Anthropological Review • Vol. 78 (3), 337–346 (2015)

Anthropological Review
Available online at: https://doi.org/10.1515/anre-2015-0026

The risk for falls in older people in the context of objective functional studies

Zofia Ignasiak[1], Anna Skrzek[2], Sławomir Kozieł[3], Teresa Sławińska[1], Paweł Posłuszny[1], Krystyna Rożek[2]

[1]Department of Physical Education, University School of Physical Education in Wrocław
[2]Department of Physiotherapy, University School of Physical Education in Wrocław
[3]Polish Academy of Sciences, Anthropology Unit in Wrocław

Abstract: Falls may occur in each ontogenesis phase, but they become more frequent in the elderly and lead to serious health consequences. Dynamic changes in senior citizens' environment and lifestyle makes studies of risk for falls necessary. To determine the relationship between the risk for falls and the objective functional and structural examination in the elderly living in Poland. The research consisted of 196 females and 61 males aged 60–88 recruited from health clinics, senior citizen centers and Universities of the Third Age between 2009–2012. Following parameters were collected: functional physical tests "30 second Chair Stand Test" and Timed Up and Go Test", the flexor muscles and knee extensors force, the bone mineral density was measured in distal radius of the forearm with the EXA – 3000, the total risk for fall assessed by 5 tests by abbreviated version of Fallscreen test. Multiple linear regression and linear correlation were used for assessment of relationship with total estimated risk for fall and other parameters. The subjects displayed significant dimorphic differences within the range of the functional parameters and bone mineral density to the advantage of males. Only in women results revealed a significant link between the risk for falls and the dynamic balance, as well as the maximum quadricep muscle force equal. Strength of the lower limb muscles seems to be critical for decreasing the risk for fall. Special programs for strengthening this part of the body for older people should be elaborate.

Key words: risk for falls, muscles strength, lower limb, bone mineral density, functional physical tests

Introduction

The 'risk for falls' issue was recognized in the second half of the last century and it has been a subject of numerous studies. The main reason for an increased interest in this problem is our prolonged life expectancy. Researchers emphasize the fact that, falls may occur in each ontogenesis phase, they become more frequent in the elderly and lead to more serious health consequences. Initially,

Original Article Received: June 20, 2015; Accepted for publication: October 12, 2015
DOI: 10.1515/anre-2015-0026

researchers were focused on determining the risk factors for falls, regarding them as environment-dependent (external factors) or resulting from health conditions and corresponding diseases – internal (biological) factors (Tinetti et al. 1986; Tinetti et al. 1988; Campbell at al. 1989; Lord et al. 1994; Richardson and Hurvitz 1995; Lord et al. 1996; Rogers and Mille 2003; Czerwiński et al. 2008). Both groups consisted of several hundred factors for falls but only a few of them (about 10) meet the requirements of Evidence Based Medicine standards (EBM) (Cummings and Newitt 1989; Perell and Nelson 2001). The most frequently reported ones include chronical diseases, sensomotoric disorders interfering with postural stability, drug (sedatives and antidepressants in particular) overuse (Thornby 1955; Studenski et al. 1991; Tinetti and Williams 1998; Leipzig et al. 1999; Błaszczyk and Czerwosz 2005; Czerwiński et al. 2006; Tinetti et al. 2006;).

The aging process leads to general muscular atrophy, which also involves the antigravity muscles of the pelvic girdle and the lower limbs, which, together with the nervous system, are responsible for body posture. As revealed in the previously cited studies, balance and postural reflexes in humans are controlled by numerous mechanisms, including the vestibular organ and the organ of sight, the proprioceptive sensory receptors located in the locomotor system and neuromuscular conduction. All of these complex processes are controlled by both the central and peripheral nervous system (Thornby 1955; Cummings and Newitt 1989; Richardson and Hurvitz 1995; Lord et al. 2003; Rogers and Mille 2003). Therefore, atrophic changes in the nervous system play a crucial role in maintaining a correct body posture and mobility. Physical activity constitutes the primary factor for the prevention of involutional changes observed in the nervous system. Hence, numerous researchers emphasize the role of physical activity and a proper selection of exercises for elder people (Carter et al. 2001; Maciaszek et al. 2002; Lord et al. 2003; Steward et al. 2005; Czerwiński et al. 2006; Kemmler et al. 2010; Toraman and Yildirim 2010; Davis et al. 2011).

