HUMAN MOVEMENT
2014, vol. 15 (2), 86–92

THE PREDICTORS OF FALLS IN ADULT AND SENIOR WOMEN FROM CITIES OF LOWER SILESIA, POLAND

doi: 10.2478/humo-2014-0005

JAROSŁAW DOMARADZKI *, ZOFIA IGNASIAK, WERONIKA STODÓŁKA
University School of Physical Education, Wrocław, Poland

ABSTRACT
Purpose. Balance disorders are considered a significant problem in the elderly as they are associated with an increased incidence of falls. In effect, they can lead to numerous injuries, disability, or even death. The aim of this study was to explore the relationships between the risk of falling and various factors (morphology, socioeconomic status, physical fitness, and physical activity level) in adult and elderly women. **Methods.** The study population sample included 149 women aged 47–89 years living in the province of Lower Silesia, Poland. The women were divided into two age groups of younger (n =83, $\bar{x}_{age}$ = 59.09 years) and older (n = 66, $\bar{x}_{age}$ = 70.77 years) participants. Measures included BMI, marital status, and physical activity, physical fitness, and education levels. Statistical analysis included a chi-squared (χ^2) test, cluster analysis, logistic regression, and correspondence analysis. **Results.** BMI and physical fitness were strongly correlated with falls: the higher the BMI (overweight or obese) and the lower physical fitness, the greater the risk of falling. The remaining variables showed a weak relationship with falling. **Conclusions.** The fall risk of women who are overweight or obese or with a low physical fitness level is approximately 2.5 times higher than those with normal and healthy levels of BMI and physical fitness. The presence of both risk factors increased the likelihood of falling.

Key words: predictors of falls, fall risk, elderly women, logistic analysis, BMI

Introduction

The problem of falling in the elderly is a major geriatric syndrome. Its importance is increasing together with ever-longer life expectancy, where the phenomenon of population aging is causing societies to grow increasingly older [1, 2] and the percentage of individuals aged over 65 years of age may soon approach 15% in some countries [3].

One consequence of the aging process includes deleterious changes in the vestibular system, contributing to problems with postural balance. This has been linked to an increased incidence of falls in the elderly and can lead to numerous injuries, disability, or even death [4–7]. Other biological causes for imbalance and problems with mobility include age-related multisystemic changes with the locomotor, nervous, visual, and hearing systems [8–10]. Another important cause of falls in the elderly lies with external factors such as irregular walking surface, poor lighting, unstable furniture, or the lack of adequate stair handrails.

The significance of falls in the elderly lies with the fact that approximately 30% of individuals over the age of 65 have fallen at least once per year. Fall risk is known to increase with age, with approximately 40% of seniors over 80 years of age experienced a fall [11]. Even falls that do not cause serious injury or death are a serious matter, as they often cause mental trauma that may generate fear in performing even the most basic activities of daily living.

The literature on the subject has indicated numerous factors contributing to a fall [12–14]. Generally, they have been classified as environmental factors, task-related factors, and personal factors [15, 16]. However, despite this, the predictive value of many factors has yet to be clearly determined, with little to no evaluation performed of the relationships between various factors or interactions that may modify their influence in relation to one another. At the same time, the incidence of gait and balance disorders in the elderly is not only an individual but social problem that involves both the medical and economic spheres. As a result, identifying the risk factors for falls as well as suitable preventive measures is quickly becoming one of the primary focuses of gerontological and geriatric research. This also includes finding effective methods in improving the functioning of the elderly in terms of their mobility potential. This has given rise to a relatively young scientific discipline, gerokinesiology, whose development should be based on not only recognizing how physical activity affects various aspects of health and well-being in older age but also focus on issues in terms of organizing and promoting physical activity programs for this population [17].

Therefore, the aim of the present study was to explore the relationships (co-occurrence) of various fall risk factors (body mass index, socioeconomic status, and physical fitness and physical activity levels) in a sample of adult and elderly women. This included determining the hierarchy of the above factors in terms of their relationship with the risk of falling and quantifying the risk of falling using these factors. With this is mind, the following research questions were formulated:

1. Are there any relationships between falling and age, BMI, socio-economic status (education and marital status), and fitness level, and, if so, what are they?

* Corresponding author.

