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Comparative Effects of Functional and Balance Training on Fall Risk in Diabetic Neuropathy

Andy Martahan Andreas Hariandja[1], Abdurahman Berbudi B.L.[2], Latifah Nurbaiti[3]

[1-3]Department of Physiotherapy, Polytechnic of Health, Ministry of Health Jakarta III, Jakarta, Indonesia

Corresponding author:
Name: Latifah Nurbaiti
E-mail: latifahhnurbaitii@gmail.com
Phone: +62 819 3252 3901

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Abstract

Background: Diabetic neuropathy is a common complication of diabetes mellitus that impairs sensory and motor function, leading to balance deficits, gait disturbances, and an increased risk of falls. Functional Training and Balance Training are commonly used physiotherapy interventions to improve mobility and reduce fall risk, but comparative evidence remains limited.
Objective: To compare the effects of Functional Training and Balance Training on fall risk among patients with diabetic neuropathy.
Methods: A quasi-experimental two-group pre-test–post-test study was conducted among 26 patients with diabetic neuropathy. Participants were allocated to a Functional Training group (n=13) or a Balance Training group (n=13). Both interventions were performed three times weekly for four weeks. Fall risk was assessed using the Timed Up and Go Test (TUGT). Data were analyzed using paired-sample and independent-sample t-tests. Effect sizes were calculated using Cohen's d.
Results: Both interventions significantly improved TUGT performance. Functional Training reduced TUGT scores by 9.46 seconds (95% CI 7.14–11.78; t=8.877; p<0.001; d=2.462). Balance Training reduced TUGT scores by 7.15 seconds (95% CI 4.83–9.48; t=6.703; p<0.001; d=1.859). No significant differences were observed between groups at baseline (p=0.311) or after intervention (mean difference=-0.77 seconds; 95% CI -2.21 to 0.67; p=0.282; d=-0.431).
Conclusion: Functional Training and Balance Training were both effective in reducing fall risk among patients with diabetic neuropathy, with no significant difference in effectiveness between interventions.

Keywords
Diabetic Neuropathies; Accidental Falls; Exercise Therapy; Postural Balance; Rehabilitation

Introduction

Diabetes mellitus (DM) is one of the most prevalent chronic diseases worldwide and continues to pose a significant public health challenge. According to the International Diabetes Federation, approximately 537 million adults were living with diabetes in 2021, and this number is projected to increase substantially over the coming decades. The increasing prevalence of DM is accompanied by a growing burden of chronic complications that contribute to disability, healthcare costs, and reduced quality of life.[1] Among these complications, diabetic neuropathy is one of the most common and clinically important conditions affecting individuals with long-standing diabetes.[2]

Diabetic neuropathy is characterized by progressive damage to peripheral nerves resulting from chronic hyperglycemia, microvascular dysfunction, oxidative stress, and metabolic abnormalities.[2,3] These pathological changes impair sensory and motor function, particularly in the lower extremities, leading to deficits in proprioception, vibration sense, tactile sensation, and muscle performance.[4] As the condition progresses, patients frequently experience postural instability, gait abnormalities, reduced functional mobility, and an increased risk of falls.[5,6] Previous studies have reported that approximately half of individuals with diabetes develop some degree of peripheral neuropathy during the course of the disease, highlighting the substantial clinical burden associated with this complication.[2]

Falls represent a major concern among individuals with diabetic neuropathy because they are associated with fractures, hospitalization, loss of independence, reduced participation in daily activities, and diminished quality of life.[7,8] The risk of falling is particularly elevated when sensory deficits are accompanied by reduced muscle strength, impaired balance control, and delayed neuromuscular responses.[5] Consequently, interventions aimed at improving functional mobility and postural stability are essential components of rehabilitation programs for individuals with diabetic neuropathy.[9]

The Timed Up and Go Test (TUGT) is one of the most widely used clinical tools for assessing functional mobility and fall risk.[10,11] The test evaluates a combination of sit-to-stand ability, walking performance, turning, and dynamic balance within a single functional task. Higher TUGT scores indicate greater mobility limitations and an increased likelihood of falls. Because of its simplicity, reliability, and clinical applicability, TUGT has been extensively used to evaluate rehabilitation outcomes in populations with balance impairments and mobility deficits.[10,11]

Exercise therapy is considered a cornerstone of physiotherapy management for diabetic neuropathy because it addresses many of the neuromuscular impairments that contribute to fall risk.[12] Among the available exercise approaches, Functional Training and Balance Training are frequently implemented in clinical practice.[13] Functional Training consists of task-oriented activities that replicate movements commonly performed during daily living, such as sit-to-stand transitions, reaching tasks, stair negotiation, and multidirectional weight shifting.[14–16] These activities improve lower-extremity strength, neuromuscular coordination, motor control, and movement efficiency, thereby enhancing functional performance and dynamic stability.

