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DETERMINATION OF FALL RISK PREDICTORS FROM DIFFERENT GROUPS OF VARIABLES

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Abstract

Introduction. Risk factors associated with falling in the elderly are numerous. Most existing tools use a combination of functional assessment and risk scoring based on known risk factors. The aim of the study was to verify which parameters could be used to predict fall risk (FR) in older women. ***Material and Methods.*** The study involved 56 inactive females aged 71.77 ± 7.43(SD). Backward stepwise regression analysis was performed to determine which independent variables predict FR in older women. ***Results.*** Significant predictors of FR were: in model 1 – age and body mass (in 32%); in model 2 – knee extensor strength of the right lower limb (KEs R) (in 20%); in model 3 – the Timed up and Go test (TUG) (in 25.5%); and in model 4 – medial-lateral stability index with eyes open (MLSI EO) (in 35%). By means of backward stepwise regression analysis using the above models, the variables that significantly influence FR in seniors were body mass, MLSI EO, KEs, and age. The above analysis shows that these indicators (model 5) may predict FR in older women in 59% of cases. ***Conclusions.*** It was determined that variables that significantly influence FR in seniors were body mass, age, KEs, and MLSI EO. Research should be continued to identify more predictors and define norms that indicate FR.

Key words: falls, prevention, elderly

Introduction

A fall is defined as a result of the inability to maintain control over the body position in relation to the environmental changes [1]. They are a consequence of various factors: degenerative changes in the vestibular and visual systems, deterioration of motor control, side effects of taking medication, and environmental factors [2, 3]. The probability of a fall is called Fall Risk (FR), and it can be prevented by screening for risk factors and recommending physiotherapy interventions [4].

Stabilography is a commonly used method of assessing body balance. The Biodex Balance System (BBS) SD (USA) platform is a reliable and objective diagnostic tool for equilibrium disorders. During the test, the deflections of the centre of pressure (COP) are measured and they make it possible to determine values of static stabilographic indicators (on stationary platform) and dynamic stabilographic indicator (on unstable platform). The Fall Risk Index (FRI) (determined on unstable platform) seems to be more useful, because the body's adaptation to external disturbances and quick reaction to rapid changes in body position are necessary to assess FR. Previous studies have shown that BBS platform is useful in FR assessment in older people. Perraca et al. have proved that the dynamic stabilographic parameter Fall Risk Index (FRI) had high ICC (ICC = 0.80) [5].

The prediction of fall risk (FR) is a complex multifactorial problem [2]. It involves interactions between environmental, physiological, and behavioural risk factors [6, 7]. Most existing tools use a combination of functional assessment and risk scoring based on known risk factors [8].

Increased age is not the only factor associated with the presence of falls. Anthropometric features also affect equilibrium. Obesity increases FR and the fear of falling [9]. Interestingly, waist-to-hip ratio (WHR) and fat mass index are also related to FR in community-dwelling seniors [10]. Obese people are more likely to suffer from reduced quality of life following a fall [11, 12].

Moreover, reduced muscle strength is one of the most important FR factors [13, 14]. The simplest method of muscle strength measurement is handgrip strength (HGS). HGS is widely used and is called "a gold standard" in diagnosing sarcopenia [15, 16]. However, as many authors suggest that body balance is associated with lower limb muscle strength [17, 18]. Curiously, authors present various correlations between HGS and lower limb muscle strength.

As mentioned earlier, FR diagnostics can be performed in static or dynamic conditions [19]. However, sometimes patient's health condition or other external factors do not make it possible to assess FR in dynamics. Therefore, it is necessary to verify which static stabilographic indices predict FR in older women.

It is worth mentioning that equilibrium disorders can also be assessed functionally. Older women are characterized by a greater tendency to fall and exhibit lower physical functional performance [20]. Functional tests provide a lot of information about the patient's functional capabilities and limitations [21], and commonly used in FR are: the Timed Up and Go test [22, 23], Functional Reach Test [24, 25], chair test [26], and modified Unterberger test [19]. This raises the question, which of the above tests is the most predictive of FR in seniors?

From the above information, it appears that there are many fall risk factors. The causes of falls include e.g. anthropometric parameters, a low level of physical activity connected with the functional tests results, or reduced muscle strength. Moreover, FR assessment should take place in a dynamic environment, not in a static one [19]. Sometimes it is impossible to assess FR during dynamic movement, so it is important to identify which static balance-related indices may be predictors of falls in the elderly. The aim of the study was to verify which parameters co-

uld be used to predict fall risk in older women. This raises the question, which anthropometric parameters can predict FR in elderly women? Can functional tests be predictors of FR? The strength of which muscle group should be taken into account in FR assessment, and which static balance-related indices may also predict FR in the elderly?

