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POSTURAL BALANCE IN SUBJECTS OVER THE AGE OF 50

RÓWNOWAGA POSTURALNA U OSÓB POWYŻEJ 50. ROKU ŻYCIA

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Summary

Background. Postural stability is widely recognized as one of the main determinants of the functional efficiency of a person's capability. It changes during ontogenesis and undergoes deterioration with age. Posturographic techniques enable the analysis of body sway and are used to obtain objective and quantitative data about postural equilibrium. Posturographic test results carried out in healthy subjects allow the analysis of the postural stability results obtained in institutions that do not have the possibility of testing healthy people as controls.

Materials and methods. This study was conducted among 126 subjects aged between 50 and 97, each of which devoid of neurological, motor and metabolic diseases.

Postural balance was evaluated using a static force platform (PROMED – Legionowo) which measures degree of sway, total path length, path length in the antero-posterior plane, path length in medio-lateral plane and the "coordination" parameter. Each subject was tested in three different test conditions: eyes open, eyes closed and biofeedback. The Kruskall – Wallis tests were used to investigate the effect of age on values from force platform balance tests.

Results. An age related increase in sway area, total path length, path length in antero-posterior plane, path length in medio-lateral plane was observed in the eyes open test, eyes closed test and in the biofeedback test. The "Coordination" parameter from the biofeedback test decreased with age, achieving the lowest value at ages 60 and above. Kruskall – Wallis test indicated a significant effect of age on posturographic parameters.

Conclusions. The results of the study provide normative values for the force platform balance tests at ages 50 and above. Significantly higher values in sway area, total path length, path length in the antero-posterior plane, path length in medio-lateral plane and the worsening of visual – motor coordination in subjects of ages 60 years and above were observed. It suggests that there is a deterioration of the postural control mechanisms during the aging process. Therefore, force platform balance tests are relevant to assess the systematic weakening of the postural control mechanism from age 60 onwards.

Streszczenie

Wstęp. Stabilność posturalną powszechnie uznaje się za jeden z głównych wyznaczników sprawności funkcjonalnej człowieka. Zmienia się ona w czasie ontogenezy, ulegając pogorszeniu w okresie starzenia. Technika posturograficzna daje możliwość przeprowadzenia analizy wychwiań ciała człowieka i jest stosowana w celu otrzymania obiektywnych i ilościowych danych o równowadze posturalnej. Wyniki testów posturograficznych wykonanych u zdrowych osób umożliwiają analizę wyników badań stabilności posturalnej wykonywanych w instytucjach, które nie mają możliwości przebadania osób zdrowych jako grup kontrolnych.

M a t e r i a ł i m e t o d y . Badaniem objęto 126 zdrowych osób bez stwierdzonych zaburzeń neurologicznych i motorycznych w wieku od 50 do 97 lat.

Stabilność posturalna oceniana była przy użyciu zestawu posturograficznego (PROMED – Legionowo), który wyznacza wielkość pola statokinezjogramu, długość statokinezjogramów, amplitudy jednokierunkowych wychyleń w płaszczyźnie strzałkowej i płaszczyźnie czołowej oraz parametru „koordynacja”. U każdej osoby przeprowadzono standardowy zestaw testów składający się z badania przy oczach otwartych, przy oczach zamkniętych oraz badania kordynacji wzrokowo-ruchowej w teście sprzężenia zwrotnego. Przeprowadzony został test ANOVA Kruskala-Wallisa mający na celu określenie wpływu wieku na wartości parametrów posturograficznych.

W y n i k i . W badaniu przy oczach otwartych, zamkniętych i w sprzężeniu zwrotnym zaobserwowano wzrost wartości pola statokinezjogramu, długości statokinezjogramu, a także długość stabilogramów w płaszczyźnie czołowej i płaszczyźnie strzałkowej wraz z wiekiem. Wyznaczony w teście sprzężenia zwrotnego parametr kordynacja zmniejszał się wraz z wiekiem i osiągnął najniższą wartość w grupie osób najstarszych. Test Kruskala-Wallisa wskazał na istotny wpływ wieku na wartości parametrów posturograficznych.