Balance Training, on the other hand, primarily targets the sensory and motor mechanisms responsible for postural control. Through progressively challenging static and dynamic balance exercises, this intervention promotes sensory integration, proprioceptive awareness, postural adjustment, and balance recovery strategies.[17] Studies have demonstrated that Balance Training can improve

balance performance, gait quality, and confidence during mobility tasks among individuals with diabetic neuropathy.[17,18] Although both interventions aim to reduce fall risk, they may achieve these effects through different physiological pathways. Functional Training emphasizes task-specific movement adaptation and functional strength development, whereas Balance Training focuses more directly on postural control and sensory integration mechanisms.[14,17,19]

Previous studies have demonstrated beneficial effects of both Functional Training and Balance Training when applied independently in patients with diabetic neuropathy.[14–17] However, direct comparisons between these interventions remain limited. Most published studies have examined each intervention separately, compared them with conventional exercise programs, or combined them within multimodal rehabilitation approaches. Consequently, evidence regarding their relative effectiveness remains insufficient, creating uncertainty for clinicians when selecting the most appropriate intervention for patients with diabetic neuropathy.[12]

Understanding the comparative effectiveness of these interventions has important implications for evidence-based physiotherapy practice. Determining whether one intervention provides superior outcomes, or whether both interventions yield comparable benefits, may assist clinicians in developing individualized rehabilitation programs based on patient needs, clinical objectives, and available resources. Therefore, this study aimed to compare the effects of Functional Training and Balance Training on fall risk among patients with diabetic neuropathy using TUGT as the primary outcome measure.

It was hypothesized that both interventions would significantly improve TUGT performance and reduce fall risk. Based on the task-specific nature of Functional Training and its potential influence on strength, coordination, and functional mobility, greater improvement was anticipated in the Functional Training group.[13] Nevertheless, both interventions were expected to produce clinically meaningful benefits.

Methods

This study employed a quasi-experimental two-group pre-test–post-test design to compare the effects of Functional Training and Balance Training on fall risk among patients with diabetic neuropathy. The study was conducted at Duren Sawit Community Health Center, East Jakarta, Indonesia, between January and March 2026. A quasi-experimental design was selected because random allocation was not feasible within the operational setting of the community health center, where intervention scheduling had to accommodate routine healthcare services.

The study population consisted of patients with type 2 diabetes mellitus who regularly attended the Chronic Disease Management Program (Prolanis). Participants were recruited using purposive sampling based on predefined eligibility criteria. Inclusion criteria were: age 45–85 years; diagnosis of type 2 diabetes mellitus for more than three years; diabetic neuropathy indicated by a Michigan Neuropathy Screening Instrument (MNSI) score of ≥7; moderate-to-high fall risk indicated by a Timed Up and Go Test (TUGT) score of ≥20 seconds; and willingness to participate throughout the study period.[4,20] Exclusion criteria included acute musculoskeletal injuries, active diabetic foot ulcers, severe neurological disorders affecting mobility, unstable cardiovascular conditions, severe visual impairment, severe hearing impairment, and any medical condition that could limit participation in exercise sessions.

A total of 40 individuals were screened for eligibility. Four participants were excluded because they did not meet the inclusion criteria, while ten declined participation. Consequently, 26 participants were enrolled and allocated into two intervention groups consisting of 13 participants each. All participants completed the intervention protocol and post-intervention assessment. No loss to follow-up occurred during the study.

Before intervention, baseline equivalence between groups was evaluated using an independent-sample t-test. The analysis demonstrated no statistically significant difference in baseline TUGT scores between the Functional Training group (29.69±3.71 seconds) and the Balance Training group (28.15±3.87 seconds) (mean difference=1.54 seconds; 95% CI -1.53 to 4.61; p=0.311; Cohen's d=0.406), indicating comparable initial mobility status between groups.