Material and Methods

The research involved women aged 65 or older, in good mental condition, who declared a low level of physical activity. Participants with a serious mental condition, communication problems, medications that might cause imbalance, diseases that cause balance disorders, advanced coronary disease, and a high cardiac risk, were excluded from this study. The research outcomes included anthropometric measurements. All participants had their height and weight measured according to the same study protocol, carried out by one person. Finally, the study consisted of 56 inactive females aged 71.77 ± 7.43 (SD). The group displayed the following values: body mass (70.43 ± 11.33 kg), height (157.60 ± 6.68 cm), and WHR (0.856 ± 0.092).

Measurements of the knee extensors (KEs) and flexors (KFs) torques, and handgrip strength (HGS) were performed. The muscle torques of the lower limbs were measured with special JBA (Zbigniew Staniak, Poland) equipment in static conditions. The above division was applied in accordance with the Maximum Voluntary Contraction (MVC) method. The measurement of the KEs and KFs was conducted in a sitting position with hip and knee joints flexed at 90°. The thighs and calves were stabilized by rollers. HGS was measured with a SH501 (Seaman Corporation) hydraulic hand dynamometer, calibrated by the manufacturer. The measurement was performed in a sitting position with the elbow flexed at 90°, the forearm in a neutral position and the wrist in 0° extension in accordance with the American Society of Hand Therapists. The mean values of three measurements were recorded.

The Timed Up and Go (TUG) test required participants to get out of a chair, walk a distance of 2.44 m, turn around, return to the chair, and get back into the starting position. The Functional Reach Test (FRT) was performed in a standing position. One upper limb was raised forward until it was level with the shoulder. The participants were asked to move to the position of maximum forward tilt. The distance between the middle finger in the starting position and the position at maximum tilt was measured. The Unterberger test was modified. It consisted of walking in place with eyes closed and upper limbs raised forward until they were level with the shoulders for 20 seconds. Lower limbs had to be raised to 45 degrees of flexion in the knee joints and 90 degrees in the hip joints. The test was positive if the participant moved, while walking, 21 cm to the front or side. The goal of the chair test was to determine how many times the participant could stand up from a chair and sit back down in 30s. The chair test was applied in accordance with the Fullerton test.

The Biodex Balance System SD (BBS) platform was used to assess postural balance. The BBS enables subjects to be tested on a stable or unstable platform on 12 levels (the most stable platform being level 12, the most unstable being level 1). Three protocols were conducted. Each of them lasted 20 seconds. The Postural Stability Test (PST) was performed on a stationary platform with eyes open (EO) and eyes closed (EC). On this basis, static stabilographic parameters – OSI (overall stability index), APSI (anterior-posterior stability index), MLSI (medial-lateral stability index) – were determined. The Fall Risk Test was also carried out with EO on an unstable platform. Due to the fact that a large proportion of the subjects were unable to perform the level 6-2 test due to imbalance, the study was conducted when the platform changed its level of instability from level 12 to level 6 (FRI12-6). High values of this index suggested high FR.

The recorded data were analysed with the use of STATISTICA (v.13) StatSoft USA. The sample size in this study was determined in a statistic way. We calculated the power of the test on level 0.8. The normality of distribution was analysed using the Shapiro-Wilk test. Backward stepwise regression analysis was performed to determine which independent variables predict FR in older women. In all models, the dependent variable was FRI12-6. The degree of prediction of FR was determined on the basis of the R2 coefficient. The percentage share of a given factor in the prediction of the risk of falls was determined according to the Doolittle method (% = rxb*). A significance level of $\alpha = 0.05$ was adopted.

The study received approval from the Senate Commission for Research Studies in Poland. All participants provided written consent. This work was supported by the Ministry of Science and Higher Education in 2020-2022 under Research Group no. 3 at Józef Pilsudski University of Physical Education in Warsaw "Motor system diagnostics in selected dysfunctions as a basis for planning the rehabilitation process".

Results

Four models were built by introducing variables that belong to a selected group of factors. The first model was built based on the anthropometric parameters: body mass, height, waist ratio, hip ratio, and age. Successive variables were removed by backward stepwise analysis. The obtained results allow FR to be predicted with an accuracy of just 32% on the basis of height and age. The results of the above analysis are shown in table 1.

