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AGE, BMI, PSYCHOMOTOR AND FUNCTIONAL FITNESS AS DETERMINANTS OF STATIC AND DYNAMIC BALANCE IN ELDERLY MEN WITH OSTEOPENIA OR OSTEOPOROSIS

Key words: fitness, balance, elderly.

ABSTRACT

The aim of the study was to determine the significance of selected factors of psychomotor fitness and somatic characteristics for static and dynamic balance in elderly men with identified osteopenia or osteoporosis. The study covered 53 men aged 60-83. The BMI index was calculated. To study psychomotor fitness, reaction time and correctives of decision were measured with “Decision Test” (Vienna Test System). Functional fitness was measured on the basis of selected tests from “The Senior Fitness Test”: chair stand, 8 foot up-and-go, and 2-minute step tests. Static and dynamic balance was measured using a computer posturographic system.

The level of dynamic balance in men with identified osteoporosis or osteopenia is related to the proper reaction (time and accuracy) to various types of stimuli. Whereas static balance is related mainly to age and the BMI, direct impact of other variables, including muscular strength, on static and dynamic balance is disputable.

INTRODUCTION

Bone fractures which are a consequence of the lowered bone mineral density (BMD) are an important health problem, in particular, among the elderly [13]. The main cause of fractures, including dangerous femoral neck fractures, in people with osteoporosis are falls [21]. The risk of falls increases as the efficiency of functioning of the body balance system lowers with age [20]. In the elderly a deteriorated capability of controlling the postural system is observed [14]. Particular significance is assigned here to the decreasing efficiency of the sight organ [19], the vestibular organ [26] and weaker sensory integration [25].

A significant influence on body balance can also be exerted by muscular strength which deteriorates with age [4, 10], large body mass and fat mass [9]. Old age is also related to general muscle atrophy and difficulties with producing appropriate muscular tone that disturbs correct reactions [7, 12]. In a study carried out on a group of 97 women aged 65-75 years it was noted that the strength of knee joint extensors significantly determined both static and dynamic balance. It was also found that muscular strength determined the level of body balance to a greater extent that the subjects’ age [4].

Body mass (fat mass, lean body mass, muscular mass) is not only related to body balance, but also to the BMD. Ballard et al. [1] found a statistically significant correlation between the lean body mass and the BMD of the radial bone (r = 0.30), spine (r = 0.38) and femoral neck (r = 0.42) in men aged over 65 years. Positive relations between body composition (including both fat mass and lean body mass) and the BMD were also observed in studies carried out on a group of women aged over 75 [8]. The analysis of variance in these studies indicated

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a greater significance of fat mass than lean body mass for the BMD.

Among many factors which determine body balance the significance of psychomotor fitness has been emphasized in recent years, in particular, the factor of reaction time. The studies of Lajoie [15] in which static and dynamic body balance and treaction times of 80 elderly fallers and non-fallers were compared showed significantly faster reaction times in non-fallers than fallers. Moreover, on the basis of a multiple regression analysis it was found that reaction time was indeed the best predictor of the fall status. Richerson et al. [23] studied the effect of age on movement detection reaction time in young adults, neurologically intact elderly adults, and elders with peripheral (diabetic) neuropathy. They observed that the higher prevalence of falls in elderly and elderly diabetics might be due to slowing reaction times compounded by larger amounts of imparted energy needed for detection of slipping events. Thus, beside muscular strength, the properties of the sight organ and the vestibular organ, appropriate reaction time to various disturbing factors, i.e. proper motor co-ordination, are also significant for body balance.

In a study of Canadian men and women aged over 60 it was found that more active people featured a shorter reaction time [6]. Thus, in order to prevent falls the shortening of reaction time to various stimuli should be striven at. At the same time it should be borne in mind that the appropriate reaction time is not the only thing that determines the correctness of motor action. The authors of a review [29] devoted to traumatological problems in geriatrics emphasise, among other things, the significance of the appropriate level of widely defined psychomotorics in prevention of falls in the elderly.