W n i o s k i . Otrzymane wyniki prezentują wartości prawidłowe dla testów posturograficznych prowadzonych u osób powyżej 50. roku życia. Zaobserwowany systematyczny i znaczny wzrost wartości parametrów pola statokinezjogramu, długości statokinezjogramu, długości wychyleń w płaszczyźnie czołowej i strzałkowej oraz pogorszenie koordynacji wzrokowo-ruchowej u osób powyżej 60. roku życia podczas stania swobodnego w próbie z oczami zamkniętymi, otwartymi i koordynacji wzrokowo-ruchowej wskazuje na pogorszenie funkcjonowania mechanizmów kontroli posturalnej. Badanie posturograficzne jest więc badaniem właściwym dla oceny postępującego od szóstej dekady życia osłabienia mechanizmów kontroli posturalnej.

Key words: force platform balance test; postural balance; aging
Słowa kluczowe: posturografia; równowaga posturalna; starzenie

INTRODUCTION

Anatomo-functional connections between both multiple sensory systems and motor system of a human being are the basis of postural equilibrium [1, 2 and 3]. Sensory systems, (visual, vestibular, proprioceptive and exterioceptive) are known to receive information about movement, the geometry of the body and its position in relation to the force of gravity and surroundings.

Integrated sensory signals originating from an adequate population of receptors are transmitted to the centers of analysis, which are located at different levels of the central nervous system: the spinal cord, basal ganglia, cerebellum and cerebral cortex. The central analysis of sensory information determines the type of motor response to correct imbalance.

Postural balance is widely recognized as one of the main determinants of functional efficiency in human beings. It changes during ontogenesis and undergoes deterioration with age. Involution affects the sensory systems, functionality of the central and peripheral nervous system and musculoskeletal system. As a result, the imbalance correction reactions are delayed, and less accurate [4]. Age related decline in the interaction between sensory and motor systems are known to cause physical disability. Therefore, many elderly people have difficulty maintaining balance and the risk of falls increases. Since it is thought that subjects show more static instability with age, we investigated the connection between deterioration of postural stability and age.

Posturography is a widely used method of evaluation of postural balance. It uses the analysis of human body sway in both the sagittal and frontal plane, which allows us to obtain objective information about postural balance. Despite the fact that there being many studies focused on the analysis of postural stability, there are few publications that show the reference values of posturographic tests within different age groups. Reliable information about the reference values of posturographic tests administered to patients without neurological and motor disorders at different ages seems to be essential for planning and execution of experiments in institutions that do not have the possibility to examine healthy subjects. Therefore, the aim of the paper is to present the results of tests assessing postural stability in subjects at ages 50 and above.

SUBJECTS AND METHODS

Subjects

The study comprised of 126 healthy, middle–aged to elderly people that were divided into four age groups: 50-59, 60-69, 70-79 and 80 years old and above (Table I).

Table I. *Group characteristics*
Tabela I. *Charakterystyka grup wiekowych*

Age group Grupa wiekowa	Age Wiek	N	Height Wzrost (cm)		Weight Ciężar ciała (kg)		BMI	
			$X_{śr}$	S_x	$X_{śr}$	S_x	$X_{śr}$	S_x
I	50-59	22	165.8	8.6	70.6	11.7	25.7	4.6
II	60-69	26	164.2	7.4	72.9	17.8	25.7	5.1
III	70-79	53	158.8	8.8	67.6	15.1	25.5	4.0
IV	80 ≤	25	161.1	9.9	64.5	12.7	25.0	4.4

The participants were healthy with no previous lower extremity trauma and no history of neurological, muscular or metabolic diseases. In addition, they did not drink alcohol and did not take any drugs that would have disturbed loco-motor functions. All participants showed an average physical fitness in relation to age. The study was approved by the *Ethics Commission of the Ludwik Rydygier Collegium Medicum* in Bydgoszcz.

Methods

A balance platform (PROMED, Legionowo, Poland) was used for the assessment of static postural control, which consisted of four tensometric sensors measuring body sway in eyes open tests (examination 1), eyes closed tests (examination 2) and biofeedback tests (examination 3). A posturographic system computed displacements of the center of foot pressure (COFP) and calculated parameters as follows: sway area (mm^2), total path length (mm), sway length in antero – posterior plane (mm), sway length in medio – lateral plane (mm) and coordination parameters (%).

