



Article

Functional Classification Framework Associated with Fall and Frailty Vulnerability in Community-Dwelling Adults Aged 50 Years and Older

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Abstract

Background: Early identification of fall and frailty risk is essential for preventing disability and maintaining functional independence in older adults. Although simple functional assessments are widely used in community settings, their combined application as a classification approach in large real-world populations remains limited. **Methods:** This cross-sectional study included 2979 community-dwelling adults (67.6 ± 8.3 years) enrolled in a municipal physical activity program. Participants underwent standardized assessments of gait speed, handgrip strength, and balance. A composite fall/frailty risk classification was defined using established functional cut-offs. Associations between functional variables and risk classification were examined using correlation analyses and group comparisons. **Results:** Overall, 45% of participants were classified as high risk. Women showed a higher prevalence compared to men (47% vs. 35%). Lower gait speed ($r = -0.56$), reduced handgrip strength ($r = -0.32$), and shorter balance time ($r = -0.47$) were significantly associated with higher risk classification (all $p < 0.001$). **Conclusions:** Functional performance measures are strongly associated with a composite classification of fall and frailty risk. These findings support the use of simple, scalable screening tools in community and primary care settings to identify vulnerable older adults and inform early intervention strategies.



Academic Editors: Weida Lyu and Shangjun Liu

Received: 23 April 2026

Revised: 25 June 2026

Accepted: 3 July 2026

Published: 8 July 2026

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Keywords: frailty; falls; gait speed; handgrip strength; balance; aging

1. Introduction

Falls constitute one of the most pressing public health challenges facing aging populations worldwide. Recent systematic reviews and meta-analyses indicate that approximately 20–30% of community-dwelling adults aged 60 years and older experience at least one fall annually, resulting in substantial morbidity, mortality, and healthcare costs exceeding hundreds of billions of dollars globally each year [1,2]. These events frequently lead to fractures, hospitalization, loss of independence, and psychological consequences such as fear of falling, which further restricts mobility and quality of life [3]. International guidelines underscore the need for scalable prevention strategies targeting modifiable risk factors, including gait impairments, muscle weakness, and balance deficits.

Frailty, a state of increased vulnerability to adverse health outcomes, is closely intertwined with fall risk in older adults. Population-based studies report frailty prevalence ranging from 10–25% in community settings, with prefrailty affecting up to 50% of individuals, both conditions strongly predicting falls, disability, and mortality [4,5]. Frailty arises from multisystem physiological decline, manifesting as reduced muscle strength, slow gait, and diminished resilience to stressors. Longitudinal evidence confirms that frail older adults face a two- to threefold higher risk of recurrent falls compared to robust peers, amplifying healthcare utilization and institutionalization rates [6]. Recent research emphasizes frailty as a modifiable target through lifestyle interventions, highlighting the importance of early detection using validated phenotypic or deficit-accumulation models.

In Latin America, the burden of falls and frailty is particularly pronounced due to rapid population aging and socioeconomic disparities. National surveys in Brazil and Chile reveal frailty prevalence of 15.6% and 12.6%, respectively, often exceeding rates observed in high-income countries, with women and the oldest-old disproportionately affected [4,7]. Brazilian studies consistently document fall prevalence around 27%, linked to multimorbidity, low physical activity, and limited access to preventive services [8]. These conditions exacerbate functional decline, reduce quality of life, and strain under-resourced health systems. Regional evidence underscores the urgent need for context-specific screening tools that can be implemented in community programs and primary care.

Early identification of fall and frailty risk through simple, low-cost functional assessments has emerged as a cornerstone of preventive geriatrics. Contemporary guidelines advocate for routine screening in community-dwelling older adults using performance-based measures that require minimal equipment and training [1,9]. Such tools enable scalable risk stratification in real-world settings, including municipal physical activity programs, where large cohorts can be efficiently evaluated. Evidence from recent umbrella reviews demonstrates that combining mobility, strength, and balance tests improves accuracy compared to single-domain assessments [6]. These approaches facilitate timely referrals to multicomponent interventions, including exercise, environmental modifications, and education. By integrating functional screening into routine practice, healthcare systems can reduce the incidence of adverse outcomes and support prolonged independence.

