RESEARCH PAPER

Predictors of Dynamic Balance and Functional Mobility in Community-Dwelling Older Adults: The Relative Contributions of Multi-Joint Lower-Extremity Muscle Strength

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Abstract

Background: Preserving functional mobility and dynamic balance is critical for maintaining independence and preventing falls in older populations. While overall lower-extremity weakness is known to impair physical performance, the relative and joint-specific contributions of different lower-limb muscle groups to distinct functional balance and mobility outcomes remain to be fully elucidated.

Objective: This study aimed to investigate the relationships between multi-joint lower-extremity muscle strength (hip, knee, and ankle joints) and functional performance measures, and to identify the strongest muscular predictors of dynamic mobility and multidirectional dynamic balance in community-dwelling older adults.

Methods: A cross-sectional descriptive study was conducted with community-dwelling older adults. Isometric muscle strength (peak torque, PT) for hip, knee, and ankle joint actions was measured using a standardized portable handheld dynamometer protocol. Functional mobility was evaluated using the Timed Up and Go (TUG) test. Multidirectional dynamic balance was assessed using the anterior and posterior Functional Reach Tests (FRT). Pearson correlation and simple linear regression analyses were performed to identify significant muscular predictors and determine their explanatory power (R^2).

Results: In the 24 completed participants (BMI: 24.83 ± 2.98 kg/m²), regression analyses revealed distinct predictive patterns between distal and proximal muscle groups. For functional mobility, ankle plantarflexion PT emerged as the strongest negative predictor of TUG scores, explaining 32.0% of the variance (Beta = -0.565, p = 0.004). For dynamic balance, hip abduction PT demonstrated the highest positive explanatory power for both anterior FRT (Beta = 0.540, p = 0.006, R^2 = 0.295) and posterior FRT performance (Beta = 0.507, p = 0.011, R^2 = 0.223). All other lower-extremity joint actions also served as significant positive predictors of multidirectional reaching.

Conclusion: Multi-joint lower-extremity muscle strength highly predicts functional outcomes in older adults. Rehabilitation and exercise interventions should incorporate a balanced, joint-specific approach: focusing on distal ankle plantarflexor strengthening to enhance ambulatory mobility and agility, while prioritizing proximal hip abductor strengthening to expand safe margins of dynamic postural stability.

Keywords: Handheld dynamometry, Muscle strength, Postural balance, Geriatric rehabilitation, Walk test

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I. Introduction

Maintaining functional mobility and balance is critical for preserving independence and preventing falls in community-dwelling older adults (Sherrington et al., 2019). As the human neuromuscular system ages, progressive muscular atrophy, particularly sarcopenia, and neuropathic changes result in significant declines in lower-extremity muscle strength and joint position sense (Vandervoort, 2002; de Morais & de Oliveira, 2023). These physiological deficits directly impair postural control mechanisms, elevating fall risks and reducing the overall quality of life in older populations (Horak, 2006). To mitigate these age-related declines, healthcare providers and researchers must identify the specific biomechanical and neuromuscular predictors that underpin dynamic balance and mobility.

Among clinical assessment tools, the Timed Up and Go (TUG) test and the Functional Reach Test (FRT) are widely recognized for their high reliability and clinical utility. The TUG test serves as a gold standard for evaluating functional mobility, involving complex tasks such as standing up, walking, turning, and sitting down (Alqahtani & Nasser, 2019; Rydwik et al., 2011). Conversely, the FRT quantifies static and dynamic balance margins by measuring the maximum distance an individual can project their center of mass beyond the base of support in both anterior and posterior directions (Omaña et al., 2021; Merchán-Baeza et al., 2014). While previous literature has broadly acknowledged that lower-limb weakness correlates with poorer scores on these functional outcomes (Thomas & Lane, 2005), there remains a gap in understanding which specific joint-action muscle groups (e.g., hip abductors vs. ankle plantarflexors) exert the most critical predictive influence on multidirectional balance performance.

