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Research article

Correlation and Diagnostic Utility of the Five-Repetition Sit-to-Stand Test (FRSTS) for Lower Limb Muscle Strength and Balance Assessment in Older Adults in Indonesia

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Abstract: The Five-Repetition Sit-to-Stand Test (FRSTS) is a simple functional assessment for lower limb performance, but its di-agnostic value for muscle strength and balance in Indonesian elderly remains underexplored. This study aims to exa-mine the association between FRSTS and lower limb strength and balance and also to determine cut-off points for pre-dicting functional impairment in elderly. This cross-sectional study included 83 community-dwelling elderly in Makas-sar, Indonesia. FRSTS completion time was measured and correlated with lower limb muscle strength assessed by handheld dynamometer and balance assessed by Berg Balance Scale (BBS). Receiver Operating Characteristic (ROC) analysis was used to identify its diagnostic utilization. FRSTS completion time (mean score = 11.60 ± 3.55 seconds) in-versely correlated with lower limb muscle strength especially hip flexor and ankle dorsoflexor. Shorter completion time of FRSTS also correlates to balance, with stronger associations for BBS dynamic subscore than BBS static subscore. ROC analysis showed significant predictive values for lower limb muscle strength with optimum cut-off value <11.99 se-conds (AUC = 0.663, Sensitivity = 64%, Specificity = 63%). FRSTS is a valid, practical tool for evaluating lower limb func-tion and balance in elderly. The identified cut-off points offer useful screening thresholds for early detection of lower limb muscle strength.

Keywords: FRSTS, lower limb strength, balance, diagnostic tool, elderly

1. Introduction

Global demographic shifts driven by advances in healthcare, socioeconomic development, sanitation, and nutrition have significantly increased life expectancy, resulting in a rapidly growing proportion of older adults worldwide. In Indonesia, 10.7% of the population was aged 60 years or older in 2020, and this figure is projected to reach nearly 20% by 2045 (Badan Pusat Statistik, 2021). This ageing trend is accompanied by a progressive physiological decline that affects multiple organ systems, leading to reduced functional capacity and independence in daily activities.

Among the determinants of functional capacity, lower limb muscle strength and balance play a pivotal role. Declines in these domains are strongly associated with mobility limitations, impaired activities of daily living (ADL), and increased fall risk. Globally, more than one-quarter of older adults experience falls annually [1], with prevalence in Indonesia reaching 29% [2]. Such events contribute to morbidity, loss of independence, and increased healthcare utilization. Early identification of muscle weakness and balance impairment is therefore essential for preventing functional decline and fall-related consequences.

While women generally maintain flexibility better than men beyond the age of 60, both sexes experience substantial declines in functional fitness [3]. These declines are often accompanied by balance impairments, which may be exacerbated by age-related deterioration in vestibular and other sensory systems, further reducing mobility and increasing the risk of falls [4]. A variety of clinical tests are available to assess muscle performance and balance, yet many require specialized equipment or trained personnel, limiting their practicality in primary care or community-based settings. The Five-Repetition Sit-to-Stand Test (FRSTS) offers a simple, quick, and equipment-free alternative. This functional assessment reflects a fundamental daily activity transitioning from sitting to standing, which demands coordinated muscle activation, endurance, and balance control. Previous research has shown that FRSTS performance is associated with lower limb strength and postural stability. However, its diagnostic accuracy in detecting deficits in these domains particularly among community-dwelling older adults in Indonesia remains insufficiently explored. Although studies from several Asian countries have examined FRSTS performance in older adults, differences in anthropometric characteristics, daily activity patterns, and healthcare contexts may influence normative values and diagnostic thresholds. Consequently, research focusing on Indonesian older adults is needed to provide locally relevant evidence and strengthen the clinical applicability of FRSTS in this population

Therefore, this study aims to investigate the diagnostic utility of the FRSTS for assessing lower limb muscle strength and balance in older adults. Specifically, it examines the correlation between FRSTS performance and objective measures of physical function and also evaluates its discriminative ability using receiver operating characteristic (ROC) analysis. Findings from this study are expected to provide evidence-based recommendations for the application of FRSTS as a practical, reliable, and accessible screening tool for functional capacity assessment in ageing populations.

