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Postural stability and risk of falls per decade of adult life – a pilot study

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Abstract: A gradual loss of function in the balance system may begin in the fourth decade of life. The effects of this process become visible in old age, when problems with postural stability contribute to falls, making it an important social problem. Early detection of this dysfunction is essential for minimizing the risk of age-related falls, one of the main causes of hospitalization or even death in older adults.
The aim of this study was to evaluate somatic factors that may result in the deterioration in postural stability and determine the age range in which the first changes in stability occur. The study included healthy non-sporting adults aged from 20 to 70 years. Four tests based on the Biodex Balance System were used to determine static postural stability, dynamic postural stability, risk of falling and stability limits.
The obtained results showed that dysfunctions of dynamic balance appeared significantly earlier than static balance dysfunctions, i.e. as early as at 50 years of age, and then gradually increased. Higher BMI and the percentage and absolute fat content significantly increased the risk of falls and also adversely affected the results of dynamic stability tests.

Key words: proprioception (balance) training, postural stability, risk of fall.

Introduction

A gradual loss of function in the balance system may begin in the fourth decade of life. The effects of this process become visible in old age, when problems with postural stability contribute to falls, making it an important social problem (Błaszczyk et al. 1994; Błaszczyk, Czerwosz 2005; Hsieh et al. 2013).

Early detection of dysfunction in system of balance is essential for prevention and implementation of procedures aimed at minimizing the risk of age-related falls, and also an important part of functional diagnostics and rehabilitation (Khalaj et al. 2014). The ability to comprehensively and objectively assess the status of the balance system is essential for the effectiveness of therapy and for function-

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al balance abilities in sport. However, the complex etiology of balance disorders has made them difficult to diagnose and treat (Wiszomorska et al. 2013).

The ability to maintain body balance is cited as one of the basic coordination components that determines the proper functioning of a person from a motor point of view, and is always accompanied by other coordination abilities: spatial orientation, movement differentiation, and speed of reaction (Greenwald et al. 2005).

Proprioception is a very important part of the functional stability of joints (Massion 1992). It is the ability to recognize the position of individual parts of the body in relation to one another, as well as movements in a given joint (Błaszczyk et al. 1994; Stolarczyk et al. 2000). Uninterrupted proprioception and correct central stability is one of the basic conditions of normal joint functioning (Styczyński et al. 2007). The ability to feel one's own body and the arrangement of its individual elements are needed in everyday life to perform the simplest actions and physical activity where the stimuli change very quickly. The better proprioception is developed, the easier it is to maintain balance on uneven or slippery surfaces.

Proprioception disorders can be caused by injuries in the skeletal system and neurological disorders, leading to mechanical instability. Persistent mechanical instability leads to repeated traumas and functional instability, which is manifested by abnormal motor patterns. Over time, overloading of periarticular structures may result in ligament damage and a reduction in neuromuscular control. Damage within the joint structures results in a deepening deficit of proprioception. Long-term degradation of deep-tissue receptors leads to impaired motor patterns and injuries in active individuals. Impaired motor patterns result in the appearance of compensatory mechanisms and increased difficulties in maintaining balance during walking and daily activities (Styczyński et al. 2007).

Over a long period of time, central compensatory mechanisms effectively counteract the effects of postural deficiency, but in old age a failure of these mechanisms results in a rapid decline and collapse in postural stability. The main symptom of postural instability is a lack of balance, resulting in falls – often with tragic consequences. The risk of death from such falls in people over 65 years of age is 7 times higher than in young people (Błaszczyk et al. 1994, Błaszczyk et al. 2000, Błaszczyk and Czerwosz 2005). Therefore, research has focused primarily on comparisons of postural stability between young and older people. There are no studies that enumerate changes in postural stability across the decades of human life.

The aim of this study therefore was to (i) evaluate somatic factors that may influence deterioration of postural stability and the willingness of the motor system to perform activities in natural conditions, and (ii) determine the age range in which the first age-related reductions in stability occur.

Materials and Methods

The study consisted of a group of 50 healthy non-sporting adult men aged 20-70 years, divided into five age sub-groups (group I: 20-29 years; group II: 30-39 years; group III: 40-49 years; group IV: 50-59 years; group V: 60-70 years).

The Biodex Balance System was used to assess postural stability, stability range and fall risk assessment. The research was carried out in 2017 at the Centre for Structural-Functional Research in Szczecin and was approved by the Bioethical Committee of the Regional Medical Chamber in Szczecin by Resolution No. 06/KB/VI/2016 of 30 June 2016. The study adhered to the tenets of the Declaration of Helsinki.