Different functional tasks recruit distinct muscle synergies. For instance, while sagittal plane actions like forward reaching (FRT anterior) rely heavily on ankle plantarflexion and hip flexion strength (Moffat & Spink, 2020), lateral pelvic stability during gait and backward shifting (FRT posterior) demands robust frontal-plane stabilization, primarily governed by the hip abductors (Uemura et al., 2022). Quantitative investigations that utilize precise measurement techniques, such as handheld dynamometry, are essential to systematically map the relative contributions of individual lower-extremity muscle groups to dynamic functional outcomes (Awwad et al., 2017).

Therefore, this study aimed to investigate the relationship between multi-joint lower-extremity muscle strength (including the hip, knee, and ankle joints) and functional performance measures (TUG, anterior FRT, and posterior FRT) in community-dwelling older adults. Specifically, we sought to determine the strongest muscular predictors for each functional performance test using simple linear regression models. We hypothesized that while distal ankle strength would serve as a major predictor for gait-related mobility (TUG), proximal hip strength—particularly hip abduction—would demonstrate superior explanatory power for multidirectional dynamic balance (FRT).

II. Materials and Methods

2.1 Study Design and Participants

This study employed a cross-sectional descriptive design to investigate the relationships between multi-joint lower-extremity muscle strength and functional mobility and balance in community-dwelling older adults. Participants were recruited from the local community through convenience sampling.

To be included in the study, participants had to meet the following criteria: they had to be forty years of age or older, capable of independent walking without assistive devices, capable of effective communication, and diagnosed with chronic diseases that were stably managed. Conversely, individuals were excluded from participation if they presented with a history of acute or chronic physical, cognitive, or psychiatric disorders, or if they had undergone surgery or invasive procedures on the upper or lower extremities within the past six months. Potential participants were also excluded if they had sensory system impairments, including vestibular, auditory, or visual deficits, that affected cerebellar function, or if they suffered from severe neurological or cardiovascular diseases, or rheumatologic or inflammatory diseases.

To determine the minimum required sample size, a power analysis was performed using G*Power software, version 3.1.9.4. For the multiple linear regression analysis, the sample size was calculated based on a medium effect size, where f2 was set to 0.15, the significance level alpha was set to 0.05, and the statistical power, represented as one minus beta, was set to 0.80. This power analysis indicated that a minimum of thirty-one participants was required to achieve sufficient statistical power. Before any data collection began, all participants voluntarily agreed to participate and provided written informed consent.

2.2 Experimental Procedures

All participants visited the laboratory for a single testing session during which all physical and functional outcomes were measured. Upon arrival, participants' demographic and anthropometric characteristics were recorded. Following this initial intake, they completed a standardized series of physical assessments. To minimize the potential confounding effects of physical fatigue, a standardized rest interval of approximately five minutes was strictly enforced between different tests, and additional rest was permitted whenever a participant requested it. The comprehensive assessment protocol comprised lower-limb muscle strength testing, a proprioception assessment, psychological questionnaires, and functional balance and mobility tests.

2.3 Outcome Measures

2.3.1 Lower-Extremity Muscle Strength

Isometric muscle strength was evaluated for the hip, knee, and ankle joints using a portable handheld dynamometer, following highly standardized positioning protocols validated for older populations.

For the assessment of hip muscle strength, participants were positioned supine with both hips and knees flexed at 90 degrees. The handheld dynamometer was positioned on the anterior thigh to measure flexion, on the posterior thigh for extension, and on the lateral thigh proximal to the knee joint for abduction. To prevent compensatory pelvic movements, the contralateral limb was firmly stabilized against a wall.

To evaluate knee strength, participants sat upright on a standardized stool with their feet flat on the floor and their hips and knees positioned at 90 degrees of flexion. While the thigh was manually stabilized by the researcher, the dynamometer was placed on the posterior aspect of the distal lower leg for flexion and near the anterior ankle for extension.