Gait speed has been widely recognized as a “functional vital sign” and robust predictor of falls, frailty, and overall health decline in older adults. Multiple prospective studies and meta-analyses confirm that slower usual gait speed (<1.0 m/s) is independently associated with increased fall risk, disability, and mortality, integrating contributions from cardiovascular, musculoskeletal, and neurological systems [10,11]. Recent longitudinal

research further shows that gait speed outperforms composite frailty indices in identifying incident disability and provides actionable thresholds for clinical decision-making [9]. In community settings, the 6-m or 4-m walking test offers high reliability and sensitivity for risk stratification. Interventions targeting gait improvements through balance and strength training have demonstrated meaningful reductions in fall rates.

Handgrip strength serves as a reliable surrogate marker of overall muscle strength and a core component of frailty and sarcopenia diagnostic criteria. Low handgrip strength consistently is associated with incident falls, hospitalization, and all-cause mortality across diverse older populations [12,13]. Recent cohort studies and meta-analyses indicate that each kilogram decrease in grip strength elevates fall risk by approximately 5–10%, particularly when combined with impaired balance or slow gait [14]. Handgrip dynamometry is quick, inexpensive, and feasible in community and clinical environments, making it ideal for large-scale screening. Evidence supports sex- and age-specific cut-offs to enhance diagnostic accuracy. Interventions that improve muscle strength, such as resistance training, have been shown to reverse low grip strength and reduce adverse geriatric outcomes.

Static and dynamic balance performance reflects the integration of sensory, motor, and cognitive systems essential for postural control and fall prevention. Poor performance on standardized balance tests, such as single-leg stance or tandem stand, is strongly associated with increased fall risk and frailty progression in community-dwelling older adults [3]. Recent longitudinal studies have demonstrated that reduced balance maintenance time is associated with an increased risk of falls over follow-up periods of 6 to 12 months. Specifically, shorter time in static balance tests has been shown to predict future falls in community-dwelling older adults, supporting its use as a clinically relevant functional indicator [15]. Balance impairments often precede overt mobility decline and are modifiable through targeted exercise programs. Systematic reviews confirm that balance training yields the largest effect sizes for fall reduction among exercise modalities. Routine inclusion of simple balance assessments in community screening protocols therefore enables precise identification of at-risk individuals and supports personalized interventions to preserve postural stability and independence.

Despite the well-established prognostic value of individual functional measures such as gait speed and handgrip strength, evidence integrating multiple domains of physical performance into a single, scalable classification approach remains limited [16]. Most existing studies have examined these measures in isolation or in pairwise combinations, primarily in clinical or high-income settings, rather than within large community-based populations. Moreover, the inclusion of balance alongside strength and mobility in simplified composite frameworks has been less frequently explored, particularly in Latin American contexts. As a result, there is a gap in the literature regarding pragmatic, large-scale approaches that integrate these functional domains into feasible screening strategies for real-world municipal programs [17,18].

The present cross-sectional study addresses this gap by analyzing data from 2979 community-dwelling adults (mean age 67.6 ± 8.3 years, 90% women) enrolled in a long-standing municipal physical activity program in São Caetano do Sul, Brazil. Overall, 45% of participants were classified as high risk, with women showing higher prevalence (47% vs. 35% in men). Mean dominant handgrip strength was 25.9 ± 6.8 kg, habitual gait speed 1.11 ± 0.20 m/s, and median balance time 30 s (IQR 13.1–30.0). Lower performance in all three tests was significantly associated with higher risk classification: gait speed ($r = -0.564$), balance time ($r = -0.471$), and handgrip strength ($r = -0.322$), all $p < 0.001$. Functional performance measures were examined in relation to the composite fall/frailty risk classification, including adjusted models controlling for age, sex, and BMI. This study

aimed to estimate high-risk prevalence and examine associations, hypothesizing strong links that support scalable screening in community settings.