Sway area during standing in an upright position in eyes open and closed tests were used to calculate the Romberg Quotient, described by the formula:

$$QR = 100 \cdot \frac{S_{ec}}{S_{eo}}$$

Where: S_{ec} – sway area in closed eyes test,
S_{eo} – sway area in opened eyes test.

The Romberg ratio was calculated to determine the participation of visual information in the postural control in the age groups.

In the biofeedback test at eye level, and at a distance of 2 meters, a monitor was placed. The subject was asked to keep the cursor indicating the current position of the COFP in the square located in the center of the display.

Test circumstances (e.g. noise, illumination) were in accordance with the recommendations for posturographic testing.

All tests were performed in the morning with the subjects standing without shoes on the platform (the angle between feet being approximately 30° and the distance between the heels being 2 cm). The subject was asked to keep an upright posture with his/her arms along his/her trunk.

STATISTICAL ANALYSIS

All analysis was conducted using STATISTICA 8.0 PL statistical software (Statsoft). Quantitative variables were described with means and standard deviation (SD). Analyzed variables were not distributed; therefore, non-parametric statistics were used for statistical analysis. The Kruskal Wallis test was employed to compare the means of different values obtained in posturographic tests in all age groups . The Pearson correlation coefficient was employed when comparing the values obtained in examinations 1 and 2, and also in examinations 1 and 3. The level of significance of for all tests was set at $p<0.05$.

RESULTS

The results obtained from the Kruskall-Wallis test indicate a statistically significant effect of age on posturographic parameters (Table II).

Table II. *The influence of age on posturographic parameter variability - variance analysis ($p < 0.05$)*
Tabela II. *Wpływ wieku na wartość parametrów posturograficznych – analiza wariancji ($p < 0,05$)*

Parameter Parametr	Eyes open Oczy otwarte		Eyes closed Oczy zamknięte		Visual – motor coordination Koordynacja wzrokowo-ruchowa	
	$F_{3,51}$	p-value	$F_{3,51}$	p-value	$F_{3,51}$	p-value
Sway area Pole powierzchni statokinezjogramu	3.65	0.0017*	7.09	<0.0001*	3.01	0.00150*
Total path length Długość całkowita	8.05	<0.0001*	9.58	<0.0001*	5.44	<0.0001*
Length in AP plane Długość wychyleń w płaszczyźnie strzałkowej	4.71	<0.0001*	5.62	<0.0001*	4.82	<0.0001*
Length in ML plane Długość wychyleń w płaszczyźnie czołowej	11.48	<0.0001*	14.51	<0.0001*	5.76	<0.0001*
Coordination Koordynacja					17.96	<0.0001*

The lowest readings in the age range 50 to 59 years were observed in the following areas: eyes open test sway area (Table III), total length (Table IV), length in the frontal plane (Table V) and length in the sagittal (Table VI), increasing in the higher age groups.

Table III. *Sway area*
Tabela III. *Wielkości pola statokinezjogramu*

Age group Grupa wiekowa	Sway area (cm^2) Pole statokinezjogramu (cm^2)					
	Eyes open Oczy otwarte		Eyes closed Oczy zamknięte		Visual – motor coordination Koordynacja wzrokowo - ruchowa	
	$X_{śr}$	S_x	$X_{śr}$	S_x	$X_{śr}$	S_x
I	537.18	1301.89	865.55	2216.72	428.27	297.42
II	559.35	366.97	995.89	859.95	1502.62	1119.31
III	579.66	496.75	1177.11	1522.38	1497.02	1618.83
IV	771.04	426.03	1662.56	1440.05	1631.88	1093.91

Table IV. *Total path length*
Tabela IV. *Długość całkowita wychyleń*

Age group Grupa wiekowa	Total path length (cm) Długość statokinezjogramu (cm)					
	Eyes open Oczy otwarte		Eyes closed Oczy zamknięte		Visual – motor coordination Koordynacja wzrokowo - ruchowa	
	$X_{śr}$	S_x	$X_{śr}$	S_x	$X_{śr}$	S_x
I	285.36	293.79	361.36	350.90	337.50	111.78
II	354.02	158.63	548.27	322.57	584.39	223.93
III	367.38	171.16	553.60	347.81	561.34	300.81
IV	441.24	170.91	646.96	331.24	546.24	202.17