Four tests were used to achieve the objectives of the study: static postural stability (fixed platform), dynamic postural stability (level 8 instability), risk of falling (levels 8 to 4) and stability limits. In the first three tests, the participants performed 3 tests lasting 20 seconds, while in the fourth test we measured the time taken to complete the task. All tests were performed with visual inspection and biofeedback.

Body height and body weight were measured. Body mass and body composition (body mass index (BMI), fat percentage (FAT %), fat mass (FAT kg), were determined using a Body Composite Analyzer, Tanita BC-418MA (Tanita, Tokyo, Japan) according to the manufacturer's protocol.

Statistical analysis

Arithmetic means and standard deviations of the examined features were calculated. The distributions of the examined features were examined by means of Shapiro Wilk tests and in all cases the distribution was normal. Using Statistica 13.0 software, we determined the correlation between postural stability and the risk of falls with respect to age, height, weight, BMI ratio, FAT % and FAT kg. A univariate analysis of variance (ANOVA) was calculated and differences between the examined age groups were determined with Post Hoc Fischer's least significant difference test (LSD). The level of significance was set at $p \leq 0.05$.

Results

Values of arithmetic means and standard deviations of selected morphological characteristics, BMI, fat content and selected static, dynamic, stability and fall risk categories in age categories are presented in Table 1.

Table 1. Means ± standard deviation of selected morphological characteristics, BMI, fat content and selected static, dynamic, stability and fall risk.

Experimental group number	I	II	III	IV	V
Age [yrs]	22.3±1.19	34.5±3.64	44.7±2.57	54.4±2.36	66.19±2.98
Height [cm]	177.6±3.38	181.4±5.29	178.8±5.40	177.8±6.05	178.4±4.23
Weight [kg]	76.8±9.75	92.1±17.12	91.3±14.64	94.2±13.01	91.4±14.42
BMI [kg/m^2]	24.3±2.95	27.9±4.94	28.7±5.17	29.7±3.11	28.7±4.26
FAT [%]	12.1±6.36	20.5±7.34	21.5±7.98	21.8±4.07	24.8±5.81
FAT [kg]	9.8±6.63	19.9±11.22	20.8±9.32	20.9±5.77	23.3±7.28
Static stability	0.4±0.19	0.7±0.08	0.3±0.08	0.4±0.18	0.5±0.19
Dynamic stability	1.0±0.17	1.5±0.60	1.3±0.35	1.6±0.44	1.9±1.18
Range of stability – time [s]	42.6±5.75	37.0±5.42	39.9±10.97	43.7±7.18	54.1±16.97
Fall risk	1.4±0.55	1.9±0.86	1.9±0.69	2.3±0.79	2.53±0.75

As predicted, the results of the correlation analysis (Table 2) showed that the chronological age of subjects had a statistically significantly adverse effect on all results in postural stability and fall risk. Similarly, the BMI and the percentage and absolute fat content statistically significantly increased the risk of falls and reduced dynamic stability.

Detailed results of one-factor analysis of variance with post-hoc Fischer's LSD tests among the examined five age groups for the selected static and dynamic stability indicators, stability range and fall risk are presented in Table 3.

The obtained results show that statistically significant differences in static stability occurred between the youngest and

Table 2. Results of correlation analysis

Variable	Static stability	Dynamic stability	Range of stability time (s)	Fall risk (8-4)
Age (years)	0.05	0.001	0.01	0.0001
Height (cm)	NS	NS	NS	NS
Weight (kg)	NS	0.020	NS	0.0001
BMI (kg/m^2)	NS	0.005	NS	0.0001
FAT (%)	NS	0.005	NS	0.0001
FAT (kg)	NS	0.010	NS	0.0001

Level of significance set at $p \leq 0.05$; NS – non significant

Table 3. Results of the Least Significant Difference (LSD) Post-hoc test

			Static stability index		
Age group	I	II	III	IV	V
I	-	NS	NS	NS	0.05
			Dynamic stability index		
Age group	I	II	III	IV	V
I	-	NS	NS	0.05	0.005
			Stability range (time)		
Age group	I	II	III	IV	V
V	0.05	0.001	0.005	0.05	-
			Fall risk (8-4)		
Age group	I	II	III	IV	V
I	-	NS	NS	0.015	0.002

oldest (over 60 years) group, in which the parameter significantly deteriorated.

In dynamic stability, statistically significant differences occurred between group I and groups IV and V, thus a significant deterioration of this parameter had already occurred among those over 50 years of age with respect to the 20-year-old group of respondents.

In the case of stability range (time), statistically significant differences (adverse change in parameter) occurred in the oldest group compared to the other age groups.