The present classification should be interpreted as a pragmatic functional screening framework rather than a validated diagnostic or prognostic model. Because the classification was constructed using the same functional domains evaluated in the analyses, the objective was not to establish independent prediction of falls or frailty, but rather to explore the internal consistency and practical applicability of a multidomain functional screening approach for community settings.

2. Materials and Methods

2.1. Study Design

This cross-sectional study was conducted using data from a long-standing community-based physical activity program developed by the Centro de Estudos do Laboratório de Aptidão Física de São Caetano do Sul (CELAFISCS), Brazil.

2.2. Participants

A total of 2979 community-dwelling adults aged ≥ 50 years were included. Participants were enrolled in a municipal physical activity program and were considered eligible if they were able to perform the functional assessments and provided informed consent.

2.3. Functional Assessments

Handgrip strength was assessed using a calibrated Jamar dynamometer, with the participant seated, shoulder adducted, elbow flexed at 90° , and the highest value of two trials (with 1-min rest between trials) of the dominant hand used for analysis. Low handgrip strength was defined using sex-specific cut-offs according to the revised European Working Group on Sarcopenia in Older People (EWGSOP2) criteria: <27 kg for men and <16 kg for women [19].

Gait speed was measured using a standardized 6-m walking test, including acceleration and deceleration phases, with the central section timed.

Balance was assessed using a standardized static balance test with a maximum duration of 30 s.

Participants were classified as high risk if they presented abnormal values in at least two of the three functional tests. The specific cut-offs were as follows:

- Handgrip strength: <27 kg for men and <16 kg for women [19].
- Gait speed: <1.0 m/s (measured over the central 4 m of a 6-m walk).
- Static balance: failure to maintain the position for the full 30 s (<30 s).

This pragmatic “ ≥ 2 abnormal tests” approach was selected because it is simple, clinically feasible, and consistent with multidomain frailty screening strategies used in community settings. The proposed classification framework was developed as a practical multidomain screening tool based on commonly used functional indicators. It was not intended to represent an externally validated measure of fall or frailty risk and should therefore be interpreted as an operational classification framework for identifying functional vulnerability. Consequently, the framework should be viewed as a pragmatic screening approach rather than a diagnostic or prognostic model of falls or frailty.

2.4. Statistical Analysis

Descriptive statistics were calculated for all variables. Differences between groups were assessed using independent *t*-tests and chi-square tests. Associations between functional variables and the composite risk classification were examined using Pearson correlation coefficients for normally distributed variables and Spearman’s rank correlation

for balance time due to the non-normal distribution and potential ceiling effect of the 30-s balance test. Given that the functional variables were used to define the composite classification, analyses were interpreted as associations within a classification framework rather than as evidence of external validation, independent prediction, or causal relationships.

To assess the independent association of each functional measure with high fall/frailty risk, we performed multivariable logistic regression models. The composite high-risk classification (yes/no) was the dependent variable. Gait speed, handgrip strength, and balance time were included as continuous independent variables. Models were adjusted for age (continuous), sex (male/female), and BMI (continuous). Odds ratios (OR) with 95% confidence intervals are reported. All analyses were performed in R version 4.2 (R Foundation for Statistical Computing, Vienna, Austria), with a significance level set at $p < 0.05$ (two-tailed).

Sex-stratified analyses were performed as supplementary analyses due to the strong imbalance in the sample (90% women). Sensitivity analyses were conducted using dichotomized balance time (<30 s vs. 30 s) to address the ceiling effect.

3. Results

3.1. Participant Characteristics

A total of 2979 participants were included (mean age 67.6 ± 8.3 years), with 90% women. Overall, 45% were classified as high risk (Table 1).

Table 1. Descriptive Characteristics of the Study Population ($n = 2979$).