2. Materials and Methods

2.1. Study Design

This study used an observational analytic design with a cross-sectional approach. The study was conducted between March – December 2024 among community dwelling elderly in Makassar, Indonesia. Recruitment was performed at local primary health centers. This study has obtained ethical approval from the Ethics Committee of the Faculty of Medicine Hasanuddin University with ethical recommendation number 925/UN4.6.4.5.31/PP36/2023.

2.2. Setting and Participants

Participants were recruited using purposive sampling to specifically include community-dwelling older adults who were able to perform the sit-to-stand task independently, aligning with the study's objective to assess functional performance using the FRSTS. The sample size was determined using the correlation test formula [5] with the following parameters: significance level $\alpha = 0.05$ ($Z\alpha/2 = 1.96$), statistical power = 95% ($Z1–\beta = 1.64$), and an estimated correlation coefficient of $r = 0.43$ based on a previous study [6]. This calculation yielded a minimum required sample of 64 participants. To account for a potential dropout rate of 20%, the final target sample size was set at 83 participants. Eligible individuals were those aged 60 years or older, able to perform sit-to-stand movements independently without assistive device, and having adequate vision with or without correction. Participants were excluded if they had uncontrolled comorbidities or unstable health conditions, such as myocardial infarction, uncontrolled hypertension, uncontrolled asthma, active infection, or neurological disorders affecting balance. Additional exclusion criteria included musculoskeletal pain with a visual analogue scale (VAS) score ≥ 4, a history of fractures within the past year, vestibular dysfunction indicated by a negative head thrust test, a Mini-Mental State Examination (MMSE) score below 24/30, alcohol consumption within 24 hours before testing, or experiencing pain or difficulty during the FRSTS performance.

2.3. Procedure

The Five-Repetition Sit-to-Stand Test (FRSTS) was performed following the protocol of the Centers for Disease Control and Prevention (CDC). Participants were instructed to rise from a standard chair (chair height approximately equal to the fibular head) with back support and no armrests to a full standing position and return to sitting, repeated five times as quickly as possible. The total time to completion, measured in seconds, was recorded, with shorter times indicating better functional capacity.

Isometric strength was measured for six major muscle groups—hip extensors, hip flexors, knee extensors, knee flexors, ankle dorsiflexors, and ankle plantar flexors—using a hand-held dynamometer (ActivForce® 2; ActivBody Inc., San Diego, CA, USA). Each test was performed three times with 60-second rest intervals, and the highest peak force (kgf) was recorded. Participants were instructed to contract the target muscle maximally and hold the contraction for approximately 5 seconds. To ensure consistent and safe muscle activation, participants were also instructed to avoid sudden forceful contractions **by** gradually increasing muscle force following the verbal cue "start." They were asked to stop contracting at the fifth second, and the procedure was repeated three times for each muscle group with a 60-second interval. The mean value of the three trials was then used for analysis [7].

Hip extensor strength was measured with participants standing on the contralateral leg and holding a stable surface for support. The trunk was slightly inclined forward, and the dynamometer was placed on the posterior lower leg just proximal to the ankle or on the distal posterior thigh. Participants pushed backward against the device. This standing-supported protocol is reliable and functionally relevant [8]. For hip flexors, participants were seated with hips and knees at 90°, feet unsupported, and the device placed on the anterior thigh ~5 cm above the patella [9].

Knee extensors were tested in the same position with the device on the anterior lower leg, and participants extended the knee forward [10]. Knee flexors were tested with the device placed posteriorly, and participants flexed the knee while the examiner stabilized the thigh [11].

