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Effects of balance-strength training on balance and quality of life in type 2 diabetes: a quasi-experimental study

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Abstract
Background: Individuals with type 2 diabetes mellitus (T2DM) frequently experience balance impairment, which adversely affects mobility and quality of life (QoL).
Objective: To evaluate the effects of a combined balance and lower-extremity strength training program on balance performance and quality of life in individuals with T2DM.
Methods: This non-randomized quasi-experimental pre–post control group study was conducted in community health centers and included 34 individuals with T2DM (intervention n = 17; control n = 17). Balance performance, assessed using the Timed Up and Go (TUG) test, was the primary outcome, while quality of life was measured using the WHOQOL-BREF questionnaire. The intervention group performed structured static–dynamic balance and lower-extremity strengthening exercises three times per week for six weeks, whereas the control group exercised once weekly. Data were analyzed using paired and independent t-tests or non-parametric equivalents, with effect sizes reported.
Results: The intervention group demonstrated a significant reduction in TUG time (mean change = −2.76 ± 1.10 s; d = 2.51; $p < 0.001$). Significant improvements were observed in the physical (d = 0.81; p = 0.004) and environmental domains (r = 0.74; p = 0.002), as well as in the total WHOQOL-BREF score (r = 0.69; p = 0.005). Between-group analyses showed greater improvements in TUG (d = 1.40; $p < 0.001$), environmental domain (d = 0.63; $p < 0.001$), and total WHOQOL-BREF score (p = 0.032).
Conclusion: A six-week balance and lower-extremity strength training program effectively improved balance and selected QoL domains in individuals with T2DM.

Keywords
Type 2 diabetes mellitus; postural balance; muscle strength; exercise therapy; quality of life

Introduction

Type 2 diabetes mellitus (T2DM) accounts for more than 90% of diabetes cases worldwide.[1] It is estimated that 463 million individuals aged 20–79 years were living with diabetes, a number projected to increase to 578 million by 2030.[1] Indonesia is among the ten countries with the highest prevalence of T2DM, with an estimated prevalence of 10.8%.[2] The growing burden of T2DM poses substantial challenges to health systems, particularly due to its chronic nature and the wide range of functional complications associated with long-term disease progression.

T2DM is primarily characterized by insulin resistance, in which pancreatic β-cells fail to respond adequately to insulin or produce insufficient insulin,[3] leading to impaired glucose uptake in peripheral tissues and excessive hepatic glucose production.[4] Chronic hyperglycemia contributes not only to metabolic dysregulation but also to progressive microvascular and neurological complications that adversely affect physical function. Among these complications, balance impairment represents a clinically important yet often underrecognized problem in individuals with T2DM.

Individuals with T2DM are at increased risk of balance impairment, primarily due to diabetic neuropathy, which affects nearly 50% of patients.[5] Persistent hyperglycemia induces peripheral nerve damage, resulting in somatosensory dysfunction that compromises balance control and is frequently accompanied by reduced lower-limb muscle strength.[6] In addition to neuropathy, balance impairment in individuals with T2DM has been associated with reduced muscle strength, altered sensorimotor control, and progressive proprioceptive deficits.[7,8] These impairments collectively disrupt postural stability and functional mobility.

The functional consequences of balance impairment in T2DM are substantial. Reduced balance capacity is associated with decreased walking speed, altered gait patterns, and an increased risk of falls.[9,10] Falls among individuals with T2DM are particularly concerning because they are associated with a higher risk of injury, prolonged recovery, and increased healthcare utilization. Consequently, balance-related impairments limit functional independence and contribute significantly to a decline in quality of life, particularly through activity restriction, fear of falling, and the potential for diabetes-related complications.[11]

Exercise interventions have been widely recommended as a non-pharmacological strategy to address functional impairments in individuals with T2DM. Balance training has been shown to enhance postural control by improving sensory integration and neuromuscular coordination,12,13 while lower-extremity strength training increases muscle force production and endurance, both of which are essential for maintaining stability during functional activities.14,15 Physiologically, repeated muscle contractions during exercise stimulate neuromuscular adaptations, improve phosphagen metabolism, and enhance proprioceptive feedback, thereby supporting balance regulation and movement efficiency.[14,13] Strengthening the lower-extremity musculature is particularly important for individuals with T2DM, as muscle weakness in this population is strongly associated with impaired balance and mobility limitations.[15]