2. What is the predictive value of these factors to falling?

3. Does (and how) fall risk change depending on whether an individual is considered 'at risk'?

Answers to the above questions may help determine whether fall risk cumulatively increases from the presence of certain factors and assess the predictive power in estimating the fall risk of those factors most strongly associated with it.

Material and methods

The study was performed under the auspices of the Ministry of Science and Higher Education (Project No. N404 075337) in the fall of 2011. The research staff consisted of faculty members from the Department of Biostructure Research of the University of Physical Education in Wrocław, Poland and supervised by Professor Z. Ignasiak. The study design was approved by the Ethics Committee for Scientific Research of the University of Physical Education in Wrocław. Participants were recruited from cities in the province of Lower Silesia, Poland by announcements advertising a free health check-up to adult and elderly women. Inclusion criteria required the participants to be in good health with no medical contraindications. All tested individuals provided their written, voluntary consent to participate in the study. In total, 149 women aged 47–89 years were selected (basic descriptive statistics for age and morphology are presented in Table 1.

Analysis was performed on age, BMI, and physical capacity, which was measured by the chair stand and the 8-foot up-and-go tests included in the Senior Fitness Test [18]. In addition, lower extremity muscle strength (m. quadriceps and mm. knee flexors) was also assessed by a multi-functional diagnostic rehabilitation chair (model UPR 1A, OPIW, Poland) that measured the maximum torque (N · m) produced by knee extensor (quadriceps) and flexor muscles. This device was connected to a torque gauge sensor approved for medical use by the Central Medical Technology Center in Poland. This electronic torquemeter includes a microprocessor (maximum measurement error of 1 N · m) that is connected to computer using MOMENT software (OPIW, Poland). Participants performed the strength test three times from which the best result was selected for analysis. For all testing a single lever arm was used for torque measurement and participants were stabilized at the thighs, hips, and trunk.

A survey was administered to the participants asking whether they experienced a fall within the preceding year, how much physical exercise they performed during an average week, and socio-economic factors consisting of attained education and marital status.

All of the variables were then grouped dichotomously. For age, participants were classified as younger (below 65 years of age, *n* =83) or older (above 65 years, *n* = 66), whereas for BMI they were separated into those with normal and above-normal body mass (overweight or obese). Data collected from the survey was categorized as follows: having fallen within the past year or not, marital status as either single or in a relationship, education as having a primary or vocational education (lower) or secondary or a university education (higher), and physical fitness as either low or high.

The participants were categorized in terms of physical fitness by using cluster analysis on the collected data by adopting Ward's agglomerative method with Euclidean distances. On the basis of the four exercise tests (chair stand and 8-foot up-and-go tests and the strength measures of the m. quadriceps and mm. knee flexors) agglomerative clustering determined two physical fitness levels.

Basic descriptive statistics (mean, standard deviation – *SD*, coefficient of variation – *CV*, and minimum and maximum values) were calculated for all variables. Statistically significant differences between both clusterings were assessed using Snedecor's F distribution.

The numbers of women who did or did not experience a fall for each of the studied variables are presented as a percentage (%). Statistically significant differences were assessed using the chi-squared (χ^2) test. The risk of experiencing a fall was estimated using logistic regression by the maximum likelihood estimation method [19]. Associations between the various categories assigned to each of the variables were performed using multiple correspondence analysis [20].

Statistical significance was set at $p < 0.05$ and marked in bold in the relevant data tables.

Results

The statistical characteristics for the quantitative variables (BMI and age) are presented in Table 1. As was mentioned previously, the participants were categorized in terms of their physical fitness level. Not wishing to adopt stringent criteria on what can be classified as

Table 1. Basic descriptive statistics for BMI and age

Variable/characteristic	$\bar{x}$	*SD*	*CV*	Min	Max
Younger age group (*n* = 83) [years]	59.09	4.64	7.86	47.63	64.48
Older age group (*n* = 66) [years]	70.77	4.96	7.01	64.51	89.58
Normal BMI (*n* = 45) [kg/m^2]	22.58	1.50	6.64	19.60	24.80
Overweight/obese BMI (*n* = 104) [kg/m^2]	29.18	3.45	11.84	25.00	43.60