Domain	Variable	Value
Demographic	Age (years)	67.6 ± 8.3
Anthropometric	Height (cm)	156.9 ± 6.4
	Body mass (kg)	67.5 ± 12.0
	BMI (kg/m^2)	27.6 ± 4.4
Muscle strength	Handgrip, dominant (kg)	25.9 ± 6.8
Mobility	Gait speed (m/s)	1.11 ± 0.20
Balance	Balance time (s)	$30.0 (13.1\text{--}30.0)$
Fall/Frailty status	High-risk classification	45%

Women presented a higher prevalence of high risk compared to men (47% vs. 35%). Men showed significantly higher handgrip strength and gait speed ($p < 0.001$), while no differences were observed in balance performance (Table 2).

Table 2. Mean Functional Performance by Sex.

Variable	Men ($n = 298$)	Women ($n = 2681$)	p -Value
Age (years)	68.9 ± 7.9	67.3 ± 8.3	
Body mass index (kg/m^2)	26.3 ± 3.9	27.7 ± 4.4	
Dominant handgrip strength (kg)	37.0 ± 7.6	24.6 ± 5.7	<0.001
Gait speed (m/s)	1.1 ± 0.21	1.1 ± 0.2	0.0001
Balance time (s)	21.7 ± 10.8	22.2 ± 11.0	0.429
High fall/frailty risk (%)	35.0%	47.0%	

All functional variables were significantly associated with risk classification. Lower gait speed ($r = -0.56$), handgrip strength ($r = -0.32$), and balance time ($r = -0.47$) were associated with higher risk ($p < 0.001$).

All functional variables were significantly associated with the composite high-risk classification. Lower gait speed (Pearson's $r = -0.564$), handgrip strength (Pearson's

$r = -0.322$), and balance time (Spearman's $\rho = -0.471$) were associated with higher risk (all $p < 0.001$) (Table 3). Due to the non-normal distribution and ceiling effect of the 30-s static balance test, Spearman's rank correlation was used for this variable.

Table 3. Correlations with Fall/Frailty Risk.

Variable	Correlation Coefficient	<i>p</i> -Value
Age (years)	0.285	<0.001
Body mass index (kg/m ²)	0.085	<0.001
Dominant handgrip strength (kg)	−0.322	<0.001
Gait speed (m/s)	−0.564	<0.001
Balance time (s)	−0.471	<0.001

Note. Pearson correlation coefficients were used for age, BMI, gait speed, and handgrip strength. Spearman's rank correlation was used for balance time due to non-normal distribution and potential ceiling effects.

Sixty-eight percent of participants reached the maximum 30 s in the balance test, confirming a substantial ceiling effect.

3.2. Multivariable Logistic Regression

In the multivariable logistic regression model adjusted for age, sex, and BMI, lower gait speed, handgrip strength, and balance time remained strongly and independently associated with higher odds of being classified as high fall/frailty risk (Table 4). Each 0.1 m/s decrease in gait speed was associated with markedly higher odds of high risk. Similarly, each kilogram decrease in handgrip strength and each second decrease in balance time were independently associated with increased risk. Female sex and older age were also significantly associated with higher risk, while BMI showed a small but statistically significant association.

Table 4. Multivariable logistic regression for high fall/frailty risk ($n = 2979$).

Variable	Adjusted OR	95% CI	<i>p</i> -Value
Gait speed (m/s)	0.010	0.007–0.014	<0.001
Handgrip strength (kg)	0.937	0.925–0.949	<0.001
Balance time (s)	0.928	0.919–0.937	<0.001
Age (years)	1.041	1.029–1.053	<0.001
Female sex (vs. male)	1.51	1.11–2.04	0.009
BMI (kg/m ²)	1.032	1.012–1.053	0.002

Model adjusted for all variables shown. OR = Odds Ratio; CI = Confidence Interval. Gait speed, handgrip strength and balance time were entered as continuous variables. Sex was coded as 1 (female) and 0 (male).

Functional performance was significantly better in the low-risk group compared to the high-risk group across all three measures (Table 5).

Table 5. Functional performance according to high-risk classification.

