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Original Article

Association Between Calf Muscle Strength and Self-Reported Functional Mobility in Middle-Aged Women With Type 2 Diabetes: A Cross-Sectional Study

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ABSTRACT

Background: Type 2 diabetes mellitus is associated with skeletal muscle dysfunction and lower-extremity functional limitation, but the relationship between calf muscle strength and self-reported mobility in middle-aged women remains insufficiently explored. Objective: To assess the association between calf muscle strength/endurance and self-reported functional mobility among middle-aged women with type 2 diabetes mellitus. Methods: This cross-sectional observational study included 123 women aged 40–64 years with type 2 diabetes mellitus. Calf muscle strength/endurance was assessed using the Heel Raise Test, and self-reported functional mobility was measured using the Lower Extremity Functional Scale. Descriptive statistics summarized demographic and clinical variables. Pearson correlation was used to assess the continuous association between Heel Raise Test repetitions and LEFS total score, while Chi-square testing was used as a secondary categorical analysis. Results: The mean age was 50.63 ± 4.41 years. Mean Heel Raise Test performance was 19.92 ± 5.27 repetitions, and mean LEFS score was 59.79 ± 10.71. Mild calf endurance reduction was observed in 68.3% of participants, while 95.1% reported some degree of functional limitation. Heel Raise Test repetitions showed a strong positive correlation with LEFS score ($r = 0.936$, 95% CI: 0.908–0.956, $p < 0.001$). The categorical association was significant ($\chi^2 = 72.576$, $df = 9$, $p < 0.001$), although sparse expected cell counts limited interpretation. Conclusion: Calf muscle strength/endurance was strongly associated with self-reported functional mobility in middle-aged women with type 2 diabetes mellitus. Keywords: Type 2 diabetes mellitus; calf muscle strength; Heel Raise Test; Lower Extremity Functional Scale; functional mobility; middle-aged women.

INTRODUCTION

Type 2 diabetes mellitus (T2DM) is a chronic metabolic disorder associated not only with hyperglycemia and cardiometabolic complications but also with clinically relevant impairment of skeletal muscle health. Diabetes-related insulin resistance, chronic low-grade inflammation, oxidative stress, mitochondrial dysfunction, advanced glycation end-product accumulation, and reduced physical activity may contribute to deterioration in skeletal muscle quality, strength, and functional performance. These changes are particularly important because muscle strength is a central determinant of mobility, independence, balance, and the ability to perform activities of daily living. Evidence suggests that T2DM may accelerate age-related decline in skeletal muscle function and increase vulnerability to sarcopenia, reduced physical performance, and disability, especially when metabolic dysfunction coexists with increasing age and excess adiposity (1,2).

Lower-limb muscle impairment has been repeatedly reported among individuals with T2DM, even in patients without advanced diabetic complications. Asada et al. observed that middle-aged patients with

T2DM had reduced lower-limb muscle strength despite comparable leg muscle volume, suggesting that diabetes may compromise muscle performance before severe structural loss becomes clinically obvious (3). Similarly, Orlando et al. reported reduced lower-body muscle strength and increased fatigability among individuals with T2DM, indicating that muscular endurance and repeated-force production may be sensitive markers of early neuromuscular dysfunction in this population (4). Almurdhi et al. further demonstrated reduced lower-limb muscle strength and altered muscle composition in patients with T2DM, particularly in relation to neuropathy and intramuscular non-contractile tissue, while Nomura et al. showed that diabetic polyneuropathy was associated with lower-extremity strength decline in patients with T2DM (5,6). Collectively, these findings support the need to evaluate lower-limb muscle function as part of diabetes-related rehabilitation assessment.

Functional mobility in people with T2DM is influenced by multiple interacting factors, including muscle strength, glycemic status, adiposity, neuropathy, pain, balance, and physical activity. Bentes et al. reported that poorer glycemic status was associated with reduced muscle function and physical performance among women with T2DM, highlighting the relationship between metabolic control and musculoskeletal function (7). Wu et al. demonstrated that lower-limb strength contributed to walking ability and balance-related function in older adults with diabetes, while Bhatt and Sheth found poorer Lower Extremity Functional Scale scores and reduced functional status among individuals with T2DM compared with age- and sex-matched controls (8,9). These studies indicate that lower-limb weakness is not merely a physical impairment but a clinically meaningful contributor to reduced mobility, lower independence, and diminished quality of life in people living with diabetes.

