Predictive Model of the Risk of Fall Based on Physical Fitness Assessment in Older Adults

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ABSTRACT

Falls occurring during activities of daily living pose a major threat and are the third most common cause of death in seniors. In clinical evaluations, mostly single tests are used to assess the risk of fall. However, a complex set of tests would lead to a more comprehensive assessment of the risk of falls. The purpose of this study was to develop a predictive model of the risk of falls in older adults aimed to prevent injuries. This study involved 159 older adults (≥65, 77% women) who underwent laboratory testing consisting of questionnaires, physical tests and basic anthropometric data measurement. The data were processed by a statistical method of regression analysis, the Classification and Regression Tree. Based on the analysis a predictive model of the risk of fall for older adults was created. The most important variables for the predictive model were total % of body fat mass, Timed Up and Go Test and 2 minutes walking test. Based on the predictive model, we can design a targeted intervention program for elderly adults to prevent risk of falling, promoting well-being and increase quality of their life.

Keywords: TUG; physical tests; elderly, falling; prevention

INTRODUCTION

The older population is increasing dramatically and the number of people over 60 years is growing faster than any other age group. Quality of life in later years depends to a large degree on the ability to do the things we want to do without pain or limitations, for as long as possible. As we are living longer, it is becoming increasingly important to pay attention to our physical condition (Sherrington et al., 2017; Teng et al., 2020). Many older adults are functioning dangerously close to their maximum ability level during normal activities of daily living. Standing up from the chair, climbing stairs, are examples that often require near maximum efforts for older people who are not very physically active. On the other hand, much of the usual age-related decline in physical ability is preventable and even reversible through proper attention to our fitness levels and physical activity. Especially important is the early detection of physical daily living activities and decrease the risk of falls (Rikli, 2001).

Falls are the second leading cause of unintentional death worldwide (Gschwind et al. 2013). A fall is defined as "*an event which results in a person coming to rest inadvertently on the ground or floor or other lower level, excluding intentional change in position to rest to furniture, wall or other objects*" (WHO, 2007). The Word Health Organization (2007) claims age as a key risk factor for falls. Older adults have the highest risk of serious injury or death. This risk level may be in part due to the physical, sensory, and cognitive changes associated with ageing, in combination with environments that are not adapted for an ageing population. Falls (without or with injury) also carry a heavy quality of life impact. A growing number of older adult's fear falling and therefore limit their physical and social activities (NCOA, 2021). It may cause further physical decline, social isolation, or depression, which can lead to decreased quality of life (Salkeld et al., 2000). Many people think falls are a normal part of aging. The truth is, they're not. Most falls can be prevented—and everyone have the power to reduce the risk of falls (NCOA, 2021). Although there are recommendations to assess the risk of falls in the elderly, the tools currently used have not shown sufficiently high predictive validity in differentiation between high and low risk of falls. (Park, 2018).

Falls prevention programs based on physical activities (walking, balance training or strength training) are examples of effective strategies to offset declining strength and improve balance, thus reducing falls and promoting well-being (Senderovich & Tsai, 2020). There is robust evidence that exercise can reduce the rate of falls in older people. A systematic review from 88 trials indicates that exercise in community-dwelling older adults reduced the rate of falls by 21% (Sherrington et al., 2017). In praxis, mostly single tests related to falls risk are used. However, the complex set of tests would bring valuable variables, which lead to comprehensively assess the risk of falls. Therefore, it is crucial to develop a predictive model to identify older adults vulnerable to falls and then to design tailored preventive intervention program for the elderly.

METHOD

Based on validated studies on this topic, we have defined fitness parameters that are closely related to activities of daily living (ADL) and instrumental daily activities (IADL) (Schoene et al., 2013; Rosa et al., 2018). Tests were selected for a comprehensive assessment of physical condition, anthropometry, cognitive functions, and subjective assessment of the fear of falling.