Postural stability, a sense of balance and the ability to walk are obviously linked, which explains why a disorder of one of the systems causes a higher risk for a fall. Research among the elderly who have recently experienced a fall, displays the fear of a recurrent incident and a corresponding limitation of physical activity, which subsequently leads to the depreciation of the quality of life. Eventually, there is feedback between the phenomena (Tinetti et al. 2006; Bączkowicz et al. 2008; Ostrowska et al. 2008; Pijnappels at al. 2010; Tinetti and Kumar 2010; Etman et al. 2012).

Due to the dynamic changes in senior citizens' environment and lifestyle, many regularities, formerly typical for the elderly, are challenged, making further studies and analyses necessary. Also methods of determining balance and posture of the body, which have been used until now, do not meet the expectations regarding the assessment of the risk of falls. Recently, there have been model methods in use, which allows one to determine the risks for falls in the elderly in a comprehensive, but also easy and simplified way. This kind of assessment allows the correct identification of persons vulnerable to falling (Lord et al. 1994; Lord et al. 2003). The aim of this study is to expand knowledge regarding comprehensive assessment of the risk for falls and the analysis of the correlation between this assessment and the objective functional and structural examination in the elderly living in South-West Poland.

Material and Methods

The research group consisted of 257 individuals (196 females and 61 males) aged 60–88. The selected persons came from Wrocław and its precincts. The invitations for the participation in the research project were directed to health clinics, senior citizen centers and Universities of the Third Age. The criteria for joining the group included: being above 60 years of age, the ability to walk, the absence of objections against the research. The participants expressed in writing, their consent to join the program. The project had been approved by the Academy of Physical Education's Senate Commission of Ethics and Scientific Research dated 18 February 2009. The research was conducted in the Biokinetics Laboratory of the Academy of Physical Education between 2009–2012 years. Prior to the inception of the research procedure, the medical history was taken from each participant in order to collect the retrospective data on the falls concerning the preceding year. The research was large-scale and holistic in its scope (Ignasiak et al. 2012).

The functional Strength Senior Test was used for checking this factor (Rikli and Jones 2013). The lower part of the body muscle strength was tested by using the "30 second Chair Stand Test" [n], and the dynamic balance with the 'Timed Up and Go Test" [s].

The Flexor muscles and knee extensors force were measured by the multi-functional, computerized chair by NORAXON, intended for rehabilitation and diagnostics. The maximum muscle force moments of the flexor and the dominant limb knee extensors (the quadriceps femoris) were analyzed under isometric work conditions. The bone mineral density (BMD) was measured in the area of the distal radius of the forearm with the EXA – 3000. The information on the mineral bone density (g x cm^{-2}) was provided by computer measurement.

The balance tests were established with the stabilographic platform Accu Sway Plus (ACCU GAIT SYSTEM). The study referred to the assessment of the center of mass displacement area size. The study used the assessment of point of foot plane prop point (COP – Center of Pressure). The subjects had 3 trials, 30-second each with a 1-minute break between. The tests were done with the eyes open and closed. The analysis took into account an average of three trials of each test (eyes open, eyes closed) expressed in cm^2.

The complex assessment of the risk factors was based on the abbreviated version of Fallscreen tests developed by Australian team (Lord et al. 2003). The abbreviated version states the tests as follows: sensitivity to contrast (edge contrast sensitivity – the Melbourne Edge Test), prioproception, knee extension quadriceps force, reaction time – hand and balance (sway on foam with eyes open). The above- mentioned tests results constituted the foundation for the assessment of the total risk for fall which for the subject population fluctuates from –2.5 to 5.3, with the average value of 0.22, and which was used for the calculation as a dependent variable.

