	9.00	3.40	109.00	0.188
MVML-EO	5.34	1.34	5.20	1.80	6.63	1.83	6.30	1.40	76.00	0.016*
SA-EO	325.48	233.58	255.00	315.00	325.54	134.43	317.00	166.00	130.00	0.531
MF-EO	0.63	0.26	0.61	0.36	0.77	0.30	0.64	0.55	111.00	0.211
LWAP-EO	21.69	13.00	19.00	21.00	31.15	13.03	29.00	18.00	91.00	0.056
LWML-EO	15.65	10.79	14.00	12.00	23.00	14.88	19.00	23.00	108.50	0.182

* statistically significant at $p < 0.05$.

particularly in those indicators describing the postural responses in the ML direction (Table 2).

Comparison of the results obtained in tests with eyes open and closed indicates that most indicators of stability deteriorate when visual control is off. Statistically significant changes under the influence of visual control shutdown in both groups refer to the same indicators (Tables 3, 4).

Table 5 shows values of the Romberg quotient for the path length of the moving COP point and the sizes of statokineziogram surface area. This factor was the ratio of the values obtained in tests with eyes open to the values obtained in tests without visual control. There were no significant intergroup differences in the values of the Romberg quotient, and its low values indicate impaired pro-

Table 2. Descriptive statistics for the stability indicators recorded in the test with eyes closed and Mann–Whitney U test between the study groups of women

Indicator	Group I (*n* = 23)				Group II (*n* = 13)				U	*p*
	$\bar{x}$	SD	Me	RQ	$\bar{x}$	SD	Me	RQ		
SP-EC	492.00	217.61	384.00	370.00	554.69	279.24	436.00	193.00	129.00	0.510
SPAP-EC	409.04	206.89	331.00	396.00	448.08	278.84	338.00	120.00	134.00	0.621
SPML-EC	196.13	63.62	179.00	110.00	239.00	83.27	214.00	117.00	105.50	0.152
MA-EC	4.10	1.91	3.80	2.20	3.62	1.60	3.30	1.50	124.50	0.420
MAAP-EC	3.55	1.76	3.40	2.10	3.00	1.07	2.90	1.20	120.50	0.348
MAML-EC	1.45	0.87	1.30	1.50	1.49	1.36	0.90	0.70	136.00	0.668
MaxAP-EC	14.89	8.52	12.40	8.50	12.31	4.61	12.00	5.50	137.00	0.693
MaxML-EC	5.83	3.69	4.20	4.00	4.95	3.07	3.90	3.40	118.50	0.315
MV-EC	16.40	7.25	12.80	12.30	18.50	9.30	14.50	6.40	128.00	0.489
MVAP-EC	13.63	6.90	11.00	13.20	14.95	9.29	11.30	4.00	132.00	0.576
MVML-EC	6.54	2.12	6.00	3.70	7.97	2.77	7.10	3.90	105.00	0.147
SA-EC	575.26	458.30	351.00	805.00	537.15	368.36	359.00	577.00	146.00	0.921
MF-EC	0.68	0.24	0.67	0.37	0.85	0.33	0.87	0.42	103.50	0.134
LWAP-EC	26.61	14.45	24.00	21.00	35.92	21.82	28.00	16.00	110.00	0.199
LWML-EC	24.57	13.12	25.00	19.00	31.69	17.55	26.00	24.00	118.50	0.315

Table 3. Comparison of the results obtained in the test with eyes open and eyes closed in women qualified for Group I (Wilcoxon matched pairs test)

Group I (*n* = 23)	EO		EC		Z	*p*
	$\bar{x}$	SD	$\bar{x}$	SD		
SP-EO & SP-EC	330.48	121.44	492.00	217.61	3.98	0.000*
SPAP-EO & SPAP-EC	252.43	116.65	409.04	206.89	3.98	0.000*
SPML-EO & SPML-EC	160.09	40.42	196.13	63.62	3.95	0.000*
MA-EO & MA-EC	3.26	1.68	4.10	1.91	2.71	0.007*
MAAP-EO & MAAP-EC	2.67	1.39	3.55	1.76	2.61	0.009*
MAML-EO & MAML-EC	1.39	0.97	1.45	0.87	0.90	0.369
MaxAP-EO & MaxAP-EC	9.76	5.14	14.89	8.52	3.07	0.002*
MaxML-EO & MaxML-EC	5.36	4.65	5.83	3.69	1.59	0.012*
MV-EO & MV-EC	11.02	4.05	16.40	7.25	3.98	0.000*
MVAP-EO & MVAP-EC	8.42	3.88	13.63	6.90	3.97	0.000*
MVML-EO & MVML-EC	5.34	1.34	6.54	2.12	3.98	0.000*
SA-EO & SA-EC	325.48	233.58	575.26	458.30	3.60	0.000*
MF-EO & MF-EC	0.63	0.26	0.68	0.24	1.12	0.260
LWAP-EO & LWAP-EC	21.69	13.00	26.61	14.45	1.63	0.104
LWML-EO & LWML-EC	15.65	10.79	24.57	13.12	2.89	0.004*

* statistically significant at $p < 0.05$.

