Janusz Maciaszek

BODY COMPOSITION AND MOTOR FITNESS AS DETERMINANTS OF BODY BALANCE IN ELDERLY MEN

TELESNA KONSTITUCIJA IN MOTORIČNE SPOSOBNOSTI KOT DETERMINANTI TELESNEGA RAVNOTEŽJA PRI STAREJŠIH MOŠKIH

Abstract

The aim of the study is to specify the relationships of motor fitness and body composition with body balance parameters determined during changes in its location in space. The study covers 126 men aged 60 to 83. Body composition is estimated on the basis of bioimpedance measurement. Motor fitness is measured on the basis of tests from the Senior Fitness Test (Jones & Rikli, 2001). Balance is measured using a computer posturographic system PE (a platform with four tensometric converters). During the measurements, deflections in the set scope and direction are analysed. The relationships between the age and posturographic parameters are noted. Significant relationships are found for muscle mass and the percentage of task performance and total path. The strong relations with all balance parameters are displayed by agility. However, the strength of lower limbs and endurance are significantly related with the time of reaching the specified area and percentage of task performance. It can be concluded that the capability to keep one's body balance during changes in its position in space depends on the age of the subjects and the factors of motor fitness related to muscle mass.

Key words: elderly, body balance, motor fitness, body composition

University School of Physical Education, Poznan, Poland

Corresponding author:
University School of Physical Education
Department of Theory of Physical
Education and Anthropomotorics
Ul. Królowej Jadwigi 27/39
61 – 871 Poznan, Poland
Tel.: +48 61 8355000
Fax: +48 61 8355211
E-mail: jmaciaszek@awf.poznan.pl

Izvleček

Namen raziskave je bil ugotoviti odnos med motorično sposobnostjo ter telesno konstitucijo in parametri telesnega ravnotežja, ki so posledica sprememb telesnega položaja v prostoru. V raziskavo je bilo vključenih 126 moških starih od 60 do 83 let. Telesno konstitucijo smo ugotavljali z bioimpedančnim merjenjem. Motorične sposobnosti so bile izmerjene na osnovi Senior Fitness Test – testa telesne pripravljenosti za starejše (Jones & Rikli, 2001). Ravnotežje smo merili s pomočjo računalniškega posturografičnega sistema PE (plošča s štirimi tenziometričnimi pretvorniki). Med merjenji smo analizirali odstopanja v danem območju in smeri. Rezultati so pokazali statistično značilno povezanost med starostjo in posturografičnimi parametri, prav tako pa tudi med mišično maso in deležem izvedbe nalog ter skupno potjo. Povezave vseh parametrov ravnotežja z gibljivostjo so statistično značilne. Moč spodnjih okončin in vzdržljivost sta značilno povezani s časom za doseganje določenega področja in deležem izvedbe nalog. Na podlagi rezultatov lahko zaključimo, da je sposobnost ohranjanja ravnotežja ob spremembah telesnega položaja odvisna od starosti posameznika in dejavnikov motorične pripravljenosti, ki so povezani s mišično maso.

Ključne besede: starostniki, telesno ravnotežje, motorična pripravljenost, telesna konstitucija

INTRODUCTION

Keeping one's body balance and preventing falls are jointly controlled by the sense of vision, the vestibular organ, and sensory integration. With age, the effectiveness of the functioning of the postural system deteriorates (Kannus et al., 1999). About a third of elderly people living in their own houses fall down at least once a year. It happens even more often in nursing homes (Lord, McLean, & Stathers, 1992).

The function of the postural control system is to keep one's balance by responding to the displacement of the centre of gravity. This displacement may be performed in a controlled manner using an intentional movement or may result from an unexpected movement. Normal displacement of one's centre of gravity takes place within strictly specified limits, depending on the individual support base (Riley, Mann, & Hodge, 1990). The basic task of keeping one's body balance is to keep the location of the body's centre of gravity within the limits of stability (Maureen & Thornby, 1995). The possibilities of the controlled moving of one's centre of gravity depend on the effectiveness of the functioning of organs and systems co-operating in the process of keeping one's body balance (Boucher & Wagner, 1992).