For ankle strength measurements, participants lay supine with their lower limbs secured and the ankle joint in a neutral position. The dynamometer was applied against the dorsal aspect of the foot at the metatarsophalangeal joints for dorsiflexion and against the plantar surface of the heel for plantarflexion.

For each joint action, participants performed three trials of five-second maximal voluntary isometric contractions, with a sixty-second rest period allocated between consecutive trials. Peak torque and time to peak torque were recorded, and the maximum values achieved across the trials were used for statistical analysis.

2.3.2 Functional Mobility: Timed Up and Go Test

The Timed Up and Go test was utilized to evaluate participants' dynamic functional mobility and agility. Participants started in a seated position on a standard armchair. Upon the evaluator’s verbal cue, they stood up, walked at their comfortable and safe pace to a line marked exactly three meters away, turned around, walked back to the chair, and returned to the initial seated position. The time taken from the initial movement of the back off the chair seat to the moment the buttocks touched the seat upon return was recorded in seconds using a digital stopwatch.

2.3.3 Functional Balance: Functional Reach Test

The Functional Reach Test was performed to quantify the maximum distance a participant could project their center of mass forward and backward while maintaining a fixed base of support.

For the anterior Functional Reach Test, participants stood relaxed next to a wall, raised their right arm to 90 degrees of shoulder flexion with the elbow fully extended, and reached forward as far as possible along a yardstick mounted on the wall at acromion level. The tip of the third metacarpal was used as the anatomical landmark to measure the reach distance in centimeters. The trial was discarded and repeated if the participant took a step, lost contact with the floor, or touched the wall or the yardstick.

The posterior Functional Reach Test followed a similar procedure, where the participant reached backward as far as possible without moving their feet. Each participant completed two practice trials followed by three recorded trials, and the average of the three recorded trials was calculated and used as the final score for analysis.

2.4 Statistical Analysis

Statistical analyses were performed using IBM SPSS Statistics for Windows, version 26.0, and the statistical significance level was set a priori at $p < 0.05$. Descriptive statistics, including means and standard deviations for continuous variables and frequencies with percentages for categorical variables, were calculated to summarize participants’ demographic and clinical characteristics.

Pearson correlation coefficients, represented as r, were used to evaluate the strength and direction of the linear relationships between lower-extremity muscle strength variables and functional outcomes, specifically the Timed Up and Go test, the anterior Functional Reach Test, and the posterior Functional Reach Test. Correlation coefficients were interpreted as trivial if r was less than 0.1, small if r ranged from 0.1 to 0.3, moderate if r ranged from 0.3 to 0.5, large if r ranged from 0.5 to 0.7, very large if r ranged from 0.7 to 0.9, and virtually perfect if r was greater than 0.9.

Finally, simple linear regression analyses were conducted to identify the individual muscular predictors of functional mobility and multidirectional dynamic balance, with coefficient of determination, or R-squared, values utilized to determine the proportion of variance explained by each muscle strength variable.

III. Results

3.1 Participant Characteristics

A total of twenty-four participants completed the study, and their demographic and outcome characteristics are summarized in Table 1. The average body mass index (BMI) of the participants was 24.83 ± 2.98 kg/m². The descriptive statistics for lower-extremity muscle strength, represented by peak torque (PT), showed that hip extension PT (126.49 ± 52.05) and hip abduction PT (129.71 ± 45.02) were higher than hip flexion PT (106.76 ± 34.58). For the knee joint, knee extension PT (193.26 ± 65.94) was substantially greater than knee flexion PT (75.21 ± 29.43). For the ankle joint, ankle dorsiflexion PT and ankle plantar flexion PT were 103.00 ± 30.27 and 106.10 ± 46.16, respectively. Regarding functional outcomes, the mean score for the anterior Functional Reach Test (FRT) was 29.53 ± 7.99 cm, and the posterior FRT score was 19.04 ± 7.71 cm, while the average time to complete the Timed Up and Go (TUG) test was 9.19 ± 3.01 seconds.