Table 4. Comparison of the results obtained in the test with eyes open and eyes closed in women qualified for Group II (Wilcoxon matched pairs test)

Group II (n = 13)	EO		EC		Z	p
	$\bar{x}$	SD	$\bar{x}$	SD		
SP-EO & SP-EC	396.08	132.64	554.69	279.24	2.97	0.003*
SPAP-EO & SPAP-EC	297.08	134.12	448.08	278.84	3.11	0.002*
SPML-EO & SPML-EC	199.15	55.20	239.00	83.27	2.27	0.023*
MA-EO & MA-EC	2.88	0.85	3.62	1.60	1.76	0.077
MAAP-EO & MAAP-EC	2.11	0.60	3.00	1.07	2.94	0.003*
MAML-EO & MAML-EC	1.48	0.80	1.49	1.36	0.10	0.916
MaxAP-EO & MaxAP-EC	8.88	3.81	12.31	4.61	2.93	0.003*
MaxML-EO & MaxML-EC	4.78	2.01	4.95	3.07	0.31	0.753
MV-EO & MV-EC]	13.21	4.42	18.50	9.30	2.97	0.003*
MVAP-EO & MVAP-EC	9.90	4.47	14.95	9.29	3.11	0.002*
MVML-EO & MVML-EC	6.63	1.83	7.97	2.77	2.34	0.013*
SA-EO & SA-EC	325.54	134.43	537.15	368.36	2.34	0.019*
MF-EO & MF-EC	0.77	0.30	0.85	0.33	1.40	0.162
LWAP-EO & LWAP-EC	31.15	13.03	35.92	21.82	1.01	0.311
LWML-EO & LWML-EC	23.00	14.88	31.69	17.55	2.24	0.025*

* statistically significant at $p < 0.05$.

Table 5. Romberg quotient descriptive statistics and the Mann–Whitney U test between the study groups of women

Indicator	Group I (n = 23)				Group II (n = 13)				U	p
	$\bar{x}$	SD	Me	RQ	$\bar{x}$	SD	Me	RQ		
RQSP	0.73	0.20	0.73	0.30	0.77	0.17	0.75	0.18	129.00	0.510
RQSA	0.67	0.36	0.59	0.42	0.78	0.41	0.64	0.38	120.50	0.348

prioception mechanisms in the subjects' postural control (Table 5).

4. Discussion

Aging is a natural process of the body in the human biological existence, which includes both anatomical structures, as well as their general interrelated functions [25]. Due to the increasing proportion of older people, the issue of the processes associated with aging is becoming increasingly important. Much of scientific research is devoted to the involutional changes, their nature and variability, including the analysis of the factors causing postural instability, especially in the context of the risk of falls. Involutional changes within the tissue structures of the musculoskeletal system, such as a weakening capsule-ligament system and muscle strength, consequently result in the deterioration of the posture. Vertical positioning of the body axis with regard to a small surface of support characterizing human bipedal posture, requires constant and active regulation of posture through the system of balance control to ensure adequate stability [4], [7], [19]. Balance control is based on the mechanisms formed during the phylogeny and ontogeny that can take diverse forms depending on the nature of the motor task or destabilizing factor. According to Golema [11], human body posture control in the standing position is characterized by a greater stability in the frontal plane. The center of gravity of the body oscillates between the points of the body stance. On the other hand, in the sagittal plane feet form a bilateral lever with the axis of rotation in the ankles, and the body is subjected to the two torques, which are not always balanced. Increased postural sway in standing position may grow as a result of emphasized by Błaszczyk and Czerwosz [4] progressive failure of the neuromuscular system, resulting in the elderly in the increase of the activity thresholds of sensory systems, as well as increase of uncontrolled muscle activation. Degradation of sensory systems (especially the somatosensory one in the vicinity of foot and ankle) links with the involutionary changes in muscles, forcing older people to rely on other sources of sensory information (visual and vestibular), as well as motor systems, in maintaining the balance [8], [23]. This condition leads to an increase in sway and a bigger role of sight in the process of visual stability control [8]. The role of visual information is ambiguous, as in the studies authors suggest its greater importance in the younger age groups [3]. The results of this study indicate that the lack of visual control significantly impairs the stability of the women in the eighth and ninth decades of life.

