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Predicting the Occurrence of falls among Portuguese Community-Dwelling Adults Aged 50–60, 60–70, and 70 or Older Using the Timed Up and Go Test

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Abstract: Falls are a major cause of morbidity and mortality among older adults. While the Timed Up and Go (TUG) test has recently been identified as the best predictor of falls, it should not be used in isolation to identify individuals at risk. This study aims to develop a predictive model by combining the TUG test with other risk factors associated with falls in Portuguese community-dwelling adults aged 50–60, 60–70, and 70 years or older. A total of 403 participants aged 50 or older completed a questionnaire on demographic information and fall risk factors, underwent the TUG test, and were monitored for 12 months to record falls. ROC curve analysis demonstrated that the TUG test alone effectively distinguished fallers from non-fallers exclusively among adults aged 50–60, with a cut-off time of 6.9 seconds. Multivariate logistic regression defined three predictive models based on age groups, with ROC curve results as follows: 50–60 (AUC=0.825, cut-off=18.1), 60–70 (AUC=0.754, cut-off=17.8), and 70 or older (AUC=0.708, cut-off=24.8). These findings are clinically significant, demonstrating that the TUG test combined with a few self-reported questions can efficiently identify individuals at risk of falling in just a few minutes, without requiring specialized equipment.

Keywords: Unintentional Falls; Multifactorial Risk Factors; Community-Dwelling Adults; Timed Up and Go Test; Logistic Regression Model

1. Introduction

Falls have become a major public health concern due to their significant impact on quality of life [1] and their status as a leading cause of morbidity and mortality [2]. Identifying individuals at risk of falling is essential and requires a multifactorial assessment [1]. Early intervention relies on fall risk screening through a brief evaluation to estimate an individual's risk, allowing professionals to determine who requires a more detailed assessment [3,4].

Fall risk assessment should encompass an evaluation of fall history (HoF), fear of falling (FoF), health conditions, medication use, environmental hazards, and functional abilities, including gait, lower extremity muscle strength, balance, and

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mobility [5,6]. HoF is a significant risk factor, as older adults who have experienced one or more falls are three times more likely to fall again within the following year compared to those without a history of falls [7,8].

FoF, defined as the concern about falling, often causes individuals to avoid activities they are still capable of performing [9] and is associated with an increased risk of functional decline [10]. This decline, particularly in lower extremity muscle strength, may lead to reliance on the upper extremities for assistance when standing up from a chair (UpExt) [11]. Additionally, certain health conditions—such as hypertension, high cholesterol, osteoarthritis, osteoporosis, urinary incontinence, and vision impairment—further increase the risk of falling [12].

Medications are frequently linked to a higher likelihood of falls [13], and it is widely acknowledged that the risk of falling rises with the number of medications used, with individuals taking four or more medications (polypharmacy) being at a particularly elevated risk [14]. Moreover, significant associations have been identified between falls and the use of sedatives, hypnotics, antidepressants, and benzodiazepines [13,15,16].

The literature highlights the importance of identifying and mitigating environmental hazards [5,17]. Home environment screening has proven to be an effective intervention for individuals with a history of falls or other fall risk factors [5]. Additionally, it is well-documented that stairways are common locations for falls, representing a significant risk, especially for older adults, as these incidents are related to both the task and the environment, and are associated with severe injuries [6,18].

Several functional tests assess lower extremity muscle strength, including the 30-second sit-to-stand test [19] and gait speed measurements, such as the 10-meter walking speed test [20]. However, recent literature identifies the Timed Up and Go (TUG) test as one of the best predictors of falls [21]. TUG test evaluates dynamic balance, mobility, and lower extremity muscle strength [22]. This test involves performing basic motor tasks essential for independent living, such as standing up from and sitting down on a chair, walking a short distance, and changing direction while walking [23]. TUG test is recommended as a routine screening tool to assess gait and balance in fall risk evaluations [2,5]. Nonetheless, it should not be used in isolation to identify individuals at high risk of falling; other risk factors must also be considered [4, 24,25].

Given the diversity of risk factors to be evaluated, it is essential to establish a brief protocol that more effectively predicts the occurrence of falls. Although research on falls primarily focuses on adults ages 65 or older, individuals aged 50 or older often tend to underestimate their likelihood of experiencing a fall [26]. This study aims to develop a predictive model by combining the TUG test with other risk factors associated with falls among Portuguese community-dwelling adults aged 50 years or older.