The study used the Statistica v. 10 program (StatSoft 2011) and the analysis consisted of the elements of descriptive statistics (average, standard deviation) taking into consideration the sex and age. The analysis was also based on Shapiro-Wilk test, which enabled the researchers to assess the normality of the subject parameters distribution. The dimorphic differences were assessed with a t-Student test on alpha level = 0.05. The assessment of the selected measurements potentially responsible for a higher risk for falls also referred to the multi-dimension linear regression where the variable was the risk for falls and the independent invariables potentially responsible for a higher risk for falls: age, strength of the lower part of the body, dynamic balance, the flexor muscles and the knee extensors force, as well as bone density and the COP area with the eyes open and closed, separately for the males and females. However, the dependencies between the analyzed parameters were assessed with Pearson's line separately for both sexes. All calculations were done in 2014 year.

Research results

For the purpose of this study the collected research results have been divided into two categories of age and sex: The females younger than 65 years of age (n=117) and the ones older than 65 years of age (n=79). A similar division was attributed to the males (n=25, n=36). However, the number in two age groups can differ because of incompleteness of data.

The muscle strength of the lower body part does not differentiate significantly between the younger males from females (however, the males display a higher strength level than their female peers). Whereas the elder male group is characterized with a significantly higher strength level compared to their female peers. Moreover, the men from both age groups presented a considerably more favorable dynamic balance level than the women (Table1).

Almost all functional parameters in both age groups reveal a significant advantage of the males compared to the females (Table 1). A similar direction of the within-the-group change was noted in the case of the maximum force moment of the flexors and knee extensors, as well as in the case of the bone density. Both sexes, however, do not present the point of net reaction ground force application (COP). The risk for falls assessed generally does not present dimorphic differences among the subjects aged less than 65 years of age. The females of more advanced age tend to display a considerably higher risk for falls compared to their male peers (Table. 1).

The regression results, which only in women reveals a significant link between the risk for falls and the dynamic balance, as well as the maximum quadricep muscle force equal with the simultaneous control of the other variables (Table 2).

The simple correlation results reveal that women are more prone to display the negative correlation between their age and the functional strength tests, knee extensors and flexor muscle force and mineral bone density. More advanced women's age is also related to the higher risk for falls (Table 3). The analysis of the significant correlation in the males displays only a gradual lessening of the bone mineral density. As age-related dynamic balance worsens, lower knee extensor force and the higher risk for falls are observed, nevertheless, the correlation force is quite low. The t males subjects presented a considerable link

Table 1. Descriptive statistics for risk of fall and functional and structural parameters

	Males			Females			
	N	mean	SD	N	mean	SD	T
Chair stands [n/30s]							
60–65 y	21	18.81	5.13	112	17.20	3.92	–1.64
>65 y	25	18.40	5.26	63	16.05	3.61	–2.40*
8–feet up–and–go [s]							
60–65 y	21	5.33	0.76	112	5.93	0.96	2.71**
>65 y	25	5.81	0.84	63	6.59	0.88	3.80***
Knee extensor [Nm]							
60–65 y	24	285.71	123.77	117	227.88	91.81	–2.64**
>65 y	30	284.00	94.17	73	194.22	86.82	–4.65***
Knee flexor [Nm]							
60–65 y	24	140.9	59.84	117	105.05	44.89	–3.36**
>65 y	30	131.1	54.64	73	91.97	37.54	–4.18***
BMD [g/cm^2]							
60–65 y	25	0.54	0.07	119	0.36	0.07	–11.17***
>65 y	37	0.50	0.09	79	0.31	0.07	–12.00***
Area of circulation with closed eyes [cm^2]							
60–65 y	25	6.20	3.50	117	4.95	3.56	–0.87
>65 y	36	6.47	4.44	79	5.43	3.11	0.69
Area of circulation with open eyes [cm^2]							
60–65 y	25	2.76	1.35	117	2.51	1.30	–1.60
>65 y	37	2.88	1.24	79	3.16	2.24	–1.45
Risk of fall							
60–65 y	25	–0.25	0.86	119	0.10	0.92	1.74
>65 y	37	0.01	1.04	79	0.66	1.21	2.81**

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Table 2. Results of multiple linear regression in males and females