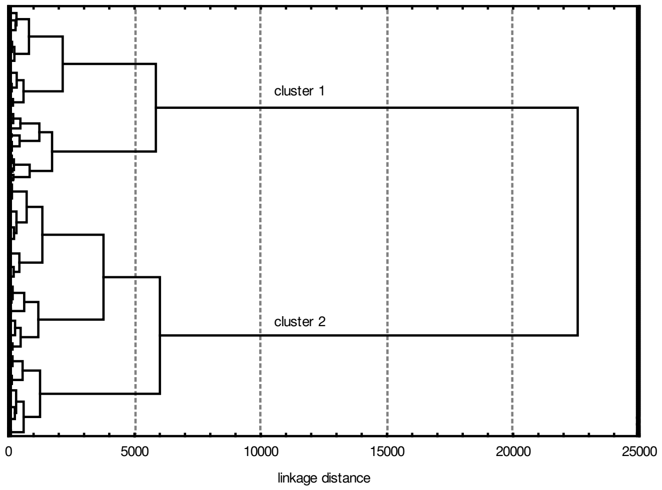


Figure 1. Results of agglomerative cluster analysis for physical fitness level (Cluster 1 – low, Cluster 2 – high)

low or high physical fitness while recognizing the four administered physical fitness tests, it was decided to adopt a multi-dimensional approach by using cluster analysis. Agglomerative clustering of the results of all four tests created two clusters (Fig. 1). The results obtained by the participants from both clusters are illustrated in Figures 2 and 3. The women in Cluster 2 were characterized by significantly better results in each of the tests compared with the women in Cluster 1 (Tab. 2). As a result, the women from Cluster 1 were treated as those with a low physical fitness level whereas Cluster 2 signified women with a high physical fitness level.

In response to the first research question, multiple correspondence analyses were performed to determine the associations of each of the categories of the analyzed factors. This helped determine the nature of the relationships between the different variables more accurately and in more dimensions than Spearman's rank correlation.

One of the primary purposes of correspondence analysis, as well as factor analysis, is to describe a large quantity of results in a reduced dataset while maintaining most of the variance. For this reason the multidimensional space of the data was first reduced to its original, statistically significant, two-way form corresponding to two dimensions (Fig. 4). Both dimensions explained 34.5% of the total inertia, of which 18.3% was the first dimension and 16.2% the second (Tab. 3). The obtained results indicated that the first two dimensions moderately represent the original data. Additional dimensions explained increasingly smaller proportions of inertia and thereby did not provide any new information.

The interdependence (association) of the individual factors (per category) is presented in Figure 4. This representation primarily illustrates the close links between

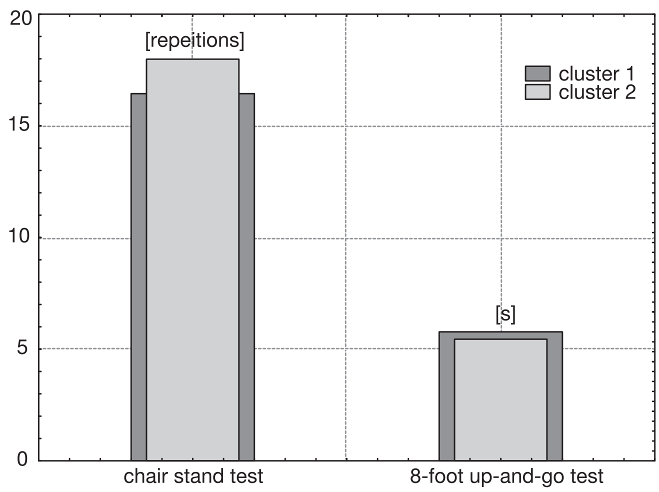


Figure 2. Mean results for the chair stand and the 8-foot up-and-go tests for each physical fitness level cluster