2. Materials and Methods

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This study employed a prospective longitudinal design with a convenience sampling method. Ethical approval was obtained from the Research Ethics Committee of the Polytechnic University of Coimbra (Approval Number: 6/2017). All participants provided written informed consent prior to data collection, in accordance with the Declaration of Helsinki. The study was registered on ClinicalTrials.gov under the identifier NCT03619200. The anonymity and confidentiality of the collected data were ensured. The study was conducted exclusively for scientific purposes.

2.1 Participants

Portuguese community-dwelling adults aged 50 years or older were recruited from parish councils, physical therapy clinics, senior universities, and other community facilities. Participants were eligible for inclusion if they could stand and walk independently, with or without walking aids, and provided informed consent to participate in the study. Exclusion criteria included severe sensory impairments, such as deafness or blindness, as well as cognitive impairments. A total of 428 individuals met the eligibility criteria and consented to participate. After 25 participants dropped out during the 12-month follow-up period, the final study sample consisted of 403 individuals (mean age = 69.7 ± 10.3 years; 70% women).

2.2 Definition of Fall

In this study, a fall is defined as 'an unexpected event in which the participant comes to rest on the ground, floor, or a lower level,' excluding cases where the participant comes to rest against furniture, a wall, or another structure [2,16].

2.3 Functional Ability Assessment

The TUG test measures the time, in seconds, required to stand up from a chair, walk straight for 3 meters, turn around, return to the chair, and sit down. Participants are instructed to walk as quickly and safely as possible, using their walking aids if needed and wearing their regular footwear [23,27]. The assessments were conducted by two younger researchers with advanced training. The test is performed once, with timing starting at the instruction 'go' and stopping when the participant sits back on the chair.

2.5 Assessment of Other Variables

Participants completed a structured questionnaire that collected data on demographics (age, gender), medical conditions (e.g., hypertension, high cholesterol, osteoarthritis, osteoporosis, Parkinson's disease, urinary incontinence, vision impairment), HoF, FoF, UpExt, presence of stairs at home, and medication usage (number and pharmaceutical group). HoF within the previous 12 months was assessed through self-report with the question: 'Did you fall in the past 12 months? Yes/No.' FoF was evaluated via the question: 'Are you afraid of falling? Yes/No.' UpExt was determined by asking: 'Do you need assistance from your upper extremities to stand up from a chair? Yes/No.' The number of medications was assessed with the question: 'Do you take four or more different medications per day?' Additionally, participants' daily medications were classified by pharmaceutical group.

2.6 History of Falls After 12 Months

Participants were prospectively followed for 12 months through monthly phone calls to document fall occurrences. Fall rates were recorded from the date of inclusion until voluntary withdrawal, loss of phone contact, or the end of the follow-up period (365 days). Participants who reported at least one fall during the 12-month follow-up were classified as *fallers*, while those who reported no falls were classified as *non-fallers* [29].

2.7 Statistics

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Statistical analyses were performed using IBM SPSS software (version 28) for Windows. Descriptive statistics included mean and standard deviation for quantitative variables and frequency distributions for qualitative variables. Differences between fallers and non-fallers were analyzed using the Student's t-test for independent samples or the Chi-square test. Logistic regression analysis was conducted to develop a predictive model for falls based on functional tests and other variables.

Receiver Operating Characteristic (ROC) curve analysis was used to differentiate fallers from non-fallers. Sensitivity (the percentage of fallers correctly identified), specificity (the percentage of non-fallers correctly identified), and the area under the curve (AUC) of the model were calculated to predict falls during the follow-up period. A significance level of 0.05 was applied to all comparisons, except for the goodness of fit of the regression models, assessed using the Hosmer-Lemeshow test, where significance was defined as $p > 0.05$.

3. Results

Of the 428 individuals who met the inclusion criteria, 25 (5.8%) dropped out during the one-year follow-up period. The final sample consisted of 403 participants aged 50 to 95 years, with the following age distribution: 83 participants (20.6%) aged 50–60 years, 106 (26.3%) aged 60–70 years, and 214 (53.1%) aged 70 years or older. The most prevalent self-reported health conditions were hypertension (59.5%), high cholesterol (47.8%), osteoarthritis (46.9%), and urinary incontinence (30.5%). The characteristics of the participants are presented in Table 1.