Table V. *Sway length in medio-lateral plane*
TabelaV. *Długość wychyleń w płaszczyźnie czołowej*

Age group Grupa wiekowa	Sway length in medio-lateral plane (cm) Długość wychyleń w płaszczyźnie czołowej (cm)					
	Eyes opened Oczy otwarte		Eyes closed Oczy zamknięte		Visual-motor coordination Koordynacja wzrokowo-ruchowa	
	$X_{śr}$	S_x	$X_{śr}$	S_x	$X_{śr}$	S_x
I	156.36	104.74	201.50	171.37	221.45	85.57
II	187.42	82.43	272.89	143.11	359.73	157.68
III	184.53	85.64	247.23	156.08	361.15	269.98
IV	214.16	98.40	305.72	164.44	319.80	125.91

A similar trend was observed in the closed eye study. The mean values were higher than those obtained in the study with eyes open. Therefore, it indicates that visual input is an important part of the balance system in a group of subjects. The calculated values of the Romberg's coefficients confirm the significant impact of visual information on the process of maintaining balance in a standing position with people from groups 2, 3 and 4 (Table VII). In the feedback test, weaker visual – motor coordination was observed in subjects above 60 years of age (Table VIII). In all posturographic tests (open eyes, closed eyes and biofeedback test) large standard deviations were observed.

Table VI. *Sway length in antero-posterior plane*
Tabela VI. *Długość wychyleń w płaszczyźnie strzałkowej*

Age group Grupa wiekowa	Sway length in antero-posterior plane (cm) Długość wychyleń w płaszczyźnie strzałkowej (cm)					
	Eyes opened Oczy otwarte		Eyes closed Oczy zamknięte		Visual-motor coordination Koordynacja wzrokowo-ruchowa	
	$X_{śr}$	S_x	$X_{śr}$	S_x	$X_{śr}$	S_x
I	197.77	256.04	252.59	272.41	202.59	74.25
II	255.38	140.14	410.19	284.18	369.19	181.72
III	272.30	146.05	439.83	293.73	226.91	137.44
IV	335.40	134.65	500.68	274.99	365.64	159.67

Table VII. *Romberg coefficients*
Tabela VII. *Wartości współczynnika Romberga*

	Romberg coefficient Współczynnik Romberga	
Age group Grupa wiekowa	$X_{śr}$	S_x
I	154.58	57.35
II	189.72	118.53
III	203.20	141.15
IV	210.66	131.73

Table VIII. *Coordination in different age groups*
Tabela VIII. *Wartości parametru koordynacja w poszczególnych grupach wiekowych*

	Coordination (%) Koordynacja (%)	
Age group Grupa wiekowa	$X_{śr}$	S_x
I	61.40	21.58
II	32.65	21.38
III	28.03	15.95
IV	17.96	12.98

In both open and closed eyes tests, the amplitude of antero-posterior postural sway was greater when compared to the medio-lateral sway in all age groups. This confirms the use of the ankle strategy during quiet standing with eyes closed and open as well. Postural sway increased with age in both planes during both aforementioned tests (Table V, VI). The elimination of visual information resulted in the increase in amplitude of postural sway in both frontal and sagittal plane. In contrast to eyes open and closed tests, the amplitude of antero-posterior postural sway was no greater in the visual-motor coordination test, since the body sway in this examination is aimed at adjustment of COFP position. Therefore, increased motor activity in the subjects was associated with larger oscillations in the sagittal and frontal plane.

Spearman correlation coefficients indicate very high, high or moderate correlation of posturographic parameters between the open and closed eyes examinations in all age groups. The correlation between the open eyes test and the feedback test is high (group I - sway area), moderate (group I - total path length, sway length in ML plane, sway length in AP plane; group III, IV - sway length in AP plane) or absent. The correlation between the closed eyes test and the feedback test is high (group I - sway area), moderate (group I - total path length, sway length in ML plane, sway length in AP plane; group III, IV - sway length in AP plane) or absent (Table IX).