Previous studies have demonstrated that balance training and lower-extremity strengthening exercises can improve balance performance, gait, physical function, and quality of life in individuals with diabetes, particularly those with diabetic peripheral neuropathy (DPN). Akbari and Naimi reported that exercise therapy, including balance and strengthening components, was effective in improving postural stability in patients with DPN.[16] Similarly, Jaha and Haleem et al. demonstrated significant improvements in balance, gait, and quality of life following structured balance and strength training programs in individuals with DPN.[17,18] However, these studies predominantly focused on patients with established neuropathy, limiting the generalizability of their findings to the broader population of individuals with T2DM.

Furthermore, existing studies vary considerably in terms of exercise frequency, duration, and intervention components, and many employ high-frequency or long-duration protocols that may not be feasible in routine community or primary care settings. Importantly, few studies have evaluated structured programs that integrate static and dynamic balance exercises with lower-extremity strengthening using standardized and pragmatic training parameters. As a result, it remains unclear whether such integrated interventions are effective for individuals with T2DM who are not specifically selected based on the presence of peripheral neuropathy.

Evidence focusing on individuals with T2DM without restricting samples to those with DPN remains limited, particularly in low- and middle-income countries. To date, no quasi-experimental studies in Indonesia have evaluated the effects of a structured six-week program, performed three times per week, that combines static and dynamic balance training with lower-extremity strengthening in individuals with T2DM. This gap highlights the need for research using standardized exercise protocols and clearly defined outcomes to better understand the potential benefits of integrated balance and strengthening interventions in this population.

Therefore, the aim of this study was to evaluate the effects of a program integrating static and dynamic balance exercises with lower-extremity strengthening on balance performance and quality of life in individuals with T2DM. We hypothesized that a six-week integrated balance and strength training program performed three times per week would result in greater improvements in balance performance and quality of life compared with a low-frequency exercise program.

Methods

Study Design and Setting

This study employed a non-randomized quasi-experimental pre–post control group design. The study was conducted in four community-based elderly health centers (posyandu lansia) in Surakarta City, Central Java, Indonesia. Group allocation was performed at the health center level rather than at the individual level, with two centers assigned to the intervention group and two to the control group. All participants attending the same health center were allocated to the same study group. Because allocation was non-random, the potential for selection bias and baseline imbalance was addressed by reporting and comparing baseline demographic and clinical characteristics between groups.

Participants and Recruitment

Participants were recruited using purposive sampling from approximately 150 individuals with T2DM who routinely attended elderly health services at the selected health centers. Recruitment was conducted through written invitations distributed during routine health center sessions, followed by brief health education sessions explaining the study objectives, procedures, potential risks, and anticipated benefits. Individuals who expressed interest in participation underwent eligibility screening through medical record review and brief structured interviews conducted by the research team.

A total of 150 individuals were screened for eligibility. Of these, 116 were excluded because they did not meet the inclusion criteria, and no individuals declined participation or were excluded for other reasons. Thirty-four eligible participants provided written informed consent and were included in the study. Participants were allocated to the intervention group (n = 17) or the control group (n = 17) according to their respective health centers. Data collection was conducted between August and September 2025.

An a priori sample size calculation was not performed due to the pragmatic, community-based nature of the study and the use of purposive sampling, with sample size determined by participant availability and intervention feasibility. Following completion of the study, a post hoc power analysis was conducted based on the observed effect size of the primary outcome, indicating a moderate-to-large intervention effect and suggesting that the sample size was adequate to detect between-group differences.

Eligibility Criteria

Participants were eligible for inclusion if they met the following criteria: (1) age between 45 and 74 years; (2) a clinical diagnosis of T2DM for more than five years; (3) ability to walk and stand independently, with or without assistive devices; (4) adequate communication ability; and (5) ability to understand and follow exercise instructions.

Exclusion criteria included: (1) current lower-extremity musculoskeletal injuries affecting walking; (2) neurological disorders such as stroke or Parkinson's disease; (3) severe vertigo or balance disorders of non-diabetic origin; (4) severe diabetes-related complications, including active diabetic foot ulcers; and (5) unstable coronary heart disease or severe heart failure.