The second model was built based on the knee extensor strength of the right (KEs R) and left lower (KEs L) limb, the knee flexor strength of the right (KFs R), and left (KEs L) lower limb, and the handgrip strength of the right (HGS R), and left hand (HGS L). Successive variables were removed by backward stepwise analysis. The obtained results allow FR to be predicted with an accuracy of just 20% on the basis of KEs R. The results of the above analysis are presented in table 2.

The third model was built based on UT, FRT, chair test, and TUG. Successive variables were removed by backward stepwise analysis. The obtained results allow FR to be predicted with an accuracy of just 25% on the basis of the TUG test. The results of the above analysis can be found in table 3.

The fourth model was built based on the static stability parameters with EO and EC: OSI EO, APSI EO, MLSI EO, OSI EC, APSI EC, and MLSI EC. Successive variables were removed by

Table 1. The results of the regression analysis for anthropometric factors in FR

R2 = 0.319; F(2.53) = 12.418; p < 0.00004; SE: 0.445				
	b*	**b**	**t(52)**	**p**
constant term		-3.197	-4.398	0.00005
body mass [kg]	0.392	0.018	3.436	0.0012
age [years]	0.452	0.032	3.968	0.0002

R2 – coefficient of determination; b – regression coefficient; p – probability value; SE – the standard error of estimate; b* – ß coefficient.

Table 2. The results of the regression analysis for the muscle strength of the various groups in FR

R2 = 0.195; F(1.54) = 13.08; p < 0.0007; SE: 0.479				
	b*	b	t(52)	p
constant term		0.957	5.638	0.000001
KEs R [Nm]	-0.442	-0.008	-3.617	0.0007

R2 – coefficient of determination; b – regression coefficient; p – probability value; SE – the standard error of estimate; b* – ß coefficient; KES R – knee extensor strength of the right limb.

Table 3. The results of the regression analysis for functional tests in FR

R2 = 0.255; F(1.49) = 16.78; p < 0.0002; SE: 0.458				
	b*	b	t(52)	p
constant term		-1.460	-3.220	0.002
TUG [ms]	0.505	0.912	4.096	0.0002

R2 – coefficient of determination; b – regression coefficient; p – probability value; SE – the standard error of estimate; b* – ß coefficient; UT – modified Unterberger test; TUG – Timed Up and Go test; FRT – Functional Reach Test.

Table 4. The results of the regression analysis for static stability factors in FR

R2 = 0.346; F(1.53) = 28.013; p < 0.00000; SE: 0.434				
	b*	b	t(52)	p
constant term		1.159	7.446	0.000000
MLSI EO	0.588	0.484	5.293	0.000002

R2 – coefficient of determination; b – regression coefficient; p – probability value; SE – the standard error of estimate; b* – ß coefficient; MLSI – medial-lateral stability index; EO – eyes open.

Table 5. The results of the regression analysis for static stability factors in FR

R2 = 0.589; F(4.50) = 17.881; p < 0.00000; SE: 0.354						
	b*	b	t(52)	p	Doolittle's method	
constant term		-0.824	-1.129	0.264		
body mass [kg]	0.332	0.015	3.609	0.0007	11%	
age [years]	0.212	0.015	2.094	0.041	9%	
KES R [Nm]	-0.271	-0.005	-2.784	0.008	12%	
MLSI EO [-]	0.46	0.383	4.889	0.00001	24%	

R2 – coefficient of determination; b – regression coefficient; p – probability value; SE – the standard error of estimate; b* – ß coefficient; KES P – knee extensor strength of right lower limb; MLSI EO – medial-lateral stability index with eyes open.

backward stepwise analysis. The obtained results allow FR to be predicted with an accuracy of just 39% on the basis of the medial-lateral stability index (MLSI) with eyes open. The regression results are shown in table 4.

From the above models, variables significantly influencing FR were selected. On this basis, a model consisting of the following variables was created: age, body mass, KEs R, TUG, and MLSI EO. By means of backward stepwise regression analysis using the above models, it was found that the variables that significantly influence FR in seniors were body mass, MLSI EO, KEs, and age. Moreover, it was determined to what extent the factor determines FR using the Doolittle method. The above analysis shows that these indicators may predict FR in older women in 59% of cases. It is worth mentioning that in the regression equation, about 40% of other quantities that also affect FR were not taken into account. The results of the above analysis are presented in table 5.

Discussion

In the above study, each of four models was made up of factors belonging to the following group indicators: anthropometric, muscle strength, functional tests, and static stabilographic indicators. The obtained results allow FR to be predicted with an accuracy of just 32% on the basis of height and age in the first model, 20% on the basis of KEs R in the second model, 25.5% on the basis of the TUG test, and 35% on the basis of the MLSI EO in the fourth model. In the summary model (model 5), by means of backward stepwise regression analysis using the above models, it was determined that variables that significantly influence FR in seniors (59% of cases) were body mass, age, KEs, and MLSI EO.