Although previous research has examined generalized lower-limb strength, sarcopenia, gait performance, and functional decline in T2DM, comparatively less attention has been given to the calf muscle group as a specific contributor to self-reported functional mobility in middle-aged women. The gastrocnemius and soleus muscles are biomechanically essential for ankle plantar flexion, forward propulsion during gait, stair negotiation, postural control, and balance recovery. Reduced calf muscle strength or endurance may therefore limit walking efficiency, increase fatigue during daily activity, and contribute to perceived difficulty in lower-extremity functional tasks. Calf muscle quality has also been independently associated with better physical function in older adults, supporting the clinical relevance of this muscle group for mobility assessment (10). The standing heel-rise test provides a simple clinical measure of plantar-flexor strength and endurance and has been used as a practical functional test for calf muscle performance (11,12).

Middle-aged women with T2DM represent an important but relatively underexplored population because they may experience early metabolic, hormonal, and musculoskeletal changes before the onset of advanced disability. Identifying modifiable functional impairments during this stage may help clinicians recognize patients at risk of mobility decline and guide targeted rehabilitation planning. However, evidence remains limited regarding the specific association between calf muscle strength, assessed through heel-rise performance, and self-reported lower-extremity functional mobility among middle-aged women with T2DM. Addressing this gap may provide clinically useful information for physiotherapy screening, functional assessment, and future intervention development. Therefore, this study aimed to assess the relationship between calf muscle strength and self-reported functional mobility in middle-aged women with T2DM. The study hypothesis was that higher calf muscle strength, measured by Heel Raise Test repetitions, would be positively associated with better self-reported functional mobility, measured by the Lower Extremity Functional Scale.

MATERIALS AND METHODS

This cross-sectional observational study was conducted to assess the association between calf muscle strength and self-reported functional mobility among middle-aged women with type 2 diabetes mellitus. The study was carried out at the University of Lahore Teaching Hospital, Islam Hospital Zafarwal, and local diabetic clinics over a six-month period following synopsis approval. A cross-sectional design was selected because the objective was to examine the relationship between calf muscle performance and functional mobility at a single point in time, without assigning any intervention or follow-up exposure.

The study population consisted of women aged 40 to 64 years with physician-diagnosed T2DM of at least one year's duration. Participants were selected through convenience sampling from the participating clinical settings. Women were considered eligible if they were diagnosed with T2DM, were within the required age range, were able to perform the Heel Raise Test, and were able to understand and complete the self-reported functional mobility questionnaire. Women were excluded if they were younger than 40 years or older than 64 years, had cognitive impairment affecting questionnaire completion, had a history of neurological disease such as stroke, or had severe musculoskeletal impairment that could independently restrict heel-rise performance or lower-extremity function. Male patients were not included because the study was specifically designed to evaluate the association in middle-aged women.

Eligible participants were screened according to the inclusion and exclusion criteria. The purpose and procedures of the study were explained to each participant, and written informed consent was obtained before data collection. Participation was voluntary, and participants were informed that they could withdraw at any stage without any effect on their clinical care. Participant identity was kept anonymous during data collection and analysis, and all information was handled confidentially. The study was conducted in accordance with institutional ethical requirements and the principles of the Declaration of Helsinki.

Data were collected using a structured proforma that recorded demographic and clinical information, including age and duration of T2DM. Medical characteristics relevant to functional mobility, including diabetes-related and comorbid conditions where reported, were documented to support interpretation of potential confounding factors. The independent variable was calf muscle strength/endurance, operationally defined as the number of correctly completed heel-rise repetitions performed until fatigue or inability to maintain proper form. The dependent variable was self-reported functional mobility, operationally defined as the total score obtained on the Lower Extremity Functional Scale.

Calf muscle strength/endurance was assessed using the Heel Raise Test. Participants were instructed to perform repeated heel raises until fatigue or until they were unable to maintain the required movement pattern. The number of successful repetitions was recorded as the Heel Raise Test score, with a higher number of repetitions indicating better calf muscle strength/endurance. Heel-rise performance was also categorized for descriptive analysis using the study's predefined thresholds: fewer than 10 repetitions indicated significant calf weakness, 10–19 repetitions indicated moderate weakness or endurance deficit, 20–24 repetitions indicated mild reduction in calf endurance, and 25 or more repetitions indicated normal calf strength/endurance. The Heel Raise Test was selected because it is a clinically practical measure of ankle plantar-flexor performance and calf muscle endurance (11,12).