3.1 Univariate analysis

During the one-year follow-up, 97 participants (24.1%) reported falls. The incidence of falls was 19.3% among adults aged 50–60 years (16 fallers out of 83 participants), 20.8% among adults aged 60–70 years (22 fallers out of 106 participants), and 27.6% among adults aged 70 years or older (59 fallers out of 214 participants). Significant differences were observed between fall occurrences during the 12-month follow-up period and gender (27% in women vs. 17.4% in men; p=0.039). Persons on multiple medications showed a significantly higher likelihood of falling compared to non-individuals (28.9% vs. 17.5%; p=0.009), particularly those taking benzodiazepines (34.9% vs. 19.7%; p=0.002), antidepressants (34% vs. 20.6%; p=0.008), and antihypertensives (27.1% vs. 17.4%; p=0.031). Additionally, individuals who fell during the follow-up period reported taking, on average, more medications per day (5.20 ± 3.2 vs. 4.15 ± 3.1; p=0.002). A significantly higher probability of falling was also identified in participants who reported a history of falls (HoF) in the 12 months prior to the baseline assessment (37% vs. 18.1%; p<0.001) and in those requiring upper limb assistance to rise from a chair (UpExt) (31.1% vs. 20.7%; p=0.026). (Table 1).

The factors significantly influencing fall events varied across different age groups. Among adults aged 70 years or older, falls were significantly associated only with HoF (p=0.004). In adults aged 60–70 years, significant associations were observed with benzodiazepine use (p=0.029), polypharmacy (p=0.045), number of medications per day (5.64 ± 3.2 vs. 3.69 ± 2.7, mean ± standard deviation for fallers and non-fallers, respectively; p=0.005), and UpExt (p=0.021). Among adults aged 50–60 years, significant associations were identified between falls and the number of medications per day (3.81 ± 3.4 vs. 1.85 ± 2.2, mean ± standard deviation for fallers and non-fallers, respectively; p=0.041), as well as all other factors presented in Table 1, except for the use of antihypertensive medications.

Table 1. Characteristics of individuals by fall occurrence during follow-up, stratified by age groups and for all adults aged 50 and older.

Variables	Total sample	Fallers After 12 Months							
		≥50 years (n=97)		50–60 years		60–70 years		≥70 years	
	(n=403)	(n=97)	p	(n=16)	p	(n=22)	p	(n=59)	p

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Gender			**0.039**		0.064		0.776		0.054
Male	121 (30)	21(17.4)		0 (0.0)		4 (16.7)		17 (20.2)	
Female	282(70)	76 (27.0)		16 (22.9)		18 (22.0)		42 (32.3)	
Medication									
Benzodiazepines			**0.002**		**0.012**		**0.029**		0.269
Yes	106(26.8)	37(34.9)		7 (43.8)		8 (38.1)		22 (31.9)	
No	289(73.2)	57(19.7)		9 (13.6)		14 (16.5)		34 (24.6)	
Antidepressants			**0.008**		**0.038**		0.476		0,095
Yes	94 (23.8)	32(34.0)		7 (38.9)		6 (26.1)		19 (35.8)	
No	301(76.2)	62 (20.6)		9 (14.1)		16 (19.3)		37 (24.0)	
Antihypertensive			**0.031**		0.579		0.078		0,193
Yes	255(64.6)	69 (27.1)		6 (23.1)		17 (26.6)		46 (27.9)	
No	138(34.9)	24 (17.4)		10 (17.9)		5 (12.2)		9 (22.0)	
Polypharmacy			**0.009**		**0.003**		**0.045**		0.876
Yes	232(57.6)	67 (28.9)		9 (42.9)		16 (28.1)		42 (27.3)	
No	171(42.4)	30 (17.5)		7 (11.3)		6 (12.2)		17 (28.3)	
HoF			**<0.001**		**0.003**		0.346		**0.004**
Yes	127(31.5)	47(37.0)		7 (11.3)		8 (26.7)		30 (39.5)	
No	276(68.5)	50(18.1)		9 (42.9)		14 (18.4)		29 (21.0)	
FoF			0.113		**0.016**		0.842		0.754
Yes	192(47.6)	53(27.6)		9 (36.0)		11 (21.6)		33 (28.4)	
No	211(52.4)	44(20.9)		7 (12.1)		11 (20.0)		26 (26.5)	
UpExt			**0.026**		**0.017**		**0.021**		0.910
Yes	132(32.8)	41(31.1)		7 (41.2)		9 (39.1)		25 (27.2)	
No	271(67.2)	56(20.7)		9 (13.6)		13 (15.7)		34 (27.9)	
Mobility assistive			0.800		**0.035**		1.00		0.531
Yes	51 (12.7)	13 (25.5)		2 (100)		0 (0.0)		11 (23.9)	
No	352 (87.3)	84 (23.9)		14 (17.3)		22 (21.4)		49 (28.6)	
Stairs			0.667		0.721		0.342		0.892
Yes	91 (22.6)	27 (29.7)		2 (16.7)		2 (15.4)		23 (34.8)	
No	312 (77.4)	100(32.1)		19 (26.8)		28 (30.1)		53 (35.8)	

