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Improving dynamic and static balance in older people through core stability and tandem walking exercises

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Abstract

Ageing often causes a decline in strength and balance, increasing the risk of falls in older adults. However, few studies have examined the combination of core stability exercises and paired walking and compared responses based on gender. This study presents a novel approach by applying a 2×2 factorial design to evaluate the effects of both exercises on static and dynamic balance. Forty older adults (20 men and 20 women) participated in 16 training sessions over an eight-week period. Dynamic balance was measured using the Timed Up and Go (TUG) test, while static and dynamic balance were assessed using the Berg Balance Scale (BBS). The results showed significant improvements: TUG scores decreased from 24.53 to 15.34 seconds (∆ = –9.19 seconds), indicating improved functional mobility and reduced risk of falling. On the BBS, women showed greater static improvement (+10.15 points) than men (+7.95 points), while dynamic improvement was similar in both genders. Clinically, the improvement in TUG to the safe range (<20 seconds) and the increase in BBS scores indicate a relevant improvement in postural stability for fall prevention. Overall, the combination of core stability exercises and paired walking is an effective, inexpensive intervention that can be implemented in community programs to support the mobility and functional independence of older adults.

Keywords: Core Stability, tandem walking, balance improvement, older adults, gender differences.

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Authors contribution: a – Preparing concepts; b – Formulating methods; c – Conducting research; d – Processing results; e – Interpretation and conclusions; f - Editing the final version.

INTRODUCTION

Previous research on fall risk and balance interventions in older adults has shown considerable variation, influenced by differences in exercise type, intervention duration, participant characteristics, and community context (Kang, 2015; Astriani et al., 2020; Melani et al., 2021). These variations indicate that stronger and more consistent evidence is needed to determine effective, low-cost, and community-applicable balance training

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approaches. This urgency is reinforced by demographic changes. The global older population continues to rise rapidly; by 2030, one in six people worldwide will be aged ≥60 years or older, and the number is projected to reach 2.1 billion by 2050 (WHO, 2020; WHO, 2023). In Indonesia, older adults are dominated by the 60–69 age group (63.59%), followed by ages 70–79 (26.76%) and ≥80 (8.65%), with women slightly outnumbering men (Candra et al., 2024). The Special Region of Yogyakarta has the highest proportion of older adults nationally, while Sleman Regency has the largest absolute number (Purnomo, 2024), creating an increasing need for programs that address fall-related health issues.

Falls among older adults are strongly linked to age-related declines in neurological, sensory, and musculoskeletal functions (Kang, 2015; Astriani et al., 2020; Melani et al., 2021). Epidemiological data show that approximately 25% of individuals aged 65–74 experience falls each year, increasing to 29% at ages 75–84 and reaching 39% among those ≥85 years (Taman, 2018; Park, 2018). Beyond causing fractures and disability, falls also lead to fear of falling, social withdrawal, and depression (Bolding & Corman, 2019; Bhasin et al., 2020), and their annual prevalence of around 30% makes them one of the leading factors limiting mobility and quality of life (Paliwal et al., 2017). One major contributor to impaired balance is sarcopenia, a progressive decline in muscle mass and strength that accelerates after age 65 (Liguori et al., 2018). Sarcopenia is associated with mobility limitations, reduced postural control, increased risk of falls, and higher hospitalization and mortality rates (Cruz-Jentoft et al., 2010; Strandberg et al., 2021; Njoto, 2023), and in Indonesia it often goes undetected or undertreated in primary care settings.

Prior studies indicate that structured balance exercises can improve functional abilities and reduce fall risk in older adults. However, programs commonly implemented in community settings often involve only light activities, such as casual walking, stretching, or general gymnastics, which do not adequately target core strength and sensorimotor integration—two components essential for static and dynamic balance. Core stability exercises strengthen the muscles supporting the spine and pelvis, enhancing postural control and functional alignment (Melani et al., 2021; Kang, 2015). Research has shown that these exercises improve balance and weight distribution and reduce fall risk (Cabanas-Valdés et al., 2016; Bagherian et al., 2019; Zheng et al., 2022). Walking-based exercises, including paired or tandem walking, also demonstrate benefits by challenging proprioception and coordinating body movements during dynamic tasks (Nakagawa et al., 2016; Suzuki et al., 2017; Joo et al., 2022). A community-based study even reported a 78% improvement in dynamic balance after walking-based training (Bayu Putra, 2024), highlighting its strong potential in public health applications.