Formal screening for diabetic peripheral neuropathy (DPN) was not conducted because this study aimed to evaluate individuals with T2DM in general rather than restricting the sample to those with confirmed neuropathy. Consequently, the presence of DPN among participants could not be ruled out and is acknowledged as a limitation of the study.

Intervention

Intervention Group

Participants in the intervention group received a structured balance and lower-extremity strengthening exercise program consisting of static balance exercises, dynamic balance exercises, and lower-extremity strengthening exercises. Static balance exercises included one-leg standing and tandem standing. Dynamic balance exercises included tandem walking and walking across obstacles. Lower-extremity strengthening exercises included sit-to-stand, squats, and bridging exercises.

Static balance exercises were performed with a holding duration of 30–45 seconds per repetition. Dynamic balance exercises were performed over a distance of approximately 3–6 meters per trial. Strengthening exercises were performed through a pain-free range of motion. Each exercise was performed for six repetitions per set, with two to three sets depending on participant tolerance. Rest intervals of approximately 1–2 minutes were provided between sets.

The exercise program was conducted three times per week for six consecutive weeks, with each session lasting approximately 30–45 minutes. Exercise intensity was maintained at a light-to-moderate level, corresponding to a rating of perceived exertion (RPE) of 11–13. Exercise parameters were kept constant throughout the intervention period, and no structured progression was implemented.

Control Group

Participants in the control group received usual care consisting of routine weekly elderly health center activities. In addition, they performed simple balance exercises (one-leg standing and tandem walking) and lower-extremity strengthening exercises (sit-to-stand) once weekly for six weeks. Each session lasted approximately 15–20 minutes and was delivered without structured progression. The control intervention was designed to reflect low-frequency exercise commonly provided in community settings and to serve as a pragmatic comparator rather than a no-treatment control.

Intervention Fidelity and Adherence

All exercise sessions were delivered by members of the research team under the direct supervision of licensed physiotherapists with clinical experience in balance and therapeutic exercise. Participant attendance was recorded at each supervised session, with attendance of at least 75% of sessions considered acceptable adherence.

Home-exercise adherence was assessed using participant exercise logs and weekly follow-up via WhatsApp messaging. Participants who reported completing at least two home exercise sessions per week were classified as adherent. Exercise fidelity was monitored through standardized exercise protocols and direct supervision to ensure consistent delivery across sessions.

Outcome Measures

Primary Outcome

The primary outcome was balance performance, assessed using the Timed Up and Go (TUG) test. The TUG measures the time required for an individual to stand up from a chair, walk three meters, turn, return to the chair, and sit down. The TUG has demonstrated excellent validity and reliability in Indonesian clinical populations, with reported validity (r = 0.986), intra-rater reliability (ICC = 0.986), and inter-rater reliability (ICC = 0.999). Although these values were reported in stroke populations, the TUG is widely used and considered appropriate for assessing balance and mobility in older adults and individuals with T2DM.

Secondary Outcomes

Quality of life was assessed using the World Health Organization Quality of Life–Brief Version (WHOQOL-BREF) questionnaire, which consists of 26 items across four domains: physical, psychological, social, and environmental. Each item is rated on a five-point Likert scale. Raw domain scores were calculated by summing item scores within each domain and were transformed to a 0–100 scale. The total WHOQOL-BREF score was calculated as the mean of the four domain scores without additional transformation, with higher scores indicating better quality of life. The WHOQOL-BREF has demonstrated good validity and reliability in Indonesian populations, with reported validity (r = 0.949), internal consistency (Cronbach's alpha = 0.835), and reliability (ICC = 0.974).

Blinding and Outcome Assessment

Outcome assessments were conducted by an independent assessor with a physiotherapy background who was not involved in intervention delivery and was blinded to group allocation. Due to the nature of the intervention, participant blinding was not feasible.

Statistical Analysis

Data analysis was conducted according to a predefined analysis protocol and reviewed in consultation with a statistician. Descriptive statistics were used to summarize participant characteristics. Data normality was assessed using the Shapiro–Wilk test. Within-group comparisons were performed using paired-samples t-tests for normally distributed data or Wilcoxon signed-rank tests for non-normally distributed data. Homogeneity of variance for variables analyzed using t-tests was assessed using Levene's test.