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Values were expressed as frequency (percentage). HoF: History of fall; FoF: Fear of fall; UpExt: assistance of upper extremities to stand up from a chair. Significant result: p≤0.05

3.2 ROC Curves for TUG

ROC curve analysis was conducted to assess the ability of the TUG test to predict falls during the 12-month follow-up period. When analyzing the overall sample without age stratification, the TUG test did not demonstrate significant discriminatory ability (p=0.136). However, when applying the ROC curve to the three previously defined age groups, distinct results were observed. For the ones aged 50–60 years group, a cut-off point of 6.9 seconds was identified, yielding a sensitivity of 86.7%, specificity of 66.7%, and an AUC of 78.3%, indicating a good ability to distinguish between fallers and non-fallers (p=0.001). In contrast, for the aged 60–70 years and aged 70 or older groups, the TUG test did not show significant discriminatory ability (p=0.300 and p=0.137, respectively).

3.3 Logistic Regression

In the logistic regression analysis, the dependent variable was whether a participant experienced falls during the 12-month follow-up period (1: yes, 0: no). The independent variables included the TUG score (used for the aged 60-70 and 70 or older groups), TUG cut-off (0: TUG ≥ 6.9 seconds [risk of falling], 1: TUG < 6.9 seconds) for the aged 50-60 years group, and other variables that showed a statistically significant association with falls during the follow-up period. The outcome measures that demonstrated a statistically significant effect on the dependent variable (p < 0.05) were as follows: TUG (a), HoF (1: yes, 0: no) (b), UpExt (1: yes, 0: no) (c), and benzodiazepine use (1: yes, 0: no) (d) in all participants; TUG cut-off (e) and HoF (b) in the aged 50-60 years group; TUG (a), UpExt (c), and number of medications per day (f) in the aged 60-70 years group; and TUG (a), HoF (b), and benzodiazepine use (d) in the aged 70 or older group (Table 2).

Table 2. Factors associated with falls among community-dwelling adults aged 50 and older, identified through logistic regression.

Models	β	SE	Wald	p	OR	95% CI
≥50 years						
(a) TUG	-0.185	0.022	67.424	<0.001	0,831	0.796-0.869
(b) HoF (1)	0.848	0.263	10.382	0.001	2.335	1.394-3.911
(c) UpExt (1)	0.585	0.285	4.212	0.040	1.794	1.107-21.44
(d) Benzodiazepines (1)	0.834	0.280	8.856	0.003	2.302	1.329-3.986
50-60 years						
(e) TUG cut-off (1)	-2.528	0.832	9.234	0.002	0,080	0.016-0.408
(b) HoF (1)	1.666	0.689	5.856	0.016	5.293	1.373-20.412
Constant	-1.136	0.448	6.443	0.011	0.321	-
60-70 years						
(a) TUG	-0.173	0.072	5.806	0.016	0.841	0.731-0.968
(c) UpExt (0)	-1.345	0.468	8.245	0.004	0.261	0.104-0.653
(f) Medications/day	0.215	0.086	6.214	0.013	1.240	1.047-1.469
≥70 years						
(a) TUG	-0.056	0.027	4.444	0.035	0.945	0.897-0.996
(b) HoF (1)	1.125	0.347	10.497	0.001	3.081	1.560-6.085
(d) Benzodiazepines (1)	0.797	0.362	4.836	0.028	2.218	1.091-4.512
Constant	-1.093	0.356	9.422	0.002	0.335	-