Fall risk was assessed using the Timed Up and Go Test (TUGT), a standardized and widely validated measure of functional mobility and fall risk.[11,21] During the assessment, participants were instructed to stand up from a chair, walk three meters at a comfortable pace, turn around, return to the chair, and sit down. The total completion time was recorded in seconds using a stopwatch. Higher scores indicate poorer functional mobility and greater fall risk.[22]

Diabetic neuropathy was screened using the Michigan Neuropathy Screening Instrument (MNSI), which is commonly used to identify peripheral neuropathy among individuals with diabetes mellitus.[3] Baseline demographic and clinical data including age, sex, body mass index, duration of diabetes, MNSI score, and TUGT performance were collected before intervention.

The Functional Training group participated in supervised exercise sessions three times per week for four consecutive weeks, resulting in a total of 12 sessions. Each session lasted approximately 45 minutes and consisted of a five-minute warm-up, 35 minutes of exercise, and a five-minute cool-down. Functional Training emphasized task-oriented activities that simulated activities of daily living, including sit-to-stand movements, multidirectional reaching, stair climbing, and mini-hopping exercises. Participants performed two to three sets of each exercise with progressive increases in repetitions and task complexity according to individual tolerance.[14–16]

The Balance Training group participated in supervised exercise sessions with the same frequency and duration. Exercises included one-leg standing, tandem standing, heel standing, toe standing, and progressively challenging balance activities. Progression was achieved by increasing task duration, reducing upper-extremity support, and introducing more challenging postural conditions.[17] The intervention aimed to improve proprioception, sensory integration, postural control, and balance performance.

To reduce measurement variability, all assessments were performed by physiotherapists trained in standardized testing procedures. The same equipment, testing environment, and assessment protocol were used throughout the study. Due to the nature of the intervention, assessor blinding was not feasible. However, standardized assessment procedures were implemented to improve measurement consistency. Participant safety was monitored during every intervention session. No adverse events, exercise-related injuries, falls, or medical complications were reported throughout the intervention period.

Data analysis was performed using Statistical Package for the Social Sciences (SPSS). Descriptive statistics were used to summarize participant characteristics and outcome measures. Continuous variables were presented as mean and standard deviation, whereas categorical variables were reported as frequencies and percentages. Normality was assessed using the Shapiro–Wilk test. Baseline comparability between groups was evaluated using an independent-sample t-test.

Within-group changes in TUGT scores were analyzed using paired-sample t-tests. Between-group comparisons were performed using independent-sample t-tests. Effect sizes were calculated using Cohen's d and interpreted according to conventional criteria. Ninety-five percent confidence intervals (95% CI) were reported to improve interpretation of clinical relevance. Statistical significance was established at $p<0.05$ using two-tailed testing.

Results

The participant flow from eligibility assessment to final analysis is presented in Figure 1. Of the 40 participants assessed for eligibility, 14 were excluded, including 4 who did not meet the inclusion criteria and 10 who declined participation. The remaining 26 participants were allocated equally to the Functional Training group (n = 13) and the Balance Training group (n = 13). All participants in both groups completed the intervention and post-test assessment, resulting in 26 participants included in the final analysis.