Between-group differences were analyzed using change scores (Δ) and compared using independent-samples t-tests or Mann–Whitney U tests, as appropriate. Effect sizes and 95% confidence intervals were calculated and reported for primary and secondary outcomes where applicable. A two-sided p-value < 0.05 was considered statistically significant. All statistical analyses were performed using standard statistical software.

Ethical Considerations

This study was approved by the Ethics Committee of the Faculty of Health Sciences, Muhammadiyah University of Surakarta (Ethical Approval No. 1534/KEPK-FIK/IX/2025). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection. Potential risks, including fatigue or loss of balance during testing or exercise, were minimized through direct supervision by trained personnel and the implementation of appropriate safety measures.

Results

Participant Flow and Baseline Characteristics

A total of 150 individuals were assessed for eligibility, of whom 34 met the inclusion criteria and were included in the study (Figure 1). The remaining 116 individuals were excluded because they did not meet the inclusion criteria. No participants declined participation or were excluded for other reasons. Participants were allocated to either the intervention group (n = 17) or the control group (n = 17). During the six-week intervention period, no participants were lost to follow-up or discontinued the intervention in either group. Consequently, all enrolled participants (n = 34) were included in the final analysis using a complete-case approach.

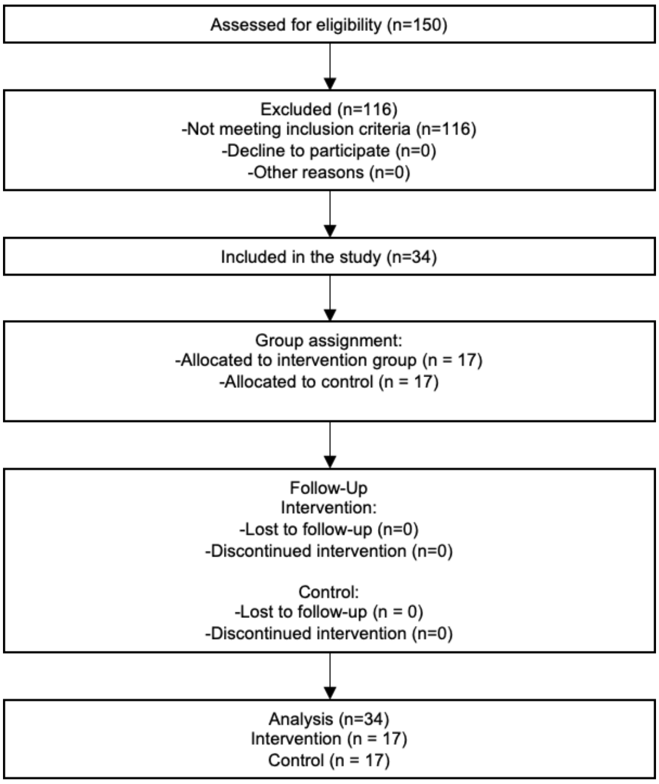

Figure 1. Flow diagram of participant recruitment, allocation, follow-up, and an

Baseline demographic and clinical characteristics of the participants are presented in Table 1. Women constituted the majority of participants in both groups. The mean age of participants ranged from 65 to 68 years, indicating an elderly population. The duration of diabetes mellitus differed between groups, with all participants in the control group having a disease duration of 5–10 years, whereas 35.3% of participants in the intervention group had a duration exceeding 10 years. At baseline, participants in the intervention group demonstrated poorer balance performance, as indicated by longer TUG times, and lower WHOQOL-BREF scores across all domains compared with the control group.