The risk of falls increased statistically significantly after 50 years of age (groups IV and V) compared to the youngest subjects.

Discussion

Reduced postural stability results in difficulty in performing daily activities, which significantly affects the quality of life of patients (Hsieh et al. 2013). Early recognition of a balance impairment in conjunction with targeted rehabilitation may improve this component of the motor system, which may translate into increased mobility and quality of life in older adults. Postural stability depends on a complex balance system consisting of the vestibular system located in the inner ear, visual input, and receptors sensitive to compression, stretching and tension located in muscles, tendons and articular capsule. Disorders of body balance are related to imperfections in any of these elements (Nowicki 2004; Held-Ziółkowska 2006). Testing balance ability is very complex and so efforts are being made to develop effective diagnostic methods for the detection of balance disorders in the asymptomatic period. For this purpose, we need new methods of quantifying the efficiency of the balance system (Błaszczyk and Czerwosz 2005; Błaszczyk et al. 2014; Błaszczyk 2016). One of the devices used to evaluate and train balance and proprioception is the Biodex Balance System. Tests on the Biodex platform with an unstable ground give a more detailed way to learn and interpret the qualities of the mechanism of balance (Parraca et al. 2001). Various studies show that stimulation of mechanoreceptors in extreme ranges of motion in the joint provide an optimal stimulation of afferent information necessary to produce correct responses to the respective muscle groups (Paterno 2004).

Our research and a survey of literature have shown that postural stability control deteriorates with age (Skalska et al. 2004; Abrahamova and Hlavacka 2008; Błaszczyk at al. 2000; Błaszczyk and Michalski 2006; Wiszomorska et al. 2013; Nagy et al. 2007; Czwalik 2017). However, the complex etiology of imbalance makes diagnosis difficult (Horak 2006; Massion 1992; Błaszczyk et al. 2009). Our research shows that dynamic stability indicators were higher than static stability indicators in the study groups, similar to results obtained by Wiszomirska et al. (2013) and Davlin-Pater (2010). Dynamic balance requires the appropriate involvement of ankle strategy, hip strategy, and step strategy, whereby the type of strategy depends on the size of the base area, degree of deviation from the centre of gravity and the angular velocity of these deviations (Horak and Nashner 1986; Błaszczyk et al. 1993, Błaszczyk et al. 1994; Błaszczyk et al. 2000; Błaszczyk et al. 2014; Błaszczyk 2016). Incorrect selection and coordination of sensory stimuli results in an increase in the range of deviation of the centre of gravity and the use of inappropriate motor strategies to maintain balance. The obtained results confirm that dysfunctions of complex dynamic equivalent reactions appear significantly earlier than static balance disorders, as early as 50 years of age. It is therefore justified to introduce early training and exercises in co-ordination and balance, multi-tasking exercises, biofeedback training, or virtual reality technology. Our research also showed that a higher BMI and percentage and absolute fat content significantly correlated to the risk of falls and deterioration in dynamic stability. The highest BMI was recorded among men over 50, and the risk of fall was statistically significantly higher in that group (i.e. in IV and V age groups) compared to the youngest men tested. The relation between body balance and body mass has been well established in literature (Prado et al. 2007; Swanenburg 2008). However, only a few studies have discussed the effect of body weight on dynamic balance. In a study on the relationship between anthropometric factors, gender and balance under unstable conditions in young adults, significant correlations were shown between dynamic stability and BMI in men, while in women these correlations were only moderate (Greve et al. 2013). Similarly, Czwalik (2017), testing the influence of age and chosen components of body weight on the postural stability of women over 60, showed that postural control correlated with the height and BMI as well as the content on fatless body mass. Błaszczyk et al. (2009), testing the effects of excessive body weight on postural control, also showed that main postural stability parameters were negatively correlated with body mass index (BMI). It may be concluded that maintenance of an appropriate body mass is an extremely significant factor in preventing deterioration of body balance functions in later ages.

Conclusions

The obtained results confirm that dysfunctions of complex dynamic equivalent reactions appear significantly earlier than with static balance, i.e. over 50 years old, and then gradually increase. It is therefore justified to introduce early training and exercises enhancing co-ordination and balance, as well as multi-tasking exercises, biofeedback training, or virtual reality technology to improve postural stability and mitigate the risk of falls.

Authors' contributions

ESA conceived of the presented idea, was project investigator, wrote the working and final versions of the manuscript, collected the literature; AL was project investigator, performed statistical analyses, wrote the final version of the manuscript; PK was project investigator, wrote the draft manuscript; MCH was project investigator, performed statistical analyses and interpreted study results, wrote the final version of the manuscript. All authors contributed to the final manuscript.

Conflict of interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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