Self-reported functional mobility was measured using the Lower Extremity Functional Scale, a 20-item patient-reported questionnaire designed to assess difficulty in lower-extremity activities such as walking, stair climbing, squatting, running, and other daily functional tasks. Each item is scored from 0 to 4, giving a total score range from 0 to 80, with higher scores indicating better lower-extremity function and less functional limitation. For descriptive reporting, LEFS scores were categorized according to the study's predefined functional mobility levels: 0–20 as severe functional limitation, 21–40 as moderate functional limitation, 41–60 as mild to moderate limitation, and 61–80 as minimal or no functional limitation. The LEFS was selected because it is a widely used patient-reported measure of lower-extremity functional status with established clinical application (13).

To reduce measurement bias, participants were screened using the same eligibility criteria, data were collected through a structured proforma, and the same outcome measures were used for all participants. The Heel Raise Test and LEFS were administered in a consistent sequence, with participants first completing the LEFS questionnaire followed by calf muscle strength assessment. This order was used to prevent immediate physical fatigue from influencing questionnaire responses. Safety precautions were observed during physical testing, and participants were allowed to stop the test if they experienced discomfort, fatigue, imbalance, or inability to maintain correct form. Data were checked for completeness and consistency before statistical analysis.

The sample size was 123 participants. Data were entered and analyzed using SPSS version 26.0. Continuous variables, including age, Heel Raise Test repetitions, diabetes duration, and LEFS total score, were summarized using mean and standard deviation where appropriate. Categorical variables, including calf muscle strength categories and LEFS functional mobility categories, were summarized using frequencies and percentages. The primary analysis assessed the relationship between Heel Raise Test repetitions and LEFS total score using correlation analysis. Pearson correlation was used when the relationship was approximately linear and the variables were suitable for parametric analysis; if distributional assumptions were not met, Spearman rank correlation was considered more appropriate. The strength and direction of association were interpreted using the correlation coefficient and corresponding p-value. Categorical association between calf muscle strength category and LEFS mobility category was examined as a secondary analysis using the Chi-square test. Because sparse expected cell counts can weaken Chi-square validity, results from categorical analysis were interpreted cautiously when expected cell assumptions were not satisfied. A p-value less than 0.05 was considered statistically significant.

RESULTS

A total of 123 middle-aged women with type 2 diabetes mellitus were included in the analysis. The results are presented as descriptive characteristics, diabetes duration, calf muscle strength classification, self-reported functional mobility classification, and association analyses between Heel Raise Test performance and Lower Extremity Functional Scale score.

Table 1. Descriptive Characteristics of Participants and Study Variables

Variable	N	Minimum	Maximum	Mean ± SD
Age, years	123	41	59	50.63 ± 4.41
Heel Raise Test, repetitions	123	8	33	19.92 ± 5.27
LEFS total score, 0–80	123	32	80	59.79 ± 10.71

Abbreviations: LEFS, Lower Extremity Functional Scale; SD, standard deviation.

The mean age of the participants was 50.63 ± 4.41 years, indicating that the sample represented middle-aged women within the intended eligibility range. The mean Heel Raise Test performance was 19.92 ± 5.27 repetitions, while the mean LEFS total score was 59.79 ± 10.71 out of 80. These values indicate that, on average, participants had reduced calf muscle endurance and mild-to-moderate lower-extremity functional limitation.

Table 2. Duration of Type 2 Diabetes Mellitus Among Participants

Duration, years	n (%)	Cumulative %
1	1 (0.8)	0.8
2	6 (4.9)	5.7
3	10 (8.1)	13.8
4	10 (8.1)	22.0
5	18 (14.6)	36.6
6	21 (17.1)	53.7
7	21 (17.1)	70.7
8	22 (17.9)	88.6
9	11 (8.9)	97.6
10	2 (1.6)	99.2
12	1 (0.8)	100.0
Total	123 (100.0)	—

The duration of T2DM ranged from 1 to 12 years. The largest proportion of participants had diabetes duration of 8 years (17.9%), followed by 6 years (17.1%) and 7 years (17.1%). Overall, most participants had lived with T2DM for 5–8 years, suggesting a sample with established disease duration rather than newly diagnosed diabetes.