Ankle dorsiflexors were measured with participants seated and the device placed on the dorsal foot near the second metatarsal, lifting the foot upward. Plantar flexors were measured with the device on the plantar surface near the metatarsal heads, pressing downward while maintaining heel contact [12].

Balance function was evaluated using the Berg Balance Scale (BBS), a 14-item performance-based assessment with a maximum score of 56, where higher scores denote better balance. A score of 46 or above was classified as good balance, while scores of 45 or below indicated impaired balance [13]. The BBS has been widely used in several Indonesia-based studies, supporting its clinical applicability in local geriatric and rehabilitation settings [14,15]. In this study, the BBS was further analyzed by separating its items into static and dynamic components to determine which aspect of balance was more closely associated with sit-to-stand performance. Static balance was assessed using items 2, 3, 6, 7, 13, and 14, while dynamic balance was assessed using items 1, 4, 5, 8, 9, 10, 11, and 12.

Data were collected in a single session in the following sequence: BBS, FRSTS, and lower limb muscle strength testing. A 5-minute rest was provided between tests to minimize fatigue [16]. Each assessment was conducted by a different examiner and in a separate room to ensure that no assessor was influenced by the results of the others.

2.4. Analysis

Data homogeneity was assessed using the Kolmogorov-Smirnov test. FRSTS and BBS data were not normally distributed. Correlation analysis between FRSTS and lower limb muscle strength and balance function was performed using Partial correlation by assessing the cofounder. A p-value < 0.05 was used as the threshold for significant results. ROC curve analysis and area under the curve (AUC) were used to determine the optimal cut-off value in FRSTS examination of lower limb muscle strength, along with sensitivity (sn) and specificity (sp) values.

3. Results

3.1. Characteristic of Participants

Table 1 shows that the majority of participants were female (78.3%), with a mean age of 67.5 ± 5.4 years. The average BMI was 25.88 ± 3.43 kg/m^2. The mean overall lower limb muscle strength averaged was 14.28 ± 3.80 kg. The mean Berg Balance Scale (BBS) score was high (54.59 ± 2.19), indicating good balance. The mean FRSTS completion time was 11.60 ± 3.55 seconds.

In terms of health status, nearly 75% of participants reported at least one comorbidity, with hypertension (62.6%) being the most prevalent, followed by diabetes mellitus (21.7%) and dyslipidemia (13.2%). A similar pattern was observed in medication use, where 62.6% were taking antihypertensive drugs, and a smaller proportion were using hypoglycemic or lipid-lowering agents. This clustering of cardiometabolic conditions is typical of older adult populations and may influence physical performance outcomes.

Regarding lifestyle factors, the majority of participants (72.3%) engaged in less than 75 minutes of physical activity per week, indicating predominantly low activity levels. Only 27.7% met the 75–150-minute weekly threshold, and none exceeded 150 minutes.

Table 1. Participants Demographics and clinical outcomes

Characteristic (n=83)	Result (mean ± SD)
Age (years)	67.5 ± 5.4
Sex	
Female	65 (78.3%)[a]
Male	18 (21.7%)[a]
Body weight (kg)	61.47 ± 10.45
Height (cm)	154.09 ± 8.21
Body Mass Index (kg/m²)	25.88 ± 3.43
MMSE score	27.53 ± 1.77
Total BBS	54.59 ± 2.19
FRSTS (seconds)	11.6 0± 3.55
Comorbid	
None	21 (25.3%)[a]
Single	41 (49.4%)[a]
Multiple	21 (25.3%)[a]
Hypertension	52 (62.6%)[a]
Diabetes Mellitus	18 (21.7%)[a]
Dyslipidemia	11 (13.2%)[a]
Hyperuricemia	1 (1.2%)[a]
Cardiovascular disease	2 (2.4%)[a]
Medication	
None	21 (25.3%)[a]
Single	42 (50.6%)[a]
Multiple	20 (24.1%)[a]
Anti hypertensive	52 (62.6%)[a]
Hypoglicaemic agent	13 (15.6%)[a]
Anti dyslipidemia	12 (14.4%)[a]
Anti coagulant	2 (2.4%)[a]
Physical Activity Level	
<75 minutes	60 (72.3%)[a]
75 – 150 minutes	23 (27.7%)[a]
>150 minutes	0 (0%)[a]

[a] Data are presented in total numbers (percentages).