	Males			Females		
	Betas	SE betas	t	Betas	SE betas	t
Age	0.099	0.175	0.56	0.145	0.086	1.70
Chair stands	0.122	0.218	0.56	0.103	0.082	1.25
8-feet up-and-go	–0.013	0.230	–0.06	0.178	0.084	2.11*
Knee extensor	–0.365	0.203	–1.80	–0.238	0.097	–2.45*
Knee flexor	0.057	0.189	0.30	0.044	0.095	0.47
BMD	–0.068	0.165	–0.41	–0.048	0.079	–0.61
Area closed eyes	0.054	0.166	0.33	–0.012	0.078	–0.16
Area open eyes	0.258	0.155	1.67	0.031	0.078	0.40
	R=0.499; R^2=0.249; F=1.49			R=0.358; R^2=0.129; F=3.00**		

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

Table 3. Matrix Pearson Moment Product Correlation for males and females. M – males, F – females

M n=45 F n= 174	1	2	3	4	5	6	7	8	9
1 Age	–	–0.24**	0.40***	–0.19*	–0.19*	–0.37***	0.14	0.10	0.26**
2 Chair stands	–0.05	–	–0.41***	0.24**	0.18*	0.04	–0.08	0.001	–0.08
3 8-ft up-and-go	0.28	–0.68***	–	–0.10	–0.08	–0.14	0.06	–0.01	0.23**
4 Knee extensor	–0.22	0.24	–0.23	–	0.61***	0.07	0.04	–0.11	–0.24**
5 Knee flexor	–0.04	0.16	–0.13	0.63***	–	0.19*	–0.04	–0.04	–0.17*
6 BMD	–0.37*	0.20	–0.08	0.15	–0.01	–	0.001	–0.05	–0.16*
7 Area closed eyes	0.09	0.10	–0.27	–0.23	–0.08	–0.001	–	0.29***	0.02
8 Area open eyes	0.08	–0.15	–0.01	–0.13	–0.12	–0.04	0.28	–	0.06
9 Risk of fall	0.22	0.001	–0.001	–0.37*	–0.19	–0.14	0.23	0.31*	–

* $p<0.05$; ** $p<0.01$; *** $p<0.001$.

between the risk for falls, the knee extensor force and a sense of balance with the eyes open. The decreasing quadricep force and the increased COP area with the eyes open, leads to an evidently higher risk for falls. The study displays, in the women, a significant correlation between the risks for falls, the dynamic balance, flexor muscles and knee extensor force and bone mineral density. The risk for falls in the females does not show the considerable correlation, only with the COP both with the eyes open and closed (Table 3).

Only two distinct correlations between the functional tests were observed in the males: the higher muscle strength of the lower body parts results in the more favorable dynamic balance level (r=–0.68); and the higher the maximum knee flexors muscle force movement is, the higher is the quadriceps force movement (r=0.63) (Table 3).

In the female group, the lower body part strength displays significant correlations with the dynamic balance (r=–0.41) and the maximum movement strength of the knee extensors and flexors (r=0.24, 0.18). As expected, in the knee joint muscles, the extensors and flexors are distinctly correlated. Furthermore, the flexors are positively correlated with bone mineral density. It should be noted that as in the males, there is no significant correlation between the functional characteristics and mineral bone density and the oscillation field of the foot plane prop.