The data used in this study were collected during an observational cross-sectional study. Participants (n=159) were tested and filled questionnaires at Faculty of Sports Studies, Masaryk University in Brno, The Czech Republic. The key was the sequence of tests. Participants started with filling three questionnaires (basic anamnesis, The Montreal Cognitive Assessment and Falls Efficacy Scale- International test) in a quiet environment to promote concentration. Physical tests took place in laboratories of Faculty. Participants started by assessing human body composition (BIA) followed balance (The Functional Reach test), mobility (Timed Up and Go Test), strength assessment (Hand grip and 30-Second Chair Stand Test) and finished with an endurance test (2-minute walking test).

The study was carried out according to the Declaration of Helsinki and was approved by Masaryk University (EKV-2021-102).

Participants Characteristics

The study involved 159 older adults (≥65,) who don´t suffer from acute or chronic diseases that would make it impossible to complete testing. Participants were recruited through snowball method specially in educational organizations for the elderly (e.g., the University of the Third Age or the Senior Academy) and in leaflets form in medical centres or homes for the elderly in Brno, Czech Republic, between February 2021 and December 2021. The Inclusion criteria were age ≥65 and self-sufficiency. The exclusion criteria were limitations for measurement o a bioimpedance device (e.g., pacemaker, epilepsy, or metal prothesis) and any health restriction which limits doing physical activities and cognitive tests. Prior to recruitment approval was obtained from an institutional research ethics committee. All participants provided written informed consent, approved by Masaryk University Faculty of Sports Studies in Brno.

Data Collection

Questionnaires

This research involved three questionnaires.

Basic anamnesis. This anamnesis contained personal information, demographic data, medication, socioeconomic status, level of physical activity and history of falls – number of falls during last year.

The Montreal Cognitive Assessment (MoCA) is a 10-minute cognitive screening tool which was validated as a highly sensitive tool for early detection of mild cognitive impairment (Nasreddine et al., 2019). MoCA accurately assesses the short-term memory, visuospatial abilities, multiple aspects of executive functions, Attention, concentration, and working memory, language and orientation to time and place (MOCA, 2022).

Falls Efficacy Scale – International (FES-I). The FES-I is a diagnostic tool for assessing the fear of falling in the elderly and consist of 16 questions participants' concerns about falling during normal day-to-day activities. The answers are evaluated in 1–4 points, where 1 means no fear of falling and, conversely, 4 points indicate great fear of falling during the implementation of the activity. Respondents can complete the FES-I themselves or with a researcher who must make sure that the respondents have a sufficient understanding of the meaning of the asked question. This diagnostic tool has been successfully translated into several languages using the methodology of Ten Step Translation Protocol. The valid translation of Falls Efficacy Scale – International for use in the Czech Republic was used for this research. (Reguli & Svobodová, 2011).

Assessment of body composition - BIA

Bioelectrical impedance analysis (BIA) is a practical and non-invasive method to assess human body composition. Initial applications of BIA at 50 kHz used whole-body measurements of resistance, derived by using surface electrodes placed on a hand and a foot (Shafer et al., 2009). For our research we used device Inbody 270 to estimate total body composition - weight, %fat mass, FM, and FFM.

Participants stood barefoot on the device's scale with the soles of their feet positioned on four metallic electrodes, held the handles in both hands making contact with metallic grip electrodes in contact with the palm and thumb, arms were fully extended and abducted approximately 20 degrees laterally., and the device collected weight. Participants waited until their weight stabilized, height, sex and age were entered into the Inbody software and participants stood still for the duration of the assessment (Brewer et al., 2021). Measurement on Inbody 270 (BIA) was conducted before physical assessments to minimize the effect of hydration status on measurements.

Assessment of physical fitness

The Functional Reach Test is used to assess balance and postural control. It is conducted using a wall meter at the height of a participant's shoulder. The participant stands so the top of the shoulder is perpendicular to the wall meter. With the participant's fist in line with the wall meter, the participant leans forward as far as possible without taking a step or losing balance. Measured is the distance of the fist between the starting point (measured when standing straight) and end point (measured when leaning forward) to give the total reach measurement. The result 25 cm and more indicates a low risk of falling (Greenberg, 2020); (Newton, 2001).