3.2. Correlation of FRSTS performance, lower limb muscle strength, and balance

Table 2 showed the correlation analysis revealed that FRSTS performance time was significantly associated with several measures of lower limb muscle strength and balance. For muscle strength, significant negative correlations were observed with hip flexors ($r = -0.217$, $p = 0.049$), knee extensors ($r = -0.231$, $p = 0.036$), ankle dorsiflexors ($r = -0.236$, $p = 0.032$), and total muscle strength ($r = -0.263$, $p = 0.016$). In terms of balance, FRSTS performance showed a significant negative correlation with BBS dynamic subscore ($r = -0.344$, $p = 0.001$) and total BBS score ($r = -0.258$, $p = 0.018$), while no significant association was found with BBS static subscore ($p = 0.138$). The negative correlation values indicate that shorter FRSTS completion times were associated with greater muscle strength and better balance performance.

Table 2. Correlation between FRSTS performance, lower limb muscle strength, and balance

Variable	Correlation with FRSTS (r)	*p*-value	CI (95%)
Muscle Strength			
Hip extensor	-0.106	0.342	-0.31 – 0.11
Hip flexor	-0.217	0.049[a]	-0.41 – (-0.001)
Knee extensor	-0.231	0.036[a]	-0.42 – (-0.016)
Knee flexor	-0.168	0.128	-0.37 – 0.049
Ankle plantarflexor	-0.206	0.062	-0.404 – 0.010
Ankle dorsiflexor	-0.236	0.032[a]	-0.430 – (-0.021)
Total strength	**-0.263**	**0.016**[a]	**-0.453 – (-0.050)**
Balance			
BBS static subscore	-0.164	0.138	-0.36 – 0.054
BBS dynamic subscore	-0.344	0.001[a]	-0.521 – (-0.139)
BBS total	**-0.258**	**0.018**[a]	**-0.449 – (-0.045)**

[a] $p < 0.05$ indicates statistical significance.

3.3. Diagnostic Utility of FRSTS

The ROC curve analysis (figure 1) for the FRSTS test demonstrated significant predictive ability for lower limb muscle strength. The optimum cut-off point is 11.99 seconds. The area under the ROC curve (AUC) for muscle strength was 0.663. Although the AUC value does not reach a strong level of accuracy, it remains statistically significant (p = 0.031). At this cut-off threshold, the FRSTS demonstrated **a** sensitivity of 64% and specificity of 63% (Table 3). Unfortunately, in this study, ROC for balance could not be assessed due to the ceiling effect.

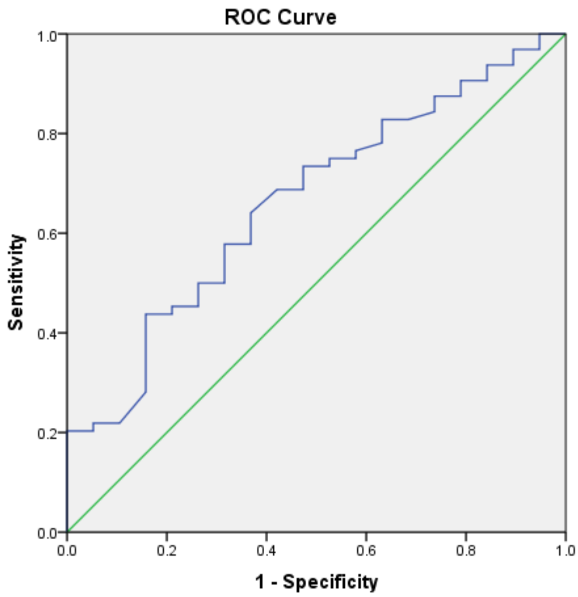

Figure 1. ROC curve of FRSTS predicting lower limb muscle strength

Table 3. ROC FRSTS

Parameter	AUC	P value	CI (95%)	Cut-off Point	Sn	Sp
Muscle Strength	0.663	0.031	0.530 – 0.797	11.99 s	64%	63%