Discussion

The risks for falls, their origin and effects, as well as the corresponding factors, have been the subject of numerous studies. However, the worsening physiological condition and subsequent chronic diseases still constitute crucial factors (Thornby 1955; Tinetti et al. 1988; Lord 2003; Błaszczyk and Czerwosz 2005; Steward et al. 2005; Bledowski at al. 2011; Skalska and Gałaś 2011). The age-triggered involutional processes of the particular organs and systems are characterized by different dynamics. Nevertheless, due to the stunning flexibility of the nervous system, the dysfunctions, especially the ones occurring in both the passive and active locomotor system, may be partly compensated. The most important, from the risk for falls- view, is the balance organ, closely related to the efficient skeletal muscle work. The balance disorders significantly restrict daily activities, simultaneously increasing the risk for falls, and frequently leading to soft tissues injuries or bones fractures. It needs to be noted that in the case of balance disorder and osteoporosis, the risk for falls increases dramatically (Rogers and Mille 2003; Stel et al. 2004; Tinetti et al. 2006; Pijnappels et al. 2010; Tinett and Kumar 2010; Etman et al. 2012). Proper balance is the result of the control of the body center of mass displacement and is regulated by the particular structures of the central nervous system, mainly the vestibular organ as well as the organ of vision, which controls the active locomotor system and (postural) antigravity muscles. The age-based weakening of the force of the postural muscles (dorsal muscles, muscles of the hips and knees) usually results in lateral destabilization, which leads to a considerable decrease of the sense of balance and effective mobility of seniors (Thornby 1955; Błaszczyk and Czerwosz 2005; Tinett and Kumar 2010; Yoon et al. 2012). Yoon et al. (2012) proved that foot plane prop change (Center of Pressure) does not reveal dimorphic differences in persons aged 21-69. This study's results are in accordance with the above-mentioned ones – the foot plane prop point did not reveal the differences between the elderly of both sexes. It might be for the fact that the centers responsible for the postural reactions are subject to the involutional changes, irrespectively of sex. Simultaneously, falls occur more often in females than the males (Cummings and Newitt 1989).

While taking into consideration the fact the research is mainly retrospective, it may be assumed that the women, whose life expectancy exceeds the one for men, may join research projects more frequently than their male peers. This study reveals the risk for falls in women older than 65 years of age, is higher than among their male peers. Seniors of a less advanced age do not present a significant dimorphic difference while assessed for a risk for falls. Simultaneously, the women compared to the men, more frequently display a considerable link between the risk for falls assessment and the subject functional parameters, as well as bone density. The lack of a distinctive correlation in the females might be due to the large-scale character of the study and a small number of research participants. It is even more puzzling, as the other researchers emphasize the positive link between the raised and properly selected physical activity of the elderly and a sense of balance and a decreasing risk for falls (Carter et al. 2001; Lord et al. 2003; Kemmler et al. 2010; Toraman and Yildirim 2010).

In the studies conducted currently, particular attention needs to be drawn to the existence of the major and dynamic changes of the environment that may link with the more severe complications in the daily mobility of senior citizens. Observed is a growing interest in the studies that take into account living conditions (independent apartment or residing in various seniors' nursing homes) (Tinetti et al. 1988; Lord et al. 1994; Lord et al. 1996; Tinetti and Williams 1998; Lord et al. 2003). The research results, however, are not unequivocal. The authors have different opinions on the questions whether the falls occur more frequently with the independent seniors or the nursing home residents. Independent seniors might be more vulnerable to balance loss and fall during their daily activities. On the other hand, the elderly looked after on a daily basis are excused from self-care, which leads to a decrease in their mobility, creating favorable conditions for falls (Tinetti et al.1988; Cummings and Newitt 1989; Tinetti and Williams 1998; Czerwiński et al. 2008).

Another issue is the method aimed at assessing various risks for falls factors. Estimating single, subsequent factors seems not to be recommended while taking into consideration that the fall is a consequence of different factors, both external and internal (biological). Due to the fact that the external factors depend on the home environment, which should respond to the senior's needs, the factors related to the functioning of the elderly body may be predicted and assessed to some extent. Therefore, it is crucial to elaborate on the risk assessment model, which takes into consideration various aspects, including sight acuity, perceptiveness, proprioreceptive sensation, maintaining balance and muscle strength of, especially, lower body parts. Not less important is the feeling of optimal life quality followed by an increased feeling of safety in daily life activities. What seems to be advisable is the application of a multi-aspect assessment tool, taking into consideration biological factors linked with the risk for falls, which basically means primarily the factors responsible for keeping balance and postural reactions, enhanced by the somatic characteristics (adipose tissue breaks a fall) and l bone mineral density check (osteopenia, osteoporosis). Such a significantly more reliable approach to the subject, will allow to extract or indicate vulnerable individuals. According to the authors, their equipment used for the risk assessment research, as well as the additional parameters – functional and structural, meet the requirements for complete assessment of a senior citizen, paying the special attention to the risk for falls (Lord et al. 2003). The known fact of co-existence of age and adverse changes in the human body resulting in the increase of the risk for falls that is also related to the sex, body building, race, lifestyle is not an excuse from further investigation, as the problem persists and influences health as well as the social and economic aspects of life (Yoshida 2007).