Table 1. Descriptive Statistics of Participant Characteristics and Outcome Variables (N = 24)

Variables	**Minimum**	**Maximum**	**Mean ± SD**
BMI (kg/m²)	19.68	29.35	24.83 ± 2.98
Hip Flexion PT	56.22	175.54	106.76 ± 34.58
Hip Extension PT	49.69	222.28	126.49 ± 52.05
Hip Abduction PT	80.41	246.47	129.71 ± 45.02
Knee Flexion PT	39.55	145.14	75.21 ± 29.43
Knee Extension PT	79.76	301.39	193.26 ± 65.94
Ankle Dorsiflexion PT	34.32	168.02	103.00 ± 30.27

Variables	Minimum	Maximum	Mean ± SD
Ankle Plantar Flexion PT	40.53	206.59	106.10 ± 46.16
FRT Anterior (cm)	11.67	45.33	29.53 ± 7.99
FRT Posterior (cm)	0.00	30.00	19.04 ± 7.71
TUG (seconds)	4.51	15.70	9.19 ± 3.01

Note: BMI = Body Mass Index; PT = Peak Torque; FRT = Functional Reach Test; TUG = Timed Up and Go.

3.2 Correlation Analysis

Pearson correlation analysis revealed significant associations between specific lower-extremity muscle strength variables and functional performance measures.

For the TUG test, three muscle groups demonstrated significant negative correlations, indicating that greater muscle strength was associated with a shorter time to complete the test (reflecting better functional mobility). Specifically, TUG performance was significantly correlated with hip abduction PT ($r = -0.430$, $p = 0.036$), knee flexion PT ($r = -0.424$, $p = 0.039$), and ankle plantar flexion PT ($r = -0.565$, $p = 0.004$). Among these, ankle plantar flexion PT exhibited the strongest correlation with dynamic mobility.

For the anterior FRT, all evaluated lower-extremity muscle strength variables demonstrated significant positive correlations, showing that higher muscle strength was associated with a greater forward reach distance. Significant positive correlations were observed for hip flexion PT ($r = 0.517$, $p = 0.010$), hip abduction PT ($r = 0.540$, $p = 0.006$), knee flexion PT ($r = 0.509$, $p = 0.011$), knee extension PT ($r = 0.456$, $p = 0.025$), ankle dorsiflexion PT ($r = 0.484$, $p = 0.016$), and ankle plantar flexion PT ($r = 0.509$, $p = 0.011$). Hip abduction PT showed the strongest relationship with anterior reach performance.

Similarly, for the posterior FRT, all lower-extremity muscle strength variables were significantly and positively correlated with backward reaching distance. These included hip flexion PT ($r = 0.506$, $p = 0.012$), hip abduction PT ($r = 0.507$, $p = 0.011$), knee flexion PT ($r = 0.415$, $p = 0.044$), knee extension PT ($r = 0.427$, $p = 0.037$), ankle dorsiflexion PT ($r = 0.449$, $p = 0.028$), and ankle plantar flexion PT ($r = 0.486$, $p = 0.016$). Similar to the anterior reach, hip abduction PT demonstrated the strongest correlation with posterior reach performance.

3.3 Simple Linear Regression Analysis

3.3.1 Predictors of Functional Mobility (TUG)

Simple linear regression analyses were performed to identify the significant predictors of TUG performance, and the results are detailed in Table 2. Hip abduction PT (B = -0.029, Beta = -0.430, t = -2.232, $p = 0.036$), knee flexion PT (B = -0.043, Beta = -0.424, t = -2.195, $p = 0.039$), and ankle plantar flexion PT (B = -0.037, Beta = -0.565, t = -3.214, $p = 0.004$) were all confirmed as significant negative predictors of TUG scores. Among these variables, ankle plantar flexion PT emerged as the strongest predictor, explaining 32.0% of the total variance in dynamic mobility (R2 = 0.320), followed by hip abduction PT (R2 = 0.185) and knee flexion PT (R2 = 0.180).