Legend : AUC = area under curve; Sn = sensitivity; Sp = specificity

4. Discussion

This study demonstrates that the Five-Repetition Sit-to-Stand Test (FRSTS) has a significant association with several parameters of lower limb muscle strength and balance in elderly. Specifically, longer FRSTS completion times were correlated with reduced muscle strength in the hip flexors, knee extensors, and ankle dorsiflexors. These findings are consistent with previous research reporting a strong negative correlation between lower limb muscle strength and functional mobility in elderly [17]. Moreover, lower limb torque capacity, which includes both strength and fatigue resistance, has been identified as a significant predictor of physical function in elderly with mobility limitations [18]. Core muscle strength has also been shown to have a strong positive correlation with lower limb functional status [19]. The decline in functional capacity due to aging appears to accelerate approaching the age of 80, at which point lower limb power plays a crucial role in maintaining functional balance and walking ability [20]. Reduced muscle strength compromises the ability to perform transitional movements such as standing up, which are key components of daily mobility and independence. Consequently, interventions that specifically target lower-limb strengthening have been shown to enhance functional outcomes in older adults. In line with this, Murgoci reported that a targeted lower-limb rehabilitation program using a stationary horizontal bicycle significantly improved muscle performance and functional independence in older adults [21]. These findings reinforce the present results, suggesting that FRSTS performance may serve as a sensitive indicator of lower-limb strength and overall physical function in community-dwelling elderly populations.

Beyond the mechanical aspects of muscle strength, metabolic and nutritional factors may also influence functional performance among older adults. Complementary evidence from Indonesian populations further supports this relationship. A recent study by Aulia et al in Makassar demonstrated a significant association between serum vitamin D levels and performance in the 30-Second Sit-to-Stand Test (30STS) among patients with knee osteoarthritis. Lower vitamin D levels were associated with reduced functional mobility and poorer sit-to-stand performance, indicating that both musculoskeletal integrity and metabolic factors may contribute to lower-limb function in older adults [22]. This regional evidence aligns with the current findings and underscores the importance of using accessible, population-appropriate functional assessments, such as the FRSTS, for early identification of mobility decline within Indonesian elderly populations.

The significant correlation between FRSTS performance and both total and dynamic BBS subscore, with a stronger association observed in dynamic balance, suggests that this test more accurately reflects the demands of functional balance commonly encountered in daily activities, such as walking, turning, and transferring. Previous studies have shown that both static and dynamic balance assessments are associated with fall risk, but they evaluate different aspects of postural control [23,24]. Dynamic balance, in particular, reflects the ability to maintain postural stability during movement, which has been identified as a more sensitive indicator of functional decline in older adults. Supporting this view, Gherghel et al reported that alterations in the center of pressure oscillations significantly impair postural control among older adults, emphasizing the critical role of dynamic stability in fall prevention [25]. These findings are consistent with the present study, suggesting that FRSTS, which involves repeated transitional movements and continuous postural adjustments, can effectively detect subtle impairments in dynamic balance that may not be captured by static balance tests.

ROC analysis identified FRSTS cut-off point was 11.99 seconds with AUC indicating moderate discriminatory ability of FRSTS to differentiate between older adults with good versus reduced lower limb muscle strength. Although the AUC value does not reach a strong level of accuracy, it remains statistically significant ($p = 0.031$), demonstrating that the FRSTS has meaningful predictive value. At this cut-off threshold, the FRSTS demonstrated a moderate sensitivity and specificity. Taken together, these findings indicate that while FRSTS should not replace direct muscle strength testing, it serves as a practical and moderately accurate screening tool for detecting reduced lower limb strength among community-dwelling older adults.