Sakari-Rantala et al. [24] investigated mobility in elderly men and women (75 and 80-years-old) and suggested that sensory-motor functions have individual importance for mobility and that they do not compensate each other. Moreover, it was observed that a significant number of falls in the elderly took place during standing up from a chair or bed, i.e. when the body changes its position in the space [27]. In this case the level of functional fitness and the proper functioning of the whole sensory-motor system and the sight organ become particularly significant. The appropriate use of processing information by the nervous system and an integrated action of organs (including antagonist muscles) determine the success and safe course of the getting-up action. Wong et al. [28] indicated an influence of co-ordination exercise on body balance. They found that elderly people who regularly practiced Tai-Chi (co-ordination exercise) displayed better body balance in more difficult circumstances then those who did not. In simple posturopgraphic tests such differentiation of results was not noted. The aim of the study was to determine the significance of selected factors of psychomotor fitness and somatic characteristics for static and dynamic balance in elderly men at particular risk of effects of falls, i.e. with identified osteopenia or osteoporosis.

We suspect that different factors affect static and dynamic balance. Static balance is mainly dependent on somatic characteristics, whereas dynamic balance is related to psychomotor fitness.

METHODS

Participants

The study covered 53 men aged 60-83 ($\bar{x} = 69 \pm 5.8$ years) with identified osteopenia or osteoporosis, i.e. T –score -1.0 and lower. All subjects were predominantly healthy, and those who had a history of significant cardiovascular, pulmonary, metabolic, or musculoskeletal disease (e.g. joint fracture, artificial joint replacement) or neurological diseases (e.g. stroke, Parkinson’s disease, poor vision) were excluded. All subjects provided written consents to participate in the study. The project was granted approval of the Local Committee of Ethics in Research.

Measurements

Their height and body mass were measured and the BMI index was calculated. In the analysis of psychomotor fitness reaction time and correctives of decision were measured with “Decision Test” (Vienna Test System, software for psychological diagnosis, Schuhfried, Austria). This test needs a correct and fast reaction of the right or left leg or hand to a particular signal (a color or high or low tone). Before the main 4-min trial, each subject took part in an initial test. The subject was sitting in front of a monitor on which visional signals were displayed. High and low tones were emitted from a loudspeaker. For each signal only one specific reaction was correct. In statistical analysis correctness (DT) and reaction time were used.

Functional fitness was measured on the basis of selected tests from “The Senior Fitness Test” [11]: chair stand test, 8 foot up-and-go test, and 2-minute step test.

Static and dynamic balance was measured using a PE computer posturographic system produced by the Military Institute of Aviation Medicine (Wojskowy Instytut Medycyny Lotniczej) in Warsaw (a platform with four tensometric force transducers) with modified Pro-Med software (Warsaw, Poland). Reliability of this system was verified for each trial. Each subject had been precisely informed about the kind and performance of the test prior to the experiment. Each subject declared good functioning of their sight organ. Before the proper measurement was taken, each subject took part in a 32-second preliminary test on the posturographic platform. He could observe and control the movement of the projection of his own centre of body pressure on the floor on a monitor situated 1.5m in front of the subject.

Static balance was also measured on the posturographic platform. A subject's task was to maintain a still standing position for 32 seconds. The subject's feet were placed one behind the other in a straight line on a fibular plane. The following parameters were analyzed: a) mean radius (MR) – mean momentary sway from the centre of the vertical projection of the centre of pressure on the support place (COP); b) sway area (SA) – sum of areas generated by consecutive points of momentary sway from the COP base; c) total length (TL) – sum of distances between consecutive sway points in the Cartesian system; and d) mean speed of left-to-right movement (MSL-R).

During the measurement of dynamic body balance, the capacity to perform specific tasks was analysed (deflections in the set scope and direction). Subjects were standing barefooted on the posturographic platform in the upright position. Opposite, 1.5 m from the platform and 1.5 m over the floor (Fig. 1), there was a screen with a point showing a vertical projection of the centre of body pressure (Fig. 2). The task involved keeping the posture while standing with both feet on the posturographic platform so that the point C displayed on the screen was placed one by one in specific areas.