Frequently indicated factors which determine the lowering of one's capacity to keep one's body balance are the advanced age of the participants (Hageman, Leibowitz, & Blanke, 1995; Wright & Schurr, 2001) and changes accompanying ageing of the body. It has been observed that the general lowering of fitness and increased proneness to disease accompany the lowering of the capacity to keep one's body balance (Boucher & Wagner, 1992; Chodzko-Zajko & Ringel, 1987). In a comparison of the body balance of adults (20-36 years old) and the elderly (60-75 years old), Hageman, Leibowitz and Blanke (1995) noted a lower level of balance in the elderly in each trial (open eyes, closed eyes, and with feedback). A study of Chinese men and women indicates a significantly lower level of balance when standing on one leg with open and closed eyes in a group of people aged 75-80 than in a group of 65-70-year-olds (Liang & Cameron Chumlea, 1998).

The effect of morphological parameters in the process of keeping one's body balance and the number of falls has not been sufficiently recognised. It has been noted that in boys aged up to 20 that the level of one's body balance is negatively correlated with one's body mass, BMI and fat mass (Goulding, 2003). However, Pollock, Foster, Knapp, Rod and Schmidt (1987) found that the risk factor in falls of the elderly is having a low content of lean body mass in total body mass. Jürimäe and Jürimäe (1998) studied women aged 35 to 45 years and obtained results indicating negative relations between one's body balance and the degree of one's body fat.

Moreover, muscle power and even body mass, BMI and fat body mass may have a significant influence on the process of keeping one's body balance (Carter et al., 2002; Goulding, 2003; Maureen & Thornby, 1995). Old age is also related to general muscle atrophy as well as difficulties producing appropriate muscle tension which enables reflex reactions (Judge, Whipple, & Wolfson, 1994) which help to control the keeping of one's body balance. In a study carried out on a group of 97 women aged 65 to 75, it was noted that the strength of the extensors of the knee joint significantly determines the keeping of one's balance in both static tests and in dynamic tests. It was also found that muscle power determines the level of one's balance to a greater extent than the age of the subjects (Carter et al., 2002). However, in other studies of women aged 75 no relationship was noted between the muscle power of the lower limbs (extensors and flexors of the knee joint and dorsiflexors of the ankle joint) and body balance measured by standing on one leg (Ringsberg, Gerdhem, Johansson, & Obrant, 1999). In studies by Stemplewski, Salamon, Szeklicki and Maciaszek (2001) carried out on elderly women, statistically significant positive relations were noted between body mass and BMI and the parameters of static body balance determined using computer posturography. Yet no relations between body balance and height were found.

The aim of the study is to specify the relationships of selected factors of motor fitness and body composition with body balance parameters determined during changes in its location in space. The study involves an analysis of the capacity to perform deflections in a set range and direction by men over 60. The registered parameters were adopted as a measure of body balance in dynamic conditions, that is, conditions simulating natural everyday situations.

METHOD

Participants

The sample was 126 men aged 60 to 83 (M = 69 years, SD = 5.8 years). They were recruited from the community by using direct mailings and community efforts. All participants 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. Participants provided written informed consent to participate in this study, which the Local Committee of Ethics in Research approved.

Instruments

Their height and body mass were measured. Fat mass (FM%), fat free mass (FFM%), and muscle mass (MM%) in total body mass were estimated on the basis of a bioimpedance measurement (the body impedance analyser of Akern_RJL systems – BIA 101/S). All measurements were taken before breakfast in the morning.

Motor fitness was measured on the basis of selected tests from the Senior Fitness Test (Jones & Rikli, 2001): chair stand test (number of full stands from a seated positioning); 8-foot up-and-go test (number of seconds required to get up from a sitting position, walk 8 feet, turn, and return to the sitting position; 2 minute step test (number of full steps completed in 2 minutes); chair sit-and-reach test (number of centimetres between the extended fingers and the tip of the toe in a sitting position).