Table 3. Distribution of Calf Muscle Strength Categories Based on Heel Raise Test Performance

Calf Muscle Strength Category	n (%)	Cumulative %
Significant calf weakness	2 (1.6)	1.6
Moderate weakness/endurance deficit	17 (13.8)	15.4
Mild reduction in calf endurance	84 (68.3)	83.7
Normal calf strength/endurance	20 (16.3)	100.0
Total	123 (100.0)	—

The most frequent calf muscle strength category was mild reduction in calf endurance, observed in 84 participants (68.3%). Moderate weakness or endurance deficit was present in 17 participants (13.8%), while significant calf weakness was observed in 2 participants (1.6%). Normal calf strength/endurance was recorded in 20 participants (16.3%). These findings show that most participants had some degree of reduced calf muscle performance, although severe reduction was uncommon.

Table 4. Distribution of Self-Reported Functional Mobility Based on LEFS Categories

LEFS Functional Mobility Category	n (%)	Cumulative %
Severe functional limitation	4 (3.3)	3.3
Moderate functional limitation	50 (40.7)	44.0
Mild-to-moderate functional limitation	63 (51.2)	95.1
Minimal or no functional limitation	6 (4.9)	100.0
Total	123 (100.0)	—

Most participants reported lower-extremity functional limitation on the LEFS. Mild-to-moderate limitation was the most common category, affecting 63 participants (51.2%), followed by moderate functional limitation in 50 participants (40.7%). Severe functional limitation was present in 4 participants (3.3%), while only 6 participants (4.9%) reported minimal or no functional limitation. Overall, 117 participants (95.1%) reported at least some degree of functional limitation.

Table 5. Correlation Between Heel Raise Test Repetitions and LEFS Total Score

Variables	N	r	95% CI	p-value
Heel Raise Test repetitions and LEFS total score	123	0.936	0.908 to 0.956	<0.001

Abbreviations: CI, confidence interval; LEFS, Lower Extremity Functional Scale. Pearson correlation coefficient was reported in the manuscript; 95% CI was derived using Fisher's z transformation.

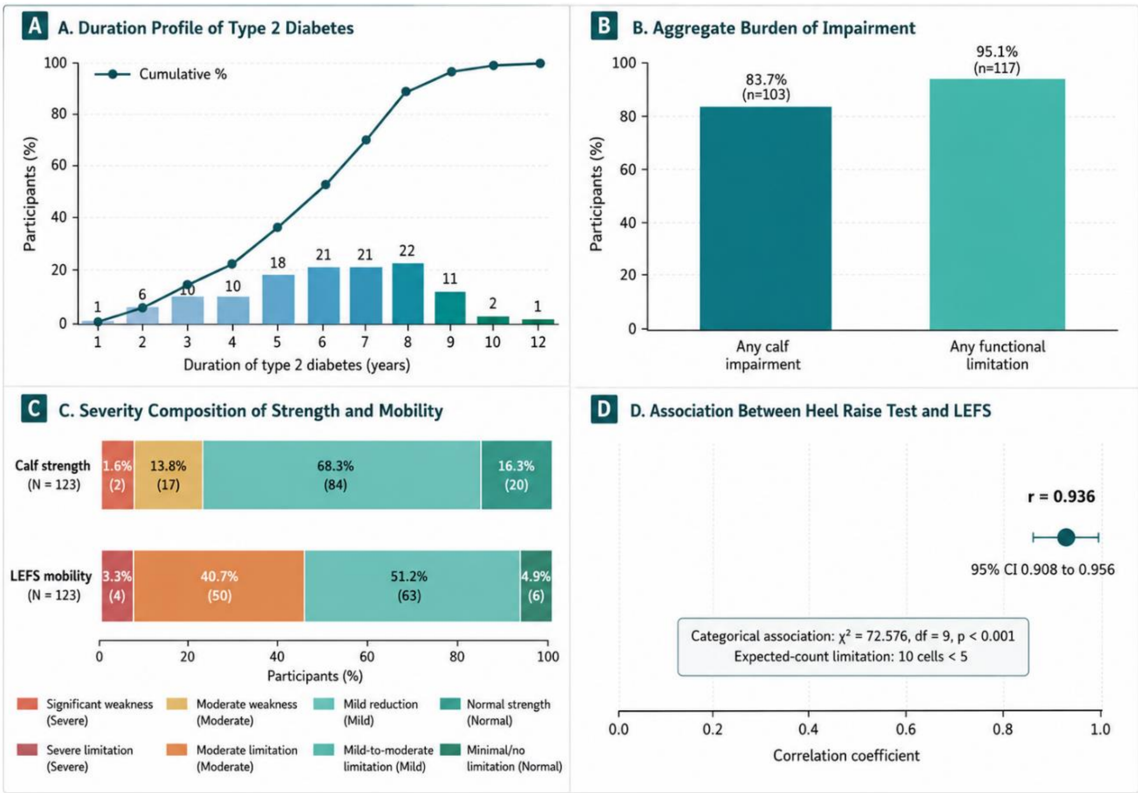
A strong positive correlation was observed between Heel Raise Test repetitions and LEFS total score ($r = 0.936$, 95% CI: 0.908 to 0.956, $p < 0.001$). Participants with higher calf muscle strength/endurance scores generally reported better lower-extremity functional mobility. Because the study design was cross-sectional, this finding indicates association rather than causation.