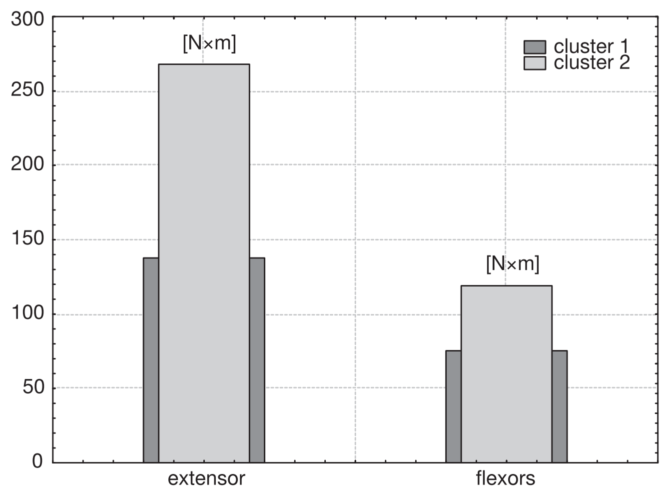
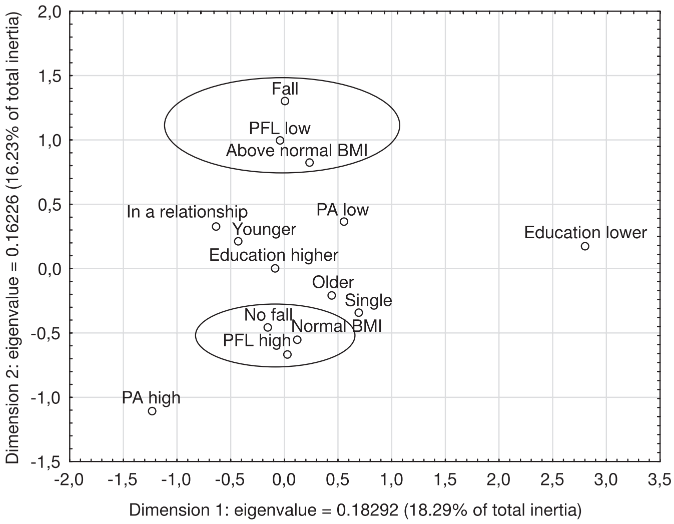


Figure 3. Mean results for lower extremity muscle strength for m. quadriceps and mm. knee flexors for each physical fitness level cluster

Table 2. Descriptive statistics for the results of the physical fitness (chair stand and the 8-foot up-and-go) and muscle strength tests (knee extensor and flexors) including Snedecor's F values and statistically significant differences between the physical fitness level clusters

Test	Cluster 1		Cluster 2		*F*	*p*
	$\bar{x}$	*SD*	$\bar{x}$	*SD*		
Chair stand [repetitions]	16.44	3.86	17.98	4.32	**22.645**	**0.000**
8-foot up-and-go [s]	5.77	1.02	5.44	0.98	**16.574**	**0.000**
Extensors [N · m]	137.70	40.02	267.95	55.22	**1217.325**	**0.000**
Flexors [N · m]	75.32	32.00	119.05	38.24	**248.475**	**0.000**



PFL – physical fitness level, PA – physical activity

Figure 4. Associations between each of the categories of the analyzed factors

falls with high BMI levels and low physical fitness. The other categories of these factors were also found to be closely linked to each other. Most of the individuals who had not fallen in the past year were slimmer and more physically fit. The remaining factors that were associated with each other were marital status and age. This result is not surprising, as younger individuals are more likely to have a partner as those who are older are more often single (widowed). The younger women were also more likely to hold a higher education. Completely unrelated with the other factors were the factor physical fitness level (high or low) and the lower education category.

The second research question was answered by assessing the statistically significant differences in the percentage of women who declared they had experienced a fall or not in the past year by those categories most strongly associated with falling. The number as well as percentage of women who did or did not experience a fall according to BMI and physical fitness level as well as the chi statistic (χ^2) is presented in Table 4.

Table 3. Eigenvalues and their proportion to total inertia and the chi statistic (χ^2) resulting from multiple correspondence analysis

No. of dimensions	Eigenvalues	Inertia [%]	χ^2
1	**18.29**	**18.29**	**161.427**
2	**16.23**	**34.52**	**143.192**
3	13.77	48.29	121.504
4	12.40	60.69	109.466
5	11.93	72.62	105.246
6	10.93	83.55	96.493
7	8.66	92.21	76.448
8	7.79	100.00	68.730

Variation in the number of women who had experienced a fall or not, for the categories of both factors, proved to be statistically significant. A significantly greater amount of falls were experienced by women with above-normal BMI or, in other words, those who were overweight or obese It was also found that significantly more falls were experienced by women with a lower physical fitness level compared with women with higher physical fitness.