Table 2. Simple Linear Regression Models for Predictors of TUG Performance

Predictor Variables	**B**	**Beta**	**t**	**p-value**	**R²**
Hip Abduction PT	-0.029	-0.430	-2.232	0.036	0.185
Knee Flexion PT	-0.043	-0.424	-2.195	0.039	0.180
Ankle Plantar Flexion PT	-0.037	-0.565	-3.214	0.004	0.320

Note: PT = Peak Torque; B = Unstandardized coefficient; Beta = Standardized coefficient; R² = Coefficient of determination.

3.3.2 Predictors of Anterior Balance (FRT Anterior)

As shown in Table 3, all six lower-extremity muscle strength variables were significant positive predictors of anterior FRT performance. Hip flexion PT was a significant predictor, accounting for 23.3% of the variance (B = 0.119, Beta = 0.517, t = 2.830, p = 0.010, R2 = 0.233). Hip abduction PT showed the strongest positive association and explanatory power, explaining 29.5% of the variance in forward reach (B = 0.096, Beta = 0.540, t = 3.010, p = 0.006, R2 = 0.295). Knee flexion (B = 0.138, Beta = 0.509, t = 2.771, p = 0.011, R2 = 0.225), knee extension (B = 0.055, Beta = 0.456, t = 2.403, p = 0.025, R2 = 0.172), ankle dorsiflexion (B = 0.128, Beta = 0.484, t = 2.596, p = 0.016, R2 = 0.200), and ankle plantar flexion (B = 0.088, Beta = 0.509, t = 2.775, p = 0.011, R2 = 0.226) were also significant positive predictors of the anterior reach performance.

Table 3. Simple Linear Regression Models for Predictors of FRT Anterior Performance

Predictor Variables	**B**	**Beta**	**t**	**p-value**	**R²**
Hip Flexion PT	0.119	0.517	2.830	0.010	0.233
Hip Abduction PT	0.096	0.540	3.010	0.006	0.295
Knee Flexion PT	0.138	0.509	2.771	0.011	0.225
Knee Extension PT	0.055	0.456	2.403	0.025	0.172
Ankle Dorsiflexion PT	0.128	0.484	2.596	0.016	0.200
Ankle Plantar Flexion PT	0.088	0.509	2.775	0.011	0.226

Note: PT = Peak Torque; B = Unstandardized coefficient; Beta = Standardized coefficient; R² = Coefficient of determination.

3.3.3 Predictors of Posterior Balance (FRT Posterior)

For the posterior FRT, regression models demonstrated that all lower-extremity strength variables were significant positive predictors of backward reaching ability, as presented in Table 4. Hip flexion PT was significantly associated with posterior reach performance (B = 0.113, Beta = 0.506, t = 2.749, p = 0.012, R2 = 0.222). Hip abduction PT again exhibited the highest explanatory power among all the assessed predictors, accounting for 22.3% of the variance (B = 0.087, Beta = 0.507, t = 2.759, p = 0.011, R2 = 0.223). Additionally, knee flexion PT (B = 0.109, Beta = 0.415, t = 2.140, p = 0.044, R2 = 0.135), knee extension PT (B = 0.050, Beta = 0.427, t = 2.217, p = 0.037, R2 = 0.145), ankle dorsiflexion PT (B = 0.114, Beta = 0.449, t = 2.350, p = 0.028, R2 = 0.166), and ankle plantar flexion PT (B = 0.081, Beta = 0.486, t = 2.611, p = 0.016, R2 = 0.202) served as significant positive predictors of posterior dynamic balance.

Overall, these regression outcomes suggest that while distal muscle strength (specifically ankle plantar flexion) has a dominant predictive role in dynamic mobility (TUG), proximal hip muscle strength (specifically hip abduction) provides the greatest explanatory capability for multidirectional dynamic balance (both anterior and posterior FRT).