Table 1. Baseline Characteristics of Participants

A. Categorical Variables

Variable	Category	Intervention (n = 17)	Control (n = 17)
Duration of diabetes mellitus	5–10 years	11 (64.7%)	17 (100%)
	>10 years	6 (35.3%)	0 (0%)
Sex	Female	12 (70.6%)	10 (58.8%)
	Male	5 (29.4%)	7 (41.2%)

B. Continuous Variables

Variable	Intervention (Mean ± SD)	Control (Mean ± SD)
Age (years)	68.41 ± 5.67	65.71 ± 5.39
Duration of diabetes (years)	9.94 ± 3.28	7.29 ± 1.26
TUG (seconds)		
– Pre-test	14.72 ± 2.47	12.60 ± 1.54
– Post-test	11.96 ± 2.31	11.84 ± 2.35
WHOQOL-BREF (Pre-test)		
– Physical	48.73 ± 4.71	54.83 ± 3.07
– Psychological	56.61 ± 5.90	61.27 ± 5.84
– Social	45.09 ± 7.25	55.39 ± 7.18
– Environmental	65.62 ± 9.17	71.69 ± 2.81
– Total score	12.64 ± 0.80	13.72 ± 0.46
WHOQOL-BREF (Post-test)		
– Physical	51.68 ± 4.57	56.09 ± 3.73
– Psychological	56.61 ± 4.18	60.78 ± 3.91
– Social	46.07 ± 7.86	56.86 ± 6.06
– Environmental	69.85 ± 7.24	71.69 ± 2.81
– Total score	12.96 ± 0.75	13.81 ± 0.38

Notes:
TUG = Timed Up and Go; WHOQOL-BREF = World Health Organization Quality of Life–Brief Version.
WHOQOL-BREF domain scores were transformed to a 0–100 scale.
Total score represents the mean of the four domains.

Within-Group Changes in Balance and Quality of Life

Within-group changes in balance performance and quality of life are summarized in Table 2. In the intervention group, balance performance improved significantly following the six-week exercise program. Mean TUG time decreased from 14.72 ± 2.47 seconds at baseline to 11.96 ± 2.31 seconds post-intervention, corresponding to a mean change of −2.76 ± 1.10 seconds ($p < 0.001$) and a very large effect size ($d = 2.51$; 95% CI 2.19–3.32).

In contrast, the control group showed a smaller and non-significant improvement in balance performance. Mean TUG time decreased from 12.60 ± 1.54 seconds to 11.85 ± 2.35 seconds, with a mean change of −0.76 ± 1.70 seconds (p = 0.084).

Table 2. Within-Group Effects of Balance and Strength Training

Outcome	Group	Pre-test	Post-test	Δ Change	Effect Size	95% CI	p-value
TUG (seconds)	Intervention	14.72 ± 2.47	11.96 ± 2.31	−2.76 ± 1.10	d = 2.51	2.19–3.32	<0.001*
	Control	12.60 ± 1.54	11.85 ± 2.35	−0.76 ± 1.70	d = 0.45	−0.11–1.63	0.084
WHOQOL-BREF							
Physical	Intervention	48.74 ± 4.71	51.68 ± 4.57	+2.94 ± 3.62	d = 0.81	−4.80 to −1.07	0.004*
	Control	53.57 (IQR 3.57)	58.93 (13.50)	+5.36	r = 0.59	–	0.014*
Psychological	Intervention	58.33 (10.42)	54.17 (6.25)	−4.16	r = 0.01	–	0.951
Social	Intervention	41.67 (8.33)	41.67 (8.33)	0.00	r = 0.24	–	0.317
Environmental	Intervention	62.50 (15.63)	68.75 (7.81)	+6.25	r = 0.74	–	0.002*
Total WHOQOL	Intervention	12.38 (1.16)	12.87 (0.99)	+0.49	r = 0.69	–	0.005*

Notes:
Values are presented as mean ± SD (parametric) or median (IQR) (non-parametric).
CI not available for non-parametric tests.
*Statistically significant (p < 0.05).

Regarding quality-of-life outcomes, the intervention group demonstrated significant improvements in selected WHOQOL-BREF domains. The physical domain score increased significantly following the intervention (p = 0.004), with a large effect size (d = 0.81; 95% CI −4.80 to −1.07). The environmental domain also improved significantly, with a large effect size (r = 0.74; p = 0.002). In addition, the total WHOQOL-BREF score showed a significant increase (r = 0.69; p = 0.005). No statistically significant changes were observed in the psychological or social domains within the intervention group.

In the control group, a significant increase was observed only in the physical domain of the WHOQOL-BREF (p = 0.014), while no significant changes were observed in the psychological, social, environmental, or total WHOQOL-BREF scores.