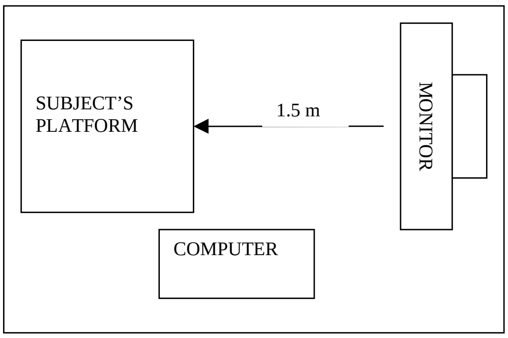

Figure 1. The posturography system. A platform (40x40cm) on which a subject is standing. The monitor is placed 1.5 m from the subject's platform. The computer collects and analyses information on the subject's body sway from the subject's platform

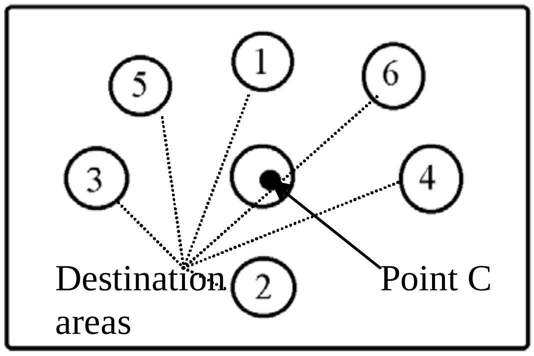

Figure 2. Test screen. Point C (image of the vertical projection of the gravity centre on the support platform) appears in areas 1-6

The areas marked as 1, 2 ... 6, in which point C should be placed one by one, were displayed in specified places, from 1 to 6, which required a subject to adjust his body posture by moving in the desired direction.

The task of each subject was to bring point C to six areas appearing in the set place of the screen for 10 seconds. After succeeding in an attempt to maintain his or her body in the required position, the subject returned to the starting position. Each subject had one trial before the actual test.

The following parameters were taken into consideration:

1) T – time of reaching the set area by point C,
2) D – percentage of the reaching path to the set area, (straight path was 100%),
3) E – percentage of task performance (keeping point C in the set area),
4) TD – total-length path covered by point C.

Statistical analysis

For each parameter determined in this way, mean and standard deviation were calculated for the entire group of subjects. In order to examine the relation between the variables, Pearson's correlation was used. We also constructed two stepwise regression models to determine the most robust predictors of static and dynamic balance.

RESULTS

Table 1 shows the mean values of the subjects' age, somatic characteristics, functional and psychomotor fitness and static and dynamic balance parameters. The values of straight correlation between variables which characterise the level of individual parameters in the measurement of static and dynamic balance have been presented in Table 2. No statistically significant relations between the analysed variables were noted.

Table 3 presents values of correlation coefficients between the static and dynamic body balance and age, somatic characteristics and psychomotoric and functional fitness. Statistically significant relations were noted between the subjects' age and three parameters of static balance (SA, TL, MSL-R). With the subjects' age the total area (SA, $r = 0.43$, $p \leq 0.01$) and total length of sway (TL, $r = 0.49$, $p \leq 0.01$) of the vertical projection of the centre pressure on the support place (COP) increase. Also the speed of sway increases with age (MSL-R, $r = 0.49$, $p \leq 0.01$). The BMI correlates with static balance parameters ($r = –0.30$ for SA and $r = –0.35$ for TL and MS).

Each increase in the BMI results in a decrease of SA and TL with reduction of speed of sway at the same time. The relations of the BMI with dynamic balance parameters are of a different kind ($r = 0.34$ for T and $r = 0.33$ for D, $p \leq 0.05$). A higher BMI is related to an increase in time – T and path – D necessary to perform an appropriate sway.

The reaction time is significantly correlated with all the parameters of dynamic balance (from $r = 0.31$, $p \leq 0.05$ for TD to $r = –0.51$, $p \leq 0.01$ for E). With the increase of reaction time noted in the psychomotor test, also time – T ($r = 0.45$, $p \leq 0.01$) and the length of path – D ($r = 0.42$, $p \leq 0.01$) necessary to perform an appropriate body sway increase, and the effectiveness of performance of the balancing task – E (–0.51, $p \leq 0.01$) is reduced. The reaction time does not show any statistically significant relations with the static balance.