Equilibrium is complex motor coordination based on the interaction of many processes. Despite Lastrucci et al. [27] suggesting that it is possible to identify patients at higher FR by going through their current medical records, without adding any extra workload to that already borne by healthcare personnel, it must be determined which parameters are relevant. It should be noted that, despite the possibility of identifying patients at higher FR by going through their current medical records, this is not a substitute for functional assessment. In all models, the dependent variable was FRI12-6. FRI is a dynamic indicator of imbalances (the platform changes the degree of instability). Previous studies show that falls most often occur in motion [28]. Therefore, the FRI is the most reliable parameter in determining imbalances.

Interestingly, women are generally more likely to fall than men [29]. Moreover, the body's balance skills deteriorate because of senility-related processes [2]. Bergen et al. [30] proved that adults aged 65 and older are at a higher FR than younger ones, and effective strategies for reducing falls include a multifactorial clinical approach.

The results of the above study showed that body height and weight are some of the predictors of FR. An increased amount of fatty tissue has a negative impact on a person's health [31]. It is worth mentioning that adipose tissue does not directly affect FR. Probably, FR is associated with significant body weight and insufficient muscle strength. The previous studies showed that obesity plays a major role in FR [9, 11, 32]. Yi et al. [33] proved that obesity is associated with greater FR in females. Moreover, Ogliari et al. [34] conducted research to investigate BMI and FR associations. In their study population, aspects that were associated with falls included an older age, female sex, previous falls, and taking medication. However, they also proved that increased FR was seen in both obese and underweight people, compared with participants of normal weight. Furthermore, the association between obesity and falls was significant in younger and older groups of males and females.

The above study shows that the KEs R is probably yet another fall predictor. Low muscle strength was positively associated with FR in the elderly [14]. According to the European Working Group on Sarcopenia, handgrip strength (HGS) is the gold standard for assessing muscle strength and sarcopenia [16]. However, Alonso et al. [35] showed that there is no connection between HGS and FR. On the other hand, it has been repeatedly shown that there is a diagnostic dependence between the muscle strength of lower limbs and FR in older women [36].

Menant et al. [37] proved that lower limb strength is an effective tool in predicting functional mobility and falling. In light of the above reports, it is worth mentioning a condition called sarcopenic obesity, which is the combination of increased body mass, especially fatty tissue, and sarcopenia. Follis et al. [38] proved that sarcopenic obesity is an important fall risk factor and sarcopenic obesity-related FR was high in women both younger and older than 65.

Furthermore, when evaluation is not possible in a dynamic environment [19], it is important to identify which static balance-related indices may be used to predict equilibrium disorders. The results of the above analysis suggest that MLSI EO is also a strong FR predictor. Nitz et al. [39] tried to document changes in balance in women. They concluded that there was a significant decline in medial-lateral body balance in females between 40-60 years old. Moreover, Aoki et al. [40] proved that feedback mechanism based on body velocity information positively contributes to the falls prevention in the elderly, and medial-lateral direction could be the best predictor of FR in the elderly. Smith et al. [41] created a rehabilitation program to investigate the clinical and quantitative measures of balance in people with chronic respiratory disease. The results showed improvements with respect to medial-lateral balance control.

However, the available literature shows many more factors that can predict FR. Zhao et al. [42] conducted a study to determine risk factors and develop a scoring nomogram to predict the risk of injurious falls in older people in acute hospitals. They suggested that a history of fractures, orthostatic hypotension, sedative hypnotics, low serum albumin levels, and functional status can influence the risk of injurious falls in the elderly. They found that patients with a history of fractures were associated with a risk of after-fall re-fracture. This was probably related to a decrease in muscle strength due to limited activity. They used the ADL scale to assess patients' functional status.

Additionally, al Tehewy et al. [43] tried, among other things, to identify different predictors and characteristics of falls. Logistic regression identified independent predictors of falls, namely anemia, osteoporosis, and having fallen at least once. They suggested that an increased length of stay in hospital, connected with functional limitation, was a significant FR factor.

Conclusion

1. Coexistence of increased body height, older age, weaker knee extensor strength, and greater lateral deflections is presumably the best predictor in the case of FR in elderly women.
2. The study should be continued on a bigger group of participants and in male population.

Limitations of the study

Despite the possibility of identifying patients with increased FR based on the determination of predictors, it should be remembered that such an analysis anticipates this risk, and it is only a prediction and an indication for further, more detailed assessment.

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