Between-Group Comparisons

Between-group differences in balance performance and quality-of-life outcomes are presented in Table 3. The intervention group demonstrated significantly greater improvements in balance performance compared with the control group, as indicated by a larger reduction in TUG time (between-group difference Δ = −1.99 seconds; p < 0.001), with a very large effect size (d = 1.40).

Table 3. Between-Group Differences After Intervention

Outcome	Test Statistic	Between-Group Δ	Effect Size	p-value
TUG (seconds)	t = −4.064	−1.99	d = 1.40	<0.001*
WHOQOL-BREF				
Physical	Z = −1.530	–	d = 0.26	0.126
Psychological	Z = −0.419	–	d = 0.07	0.675
Social	Z = −0.343	–	d = 0.06	0.732
Environmental	Z = −3.690	–	d = 0.63	<0.001*
Total WHOQOL	t = 2.273	–	d = 0.76	0.032*

Notes:
TUG = Timed Up and Go; WHOQOL-BREF = World Health Organization Quality of Life–Brief Version.
Total WHOQOL-BREF score represents the mean of the four domains.
*Statistically significant.

For quality-of-life outcomes, between-group analyses revealed a significant difference in the environmental domain of the WHOQOL-BREF, favoring the intervention group (p < 0.001), with a moderate-to-large effect size (d = 0.63). A significant between-group difference was also observed for the total WHOQOL-BREF score (p = 0.032), with a moderate-to-large effect size (d = 0.76). No statistically significant between-group differences were observed in the physical, psychological, or social domains.

Discussion

This study demonstrated that a six-week program integrating static and dynamic balance exercises with lower-extremity strengthening, performed three times per week, significantly improved balance performance and selected domains of quality of life in individuals with type 2 diabetes mellitus (T2DM). The primary finding was a substantial reduction in Timed Up and Go (TUG) time in the intervention group, accompanied by very large effect sizes, indicating clinically meaningful improvements in functional mobility. Improvements were also observed in the physical and environmental domains of the WHOQOL-BREF, as well as in the total quality-of-life score, whereas changes in psychological and social domains were minimal.

The observed improvement in balance performance is consistent with previous studies reporting the benefits of balance and strength training in individuals with diabetes, particularly those with diabetic peripheral neuropathy (DPN). Akbari and Naimi reported that exercise therapy incorporating balance and strengthening components improved postural stability in patients with DPN.[16] Similarly, Jaha and Haleem et al. demonstrated improvements in balance, gait, and quality of life following structured balance and strength training programs.[17] Importantly, the present study extends these findings by demonstrating that a similar integrated exercise program can be effective in a broader T2DM population without restricting participation to individuals with confirmed neuropathy.

Physiologically, balance training enhances postural control through improved sensory integration and neuromuscular coordination, while lower-extremity strengthening increases muscle force generation and endurance, which are critical for maintaining stability during functional activities. Repeated muscle contractions during training stimulate neuromuscular adaptations, improve phosphagen metabolism, and enhance proprioceptive feedback, thereby supporting balance regulation. These mechanisms likely contributed to the large reduction in TUG time observed in the intervention group. The magnitude of improvement suggests not only statistical significance but also clinical relevance, as shorter TUG times are associated with lower fall risk and better functional independence in older adults.

In contrast, the control group demonstrated only modest and largely non-significant improvements in balance performance, despite participating in low-frequency exercise. This finding underscores the importance of exercise dose and program structure. Consistent with recommendations from the American College of Sports Medicine, balance and strength exercises performed at least three times per week appear more effective than low-frequency interventions in improving postural control among older adults at risk of falls. The between-group differences observed in this study further support the superiority of structured, higher-frequency training over minimal or usual-care exercise programs.

Regarding quality of life, the intervention group showed significant improvements in the physical and environmental domains of the WHOQOL-BREF. Improvements in the physical domain likely reflect enhanced functional capacity, reduced movement difficulty, and greater confidence in performing daily activities. The environmental domain, which encompasses perceptions of safety, accessibility, and independence, also improved significantly, suggesting that better balance and mobility translated into more favorable perceptions of the surrounding environment. These findings are consistent with previous studies reporting that improvements in balance and functional mobility are associated with enhanced quality of life in individuals with T2DM and older adults.