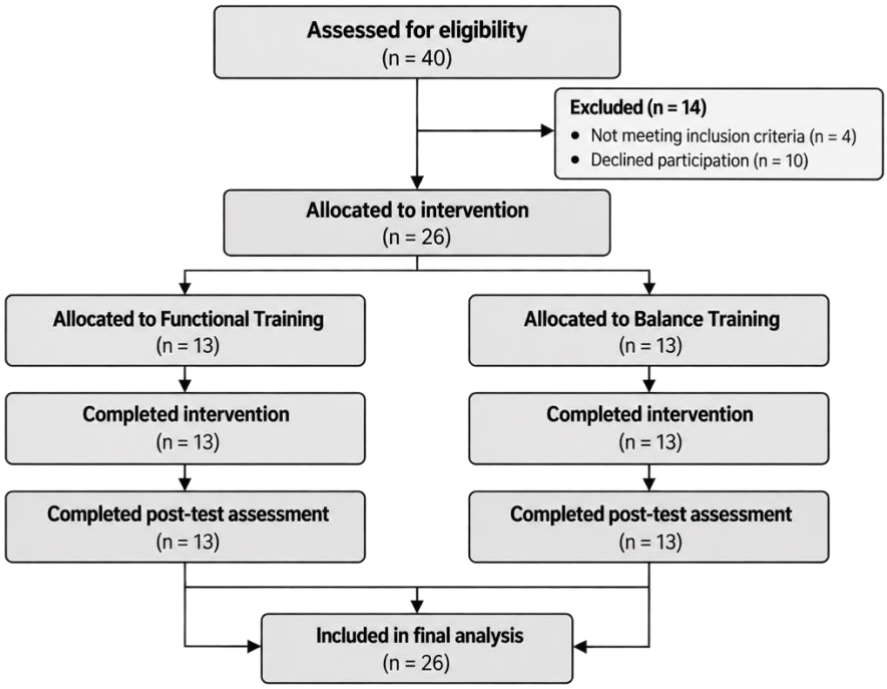

Figure 1. Participant Flow and Group Allocation

Baseline demographic and clinical characteristics were evaluated to describe the study population and assess group comparability before intervention. The majority of participants were female (53.8%), aged 61–85 years (53.8%), and classified as overweight or obese according to body mass index categories. The average duration of diabetes mellitus was 5.58±2.44 years, while the mean body mass index was 26.87±5.79 kg/m². Most participants had an MNSI score of 8, indicating clinically relevant neuropathic involvement.

To determine whether both groups were comparable before intervention, baseline TUGT scores were analyzed using an independent-sample t-test. As presented in Table 1, no statistically significant difference was observed between the Functional Training and Balance Training groups prior to intervention (p=0.311). The effect size was small to moderate (Cohen's d=0.406), and the confidence interval included zero, indicating acceptable baseline equivalence.

Table 1. Baseline Comparison of TUGT Scores Between Groups

Variable		Functional Training (n=13)	Balance Training (n=13)	Mean Difference	95% CI	p-value	Cohen's d
TUGT (seconds)	Pre-test	29.69 ± 3.71	28.15 ± 3.87	1.54	-1.53 to 4.61	0.311	0.406

The findings indicate that both groups had similar functional mobility status before intervention, thereby supporting the validity of subsequent comparisons. To evaluate the effectiveness of each intervention, paired-sample t-tests were conducted to compare pre-test and post-test TUGT scores within each group. Table 2 summarizes the magnitude of change observed after four weeks of intervention.

Table 2. Within-Group Changes in TUGT Scores

Group	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference	95% CI	t	p-value	Cohen's d
Functional Training	29.69 ± 3.71	20.23 ± 1.64	9.46	7.14 to 11.78	8.877	<0.001	2.462
Balance Training	28.15 ± 3.87	21.00 ± 1.92	7.15	4.83 to 9.48	6.703	<0.001	1.859

As shown in Table 2, both interventions resulted in statistically significant improvements in TUGT performance. Participants in the Functional Training group demonstrated a mean reduction of 9.46 seconds in TUGT completion time, whereas participants in the Balance Training group demonstrated a mean reduction of 7.15 seconds. Both interventions produced very large effect sizes, indicating substantial clinical improvement in functional mobility and fall-risk status. Following the completion of the intervention program, an independent-sample t-test was performed to determine whether one intervention produced superior outcomes. The results are presented in Table 3.

Table 3. Comparison of Post-Intervention TUGT Scores Between Groups

Variable		Functional Training (n=13)	Balance Training (n=13)	Mean Difference	95% CI	p-value	Cohen's d
TUGT (seconds)	Post-test	20.23 ± 1.64	21.00 ± 1.92	-0.77	-2.21 to 0.67	0.282	-0.431

Although the Functional Training group demonstrated a slightly lower post-intervention TUGT score than the Balance Training group, the difference was not statistically significant (p=0.282). Furthermore, the confidence interval crossed zero and the effect size remained small, indicating that the observed difference may not represent a meaningful clinical advantage of one intervention over the other.

Overall, both Functional Training and Balance Training significantly reduced TUGT completion time after four weeks of intervention. Functional Training produced a greater numerical reduction in TUGT scores compared with Balance Training; however, the between-group comparison demonstrated no statistically significant difference. These findings suggest that both interventions were effective in reducing fall risk among patients with diabetic neuropathy and provided comparable clinical benefits within the context of this study.

Discussion

This study aimed to compare the effects of Functional Training and Balance Training on fall risk among patients with diabetic neuropathy. The findings demonstrated that both interventions significantly improved Timed Up and Go Test (TUGT) performance following four weeks of supervised exercise. Participants in the Functional Training group experienced a mean reduction of 9.46 seconds in TUGT completion time, whereas participants in the Balance Training group demonstrated a mean reduction of 7.15 seconds. Both interventions produced statistically significant improvements with very large effect sizes, indicating substantial clinical benefits in reducing fall risk and improving functional mobility among patients with diabetic neuropathy.