Table 6. Categorical Association Between Calf Muscle Strength and LEFS Functional Mobility Categories

Analysis	N	χ^2	df	p-value	Expected Cell Count Issue
Calf muscle strength category × LEFS category	123	72.576	9	<0.001	10 cells below 5

Abbreviations: df, degrees of freedom; LEFS, Lower Extremity Functional Scale. Chi-square test was reported in the manuscript.

A statistically significant categorical association was reported between calf muscle strength category and LEFS functional mobility category ($\chi^2 = 72.576$, df = 9, $p < 0.001$). However, 10 cells had expected counts below 5, indicating violation of the expected-frequency assumption for Chi-square testing. Therefore, this categorical result should be interpreted cautiously. The continuous correlation analysis provides a more stable primary estimate of the relationship between Heel Raise Test performance and LEFS total score.



LEFS, Lower Extremity Functional Scale. Percentages are based on N = 123. Correlation CI derived from the reported r using Fisher z transformation.

Figure 1 Calf Muscle Strength and Self-Reported Functional Mobility in Middle-Aged Women With Type 2 Diabetes.

The panelled figure summarizes the clinical distribution and association pattern among 123 middle-aged women with type 2 diabetes. Diabetes duration was concentrated between 5 and 8 years, with the highest frequency at 8 years (17.9%). Overall, 83.7% of participants demonstrated some degree of calf muscle impairment, while 95.1% reported at least some lower-extremity functional limitation on the LEFS. Severity profiling showed that mild calf endurance reduction was the dominant strength category (68.3%), whereas mild-to-moderate functional limitation was the most common LEFS category (51.2%). The continuous association between Heel Raise Test repetitions and LEFS total score was strong and positive ($r = 0.936$, 95% CI: 0.908–0.956, $p < 0.001$), indicating that better calf muscle endurance was closely associated with better self-reported lower-extremity function. The categorical Chi-square association was also significant ($\chi^2 = 72.576$, df = 9, $p < 0.001$), but interpretation should remain cautious because 10 expected cells were below 5.

DISCUSSION

This cross-sectional study examined the association between calf muscle strength/endurance and self-reported functional mobility among middle-aged women with type 2 diabetes mellitus. The principal finding was a strong positive correlation between Heel Raise Test repetitions and Lower Extremity Functional Scale total score, indicating that participants with better calf muscle performance generally reported better lower-extremity functional mobility. The mean Heel Raise Test score was 19.92 ± 5.27 repetitions, while the mean LEFS score was 59.79 ± 10.71, suggesting that the sample had measurable reduction in calf endurance alongside mild-to-moderate functional limitation. The categorical analysis also showed a significant association between calf muscle strength category and LEFS functional mobility category; however, because 10 expected cells were below 5, this result should be interpreted cautiously. Therefore, the continuous correlation analysis provides the more stable estimate of association in the present study.

The findings are biologically plausible because the calf muscle group, particularly the gastrocnemius and soleus, plays a major role in ankle plantar flexion, forward propulsion during walking, stair negotiation, postural stability, and balance recovery. Reduced plantar-flexor strength or endurance can impair gait efficiency and increase perceived difficulty during lower-extremity tasks assessed by the LEFS. The high frequency of calf muscle impairment in this sample supports earlier evidence that T2DM may affect muscle function before severe disability becomes clinically apparent. Asada et al. reported reduced lower-limb muscle strength among middle-aged patients with T2DM even when leg muscle volume was not markedly different, suggesting that functional muscle impairment may precede overt structural decline (3). Orlando et al. similarly found reduced lower-body strength and greater muscle fatigability in individuals with T2DM, supporting the interpretation that repeated-force generation and endurance may be sensitive markers of early diabetes-related muscle dysfunction (4).