Older adults with FRSTS times exceeding these thresholds are more likely to have significant muscle weakness and may warrant further evaluation. These findings are also relevant in the context of frailty syndrome and fall risk in elderly. Studies have shown that frailty is closely associated with increased fall risk, particularly among the oldest-old population [26]. Risk factors for falls include reduced muscle strength, decreased physical fitness, and impaired balance [27]. Low muscle strength has been linked to reduced agility, which in turn influences fear of falling and increases fall risk [28]. Therefore, FRSTS with parameter-specific cut-off values may serve as an effective and efficient screening strategy for the early detection of functional impairments in the elderly population.

A ceiling effect was observed in the Berg Balance Scale (BBS), as most participants achieved high total and static balance scores. This restricted score variability reduced the sensitivity of the BBS in detecting subtle balance impairments within this relatively high-functioning sample and limited its ability to discriminate performance differences or support meaningful diagnostic analyses for balance.

To improve sensitivity in future studies involving high-functioning older adults, alternative balance assessments with a wider difficulty range should be considered. In particular, the Fullerton Advanced Balance (FAB) Scale may serve as a more suitable option, as it encompasses a broader range of sensory, musculoskeletal, and neuromuscular components that contribute to balance impairments in functionally independent older individuals [29]. The FAB Scale includes more challenging tasks that exceed the difficulty level of the BBS, offering enhanced discriminatory capacity for detecting early or mild balance deficits.

Overall, the results of this study reinforce the role of FRSTS as a simple, efficient, and cost-effective tool for assessing lower limb muscle function and balance capacity in community-dwelling elderly. Further longitudinal studies are warranted to confirm the predictive ability of FRSTS for future fall events and to evaluate its applicability in older populations with more diverse health characteristics.

Limitations

It should be mentioned that this study has certain limitations. First, its cross-sectional design prevents any causal interpretation of the relationship between FRSTS performance, muscle strength, and balance. Second, although the sample showed a predominance of female participants, we performed confounder assessmen including age, gender, body weight, height, BMI, and physical activity level and conducted partial correlation analyses that statistically adjusted for these factors. The associations between FRSTS, balance, and muscle strength remained significant after adjustment, indicating that the observed relationships were not driven by gender imbalance or lifestyle differences. Nevertheless, the unequal gender distribution may still limit the generalizability of the findings, particularly to older male populations. Third, most participants demonstrated low variability in balance function, with high BBS scores leading to a ceiling effect, which may have reduced the sensitivity of balance-related analyses, including the inability to perform ROC analysis for balance. Fourth, the diagnostic performance of FRSTS for muscle strength showed only moderate discriminative ability, as reflected by the AUC value, suggesting that FRSTS should be used alongside other assessments rather than as a standalone diagnostic tool. Finally, the study was conducted in a single geographic region, which may limit broader applicability to populations with more diverse health status, activity levels, or sociodemographic characteristics.

5. Conclusions

The Five-Repetition Sit-to-Stand Test (FRSTS) demonstrates significant associations with lower limb muscle strength and dynamic balance in elderly. ROC analysis identified practical cut-off 11.99 seconds, which may serve as benchmarks for detecting lower limb muscle weakness. Given its simplicity, safety, and predictive value, FRSTS can be recommended as an effective community-based screening tool for early identification of mobility and balance impairments in the elderly.