Body balance was measured using the PE computer posturographic system produced by the Military Institute of Aviation Medicine in Warsaw (a platform with four tensometric force transducers) with modified software made by Pro-Med (Warsaw, Poland). Every subject was precisely informed about the kind and performance of the test prior to the experiment. Each participant declared the good functioning of their sight organs. During the measurements, the capacity to perform specific tasks was analysed (deflections in the set scope and direction). Before the actual measurement, the participants took part in a 32-second preliminary test in which standing on the posturographic platform he could observe and control the movements of the projection of his own centre of body pressure on the floor. In each experimental session the participants took part in two repetitions. The second trial was analysed.

Procedure

The subject was standing barefoot on the posturographic platform in an upright position. Opposite from this, 1.5 m from the platform and 1.5 m from the floor, there was a screen with a point showing a vertical projection of the centre of body pressure (see Figure 1). The task involved keeping one's posture while standing with both feet on the posturographic platform so that point C displayed on the screen was placed one by one in specific areas.

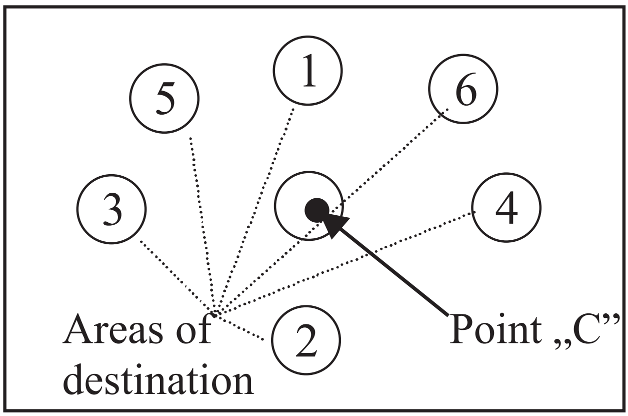

Figure 1: The screen shown to the subject

Areas 1 to 6, in which point C (image of the vertical projection of gravity's centre on the support place) should be placed one by one.

The participants were given a demonstration and instructions on what they should do. The areas marked 1, 2 ...6, in which point C was to be placed one by one were displayed in strictly specified places, from 1 to 6, which required a subject to adjust his body posture by moving in the desired direction. The task of the 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 their body in the required position, the subject returned to the starting position.

The following parameters were taken into consideration:

a) T – time of reaching the set area 1, 2…6 by point C,

b) D – percentage of the reaching path to the set area 1,2…6, the expected result-straight path is 100%,

c) E – percentage of task performance, keeping point C in the set area 1,2…6, and

d) TD – total path covered by point C.

For each parameter determined in this way, a mean and standard deviation were calculated for the whole group of subjects. In order to examine the relationship between the variables, Pearson's correlation method and a multiple regression analysis were used. The level of significance at $p<0.05$ was accepted. These data were previously checked for distribution.

RESULTS

Table 1 presents the values of characteristics obtained during the study. High values of body mass (M = 81.9 kg, SD = 11.5 kg) in relation to height (M = 170.2 cm, SD = 6.0 cm) contribute to a relatively high BMI (28.2 kg/m^2). On the basis of the electric bioimpedance method, high values of percentage fat mass content (M = 31.3, SD = 5.5%) in total body mass were also found.

Table 1: Mean values and standard deviations for somatic characteristics, motor fitness and posturographic parameters in the studied group of elderly men

	M (SD)	Range
Height (cm)	170.2 (6.0)	155.5 – 186.5
Weight (kg)	81.9 (11.5)	57.5 – 115.0
BMI (kg/m^2)	28.2 (3.4)	20.7 – 41.1
FM (%)	31.3 (5.5)	13.1 – 44.0
FFM (%)	68.1 (6.8)	22.5 – 86.9
MM (%)	47.0 (7.7)	28.8 – 65.9
Chair stand test (number)	16.0 (4.0)	6.0 – 24.0
2 minute step test (number of steps)	208.4 (50.2)	104.0 – 404.0
Chair sit-and-reach test (cm)	-5.7 (12.6)	-33.0 – 30.0
8-foot up-and-go (s)	5.9 (1.5)	4.0 – 10.0
T – time of reaching the set area by point C (sec.)	1.9 (0.4)	1.0 – 3.7
D – percentage of the reaching path to the set area (%)	293.3 (75.5)	173.7 – 534.4
E – percentage of task performance (%)	78.8 (12.5)	41.7 – 96.1
TD – total path covered by point C (mm)	3419.5 (929.6)	877.6 – 7020.1