The probability of suffering a fall, $pr(Fall)$, can then be calculated as:

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Adults aged 50 years or older $pr(Fall) = \frac{1}{1+e^{0.185(a)-0.848(b)-0.585(c)-0.834(d)}}$ (1)

Adults aged 50-60 years: $pr(Fall) = \frac{1}{1+e^{1.136+2.528(e)-1.666(b)}}$ (2)

Adults aged 60-70 years: $pr(Fall) = \frac{1}{1+e^{0.173(a)+1.345(c)-0.215(f)}}$ (3)

Adults aged 70 years or older: $pr(Fall) = \frac{1}{1+e^{1.093+0.056(a)-1.125(b)-0.797(d)}}$ (4)

3.4 Logistic Regression Models Validation – ROC curves

After defining the various models presented in Table 2, the area under the ROC curve (AUC) was used to assess their ability to accurately predict fall occurrences.In combination with the TUG cut-off, HoF emerged as the strongest self-reported question for distinguishing between fallers and non-fallers among adults aged 50–60 years (AUC = 82.5%; p < 0.001). For community-dwelling adults aged 60–70 years, the combination of UpExt and the number of medications per day with TUG proved to be the strongest (AUC = 75.4%; p < 0.001). Among adults aged 70 years or older, the model combining TUG, HoF, and benzodiazepine use demonstrated significant discriminatory ability (AUC = 70.8%; p < 0.001). However, when considering the entire group of individuals aged 50 years or older, the model combining TUG with HoF, UpExt, and benzodiazepine use exhibited only a weak ability to differentiate between fallers and non-fallers (AUC = 67.1%, p < 0.001) (Table 3).

Table 3. Comparison of the ROC curves for TUG and Logistic Regression models.

	Cut-off scores	Sensitivity (%fallers)	Specificity (%non-fallers)	AUC	95% CI	p
TUG						
≥50 years	-	-	-	54,7	48.5-60.9	0,136
50–60 years	6,9	86,7	66,7	78,3	0,66-0,91	0,001
60–70 years	-	-	-	56.8	43.9-69.8	0,300
≥70 years	-	-	-	43,4	34.6-52.1	0,137
Models						
≥50 years	26.5	69.7	61.0	67.1	60.5-73.7	<0.001
50–60 years	18.1	86.7	65.7	82.5	69.3-95.7	<0.001
60–70 years	17.8	77.3	65.1	75.4	64.7-86.1	<0.001
≥70 years	24.8	71.2	61.5	70.8	62.8-78.8	<0.001

TUG - Timed Up & Go test; AUC – Area Under the Curve; 95% CI – 95% Confidence interval

4. Discussion

According to recent evidence [2,4,6] and recommendations from reputable organizations, such as the Centers for Disease Control and Prevention (CDC) [30], the American Geriatrics Society, and the British Geriatrics Society [5], the Timed Up and Go (TUG) test is recommended as a routine screening tool for assessing gait and balance in fall risk evaluations. This recommendation is grounded in the test's minimal requirements for time, space, and material resources, as well as its ease of integration into regular clinical practice [4].

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The TUG test is strongly associated with measurements of dynamic balance, mobility, and lower extremity muscle strength [22], encompassing basic motor tasks essential for independent living, such as standing up from and sitting down on a chair, walking briskly, and changing direction while walking [6,23]. Although the TUG test is increasingly recognized as a significant predictor of falls [16,21], several studies emphasize that it should not be used as a standalone tool for identifying individuals at high risk of falling [24,25].

The National Institute for Health and Care Excellence (NICE) [2], alongside recent literature [2,4,6], advocates for a multifactorial approach to fall risk assessment and prevention. This approach encompasses factors such as HoF, self-assessment of functional ability, FoF, medication usage, home hazards, and comprehensive evaluations of gait, balance, mobility, and muscle strength. Holistic strategies incorporating these elements enable more accurate and effective fall prevention and management in older adults [4,6,16].