The significant improvement observed in the Functional Training group may be explained by the task-specific characteristics of the intervention. Functional Training emphasizes movement patterns that closely resemble activities performed in daily life, including sit-to-stand transfers, stair negotiation, multidirectional reaching, and dynamic weight shifting. Repeated exposure to these activities improves lower-extremity strength, motor coordination, movement efficiency, and neuromuscular control.[14–16] These adaptations are particularly important in patients with diabetic neuropathy because sensory deficits in the lower extremities frequently impair gait stability and increase dependence on compensatory movement strategies.[5] Consequently, improvements in functional mobility may directly contribute to reductions in fall risk, which is reflected by the substantial decrease in TUGT completion time observed in the present study.

Similarly, Balance Training produced significant improvements in functional mobility and fall-risk status. This finding is consistent with the physiological rationale underlying balance rehabilitation. Postural control requires continuous integration of sensory information from visual, vestibular, and somatosensory systems.[17,18] In diabetic neuropathy, peripheral sensory impairment disrupts this integration process and contributes to instability during standing and walking activities.[3,5] Through repeated exposure to progressively challenging balance tasks, Balance Training enhances proprioceptive awareness, postural adjustment strategies, and neuromuscular responsiveness.[17] These adaptations may explain the significant reduction in TUGT scores and the large effect size observed in the Balance Training group.

The findings of this study are consistent with previous investigations reporting beneficial effects of exercise-based interventions for patients with diabetic neuropathy. Jaha reported that both Functional Strength Training and Balance Training improved gait performance and postural stability among individuals with diabetic peripheral neuropathy.[14] Likewise, Chaudhari and Sutaria demonstrated that functional balance exercises significantly improved balance performance and reduced fall risk in patients with diabetic neuropathy.[17] Other studies have also shown that task-oriented strengthening programs and proprioceptive exercises contribute to improvements in mobility, balance confidence, and functional independence in this population.[15,16] Collectively, these findings reinforce the role of exercise therapy as a central component of physiotherapy management for diabetic neuropathy.

Although Functional Training demonstrated a greater numerical improvement than Balance Training, the between-group analysis revealed no statistically significant difference following intervention (mean difference=-0.77 seconds; 95% CI -2.21 to 0.67; p=0.282). Moreover, the confidence interval crossed zero and the effect size remained relatively small (Cohen's d=-0.431). These findings indicate that the observed difference between interventions was insufficient to establish the superiority of one intervention over the other. Therefore, the results support the interpretation that both interventions provide comparable benefits in reducing fall risk among patients with diabetic neuropathy.

Several explanations may account for the absence of a statistically significant difference between groups. First, although both interventions employ different training approaches, they ultimately target similar functional outcomes, namely improvements in mobility, stability, and movement control. Functional Training primarily enhances strength, coordination, and task-specific performance, whereas Balance Training focuses on sensory integration and postural control mechanisms.[13] Nevertheless, both pathways may converge toward improved functional mobility, thereby producing comparable TUGT outcomes. Second, the intervention period of four weeks may have been sufficient to generate meaningful improvements in both groups but insufficient to reveal substantial differences between intervention strategies. Longer intervention periods may result in more distinct adaptation profiles and should be explored in future research.

The possibility of Type II error should also be considered when interpreting the findings. Although both groups demonstrated large within-group improvements, the study included only 26 participants. Small sample sizes reduce statistical power and increase the likelihood of failing to detect a true difference when one actually exists.[23] Therefore, while no significant between-group difference was observed, future studies involving larger samples and formal power calculations are required to determine whether subtle differences in effectiveness may emerge under more adequately powered conditions.

From a clinical perspective, the findings provide valuable implications for physiotherapy practice in community and primary healthcare settings. Because both interventions produced significant improvements and comparable outcomes, clinicians may select either Functional Training or Balance Training according to patient characteristics, rehabilitation goals, resource availability, and therapist expertise. Functional Training may be particularly useful when improving daily functional performance is a primary objective, whereas Balance Training may be preferable when postural instability and sensory deficits represent the principal clinical concerns. The comparable effectiveness of both interventions provides flexibility in intervention planning and supports individualized rehabilitation strategies.

Several strengths of this study should be acknowledged. The study directly compared two commonly used physiotherapy interventions in patients with diabetic neuropathy, addressing an important gap in the existing literature. In addition, all participants completed the intervention program, resulting in complete outcome data and eliminating attrition bias. The inclusion of effect size estimates and confidence intervals also improves interpretation of clinical relevance beyond statistical significance alone.