A characteristic postural feature of people in geriatric age is much deeper thoracic kyphosis and a clear forward inclination of the trunk [1], [13]. The consequence of this is taken by the elderly strategy of "forward lean", which may limit the scope of sway in the anterior-posterior direction and develop in the lateral direction [6]. Kim et al. [14] observed a clear deterioration of the indicators of stability (an increase in the COP velocity and the total reaction force) in the elderly, particularly in the ML direction with a clear dimorphic distinction of this trend. In turn, Bączkowicz et al. [2] and Ostrowska et al. [20] found that changes in the inclination of the trunk shift the center of gravity forward, which in combination with the weakening of proprioception causes difficulty in sway correction and thereby affects the severity of body instability in the sagittal plane and increases the risk of falls.

The analysis of the obtained results indicates that the loss of postural control as a result of progressive involutional changes in the aging process is characterized by a more pronounced increase in the values of body stability in the frontal plane. On this basis it can be assumed that with the progressive aging deepens the load-relief strategy of the lower limbs. Our results confirm previous observations made by Błaszczyk et al. [6], who argue that the elderly alternatively load and relieve the lower limbs (deepening at the same time mass distribution asymmetry between the legs), paving the way for one of them to stride in response to the possible loss of balance.

Considering the observations made by Winter [24] that the COP frontal plane displacement in standing on both feet position is controlled by a load-relief mechanism regulated by the hip adductor and abductor, the increase of the body stability values in the frontal plane can be explained by the gradual decline in the efficiency of these muscle groups. Drzał-Grabiec et al. [9] claim that the structural changes in the feet have a major influence on the deterioration of balance in the medio-lateral direction in females aged over 65. The loss of stability in this plane is described by the authors on the basis of both the classic measure of stability [6], [5], [24] and the visco-elastic parameters [15]. Kuczyński [15] sees the reasons for this phenomenon in everyday life activities influencing the stability of the elderly that affect the stability in the sagittal plane, leaving the front plane without proper stimulation. Lowering the maximum range of sway in the anterior-posterior direction suggests a preference for the use of the hip strategy in the subjects [24] and the forward lean strategies, minimizing the risk of falling back, due to escalating with age decay in the back stability limit [5]. This leads to simplification and reduction of the number of possible postural strategies. Łapszo et al. [16] found the lateralization in leg strength and a strong correlation between the total strength of legs and the index of balance control ability in older people. These findings suggest that by improving the strength, seniors can improve the balance control.

The data and the analysis of literature indicate the need of using appropriate solutions in the elderly rehabilitation programmes, taking into account the exercises aimed at developing new or enhancing the decaying postural control mechanisms. An interesting proposal may be the sensorimotor exercises suggested by Mętel [18], which are based on the work in closed kinematic chains and include the following steps: static (exercises aiming at concentration on maintaining postural stability without additional movements of the limbs), dynamic (reducing the support plane by changing the position of the feet, exercises on an unstable surface, exercises excluding the visual control of body orientation in space, exercises with extra load on the vestibular system, e.g., through the turns of the head) and functional (exercises aiming at concentration on maintaining balance, combined with functional movements of the upper limbs, e.g., moving the gym rod). An alternative for that may be Tai Chi exercises, which improve the flexibility and muscle strength, as well as concentration by mindfully directing ones attention to the course and coordination. The positive effects of these exercises resulting in better balance among seniors were observed by different authors [12]. The actions aimed at delaying kinesiotherapeutic involutional changes should take into account the physical exercises strengthening postural muscles, as well as the general fitness exercises as part of the so-called active recreation. Łapszo et al. [16] suggested that the forms of motor activity which require the high speed of movements or high strength of muscles should be treated as "motor medicine" which protects older people from balance control impairment. The presented strength approach to balance control ability impairment can be treated as a theoretical basis for different exercise and intervention programs directed towards improving the balance control ability by developing leg muscles strength. The recommendations presented in the work have a diagnostic and therapeutic value. They should help improve the balance and functional capacity of people in geriatric age.

5. Conclusions

Loss of postural control as a result of progressive involutional changes in the aging process is characterized by the intensity of the body instability in the frontal plane. On this basis, it can be argued that with the advancement of the aging process in order to avoid the risk of losing balance the load-relief strategy is being alternatively developed in lower limbs in free standing position. Therefore, it seems reasonable to emphasize the forms of exercise stimulating the balance control mechanisms implemented by the abductor and adductor muscles of the hip joint.

Sight plays an important role in the control of postural stability in patients in the eighth and ninth decades of life.

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