Table 1. Age and somatic, fitness and balance characteristics (n=53). Mean values, standard deviation, minimum and maximum of measured variables

	$\overline{x} \pm SD$	Min.– max
Age (years)	69.6±6.1	59.8-82.5
Somatic traits		
Height (cm)	169.4±5.8	155.5-184.2
Weight (kg)	80.7±13.3	57.5-115.0
BMI (kg/m^2)	28.1±4.2	20.7-41.1
Psychomotor fitness		
DT (number)	161.8±36.9	35.0-212.0
Reaction time (s)	1.1±0.2	0.8-2.5
Functional fitness		
Chair stand test	15.5±4.2	5.0-24.0
2-minute step test (number of steps)	196.8±45.2	100.0-306.0
8' foot up-and-go test (s)	6.0±1.9	4.0-17.8
Static body balance		
MR(mm)	5.9±3.2	2.9-16.1
SA (mm^2)	1767.6±1529.8	223.0-7742.0
TL (mm)	882.7±342.5	405.0-1703.0
MSL-R (mm/s)	27.5±10.7	13.0-53.0
Dynamic body balance		
T (s)	2.0±0.5	1.4-4.0
D (%)	291.7±78.2	173.7-534.4
E (%)	79.8±13.5	30.0-95.2
TD (mm)	3293.2±785.6	2090.6-5600.8

Table 2. Pearson correlations between static and dynamic body balance

	T	D	E	TD
MR(mm)	–0.07	0.02	–0.04	0.06
SA (mm^2)	0.01	0.18	–0.13	0.23
TL (mm)	0.05	0.17	–0.14	0.27
MSL-R (mm/s)	0.06	0.17	–0.14	0.27

* – p ≤ 0.05 ** – p ≤ 0.01

Table 3. Pearson correlations between static balance, dynamic balance and age, height, weight, BMI, psychomotor and functional fitness components

	Age (years)	Height (cm)	Weight (kg)	BMI (kg/m^2)	DT (number)	Reaction time (s)	Chair stand test (number)	2 minute step test (number of steps)	8 foot up-and-go (s)
Static balance									
MR(mm)	0.20	–0.13	–0.21	–0.17	–0.10	0.10	–0.03	–0.29*	0.07
SA (mm^2)	0.43**	–0.14	–0.33*	–0.30*	–0.27*	0.20	–0.01	–0.38**	0.00
TL (mm)	0.49**	–0.03	–0.34*	–0.35*	–0.37**	0.25	0.07	–0.26	–0.08
MSL-R (mm/s)	0.49**	–0.03	–0.34*	–0.35*	–0.37**	0.25	0.06	–0.26	–0.08
Dynamic balance									
T (s)	0.29*	–0.18	0.23	0.34*	–0.38**	0.45**	–0.42**	–0.26	0.45**
D (%)	0.14	0.02	0.30*	0.33*	–0.35*	0.42**	–0.26	–0.25	0.27*
E (%)	–0.16	0.06	–0.07	–0.12	0.52**	–0.51**	0.18	0.26	–0.31*
TD (mm)	0.07	0.08	0.04	0.02	–0.29*	0.31*	–0.05	–0.16	0.14

* – p ≤ 0.05 ** – p ≤ 0.01

The results of the 30-second chair stand correlate only to one parameter of dynamic balance, i.e. T – time of reaching the set area by point C (r = –0.42, p ≤ 0.01). With the increase of the number of repetitions in this functional fitness test, the shortening of the time – T is observed. The results of the 2-minute step-in place test correlate with two parameters of static balance, i.e. MR (r = –0.29, p ≤ 0.05) and SA (r = –0.38, p ≤ 0.01). A higher number of steps performed within 2 minutes is tantamount to a smaller sway area (SA) and shorter radius of sway MR in the static test. On the other hand, the results of the 8'up to go test are significantly related only to the parameters of dynamic balance: T (r = 0.45, p ≤ 0.01), D (r = 0.27, p ≤ 0.05) and E (r = –0.31, p ≤ 0.05). With the improvement of body agility (8'up to go) the time – T and path – D of sway are reduced and at the same time the effectiveness E of the performance of the balance task increases.

On the basis of the stepwise regression analysis it was found that the variable which best described the level of static balance is subjects' age where the coefficient of determination ranges from D = 17.35% to D = 19.81% (Table 4). With the older subjects' age an increase in the sway area – SA and total length of sway – TL can be observed with the simultaneous increase in the speed of sway – MSL-R. The effectiveness of performance of the dynamic balance task is related to the greatest extent to the correctness of the psychomotor test performance (from D = 11.17% to D = 36.07%).