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References

1. Salari N, Darvishi N, Ahmadipanah M, Shohaimi S, Mohammadi M. Global prevalence of falls in the older adults: a comprehensive systematic review and meta-analysis. Journal of Orthopaedic Surgery and Research [Internet]. 2022;17:334. Available from: https://josr-online.biomedcentral.com/articles/10.1186/s13018-022-03222-1
2. Susilowati IH, Nugraha S, Sabarinah S, Peltzer K, Pengpid S, Hasiholan BP. Prevalence and risk factors associated with falls among community-dwelling and institutionalized older adults in indonesia. Malaysian Family Physician. 2020;15:30–8.
3. Milanović Z, Pantelić S, Trajković N, Sporiš G, Kostić R, James N. Age-related decrease in physical activity and functional fitness among elderly men and women. Clinical Interventions in Aging. 2013;8:549–56.
4. Wang J, Li Y, Yang GY, Jin K. Age-Related Dysfunction in Balance: A Comprehensive Review of Causes, Consequences, and Interventions. Aging and Disease. 2025;16:714–37.
5. Sastroasmoro. Perkiraan Besar Sampel dalam Penelitian Klinis. Dasar-dasar Metodologi Penelitian. 2011.

6. Lord SR, Murray SM, Chapman K, Munro B, Tiedemann A. Sit-to-stand performance depends on sensation, speed, balance, and psychological status in addition to strength in older people. Journals of Gerontology - Series A Biological Sciences and Medical Sciences. 2002;57:539–43.
7. Grootswagers P, Vaes AMM, Hangelbroek R, Tieland M, van Loon LJC, de Groot LCPGM. Relative Validity and Reliability of Isometric Lower Extremity Strength Assessment in Older Adults by Using a Handheld Dynamometer. Sports Health: A Multidisciplinary Approach [Internet]. 2022;14:899–905. Available from: http://journals.sagepub.com/doi/10.1177/19417381211063847
8. Lue YJ, Hsieh CL, Liu MF, Hsiao SF, Chen SM, Lin JH, et al. Influence of testing position on the reliability of hip extensor strength measured by a handheld dynamometer. Kaohsiung Journal of Medical Sciences [Internet]. Elsevier; 2009;25:126–32. Available from: http://dx.doi.org/10.1016/S1607-551X(09)70051-8
9. Ishøi L, Hölmich P, Thorborg K. Measures of Hip Muscle Strength and Rate Of Force Development Using A Fixated Handheld Dynamometer: Intra-Tester Intra-Day Reliability of A Clinical Set-Up. International journal of sports physical therapy [Internet]. 2019;14:715–23. Available from: http://www.ncbi.nlm.nih.gov/pubmed/31598409
10. Baschung Pfister P, de Bruin ED, Sterkele I, Maurer B, de Bie RA, Knols RH. Manual muscle testing and hand-held dynamometry in people with inflammatory myopathy: An intra- and interrater reliability and validity study. Jan Y-K, editor. PLOS ONE [Internet]. 2018;13:e0194531. Available from: https://dx.plos.org/10.1371/journal.pone.0194531
11. Larson D, Lorenz D, Melton B. Can Clinician-Stabilization with Hand-Held Dynamometry Yield a Reliable Measure of Knee Flexion Torque? International Journal of Sports Physical Therapy [Internet]. 2022;17. Available from: https://ijspt.scholasticahq.com/article/37907-can-clinician-stabilization-with-hand-held-dynamometry-yield-a-reliable-measure-of-knee-flexion-torque
12. Busse ME, Hughes G, Wiles CM, Rosser AE. Use of hand-held dynamometry in the evaluation of lower limb muscle strength in people with Huntington's disease. Journal of Neurology. 2008;255:1534–40.
13. Berg KO, Wood-Dauphinee SL, Williams JI, Maki B. Measuring balance in the elderly: validation of an instrument. Canadian journal of public health = Revue canadienne de sante publique [Internet]. 1992;83 Suppl 2:S7-11. Available from: http://www.ncbi.nlm.nih.gov/pubmed/1468055