Table 4. Simple Linear Regression Models for Predictors of FRT Posterior Performance

Predictor Variables	B	Beta	t	p-value	R²
Hip Flexion PT	0.113	0.506	2.749	0.012	0.222
Hip Abduction PT	0.087	0.507	2.759	0.011	0.223
Knee Flexion PT	0.109	0.415	2.140	0.044	0.135
Knee Extension PT	0.050	0.427	2.217	0.037	0.145
Ankle Dorsiflexion PT	0.114	0.449	2.350	0.028	0.166
Ankle Plantar Flexion PT	0.081	0.486	2.611	0.016	0.202

Note: PT = Peak Torque; B = Unstandardized coefficient; Beta = Standardized coefficient; R² = Coefficient of determination.

IV. Discussion

The primary objective of this study was to examine the relationships between multi-joint lower-extremity muscle strength and critical measures of functional mobility and multidirectional balance in community-dwelling older adults. Our findings demonstrated that specific lower-limb muscle groups serve as significant predictors for functional performance, validating the clinical importance of targeted muscular assessment. The most notable outcome of this study was the distinct division of predictive roles between distal and proximal lower-extremity muscle groups. Specifically, ankle plantarflexion peak torque emerged as the strongest predictor for dynamic mobility measured via the Timed Up and Go (TUG) test, whereas hip abduction peak torque consistently exhibited the highest explanatory power for both anterior and posterior directional dynamic balance measured via the Functional Reach Test (FRT).

The critical role of ankle plantarflexion strength in predicting TUG performance can be attributed to the specific biomechanical demands of the test. The TUG test requires rapid sit-to-stand transitions, acceleration during linear walking, controlled deceleration, and turning proficiency. Ankle plantarflexor muscles, particularly the gastrocnemius and soleus, are primary engines for forward propulsion and stabilization during the push-off phase of the gait cycle. This finding aligns with previous biomechanical evidence indicating that distal ankle strength is paramount for maintaining spatial-temporal gait parameters and dynamic stability during ambulatory tasks in aging populations (Moffat & Spink, 2020; Rydwik et al., 2011). Furthermore, a significant reduction in ankle mechanical output is known to be a hallmark of age-related neuromuscular decline, directly hindering an individual's capacity to execute rapid directional changes and dynamic stepping strategies (de Morais & de Oliveira, 2023; Awwad et al., 2017). In our regression analysis, ankle plantarflexion peak torque accounted for 32.0% of the total variance in TUG scores, highlighting that clinical interventions focusing primarily on distal lower-limb strengthening are imperative for preserving functional independence and basic mobility in older adults.

In contrast to the dynamic gait demands of the TUG test, the FRT evaluates the limit of stability within a fixed base of support. Our regression models revealed that hip abduction peak torque was the single most potent positive predictor for both anterior and posterior reach distances, explaining 29.5% and 22.3% of the variances, respectively. Dynamic balance control relies extensively on coordinated multi-joint strategies to control the position of the center of mass relative to the base of support (Horak, 2006). During reaching movements, proximal hip musculature acts as a critical stabilizer for the pelvis and core. In particular, the hip abductors, such as the gluteus medius, play a fundamental role in controlling lateral pelvic tilt and maintaining frontal-plane stability (Uemura et al., 2022). Our findings suggest that lateral hip stability is not only vital for lateral balance but also provides a foundational proximal anchor that permits maximal multi-directional excursion in the sagittal plane, allowing older adults to reach farther forward or backward without losing equilibrium. This underscores the assertion that proximal hip weakness is strongly related to restricted limits of stability and subsequent postural instability in the elderly (Wolfson et al., 1995; Thomas & Lane, 2005).