Table IX. *Spearman correlation coefficients between examinations: eyes opened (1), eyes closed (2) and visual - motor coordination (3)*

Tabela IX. *Wartości współczynników korelacji pomiędzy poszczególnymi próbami: oczy otwarte (1), oczy zamknięte (2) i koordynacja wzrokowo-ruchowa (3) przy p<0,05*

Age group Grupa wiekowa	Sway area Pole statokinezjogramu			Total path length Długość stabilogramu			Sway length in medio-lateral plane Długość wychyleń w płaszczyźnie czołowej			Sway length in antero-posterior plane Długość wychyleń w płaszczyźnie strzałkowej		
	1-2	1-3	2-3	1-2	1-3	2-3	1-2	1-3	2-3	1-2	1-3	2-3
I	0.99 ***	0.75 **	0.76 **	0.99 ***	0.55 *	0.62 *	0.96 ***	0.59 *	0.56 *	0.99 ***	0.45 *	0.53 *
II	0.55 *	0.08	0.01	0.77 **	0.04	0.20	0.70 **	-0.15	0.01	0.82 **	0.21	0.32
III	0.66 *	0.13	0.08	0.80 **	0.27	0.19	0.84 **	0.15	0.10	0.74 **	0.50 *	0.46 *
IV	0.62 *	-0.05	-0.02	0.87 **	0.31	0.30	0.87 **	0.24	0.09	0.84 **	0.49 *	0.53 *

***** Moderate correlation/ Korelacja umiarkowana

****** High correlation/ Wysoka korelacja

******* Very high correlation/ Bardzo wysoka korelacja

DISCUSSION

In our study, we analyzed the importance of sensory input as follows: visual, vestibular and somatosensory in the maintenance of balance in different age groups. A large group of subjects with a wide range of ages (50 to 97 years of age) were examined in order to evaluate postural stability depending on the degree of development, and the efficiency of systems involved in this process. It is imported to note that aging is individual and proceeds at different rates causing high variability among groups, which translates into large standard deviations of posturographic parameters.

Since one of the factors affecting postural stability in all stages of ontogenesis is the weight of the body, it was important to carry out posturographic tests in the people with normal or slightly increased BMI. Previous research indicates the influence of a high BMI (> 35) on reduction [5] or increase in postural sway [6, 7].

Postural stability deteriorates from the fifth decade of life [8]. Older people are not able to estimate the optimal position (COFP) due to involutional changes in both sensory systems and analyzing systems at different levels in the central nervous system. As previously reported, we observed the deterioration of postural control in patients aged 60 and above. Greater postural instability in women over 60 years of age compared to women between 50 and 59 occurred, especially after the elimination of visual input [9]. Hay et al. reported similar results in the study of people aged 70 and above, which turned out to be less stable after the elimination of visual information, compared to subjects aged 25 [10].

Our findings are also in accordance with the literature regarding significant deterioration in postural control in subjects aged 75 - 80 and above [11].

Other authors reported the age-dependent changes in the sensory systems: visual, vestibular and somatosensory in the elderly [12, 13]. The influence of vision on equilibrium seems to be controversial. Some authors reported a greater postural sway in both planes after closing of the eyes [14, 15]. In contrast, other researchers observed little effect or even its absence in postural sway [16]. Different opinions can be explained by individual differences in compensatory strategies using sensory inputs [17]. Postural control uses mainly proprioceptive signals in a static position as vestibular information is used to a lesser extent, and then the interaction of available afferent signals and compensatory mechanisms occur. Greater amplitudes of postural sway in both antero-posterior and medio-lateral planes indicate the deterioration of sensory systems or compensatory reactions. Era et al. reported similar results indicating deterioration in the efficiency of postural control during open and closed eyes tests [18, 19]. Increased postural sway in open eye tests in subjects over 60 years of age compared to younger subjects may be caused by involutionary changes including degeneration of the retina, progressive optical aberration and reduced reactivity of pupils [20].

This deterioration of visual acuity and contrast vision causes problems with the perception of contour and depth of image, which is important in postural control. It was reported that retinas in subjects aged 60-70 receive only one third of light compared to subjects aged 20, thereby visual information facilitating spatial orientation is decreased. [10].

In the elderly, the elimination of visual input significantly affects decreased postural stability in a standing position, whereby Romberg coefficients are higher. It is thought that for a population of healthy adults, the reference values are following: 125 ± 59% [21]. Our results show that a postural sway of subjects aged above 60 sway is increased.