14. Prastowo NA, Budiarta MO, Suryawinata K, Haryono IR. Comparing tools of balance tests in assessing balance of middle-aged women with or without exercises. Indonesian Journal of Medicine and Health. 2020;11:18–26.
15. Alifah N, Rosya A, Yuliadarwati NM, Rosyida A. Penerapan Pemeriksaan Berg Balance Scale untuk Menurunkan Risiko Jatuh pada Lansia di Posyandu Lansia Balearjosari , Malang , Jawa Timur. 2024;2:675–82.
16. Gephine S, Mucci P, Bielmann M, Martin M, Bouyer L, Saey D, et al. Quadriceps physiological response during the 1-min sit-to-stand test in people with severe COPD and healthy controls. Scientific Reports [Internet]. Nature Publishing Group UK; 2022;12:1–10. Available from: https://doi.org/10.1038/s41598-022-04820-z
17. Nugraha IGMN, Winaya IMN, Negara AAGAP, Andayani NLN. The relationship between leg muscle strength and functional mobility in the elderly. Physical Therapy Journal of Indonesia. 2024;5:25–8.
18. Grosicki GJ, Englund DA, Price L, Iwai M, Kashiwa M, Reid KF, et al. Lower-Extremity Torque Capacity and Physical Function in Mobility-Limited Older Adults. Journal of Nutrition, Health and Aging. 2019;23:703–9.
19. Pallavi Hoge, Dr Mayuri Khatavkar (PT). Correlation Of Core Muscle Strength and Lower Limb Muscle Strength With Lower Limb Functional Status In Healthy Middle Old Population. VIMS Health Science Journal. 2022;9:49–54.
20. Elam C, Aagaard P, Slinde F, Svantesson U, Hulthén L, Magnusson PS, et al. The effects of ageing on functional capacity and stretch-shortening cycle muscle power. Journal of Physical Therapy Science. 2021;33:250–60.
21. Murgoci N. Comparative study on the efficiency of motor rehabilitation of the lower limbs using a stationary horizontal bicycle versus a standard therapeutic program. Balneo and PRM Research Journal. 2022;13:1–18.
22. Aulia DF, Waluyo Y, Sam N, Zainuddin AA, Sahlan A, Hasan R. Relationship of serum magnesium and vitamin D levels to range of motion and 30-second sit to stand test of knee osteoarthritis patients. Nutr Clín Diet Hosp. 2025;45:78–85.
23. Poncumhak P, Srithawong A, Duangsanjun W, Amput P. Comparison of the Ability of Static and Dynamic Balance Tests to Determine the Risk of Falls among Older Community-Dwelling Individuals. Journal of Functional Morphology and Kinesiology. 2023;8.
24. Rizzato A, Paoli A, Andretta M, Vidorin F, Marcolin G. Are Static and Dynamic Postural Balance Assessments Two Sides of the Same Coin? A Cross-Sectional Study in the Older Adults. Frontiers in Physiology. 2021;12:1–8.
25. Gherghel CL, Teodorescu V, Iordan DA. Analysis of oscillations of the center of pressure in postural control. Balneo and PRM Research Journal. 2024;1–10.
26. Taguchi CK, de Lemos Menezes P, Melo ACS, de Santana LS, Conceição WRS, de Souza GF, et al. Frailty syndrome and risks for falling in the elderly community. Codas. 2022;34:1–6.
27. Lee YC, Chang SF, Kao CY, Tsai HC. Muscle Strength, Physical Fitness, Balance, and Walking Ability at Risk of Fall for Prefrail Older People. BioMed Research International. 2022;2022.
28. Rodrigues F, Monteiro AM, Forte P, Morouço P. Effects of Muscle Strength, Agility, and Fear of Falling on Risk of Falling in Older Adults. International Journal of Environmental Research and Public Health. 2023;20.
29. Rose DJ, Lucchese N, Wiersma LD, Dj AR, Lucchese N, Devel- WLD. Development of a Multidimensional Balance Scale for Use With Functionally Independent Older Adults. 2006;87:1478–85.