Given the need for fall risk screening tools to be brief, efficient, robust, and feasible, this study explored additional risk factors that can be self-reported by community-dwelling adults aged 50 years or older during fall risk screenings conducted in public spaces. Logistic regression analysis did not yield a single predictive model combining the TUG test with other risk factors. Instead, three distinct models were identified, tailored to specific age groups: 50–60, 60–70, and 70 years or older.

Although predictive models for assessing fall risk in community-dwelling older adults exist, detailed stratification by specific age groups remains limited in the current scientific literature. This study provides an innovative approach, potentially pioneering in its identification of age-specific models.

Previous research on this topic has faced limitations, including small and heterogeneous samples confined to specific age ranges [16,25,31]. This study highlights the importance of age-adjusted fall risk screening, particularly to prevent both first-time and recurrent falls in community-dwelling adults.

The findings have significant practical implications, emphasizing the need for nuanced approaches to predict fall risk accurately across different age groups. The TUG test, when combined with a few self-reported questions, requires minimal time to administer and does not rely on specialized equipment or advanced professional skills. This makes it a practical, efficient, and accessible method for assessing fall risk and implementing preventative strategies in community settings.

For adults aged 50–60 years, the combination of the TUG test with self-reported HoF demonstrated excellent predictive accuracy, reinforcing the importance of prioritizing fall histories in younger adults. This simple self-reported question significantly enhances the identification of individuals at risk, enabling timely preventative measures.

For adults aged 60–70 years, the inclusion of assistance need of upper extremities to stand up from a chair and the number of daily medications alongside the TUG test proved particularly effective. This finding highlights the interplay between physical functionality and polypharmacy in fall risk, as stated in previous studies [28,32] indicating that clinicians should focus on medication reviews and functional assessments in this age group.

For adults aged 70 years or older, benzodiazepine use was most strongly associated with fall risk. Incorporating this factor into the model underscores the compounded risk posed by sedative medications, as reported in other studies [13,15,16,9] and highlights the need for a multidisciplinary approach that encompasses medication management, fall history, and mobility-focused interventions tailored to older adults.

When evaluating the entire population aged 50 years or older, the model's weaker discriminatory ability reinforces the importance of age-specific stratification for effective fall risk assessment. As noted in previous studies, a one-size-fits-all approach may dilute predictive accuracy [33,34]. It is therefore essential for healthcare providers to adopt tailored models that account for age-related differences in risk factors [35].

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These findings offer a practical framework for stratifying fall risk and adapting interventions to the unique needs of different age groups. Furthermore, they highlight the importance of incorporating this knowledge into patient-focused materials, such as leaflets and brochures, as these are effective mediums [2] for raising self-awareness about modifiable risk factors that emerge throughout the lifespan.

5. Conclusions

In conclusion, the TUG test remains a valuable and practical tool for fall risk screening in older adults due to its minimal resource requirements and straightforward implementation. Its ability to assess dynamic balance, mobility, and muscle strength underscores its role as a significant predictor of falls. However, relying solely on the TUG test is insufficient. Comprehensive, multifactorial strategies that incorporate various factors are essential for accurate fall risk assessment.

This study identified several factors contributing to fall risk screening and emphasized the importance of age-adjusted assessments. Distinct models were developed for community-dwelling adults aged 50 and older, reflecting the varied risk factors across age groups. Specifically, the number of medications and the self-reported ability to stand up from a chair without assistance from the upper extremities were significant for adults aged 60–70 years. For adults aged 70 years or older, benzodiazepine use emerged as a critical factor. In adults aged 50–60 years, the combination of the TUG test and a history of falls in the previous 12 months was most predictive.

Integrating the TUG test with a few self-reported questions offers a robust and feasible method for fall risk assessment. This approach not only facilitates risk identification but also provides an opportunity to educate adults aged 50 and older about their fall risk and the factors contributing to it across the lifespan. Consequently, the findings of this study can support the implementation of efficient, community-based fall prevention programs.

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Data Availability Statement: The data presented in this study are available on request from the corresponding author (the data are not publicly available due to privacy restrictions).

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