The results showed that strength of the lower limb muscles seems to be critical for decreasing the risk for fall. Therefore special programs for strengthening this part of the body for older people should be elaborate, as a preventive action decreasing a risk for fall and its aftermath consequences.

Acknowledgements

The research was conducted within the scope of the project of the Ministry of Science and Higher Education in Poland, no N N 404 07 5337.

Authors' contributions

All authors had their contributions to the conception and design of the work, acquisition of data, drafting the article, final approval of the version to be published. ZI 25%, AS 20%. SK 15%, TS 10%, PP 10%, KR 20%.

Declaration of conflicting interest

The authors declare that there are no conflicting interests regarding publication of this paper.

Corresponding author

Sławomir Kozieł, Polish Academy of Sciences, Anthropology Unit in Wrocław, Podwale 75, 50-449 Wrocław
e-mail address:
skoziel@antropologia.pan.pl

References

Baczkowicz D, Szczegielniak J, Proszkowiec M. 2008. Zależności między stabilnością postawy, funkcją chodu a upadkami osób w wieku podeszłym – doniesienia wstępne. Relations between postural stability, gait and falls in elderly persons – preliminary report. Ortopedia, Traumatologia, Rehabilitacja 10:473–80.

Błaszczyk JW, Czerwosz L. 2005. Stabilność posturalna w procesie starzenia. Gerontologia Polska 13(1):25–36. (in Polish)

Campbell AJ, Borrie MJ, Spears GF. 1989. Risk factors for falls in a community-based prospective study of people 70 years and older. J Gerontol 44:M112-M7.

Carter ND, Kannus P, Khan KM. 2001. Exercise in the prevention of falls in older people: a systematic literature review examining the rationale and the evidence. Sports Med 31:427–38.

Cummings SR, Nevitt MC. 1989. A hypothesis: the causes of hip fractures. J Gerontol 44:M107-M11.

Czerwiński E, Borowy P, Jasiak B. 2006. Współczesne zasady zapobiegania upadkom z wykorzystaniem rehabilitacji. Ortopedia Traumatologia Rehabilitacja 4:380–87. (in Polish)

Czerwiński E, Kumorek A, Milert A, Borowy P. 2008. Przyczyny upadków kobiet w populacji krakowskiej. Causes of falls in women in Krakow population. Ortopedia Traumatologia Rehabilitacja 10:429–40. (in Polish)

Davis JC, Marra CA, Liu-Ambrose TY. 2011. Falls-related self-efficacy is independently associated with quality-adjusted life years in older women. Age and Ageing 40:340–46.

Etman A, Wijlhuizen GJ, van Heuvelen MJ, Chorus A, Hopman-Rock M. 2012. Falls incidence underestimates the risk of fall-related injuries in older age groups: a comparison with the FARE (Falls risk by Exposure). Age and Ageing 41:190–5.

Ignasiak Z, Rożek K, Skrzek A, Sławińska T, Domaradzki J, Fugiel J, Posłuszny P. 2012. Assessment of involution changes in selected aspects of biological condition of the elderly. Studia i Monografie AWF Wrocław 109.

Kemmler W, von Stengel S, Engelke K, Häberle L, Kalender WA. 2010. Exercise effects on bone mineral density, falls, coronary risk factors, and health care costs in older women: the randomized controlled senior fitness and prevention (SEFIP) study. Arch Intern Med 170:179–85.

Leipzig RM, Cumming RG, Tinetti ME. 1999. Drugs and falls in older people: a systematic review and meta-analysis: I. Psychotropic drugs. J Am Geriatr Soc 47:30–9.

Lord SR, Castell S, Corcoran J, Dayhew J, Matters B, Shan A, et al. 2003. The effect of group exercise on physical functioning and falls in frail older people living in retirement villages: a randomized, controlled trial. J Am Geriatr Soc 51:1685–92.

Lord SR, Lloyd DG, Li SK. 1996. Sensori-motor function, gait patterns and falls in community-dwelling women. Age and Ageing 25:292–9.