It is also noteworthy that all evaluated muscle strength variables across the hip, knee, and ankle joints demonstrated significant positive associations with the anterior and posterior reach performances. This collective predictive capacity reinforces the conceptual framework that dynamic balance is not governed by a single isolated joint but is rather the product of a well-integrated kinetic chain (Bohannon, 2019; Jonsson et al., 2021). For instance, during a forward reach, knee extension and ankle dorsiflexion strength are required to maintain the lower limb posture while the body segments lean forward. Conversely, backward reaching calls upon co-contraction patterns across the multi-joint system to prevent posterior falls (Merchán-Baeza et al., 2014; Alqahtani & Nasser, 2019). The fact that knee flexion and extension strength also significantly predicted reach outcomes concurs with classic gerontological studies establishing that generalized lower-limb weakness, particularly at the knee and ankle complexes, severely disrupts postural balance and compromises the safety margins against falling (Whipple et al., 1987; Pijnappels et al., 2008).

From a clinical perspective, the results of this study have direct implications for the design of rehabilitation protocols and fall-prevention exercise programs aimed at community-dwelling older adults (Sherrington et al., 2019). Given that different lower-extremity muscle groups contribute distinct mechanical advantages to different functional components, a one-size-fits-all approach to geriatric physical therapy may be suboptimal. Rehabilitation strategies aimed at enhancing ambulatory agility and speed should heavily incorporate resistance training targeted at the distal ankle plantarflexors (Moffat & Spink, 2020). Concurrently, to expand an individual's safe limits of stability and structural balance, interventions must prioritize proximal hip stabilization exercises, specifically focusing on strengthening the hip abductors (Uemura et al., 2022).

Several limitations should be considered when interpreting the findings of this study. First, due to the cross-sectional nature of the design, causal relationships between muscle strength gains and changes in functional performance cannot be definitively established. Longitudinal or interventional studies are warranted to verify whether selective strengthening of the hip abductors or ankle plantarflexors yields corresponding improvements in FRT and TUG metrics. Second, the sample size utilized in this analysis, while statistically justified through power calculations, was relatively modest, which may limit the generalizability of the findings to broader or more frail elderly populations. Future investigations should expand the cohort to include individuals with varying degrees of functional impairment and explicitly evaluate additional factors such as joint position sense and specific bio-signal metrics to construct more comprehensive predictive models for geriatric mobility.

In conclusion, this study demonstrates that lower-extremity multi-joint muscle strength is highly predictive of functional mobility and dynamic balance in community-dwelling older adults. Clinical assessments should recognize that distal ankle plantarflexion strength is a critical determinant of dynamic ambulatory mobility, while proximal hip abduction strength stands out as the primary contributor to multidirectional balance stability. Therapeutic exercise programs tailored for older adults should balancedly incorporate both distal propulsive training and proximal stabilization to optimally preserve physical independence and minimize fall risks.

V. Conclusions

In conclusion, this study demonstrates that multi-joint lower-extremity muscle strength is a highly significant predictor of functional mobility and multidirectional dynamic balance in community-dwelling older adults. The findings highlight a distinct biomechanical division of roles between distal and proximal lower-limb muscle groups. Specifically, ankle plantarflexion strength serves as the single most critical determinant of dynamic ambulatory mobility, explaining 32.0% of the variance in Timed Up and Go (TUG) performance. Conversely, proximal hip abduction strength emerges as the primary contributor to dynamic limits of stability, exhibiting the highest explanatory power for both anterior and posterior Functional Reach Test (FRT) performance.

These results suggest that a targeted, joint-specific approach is essential when designing physical therapy and fall-prevention exercise programs for aging populations. Clinical interventions aimed at improving walking efficiency and dynamic agility should prioritize distal resistance training for the ankle plantarflexors, whereas programs focused on expanding safe balance margins and preventing multidirectional falls must emphasize proximal pelvic stabilization, particularly hip abductor strengthening. Future longitudinal research with larger, diverse cohorts is warranted to validate whether selective strengthening of these key muscle groups directly translates to clinically meaningful improvements in functional independence and reduced fall incidence.

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