In the test on the posturographic platform, it was difficult for the subjects to make a deflection in the appropriate direction and range in order to reach the proper location of point C. The average path was 293.3%, that is almost three times more than the optimal path (straight path = 100%). The subjects managed to maintain point C in the specific area 1, 2 ...6 in 78.8%. This means that, on average, for each required 10 seconds of maintaining the body in the required position, the task was performed properly over 7.8 seconds.

Table 2 presents the results of analyses of relationships between posturographic parameters and the variables describing age, height, body mass, composition, and motor fitness of the studied men. Relatively high values of the correlation coefficient were noted for the relations between the age of men with E – the percentage of task performance, i.e. maintaining the body in the appropriate position ($r = - 0.35$, $p \leq 0.01$). The age also correlates significantly with other parameters of balance, i.e. T – time of reaching the set area ($r = 0.24$, $p \leq 0.01$), D – reaching path ($r = 0.23$, $p \leq 0.01$) and TD – total path made by point C ($r = 0.18$, $p \leq 0.05$). Thus, with age the level of the studied posturographic parameters drops. No statistically significant relations were noted between body balance parameters and body height, mass and BMI.

Table 2: Somatic characteristics and motor fitness effects on posturographic parameters of the studied men

	T – time of reaching the set area by point C	D – percentage of the reaching path to the set area	E – percentage of task performance	TD – total path covered by point C
Age (years)	0.24**	0.23**	-0.35**	0.18*
Height (cm)	-0.09	0.05	-0.05	0.15
Weight (kg)	-0.02	0.11	-0.04	-0.05
BMI (kg/m^2)	0.08	0.10	-0.02	-0.02
FM (%)	0.03	-0.01	-0.18*	-0.01
FFM (%)	-0.09	0.01	0.04	0.07
MM (%)	-0.09	-0.15	0.34**	-0.19*
Chair stand test(number)	-0.32**	-0.16	0.28**	-0.05
2 minute step test (number of steps)	-0.26**	-0.14	0.29**	-0.05
Chair sit-and-reach test (cm)	-0.08	-0.03	0.01	0.11
8 foot up-and-go (s)	0.29**	0.28**	-0.40**	0.27**

Legend: ** - $p \leq 0.01$, * - $p \leq 0.05$

However, significant values of the correlation coefficient were found for relationships between MM (%) – muscle mass and E – percentage of task performance ($r = 0.34$, $p \leq 0.01$) and TD – total path ($r = -0.19$, $p \leq 0.05$).

It was also found that the results of some motor fitness tests show significant relations with the studied posturographic parameters. The strongest relations with all balance parameters are displayed by agility (from $r = 0.27$ to $r = -0.40$, $p \leq 0.01$). However, the strength of the lower limbs and endurance are significantly related with T – the time of reaching the specified area and E – the percentage of task performance (from $r = -0.26$ to $r = -0.32$, $p \leq 0.01$).

Table 3: Multiple regression analysis of the dependent variable E – percentage of task performance

	BETA	*SD BETA*	*B*	*SD B*	*t*	*p*
Age	-0.21	0.09	-0.47	0.20	-2.36	0.02
Chair stand test	-0.14	0.11	-0.44	0.35	-1.26	0.21
2 minute step test	0.13	0.09	0.07	0.05	1.44	0.15
8 foot up-and-go	-0.32	0.10	-3.87	1.18	-3.27	0.00
FM %_	-0.05	0.10	-0.10	0.22	-0.47	0.64
MM %_	0.23	0.10	0.37	0.16	2.36	0.02