Lord SR, Menz HB, Tiedemann A. 2003. A physiological profile approach to falls risk assessment and prevention. Phys Ther 83:237–52.

Lord SR, Ward JA, Williams P, Anstey KJ. 1994. Physiological factors associated with falls in older community-dwelling women. J Am Geriatr Soc 42:1110–7.

Maciaszek J, Osiński W, Stemplewski R, Salamon A, Szeklicki R. 2002. A posturography study of balance in physically active young, adult and older women. J Hum Kinet 8:69–75.

Ostrowska B, Giemza C, Wojna D, Skrzek A. 2007. Postural stability and body posture in older women: comparison between fallers and non-fallers. Ortopedia Traumatologia Rehabilitacja 10:486–95. (in Polish)

Perell KL, Nelson A, Goldman RL, Luther SL, Prieto-Lewis N, Rubenstein LZ. 2001. Fall risk assessment measures an analytic review. J Geront A Biol Sci Med Sci 56:M761-M6.

Pijnappels M, Delbaere K, Sturnieks DL, Lord SR. 2010. The association between choice stepping reaction time and falls in older adults—a path analysis model. Age and Ageing 39:99–104.

Richardson JK, Hurvitz EA. 1995. Peripheral neuropathy: a true risk factor for falls. The J Geront A Biol Sci Med Sci 50:M211-M5.

Rikli RE, Jones CJ. 2013. Senior Fitness Test Manual. Champaign, IL: Human Kinetics.

Rogers MW, Mille ML. 2003. Lateral stability and falls in older people. Exerc Sport Sci Rev 31:182–7.

Ryushi T, Kumagai K, Hayase H, Abe T, Shibuya K, Ono A. 2000. Effect of resistive knee extension training on postural control measures in middle aged and elderly persons. Journal of Physiological Anthropology and Applied Human Science 19:143–9.

Skalska A, Gałaś A. 2011. Upadki jako czynnik ryzyka pogorszenia stanu funkcjonalnego w starszym wieku. History of falls as a risk factor for functional decline in the elderly. Gerontologia Polska 19:152–9.

StatSoft Inc. 2011. STATISTICA (data analysis software system), version 10. www.statsoft.com.

Stel VS, Smit JH, Pluijm SM, Lips P. 2004. Consequences of falling in older men and women and risk factors for health service use and functional decline. Age and Ageing 33:58–65.

Stewart KJ, Bacher AC, Turner K, Lim JG, Hees PS, Shapiro EP, et al. 2005. Exercise and risk factors associated with metabolic syndrome in older adults. Am J Prev Med 28:9–18.

Studenski S, Duncan PW, Chandler J. 1991. Postural responses and effector factors in persons with unexplained falls: results and methodological issues. J Am Geriatr Soc 39:229–34.

Thornby MA. 1995Balance and falls in the frail older person: a review of the literature. Top Geriatr Rahabil 11:35–43.

Tinetti M. E., & Kumar, C. (2010). The patient who falls: "It's always a trade-off". *Journal of American Medical Association, 303*, 258–266.

Tinetti ME, Williams CS. 1998. The effect of falls and fall injuries on functioning in community-dwelling older persons. J Geront A Biol Sci Med Sci 53:M112-M9.

Tinetti ME, Williams FT, Mayewski R. 1986. Fall risk index for elderly patients based on number of chronic disabilities. Am J Med 80:429–34.

Tinetti ME, Gordon C, Sogolow E, Lapin P, Bradley EH. 2006. Fall-risk evaluation and management: challenges in adopting geriatric care practices. Gerontologist 46:717–25.

Tinetti ME, Speechley M, Ginter SF. 1988. Risk factors for falls among elderly persons living in the community. N Engl J Med 319:1701–07.

Toraman A, Yıldırım NÜ. 2010. The falling risk and physical fitness in older people. Arch Gerontol Geriat 51:222–6.

World Health Organization 2007. WHO Global Report on Falls Prevention in Older Age. Geneva: World Health Organization.

Yoon JJ, Yoon TS, Shin BM, Na EH. 2012. Factors affecting test results and standardized method in quiet standing balance evaluation. Ann Rehabil Med 36:112–8.