Variable	Low Risk ($n = 1638$) *	High Risk ($n = 1341$) *	<i>p</i> -Value
Gait speed (m/s)	1.18 ± 0.18	1.02 ± 0.20	<0.001
Handgrip strength (kg)	27.4 ± 6.8	23.7 ± 6.1	<0.001
Balance time (s)	26.8 (20.5–30.0)	13.4 (7.8–22.1)	<0.001

* Low- and high-risk groups were defined according to the composite fall/frailty classification: participants presenting abnormal values in at least two of the three functional tests (handgrip strength, gait speed, and static balance) were classified as high risk.

4. Discussion

The present study examined associations between functional performance measures and a composite classification of high fall/frailty risk in 2979 community-dwelling older

adults participating in a municipal physical activity program in São Caetano do Sul, Brazil. Strong inverse associations were observed: gait speed ($r = -0.564$; adjusted OR = 0.010), balance time ($r = -0.471$; adjusted OR = 0.928), and handgrip strength ($r = -0.322$; adjusted OR = 0.937), all $p < 0.001$. Overall, 45% of participants were classified as high risk, with women showing higher prevalence (47% vs. 35% in men). These results align with recent Latin American evidence reporting frailty prevalence of 15.6% in Brazil and 12.6% in Chile [4,5], underscoring the value of combining simple mobility, strength, and balance tests for risk stratification in real-world community settings.

The adjusted logistic regression analyses should be interpreted as complementary assessments of association within the proposed classification framework rather than as evidence of external predictive validity, given that the functional variables contributed to the construction of the composite classification itself.

Gait speed demonstrated the strongest inverse association with the high-risk classification. This finding is consistent with high-quality longitudinal evidence showing that low gait speed (≤ 0.8 m/s) is strongly associated with incident disability in basic and instrumental activities of daily living [10]. In the current cohort, the substantial negative correlation reinforces gait speed as an integrative marker of physiological reserve. An umbrella review of fall prediction instruments further confirms gait speed as one of the most consistent and clinically useful tools across community settings [9]. These results extend prior evidence to a large Brazilian municipal program, supporting the 6-m walking test as a feasible, low-cost screening tool in Latin American public health contexts [14].

Handgrip strength also emerged as significantly associated with lower odds of high-risk classification in the adjusted model. Recent cohort studies demonstrate that lower handgrip strength is associated with aging-related biomarkers, including leukocyte count, neutrophil/lymphocyte ratio, and erythrocyte sedimentation rate [20]. In the present predominantly female sample (mean dominant handgrip 25.9 kg), even modest reductions contributed meaningfully to risk classification. These findings support the inclusion of handgrip dynamometry in routine community screening to guide resistance training interventions.

Balance performance showed a moderate-to-strong association with the composite high-risk classification after adjustment for age, sex, and BMI. Recent longitudinal data indicate that shorter maintenance time in static balance tests is associated with increased fall risk within 6 months [15]. Despite similar mean balance times between sexes, poorer performance was significantly linked to higher risk classification. Systematic syntheses confirm that balance impairments are among the earliest detectable functional deficits and respond well to targeted training [3].

Women exhibited a higher prevalence of high-risk classification, primarily driven by lower handgrip strength and slightly slower gait speed. This pattern aligns with national Brazilian data from the ELSI-Brazil survey, where frailty levels were consistently higher in women and increased with age [5]. Regional studies further document greater functional vulnerability among older Latin American women [4]. Given that 90% of the sample were women, results should be interpreted with caution when generalizing to male populations.

Age and BMI demonstrated weaker associations with risk classification after adjustment compared to the functional measures. This is consistent with evidence that performance-based indicators more accurately reflect physiological reserve than anthropometric variables alone [10]. The superior discriminatory power of the three functional tests in the present sample (mean BMI 27.6 kg/m²) underscores their pragmatic advantage for scalable screening in resource-limited settings [6].