Very high, high or moderate correlation coefficients between open and closed eyes tests in all age groups may indicate certain central mechanisms compensating for eliminated visual information in static balance tests. High or moderate correlation coefficients between both open eyes tests - feedback tests and closed eyes tests - feedback tests in the group of subjects aged 50 – 60 may also suggest the presence of the central compensatory mechanisms responsible for the efficiency of postural control system. Therefore, the absence of correlation between both open eyes tests - feedback tests and closed eyes tests - feedback tests (sway area, total path length, sway length in ML plane) in groups as follow: II, III and IV may result from inefficiency of central compensatory mechanisms in subjects aged above 60. It should be mentioned that in case of sway length in AP plane, moderate correlation between both open eyes tests - feedback tests and closed eyes tests - feedback tests was observed in group III and group IV as well. It may suggest that mechanisms responsible for the postural control in AP saggital plane are efficient in the elderly.

It is observed that postural sway in the elderly is greater in a standing position even with this increased visual information. The feedback test is an example of a balance test using the dominance of the visual system over other components of the balance system causing specific motor activity. Visual - motor coordination deteriorates with age due to both the aging of the eye and disorders in the coordination mechanisms as a result of involutional changes at different levels of the central nervous system. Teasdale et al. suggested that such additional sensory information in feedback tests results in the inability of the elderly to rapidly use visual information in order to stabilize the body in an upright position. Inability to use increased information is interpreted as reflecting a deficit in the central integrative mechanisms responsible for the reorganization of the postural system [22]. Changes in the vestibular organ with age include all of its elements. Degeneration and fragmentation of otoliths cause reduced excitability of hair cells. It was reported that the vestibular system in subjects aged 70 have got approximately 40% hair cells fewer in the otholit organs and the semicircular canals [23, 24]. From about 60 years of age there is a decrease of nerve fibres in the vestibular nerve, resulting in slowing of neuronal conductivity [25]. Deterioration of cutaneous vibratory sensation was also reported [26, 27]. Changes in the morphology of the joints with age may in turn be a cause or effect of the deterioration of the functioning of joint mechanoreceptors [28].

Deterioration of postural control in the elderly is the result of involutional changes not only in the sensory systems, but also in the different levels of the central nervous system.

Abnormality of the cerebral cortex causes disruption of sensory information and prolongation of sensory information analysis, resulting in abnormal postural reaction due to incorrect sensory – motor integration [29, 30]. Therefore, it is considered that the elderly sway more when their position is controlled by higher levels of sensory integration mechanisms, for example when correction of position takes place after a slow and small disturbance [31]. Woollacott et al. suggested that the reorganization of the postural system may be caused by slowdown or damage to the central integrative mechanisms [32]. Impaired postural control in the elderly reflects age - dependent deficits and specific pathologies that are often subclinical.

Increased body sway in the upright position in the elderly is caused also by the involution within the effector component of the postural reflex, namely the musculo-skeletal system. Reduction or disappearance of muscle fibers, decreased amount of motor neurons and muscle weakness, for example in the calf muscles, was reported [33].

It is also known that many chronic diseases, such as otologic (e.g., damage to the peripheral vestibular organ), neurological (e.g. damage of central vestibular organ), diabetes or hypertension can significantly impair postural balance in the elderly.

In summary, the aging process is associated with a well - documented decrease in the efficiency and integrity of the many physiological systems involved in the postural control. Age of the subjects affects the sensory system qualities that are involved in the maintenance of postural balance, higher integrative mechanisms and the efficiency of the musculo-skeletal system. As a result, postural sway increases with age in the eyes open test, eyes closed test and the feedback test.

CONCLUSIONS

Systematic and significant increases in sway area, total length and the length of excursions in antero-posterior and medio-lateral plane were observed in people aged above 60 during standing in the open and closed eyes tests and coordination tests. Therefore, posturography is appropriate for the evaluation of the progressive weakening of postural control mechanisms from the sixth decade of life. To assess the efficiency of postural control there are important parameters: sway area, total length, length of sway in the sagittal and length of sway in the frontal plane. Conducted research can be used as the comparative material in the analysis of the results of people suffering from various ailments.

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