Timed Up and Go Test (TUG). Timed Up and Go test assess mobility. Result is the number of seconds required to get up from a chair, walk 2.5 meters, turn, return, and sit on the chair to the start position. The timed Up and Go Test is also a simple screening test that is a sensitive and specific measure of probability for falls among older adults. An older adult who takes ≥12 seconds to complete the TUG is at risk for falling (CDC, 2017). This test assesses the agility/dynamic balance important in tasks that needs fast movement such as getting off a bus, going to the bathroom, picking up a ringing phone and getting up to attend to something in the kitchen (Rikli, 2001).

Hand grip strength (HGS) is used for the diagnosis of frailty and sarcopenia (Sousa-Santos& Amaral, 2017). This test measured the maximum isometric strength of the hand and forearm muscles with the Takei 5401 dynamometer. Participants seated on a chair without armrests. Joints of the lower limb were approximately three-flex (90 ° -90 ° -90 °). Shoulders were in the neutral position and the elbow of the examined arm was flexed at an angle of 90 °. The opposite arm was loosely placed on the thigh (on the side of the examined arm). Hand grip strength is examined three times for each hand with a rest interval of 2 minutes between tests (a total of 6 minutes of rest and approximately 2 minutes for the testing). Non-dominant arm is tested first and then the dominant one. (Sousa-Santos& Amaral, 2017)

30-Second Chair Stand test. The Chair stand test is used for measurement of lower-body strength and endurance. The result of this test is the number of stands from a chair that can be completed in 30 seconds. Arm position is across the chest. It is needed for many tasks such as climbing stairs, standing up from a chair, getting out of a car etc. Increased ability in performing this exercise may reduce the chance of falling (Rikli, 2001). This test is used by Center for disease control and prevention as a tool which indicate a risk for falls (CDC, 2017).

2-minute walking test. The 2-minute walking test is used to assess aerobic capacity and endurance. The result is the number of full steps completed in 2 minutes. The height of raising each knee is a point between the patella and the top hip bone. The final score is the number of times the right knee reaches the right height. Usually, this test is used for assessment of aerobic endurance (Rikli, 2001).

Data Diagnostic

Mining analysis and applied non-parametric classification and regression trees (C&RT) with the „Fall" as the dependent variable was chosen for this study. The C&RT classifies the individual instances based on a simple criterion. All homogeneous instances are in precisely one leaf of the tree, while all the other instances are in a different leaf in such a way that the most homogeneous ones are together. The C&RT algorithm creates several classification trees and continuously calculates the importance of the individual variables so that the n-th observation is classified in the correct category in all trees. The result is an ordered list of variables that most often affect the correct classification, even though they might not always be present in the tree structure.

The advantage of classification trees is that no assumptions that place standard statistical methods on the data need to be met. Such as normality of data, homogeneity of variances, etc. The result is the classification of cases into individual nodes with a description of their typical predictors.

RESULTS

Characteristics of the study population

The sample consisted of 159 participants (37 men and 122 women) aged 65 to 101 years (mean age ± SD = 73.59 ± 7.39 years). 52 participants (32,70%) had experienced one or more falls in the preceding 12 months. The characteristics of the study population are shown in Table 1.

Table 1. Baseline characteristic of participants

	Participants (n=159)
Demographics	
mean age in years	73.59 (7.39)
women	122
men	37
% body fat mass	37.33 (8.37)
Mean body mass index in kg/m2	25.05 (5.96)
Falls history	
yes	52
no	107

Characteristics of analysed variables from physical fitness assessment and questionnaires

The variables selected for this study are shown in Table 2.