Multiple $R = 0.54$ $R2 = 0.29$ $p<0.01$

The above analysis indicates that the posturographic parameter which shows the strongest links with the studied independent variables is E – the percentage of task performance. Due to this, a regression analysis was performed for this variable (see Table 3) in which independent variables were taken into consideration, i.e. a) age; b) lower body strength; c) aerobic endurance; d) agility; e) FM (%); f) MM (%) significantly correlating with this dependent variable. The multiple regression analysis indicates a significant effect of independent variables, i.e. age, lower body strength, endurance, agility, FM (%) and MM (%) on the possibilities of performing a balancing task ($R = 0.54$; $R2 = 0.29$; $p<0.001$).

Thus, the variables included in the regression analysis determine 29% of the level of posturographic parameter E – the percentage of performance of the posturographic task. The most significant variables related to keeping the body balance of the subjects are agility, where the regression coefficient $B = -3.87$ ($p<0.01$), followed by age ($B = -0.47$ $p<0.05$) and MM % ($B = 0.37$ $p<0.05$).

DISCUSSION

The human body is sometimes described as a solid of revolution oscillating around the ankle joints and resembling an inverted pendulum (Winter, 1995, 1998). With this assumption in mind, body height and mass should be important factors which determine the keeping of one's body balance. The lack of a relationship between these variables describing body build demonstrated in the study suggests that the inverted pendulum model does not explain the process of keeping one's balance in all conditions. None of the studied posturographic parameters showed any relations with body height and mass in the case of the studied men. Obviously, the method of measuring body balance, the test used and, in particular, the degree of difficulty of the balancing task have a huge impact on the values of the correlation coefficient describing the relationship between one's body height and mass. In relatively easy tests (motionless standing), both with open and closed eyes, a low body height is a variable which positively determines the values of posturographic parameters in groups of men (Era, Schroll, Ytting, Gause-Nilsson, Heikkinen, & Steen, 1996) which could confirm the principle of an inverted pendulum.

The negative effect of the ageing process on the capability to keep one's body balance that was observed earlier (Hageman et al., 1995; Liang & Cameron Chumlea, 1998) was confirmed. Each of the determined posturographic parameters was significantly related with the age of the subjects ($p\leq 0.05$). Subjects' capabilities of performing and controlling the imposed deflections deteriorate with age. In the upright posture, the projection of the centre of gravity is in the area approx. 5 cm forward from the side bones of the ankle joints (Juras, 2003). Maintaining one's centre of gravity in this area does not require a great muscular effort. However, each shifting of the centre of gravity forces appropriate muscle groups to work. Hence in our own studies positive relations of MM (%) with E – percentage of task performance ($r = 0.34$, $p \leq 0.01$) and negative with total length of the path covered by the vertical projection of the centre of pressure on the surface ($r = -0.19$, $p \leq 0.05$) were observed. Belenkiy, Gurfinkel and Paltswv (1967) observed that during any movement, e.g. lifting the arms in the standing position, the leg muscles needed to control one's posture are stimulated first, followed by the muscles performing the main movement.

It can be stated that the process of keeping one's body balance (in the analysed test) is independent of (FFM) fat free mass. Weak relations were noted between (FM %) fat mass and percentage of task performance – E ($r = -0.18$, $p \leq 0.05$). Thus, in the case of tasks requiring body balancing, it is not the height or body mass and relations between them nor the ratio of fat mass to fat free mass, but the appropriate muscle mass that offers an opportunity to keep one's body balance in various everyday situations.

Muscle strength is not the basic determinant of one's body balance with the standing on one leg tests (Ringsberg et al., 1999). This study shows, however, that the significance of strength increases when the subject is forced to perform imposed deflections. On the basis of the performed studies, it may be concluded that the level of one's body balance and – what follows – the possibility of preventing falls at an older age are closely related to appropriate motor fitness. The strength and aerobic endurance of the lower limb muscles and agility (from $r = -0.26$ to $r = -0.40$ $p \leq 0.01$) have particular importance. So the capability to keep one's body balance during changes in its position in space relates to the age of the participants and the factors of motor fitness which are related to muscle mass.

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