The influence of factors associated with falls and the incidence of falls was assessed using logistic regression. The purpose of this type of analysis was to determine the relationship between the likelihood of experiencing a fall depending on BMI and physical fitness level. The results of regression analysis (estimating the regression parameters) are shown in Table 5, finding this model to be statistically significant.

The risk of experiencing a fall was more strongly affected by physical fitness level than BMI as evidenced by the larger regression coefficients. The positive value indicated that if the physical fitness increases then fall risk decreases, whereas for BMI this was the opposite. Here, the negative value of this factor indicated that an increase in BMI was associated with an increased fall risk of overweight and obese individuals (Tab. 5). The predictive value of physical fitness was statistically significant.

Table 4. Statistically significant differences in the percentage of women who declared having fallen by the categories for BMI and physical fitness level

	Experienced a fall	BMI		Physical fitness level	
		Normal	Overweight/Obese	High	Low
No.	No	38	73	65	45
% of columns		84.44%	70.19%	82.28%	64.29%
% of rows		34.23%	65.77%	59.09%	40.91%
No.	Yes	7	31	14	25
% of columns		15.56%	29.81%	17.72%	35.71%
% of rows		18.42%	81.58%	35.90%	64.10%
Test		χ^2 = **3.858**; p = **0.048**		χ^2 = **6.22**; p = **0.013**	

Table 5. Estimation results of the logistic regression model

Parameter	*b0* constant	BMI	Physical fitness level
Estimate	1.153	–0.849	0.925
Standard error	1.026	0.470	0.390
t(146)	1.125	–1.805	2.369
p	0.263	0.073	**0.019**
–95%CL	–0.873	–1.778	0.153
+95%CL	3.180	0.081	1.697
Wald's chi-square	1.265	3.257	5.613
p	0.261	0.071	**0.018**
Odds ratio (OR)	3.169	0.428	2.522
–95%CL	0.417	0.169	1.166
+95%CL	24.056	1.084	5.455
χ^2 = **9.841** *p* = **0.007**			

Calculation of the odds ratio (OR) for the above factors specified how many times one group was more at risk of falling than the other groups. This found that the odds ratios for both of the analyzed factors were similar, i.e. both analyzed factors posed a comparable risk of experiencing a fall. Individuals with a lower physical fitness level have a 2.5 times (OR = 2.522) greater fall risk than those with a higher physical fitness level. The risk of falling increased 2.3 times (OR = 0.428) for those overweight or obese compared with individuals with normal BMI (Tab. 5).

Discussion

Unlike other studies, the importance of age as a predictor of falls was not observed in the present investigation. Several studies have shown age to be an important factor determining fall risk [21, 22]. The reason for this disparity may stem from the heterogeneous number of women composing the younger and older groups. Another reason may be that many researchers compared a significantly older sample of women (women above the age of 65 often composed the youngest of the analyzed age groups). The results of such studies indicate that fall risk increases in successive age groups (70- and 80-year-olds). After 65 years of age more than 30% of individuals experience a fall, after 85 years this affects every second person [12, 23]. This has been confirmed by the World Health Organization, finding that indicators of disability in the world correlate with age [24]. Hence, the calculated odds ratio for a risk of falling increases with age and is highest among individuals over 80 years of age.

Many studies on the risk of falling and its consequences have treated BMI as a predictor of lower bone mineral density and thus itself a risk factor for experiencing a bone fracture and not a fall. The relationship between low BMI and osteoporosis as well as the protective function of high BMI has been well documented in a number of studies [25–27]. In this case, the estimated risk of a fracture (OR) increases in proportion to a lower value of body mass, with many of the reports indicating that BMI is a better predictor of fractures than body mass. However, some studies have indicated no relationship between BMI and falls [28]. Furthermore, Himes and Reynolds observed a high correlation between falls and BMI and the significant predictive power of this factor [29]. Their findings show that obesity increases the risk of falls and, at the same time, individuals who are overweight or obese are less prone to experience a fracture from them. In the present study, the relationship between the number of falls and BMI were statistically significant. Women who were overweight or obese were more likely to have experienced a fall. This may stem from excessive body mass, making it difficult to control movements or vertical balance, where, with a larger moment of inertia, can make it easy to lose one's balance. Unfortunately, the present study did not study the relationship between the number of falls and high BMI with the number of bone fractures, which could have provided interesting results. The present findings are consistent with those reported on an elderly population from Poznań, Poland. Osiński et al. [30] compared the somatic characteristics of individuals who had experienced a fall with those who had (as a result of a disability) and concluded that statistically lower levels of BMI were in the first group of individuals. On the other hand, other studies on a Poznań population showed that older adults with lower BMI had better dynamic balance than those who were overweight [31].