The observed association between calf strength and functional mobility is consistent with prior research linking diabetes-related muscle impairment with lower-extremity functional decline. Almurdhi et al. demonstrated that patients with T2DM had reduced lower-limb muscle strength and altered muscle composition, while Nomura et al. reported that diabetic polyneuropathy was associated with lower-extremity strength decline (5,6). Although the present study did not perform adjusted analysis for neuropathy, obesity, or other diabetes-related complications, these factors are clinically important because they may influence both calf muscle performance and perceived mobility. The findings also align with Bentes et al., who observed that worse glycemic status was associated with poorer muscle function and physical performance among women with T2DM (7). This supports the broader interpretation that metabolic dysfunction, reduced muscle quality, and physical limitation may interact in women with diabetes.

The results also correspond with studies reporting impaired functional status among people with T2DM. Wu et al. showed that lower-limb muscle strength contributed to walking function and balance-related performance in older adults with diabetes (8). Bhatt and Sheth reported poorer LEFS scores, fatigue, and functional status among individuals with T2DM compared with matched controls, further emphasizing the clinical relevance of lower-extremity functional assessment in this population (9). In the present study, 95.1% of participants reported at least some degree of LEFS-based functional limitation, while only 4.9% had minimal or no limitation. This pattern suggests that middle-aged women with T2DM may experience functional difficulty even before reaching older age, supporting the need for earlier musculoskeletal screening within diabetes care.

The specific focus on calf muscle strength adds clinical value because most previous studies have assessed generalized lower-limb strength, gait speed, chair-stand performance, or global sarcopenia rather than calf-specific functional endurance. Calf muscle density has been independently associated with physical function in older adults, indicating that calf muscle quality may contribute meaningfully to mobility performance (10). The standing heel-rise test is also clinically practical, inexpensive, and feasible in outpatient physiotherapy and diabetic clinic settings. Previous work has supported the standing heel-rise test as a useful measure of ankle plantar-flexor performance and calf muscle function (11,12). In this context, the strong correlation between Heel Raise Test repetitions and LEFS score suggests that the Heel Raise Test may help clinicians identify patients with lower perceived mobility and monitor calf-related functional status in middle-aged women with T2DM.

Despite these clinically meaningful findings, the cross-sectional design prevents causal inference. The study cannot determine whether reduced calf muscle strength leads to poorer self-reported mobility, whether lower mobility contributes to calf deconditioning, or whether both are influenced by shared factors such as diabetes duration, obesity, neuropathy, pain, physical inactivity, or glycemic control. The convenience sampling method may also limit generalizability beyond the included clinical settings. In addition, the LEFS is self-reported and may be influenced by recall, perception, pain, fear of movement, or psychosocial factors. The categorical Chi-square analysis was limited by sparse expected cell counts, making the continuous correlation analysis more reliable for interpretation. Future studies should include objective mobility tests such as the Timed Up and Go test, 6-Minute Walk Test, gait speed, or stair-climb testing, and should apply multivariable regression to adjust for age, BMI, diabetes duration, neuropathy, physical activity, pain, and glycemic control.

Overall, the present study contributes to the rehabilitation literature by highlighting a strong association between calf muscle endurance and self-reported lower-extremity functional mobility in middle-aged women with T2DM. The findings support the clinical relevance of including calf muscle assessment in physiotherapy evaluation for patients with diabetes. However, intervention studies are required before concluding that calf strengthening directly improves functional mobility. Prospective and controlled trials should evaluate whether targeted calf and lower-limb strengthening programs can improve LEFS scores, objective mobility performance, balance, and independence in this population.

CONCLUSION

This study found a strong positive association between calf muscle strength/endurance and self-reported functional mobility among middle-aged women with type 2 diabetes mellitus. Participants with higher Heel Raise Test repetitions generally had higher LEFS total scores, indicating better perceived lower-extremity function. Most participants demonstrated some degree of calf muscle impairment and functional limitation, suggesting that calf muscle assessment may be clinically useful in identifying mobility-related concerns in this population. Because the study was cross-sectional, the findings should be interpreted as an association rather than evidence of causation. Future longitudinal and interventional studies should determine whether targeted calf and lower-limb strengthening can improve objective and self-reported mobility outcomes in women with T2DM.

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