In contrast, psychological and social domains showed minimal changes in both groups. This finding is not unexpected, as psychological well-being and social participation are influenced by multiple factors beyond physical function, including emotional support, social engagement, and mental health status. Short-term physical exercise interventions alone may be insufficient to produce measurable improvements in these domains. Previous studies have suggested that meaningful changes in psychological and social quality-of-life outcomes may require longer intervention durations or the inclusion of psychosocial components such as counseling, group-based activities, or peer-support programs.

Several methodological considerations should be taken into account when interpreting these findings. First, this study employed a non-randomized quasi-experimental design, which introduces the potential for selection bias and baseline imbalance between groups. At baseline, participants in the intervention group had poorer balance performance, longer diabetes duration, and lower quality-of-life scores compared with the control group. Although this imbalance may have increased the potential for improvement in the intervention group, the large effect sizes and consistent between-group differences suggest that the observed improvements were not solely attributable to regression to the mean.

Second, group allocation was performed at the health center level, which may have introduced cluster effects that were not explicitly accounted for in the analysis. Third, the sample size was relatively small, and the intervention duration was limited to six weeks, which may restrict the generalizability of the findings and preclude conclusions regarding long-term effects. Fourth, diabetic peripheral neuropathy was not formally assessed, and its presence among participants could not be ruled out. Finally, quality of life was assessed using a self-reported questionnaire, which may be subject to response bias.

Despite these limitations, this study has several strengths. The intervention was pragmatic, community-based, and delivered using standardized protocols under professional supervision, enhancing its feasibility and potential for implementation in routine primary care or community health settings. The use of validated outcome measures, the inclusion of effect sizes, and the absence of participant dropout further strengthen the internal validity of the findings.

Future research should employ randomized controlled trial designs with larger sample sizes, longer intervention durations, and follow-up periods to assess the sustainability of observed benefits. The inclusion of objective assessments of neuropathy, dose-matched control interventions, and psychosocial components may further clarify the mechanisms underlying improvements in balance and quality of life. Such studies would provide more robust evidence to inform clinical and community-based exercise recommendations for individuals with T2DM.

Conclusion

This study demonstrated that a six-week program integrating static and dynamic balance exercises with lower-extremity strengthening, performed three times per week, produced meaningful short-term improvements in balance performance and selected domains of quality of life in individuals with type 2 diabetes mellitus (T2DM). Balance performance improved substantially, as indicated by a significant reduction in Timed Up and Go (TUG) time, reflecting enhanced functional mobility and postural control. In addition, improvements were observed in the physical and environmental domains of the WHOQOL-BREF, as well as in the total quality-of-life score, suggesting that better balance and mobility translated into greater functional independence and more favorable perceptions of daily living environments.

Between-group analyses further confirmed that the structured, higher-frequency balance and strength training program was more effective than low-frequency exercise in improving balance performance and overall quality of life. In contrast, psychological and social domains showed minimal changes, indicating that physical exercise alone may be insufficient to influence these aspects of quality of life over a short intervention period.

Although the findings support the use of integrated balance and lower-extremity strengthening exercises as a feasible and beneficial component of T2DM management in community settings, they should be interpreted in light of the study's non-randomized design, small sample size, and short duration. Future studies using randomized controlled designs, larger samples, longer follow-up periods, and the inclusion of psychosocial components are warranted to confirm and extend these findings. Nevertheless, this intervention represents a practical approach that may help improve balance and functional independence among individuals with T2DM.

Author Contribution

Conceptualization: Larasati, Dwi Rosella Komala Sari
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Formal analysis: Larasati, Dwi Rosella Komala Sari
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Writing—original draft: Larasati
Writing—review and editing: Larasati, Dwi Rosella Komala Sari
Supervision: Dwi Rosella Komala Sari

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Conflict of Interest Statement

The authors declare no conflict of interest.

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Ethics Statement

This study was approved by the Ethics Committee of the Faculty of Health Sciences, Muhammadiyah University of Surakarta (Ethical Approval No. 1534/KEPK-FIK/IX/2025). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all participants prior to data collection.

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