The present study found an association between falls and a low physical fitness level. Women who were more physically fit were less statistically significantly prone to experience a fall. Physical fitness is treated as part of the group of personal factors [15]. In many studies, physical fitness was assessed using various motors skill tests. However, most studies only diagnose coordination skills such as simple reaction time and eye–hand coordination. This has included evaluation the relationship between falls and vision impairment [32, 33]. Other studies have made use of specialized functional tests designed specifically for clinical trials on a geriatric population (Berg Balance Scale, Timed Up and Go test, and the Performance Oriented Mobility Assessment) [34, 35]. Nonetheless, these methods are not considered to be suitable in the evaluation of fall risk. Given the high correlations between the incidence of falls and lower extremity muscle strength and stable balance, this study attempted to combine the results of two functional tests (chair stand and the 8-foot up-and-go) included in the Senior Fitness Test with muscle torque values achieved by flexion/extension of the leg. This was performed by using cluster analysis, which agglomerated the women with better or worse physical fitness results (exercise test results) simultaneously including all of the variables.

However, this method makes comparison of the results to those of the literature very difficult. Generally, the results obtained in the present study indicating an increasing risk in individuals less physically fit are consistent with those of other authors [36, 37]. No association was found between the amount of falls with the declared amount of physical activity and the selected socio-economic factors. In the literature there is reference to a slightly larger fall risk among subsequently older people [38].

Identifying the relationships between the selected factors allowed for analysis of those categories that were associated with one another. The interdependencies between these categories may cumulatively affect fall risk and thus increase the incidence of falls of those individuals who meet several of these 'at risk' conditions. The present study suggests that those particularly vulnerable to falls are overweight or obese individuals who also have a low physical fitness level. Several studies have also indicated that certain factors in conjunction with each other increase fall risk. However, the most commonly mentioned are age and sex [39], with women more at risk with increasing age [40]. Analysis on the effects of poor physical fitness on fall risk is connected with low physical fitness and a sedentary lifestyle. The consequence of such behavior may be worse postural balance and lower levels of muscle strength [41, 42].

In summary, the results of the present study find that the most important factors that require attention when assessing fall risk are BMI and physical fitness level. Due the associations between these variables and physical fitness, the need for a physically active lifestyle among seniors is especially important, not only to maintain an adequate level of physical fitness (understood as health-related fitness) and normal body mass, but also indirectly contribute to reducing the risk of falls and therefore dangerous injuries. Additionally, the role of physical activity in slowing age-related changes in the locomotor system can also work to reduce the risk of suffering from bone fractures [43].

Conclusions

1. Close associations between three categories of the analyzed factors, experiencing a fall, excessive body mass, and a poor physical fitness, indicates the cumulative effect of these risk factors. This may lead to an increase in the danger of falling in individuals meeting several of these 'at risk' conditions. Most at risk appear to be those who are overweight or obese and in poor physical condition. The incidence of falls in the groups of women with above-normal BMI and low physical fitness levels was statistically significantly higher than in other groups.

2. Both of the above factors are associated with fractures and characterized by a high predictive value, which was statistically significant for physical fitness level.

3. Both BMI and physical fitness level were factors that had a similar fall risk in the present population, where women with a low physical fitness level and above-normal BMI were approximately 2.5 times more at risk of falling.

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Paper received by the Editors: March 27, 2014
Paper accepted for publication: June 3, 2014

Correspondence address
Jarosław Domaradzki
Katedra Biostruktury
Akademia Wychowania Fizycznego
al. I.J. Paderewskiego 35
51-612 Wrocław, Poland
e-mail: jaroslaw.domaradzki@awf.wroc.pl