Table 4. Regression model of static and dynamic balance (summaries including standardized β-coefficients and coefficient of determination D)

Static balance	Predictor	Standardized β	D (%)
MR (mm)	2-minute step test (step's number)	–0.33**	10.64
SA (mm^2)	Age (years)	0.42**	17.35
	2-minute step test (step's number)	–0.27*	23.16
TL (mm)	Age (years)	0.45**	19.98
	BMI (kg/m^2)	–0.26*	26.73
MSL-R (m/s)	Age (years)	0.44**	19.81
	BMI (kg/m^2)	–0.27*	26.57
Dynamic balance			
T (s)	DT (number)	–0.53**	27.79
	BMI (kg/m^2)	0.27*	34.86
D (%)	DT (number)	–0.33**	11.17
	BMI (kg/m^2)	0.27*	18.17
E (%)	DT (number)	0.60**	36.07
TD (mm)	DT (number)	–0.41**	16.52

* – $p \leq 0.05$ ** – $p \leq 0.01$

The larger the number of light and sound stimuli a subject can react to correctly (DT), the shorter the time T and shorter the path of sway D and TD in the dynamic balance test can be noted.

DISCUSSION

In the study carried out on elderly men with osteopenia or osteoporosis no statistically significant corelations between the values of parameters of static and dynamic balance was found. As both static and dynamic body balance are related to the number of falls [18] the obtained results indicate the need of separate and detailed analysis of these aspects of body balance of the elderly.

Age was a significant determinant for static balance in the studied group of elderly men. With the number of years there is an increase in the values of posturographic parameters which describe the level of static balance, i.e. SA ($r = 0.43$, $p \leq 0.01$), TL ($r = 0.49$, $p \leq 0.01$) and MVL-R ($r = 0.49$, $p \leq 0.01$). It can be assumed that from the studied variables (age, somatic psychomotor and functional fitness parameters), the age is the most prognostic element for assessment of static body balance, which to a great extent negatively affects its level. This was noted also in the studies of Colledge et al. [5], who observed a linear increase in the values of sway of the centre of gravity with age. Baloh et al. [2] noted that differences between young (18-39 years old) and elderly people (over 75 years old) are even greater in terms of dynamic balance than in static balance. Our studies of elderly men with osteopenia or osteoporosis using the statistical method of stepwise regression analysis confirmed that the strongest determinant of static balance was age (from D = 17.35% to D = 19.81%) from all the studied variables. Age in almost 20% determines the low level of static balance in men aged 60-83. In a study of factors determining body balance in women with identified osteoporosis Carter et al. [4] indicated small significance of age in maintaining both dynamic and static balance. Thus, older age seems to exert a greater, negative influence on the level of static balance in groups of studied men with osteopenia or osteoporosis.

Out of four parameters of dynamic balance, only one – T, indicates corelations with age ($r = 0.29$, $p \leq 0.01$). No corelations between dynamic balance and height were found, and only one significant relation between the D parameter and weight was found ($r = 0.30$, $p \leq 0.05$). A factor which significantly determined both static and dynamic balance in elderly men was the BMI. At the same time, in the case of static balance, one can talk about a positive effect, i.e. with the increase of the BMI the size and area of sways of the vertical projection of the central pressure on the support place (SA and TL) decreases with the simultaneous lowering of the speed of sway (MSL-R).

In the case of dynamic balance we can note longer time necessary to perform the balance task –

T and the lengthening of the path of the sway – D with the increase of the BMI, and consequently the lowering of the effectiveness E of the balance task performance. On the basis of the stepwise regression equation it was found that among variables significantly correlated with posturographic parameters, fast (reaction time) and correct (DT) reaction to light and sound stimuli had the greatest significance for the dynamic balance (from D = 11.17% to D = 36.07%). A shorter reaction time and a larger number of correct reactions to stimuli co-occur with a higher level of dynamic balance. An increase in reaction time in the elderly is commonly regarded as one of the main factors in balance disturbances and risk of falls [17].

Due to the fact that the human nervous system at an older age requires longer time of reaction to changes in the location of the centre of gravity [3], the reaction time is often considered a significant determinant of body balance related to the controlling function also in training programmes for the elderly [22]. Lord et al. [16] in their analysis of the risk of falls found that a long reaction time and low level of muscular strength were related to greater sways in balance tests. Our studies showed, however, that the significance of good reaction speed increased in dynamic tests.

The level of dynamic balance in men with identified osteoporosis or osteopenia is related mainly to proper reaction (time and accuracy) to various types of stimuli. Whereas static balance is mainly related to age and the BMI, the direct impact of other variables, including muscular strength, on static and dynamic balance is disputable.

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