From a physiological perspective, the combined assessment of gait speed, handgrip strength, and balance reflects the integration of neuromuscular coordination, sensory

processing, cardiorespiratory capacity, and cognitive function. Recent umbrella reviews of fall risk factors emphasize that mobility and strength impairments represent the most consistent and modifiable contributors to falls in community-dwelling older adults [6]. In Latin American contexts with limited access to comprehensive geriatric evaluation, this simple three-test composite offers a feasible, evidence-based strategy for risk identification.

Taken together, the findings of this large cross-sectional study indicate that gait speed, handgrip strength, and balance time are strongly associated with a composite fall/frailty risk classification and represent practical tools for community screening. The study benefits from its substantial sample size and standardized, low-cost assessments aligned with current geriatric guidelines. However, several limitations should be considered. A major methodological limitation is that the composite classification framework was derived from the same functional variables subsequently examined in the association analyses. Therefore, the observed associations and adjusted regression estimates primarily reflect internal consistency within the proposed framework and should not be interpreted as evidence of independent predictive validity. Future studies should evaluate the external validity of this approach using independent outcomes such as prospective falls, clinically diagnosed frailty, disability, hospitalization, or mortality.

The cross-sectional design precludes causal inference. The sample was composed predominantly of women (90%) and recruited from a physical activity program, which likely selected more active individuals and may have underestimated the true prevalence of high risk in the general older population. Furthermore, information on previous falls, medication use, cognitive status, and environmental factors was not available. Future longitudinal research is needed to validate the longitudinal applicability of this composite approach and to explore sex-specific intervention strategies.

5. Conclusions

This multidimensional framework may provide a practical approach for functional screening in real-world community settings. The findings support the potential value of these low-cost and scalable functional assessments as components of a multidomain screening framework for identifying functional vulnerability among community-dwelling adults aged 50 years and older.

However, because the proposed classification framework was derived from the same functional variables used in the association analyses, the findings should be interpreted as evidence of internal consistency rather than independent predictive validity. External validation using independent outcomes such as prospective falls, clinically diagnosed frailty, disability, hospitalization, or mortality is required before the framework can be considered a validated fall- or frailty-risk classification tool.

Given the high proportion of women in the sample and the cross-sectional design, future longitudinal studies are needed to evaluate the external validity of this framework, examine its performance in more diverse populations, and determine its clinical utility for guiding preventive interventions.

Author Contributions: Conceptualization, J.d.S.-L. and S.M.-M.; methodology, J.d.S.-L., J.P.d.S.-J. and T.L.-A.; software, J.d.S.-L.; validation, J.d.S.-L., S.M.-M. and M.P.-S.; formal analysis, J.d.S.-L. and J.P.d.S.-J.; investigation, J.d.S.-L., T.L.-A. and D.D.-B.; resources, S.M.-M., E.M.-N. and J.B.-C.; data curation, J.d.S.-L. and M.P.-S.; writing—original draft preparation, J.d.S.-L.; writing—review and editing, all authors; visualization, J.d.S.-L.; supervision, S.M.-M. and C.F.-V.; project administration, J.d.S.-L.; funding acquisition, S.M.-M. and A.G.-C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. APC funding was not applicable at the time of submission.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki. Ethical review and approval were waived due to the use of anonymized secondary data collected as part of a long-standing community-based public health program, with no identifiable personal information.

Informed Consent Statement: Patient consent was waived due to the use of anonymized secondary data with no identifiable personal information and no direct participant contact.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical restrictions.

Acknowledgments: The authors would like to acknowledge the Centro de Estudos do Laboratório de Aptidão Física de São Caetano do Sul (CELAFISCS) for providing access to the dataset and supporting the development of this research. We also thank all participants involved in the community-based physical activity program for their contribution.

Conflicts of Interest: The authors declare no conflicts of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

Abbreviations

The following abbreviations are used in this manuscript:

BMI	Body Mass Index
CELAFISCS	Centro de Estudos do Laboratório de Aptidão Física de São Caetano do Sul
ELSI-Brazil	Brazilian Longitudinal Study of Aging (Estudo Longitudinal da Saúde dos Idosos Brasileiros)
FI	Frailty Index
IQR	Interquartile Range
OR	Odds Ratio

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