Table 2. Characteristic of variables from physical fitness assessment and questionnaires

	Mean	Median	Std. dev
% body fat mass	36.95	37.33	8.37
Functional Reach Test (cm)	36.27	38.20	12.68
Timed up and go test (TUG) (s)	7.51	5.50	7.34
Handgrip R (kg)	25.80	24.25	9.45
Handgrip L (kg)	24.34	23.15	8.59
Chair Stand Test (n)	13.69	14.00	4.73
2 minutes walking test (n)	77.89	85.00	32.43
MoCa test (points)	24.23	26.00	6.11
FES-I test (points)	21.78	19.00	7.01
Physical fitness (points)	6.40	7.00	1.91

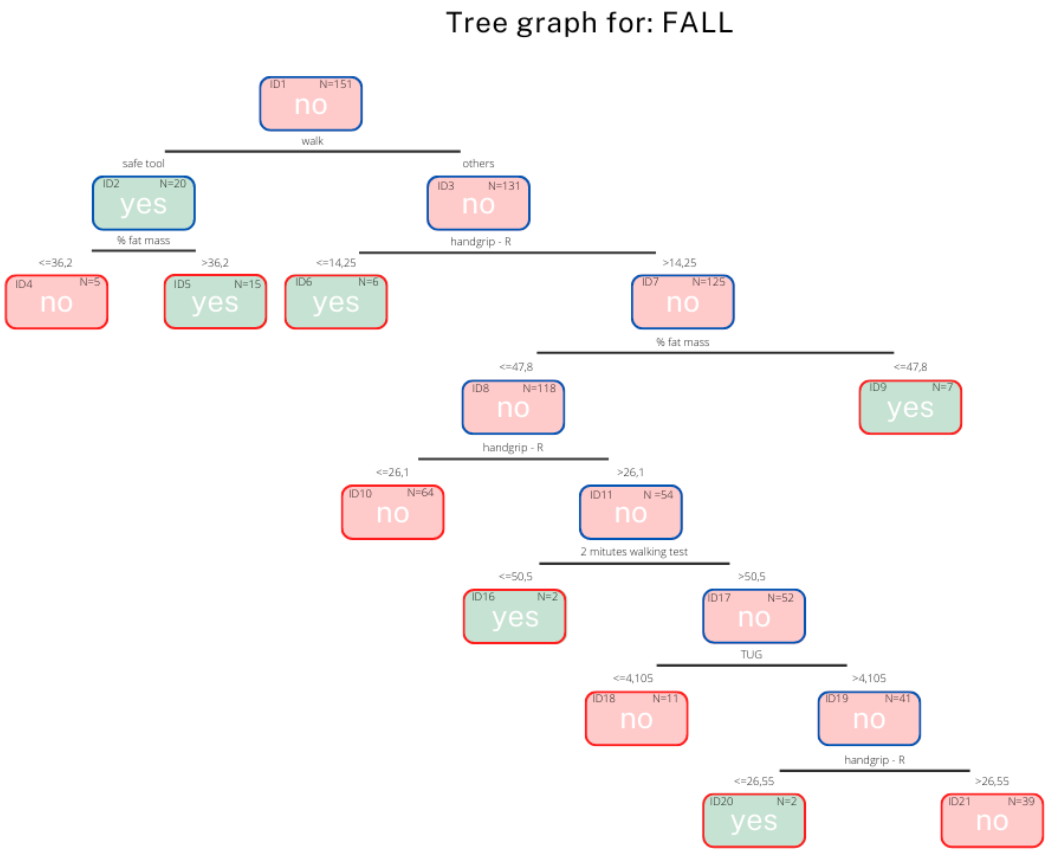

Figure 1. Resulting C&RT tree for variable fall

Results of tests are shown in Figure 1. The resulting C&RT tree describes the final division of individual cases into tree leaves. For the result, we can look at typical properties that predict the final dependent "Fall". How are the nodes where the number of falls is most characterized:

Node ID = 5: predominate in the classification "falling". There are 14 of them and it is typical for them that they walk safely with a wand, but they have a fat percentage> 36.2 % (specifically 45.5 %; which is above average)

Node ID = 6: predominate in the classification "falling". There are 5 of them and it is typical for them that they walk normally without a wand, but they have a handgrip R <47.8 (specifically 10.3, which is below average)

Predictor importants

The classification of falls is best determined by the variable "% fat" and then the test "Stand up and go" and "2 minutes walk". The variables gender, gait test and fitness do not enter the classification of falls / falls at all. Results for determined variables shows Table 3. It is a list of variables that were taken into account during the calculation of the final tree, although some of them were not ultimately included among the variables used to split the tree. Here we find the right determinants for the dependent variable - fall.