Nevertheless, several limitations should be considered. The quasi-experimental design without random allocation increases the possibility of selection bias and limits causal inference. Although baseline comparison demonstrated comparable groups before

intervention, unmeasured confounding factors may still have influenced the results. The relatively small sample size may have reduced statistical power, and the intervention period was limited to four weeks. Furthermore, TUGT was the primary outcome measure and may not fully capture all dimensions of balance, gait performance, and fall-related function.[24] Future studies should employ randomized controlled designs, larger sample sizes, longer intervention durations, and multiple outcome measures to strengthen the evidence base regarding exercise interventions for diabetic neuropathy.

Conclusion

This study demonstrated that both Functional Training and Balance Training significantly improved functional mobility and reduced fall risk among patients with diabetic neuropathy. Functional Training resulted in a mean reduction of 9.46 seconds in Timed Up and Go Test (TUGT) performance, whereas Balance Training resulted in a mean reduction of 7.15 seconds. Both interventions produced statistically significant improvements with very large effect sizes, indicating substantial clinical benefits.

Despite the greater numerical improvement observed in the Functional Training group, no statistically significant difference was found between Functional Training and Balance Training following intervention ($p=0.282$). These findings suggest that both interventions provide comparable effectiveness in reducing fall risk among patients with diabetic neuropathy.

Therefore, Functional Training and Balance Training may both be considered appropriate physiotherapy interventions for improving mobility and reducing fall risk in individuals with diabetic neuropathy. Intervention selection should be individualized according to patient characteristics, rehabilitation goals, therapist expertise, and available clinical resources.

Study Limitations

Several limitations should be acknowledged when interpreting the findings of this study. First, the quasi-experimental design without random allocation may increase the risk of selection bias and limit causal inference. Although baseline analysis demonstrated comparable groups before intervention, residual confounding factors cannot be completely excluded.

Second, the study involved a relatively small sample size, which may have limited statistical power and increased the possibility of Type II error in detecting between-group differences. Third, the intervention period was limited to four weeks and may not have been sufficient to capture long-term physiological adaptations or sustainability of treatment effects.

Fourth, fall risk was evaluated primarily using TUGT. Although TUGT is a valid and clinically relevant outcome measure, it may not fully represent all dimensions of balance performance, gait characteristics, and functional independence. Finally, factors such as glycemic control, medication adherence, physical activity levels, and lifestyle behaviors were not fully controlled and may have influenced participant outcomes.

Clinical Implications

The findings of this study have important implications for physiotherapy practice, particularly within community and primary healthcare settings where diabetic neuropathy is frequently encountered. Because both Functional Training and Balance Training demonstrated significant improvements in mobility and fall-risk reduction, clinicians may confidently incorporate either intervention into rehabilitation programs.

Functional Training may be particularly beneficial when the primary rehabilitation goal is to enhance task-specific mobility, transfer performance, and activities of daily living. Conversely, Balance Training may be more appropriate when postural instability, proprioceptive deficits, and balance impairments are the dominant clinical concerns. Given the comparable effectiveness observed between interventions, physiotherapists may select the most appropriate program based on patient needs, available resources, and service feasibility.

Future Research

Future studies should employ randomized controlled trial designs with larger sample sizes and formal power calculations to strengthen internal validity and reduce the risk of bias. Longer intervention periods and follow-up assessments are also recommended to evaluate the sustainability of treatment effects over time.

In addition, future investigations should include multiple outcome measures, such as balance performance tests, gait analysis, quality-of-life assessments, and actual fall incidence, to provide a more comprehensive understanding of intervention effectiveness. Reporting of effect sizes, confidence intervals, and clinically meaningful change scores should also be maintained to improve interpretation and translation of findings into clinical practice.

Author Contributions

Andy Martahan Andreas Hariandja: Conceptualization, Methodology, Supervision, Validation, Formal Analysis, Writing – Review & Editing.
Abdurahman Berbudi B.L.: Methodology, Investigation, Resources, Supervision, Writing – Review & Editing.
Latifah Nurbaiti: Investigation, Data Curation, Formal Analysis, Visualization, Writing – Original Draft, Project Administration.

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Conflict of Interest Statement

The authors declare that there are no conflicts of interest related to this study.

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Ethics Statement

This study was approved by the Health Research Ethics Committee of Polytechnic of Health Ministry of Health Jakarta III, Indonesia (Approval Number: DP.04.03/F.XI.22/14006/2025). Written informed consent was obtained from all participants before

enrollment and data collection. All study procedures were conducted in accordance with the ethical principles of the Declaration of Helsinki.

Data Availability Statement

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request.

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