Table 3. Determined variables

	Variable rank	Importance
% body fat mass	100	1.000000
Timed up and go test (TUG	98	0.979894
2 minutes walking test	93	0.929633
Handgrip L	86	0.864965
Chair Stand Test	84	0.844345
Handgrip R	77	0.765213
Functional Reach Test	69	0.691745
Type of housing	56	0.557762
MoCa test	53	0.528888
FES-I test	39	0.390330

DISCUSSION

This an observational cross-sectional study aimed to develop a predictive model of falls prevention in older adults is based on multifactorial variables. Our findings demonstrated that the model which best predicted falls of participants comprised total body % fat mass, Timed Up and Go Test (TUG) and 2 minutes walking test**.**

Although falls can occur at any age, the frequency of falls increases with age. (CDC, 2021). The greater risk of falls in older adults is caused when changes occurring with aging (physical, perceptual and cognitive) are combined with unsuitable environment. (Palumbo et al., 2015). Cause of falls is multifactorial so for prediction of falls combination of assessment tools has to be used. A systematic review and meta-analysis by Park (2017) examined which tools for predicting the risk of falls in older adults are the best. The conclusion was that rather than a single measure, two or more assessment tools used together would better evaluate the characteristics of falls.

Study published by Palumbo et al. (2015) pointed out a predictive tool based on a small number of variables could be preferable, as their administration is generally shorter and easier. However, this objective can clash with the need to have good accuracy in prediction. The study suggests

that fall prediction is more accurate when based on multiple fall risk factors and indicators. Thus, screening tests from three to six variables are optimal in terms of predictive accuracy.

The importance of using the TUG test as a part tool for a predictive model confirm several studies (Alexandre et al., 2012; Möller & Jakobsson, 2012; Laessoe et al., 2007; Cella et al., 2020). Findings that % fat mass and 2 minutes walking test affect fall risk are innovative. Based on these tests are also defined an important fall risk factors – obesity, low level of endurance and low level of mobility. Variables such as sex, subjective assessment physical fitness, results from FES-I and MoCa questionnaires had low variable rank and importance for predictive model (Tab.2).

An important limitation of the present study was that we did not investigate the use of drugs. There is evidence that pharmaceutical interventions can lower fall risk in older adults with Parkinson disease and people with muscle weakness (Lord &Close, 2018). In addition, the limitation of this study concerns non-inclusion of measurements gait speed. Gait speed or adaptability were important predictor for fall risk in several studies (Palumbo et al., 2015; Lord &Close, 2018; Laessoeet al., 2007). Environmental variables could be seen as another limitation since it has been suggested as an important cause of falls. All measurements took place inside at Faculty of Sports studies but the influence of environmental factors and the difficulty in daily tasks performed have to be considered as well as the individual physiological factors, which is also pointed out by Brauer et al. (2000). The influence of environmental factors is captured by the questionnaire FES-I but in our predictive model reached low importance.

CONCLUSION

In conclusion, findings from this study indicate that a total body % fat mass, Timed Up and Go Test (TUG) and 2 minutes walking test are the key variables for a predictive model of risk of fall in older adults. Several studies confirm importance of TUG test as a part of predictive models. Innovative predictive variables for the risk of fall are body fat percentage and 2 minutes walking test. Based on predictive model we defined also crucial factors on risk of falls – obesity, low level of endurance and low level of mobility, which are an important for planning specific prevention or rehabilitation programs for older adults. The validity of this predictive model must be verified in future studies.

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