Despite these promising findings, research combining core stability and paired walking remains limited, particularly in older adults, and gender-based differences in balance responses have not been systematically explored. At the same time, many previous studies were constrained by small sample sizes, short intervention durations, and insufficient control of external factors such as nutritional status, daily activity levels, or environmental risks. These limitations reinforce the need for balanced interventions that are evidence-based yet practical for real community conditions, especially in settings with limited human resources, facilities, and funding.

Core stability and walking-based exercises meet these criteria because they require no special equipment, can be conducted in groups, and are easily adapted to varying physical capacities (Kang, 2015; Melani et al., 2021). Their simplicity aligns with national promotive–preventive strategies emphasizing community empowerment. Studies also show that health-care-guided balance training can increase participation and reduce fall risk (Suzuki et al., 2017; Joo et al., 2022), underscoring the feasibility of integrating structured balance guidelines into routine elderly health posts, group exercise sessions, and home-visit programs.

Based on these gaps, this study aims to investigate the effects of combining core stability and paired walking exercises on static and dynamic

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balance in older adults. This study also provides evidence to support community-applicable fall-prevention strategies and offers direction for longitudinal research to assess long-term effects and sustainability.

METHOD

This study employed a 2×2 quantitative factorial experimental design to investigate the effects of exercise type (core stability and paired/tandem walking) and gender on static and dynamic balance in older adults. The design allowed simultaneous analysis of the main effects of the intervention, gender differences, and their interaction. The study was carried out in Padukuhan Dowangan, Yogyakarta, from January to March 2025. A total of 40 participants aged 60–75 years were recruited using purposive sampling based on inclusion criteria (age ≥60 years, ability to walk independently, MMSE ≥ 24 or no severe neurological disorder, willingness to complete all sessions) and exclusion criteria (vestibular disorders, severe musculoskeletal problems, history of severe falls in the last six months, or participation in other balance programs). Sample adequacy was determined using G*Power (effect size = 0.80, α = 0.05, power = 0.95), which required at least 36 participants. Therefore, 40 individuals (20 men and 20 women) were recruited to account for potential attrition. Participants were then assigned to four groups according to the factorial structure: men's core stability, men's tandem walking, women's core stability, and women's tandem walking.

Table 1. 2x2 Factorial design structure

Gender (A)	Core Stability (B1)	Tandem Walking (B2)
Man (A1)	A1 B1	A1 B2
Women (A2)	A2 B1	A2 B2

Instruments

Static and dynamic balance were assessed using the Berg Balance Scale (BBS) and the Timed Up and Go (TUG) test. The BBS evaluates balance through functional tasks and has high validity and reliability in older adults (Berg et al., 1992). The TUG assesses dynamic balance and functional mobility through completion time and is widely recognized for its validity and reliability in identifying fall risk in older adults (Podsiadlo & Richardson, 1991). Both instruments were administered before and after the intervention.

Procedure

Participants completed a structured training program adjusted to the 2×2 design. The intervention lasted six weeks with a frequency of three sessions per week, and each session lasted 30–40 minutes. All exercise sessions were conducted at the village meeting hall and guided by a trained instructor. To reflect recognized recommendations for achieving neuromuscular adaptation and improvements in postural control, all groups followed a standardized schedule, completing between 16 sessions over 6–8 weeks, depending on group categorization. Pre- and post-intervention balance assessments, using the BBS and TUG, were administered to each participant according to their assigned group.

Statistical Analysis

Data were analyzed using SPSS version 25. Normality was tested with the Kolmogorov–Smirnov test, and homogeneity of variance was assessed using Levene's test. Differences between pre- and post-test scores within groups were analyzed using paired t-tests. The main effects of exercise type, gender, and their interaction were examined using a 2×2 factorial ANOVA. The significance level was set at $p < 0.05$.

RESULTS

This study involved 40 elderly participants, consisting of 20 men and 20 women. Dynamic balance was measured using the Timed Up and Go (TUG) test, and static and dynamic balance were measured using the Berg Balance Scale (BBS).

Table 2. Comparisons of average time up and go results before and after treatment

Time	Mean (Second ± SD)
Before Treatment	24.53 ± 2.212
After Treatment	15.34 ± 2.172

The results presented in Table 2 show the difference in Timed Up and Go (TUG) scores between measurements before and after the

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intervention. The average TUG score before the intervention was 24.53 seconds, while after the intervention, the average TUG score was 15.34 seconds. The difference in TUG time between the two measurements is listed in Table 2 and analyzed further using statistical tests in the next section.

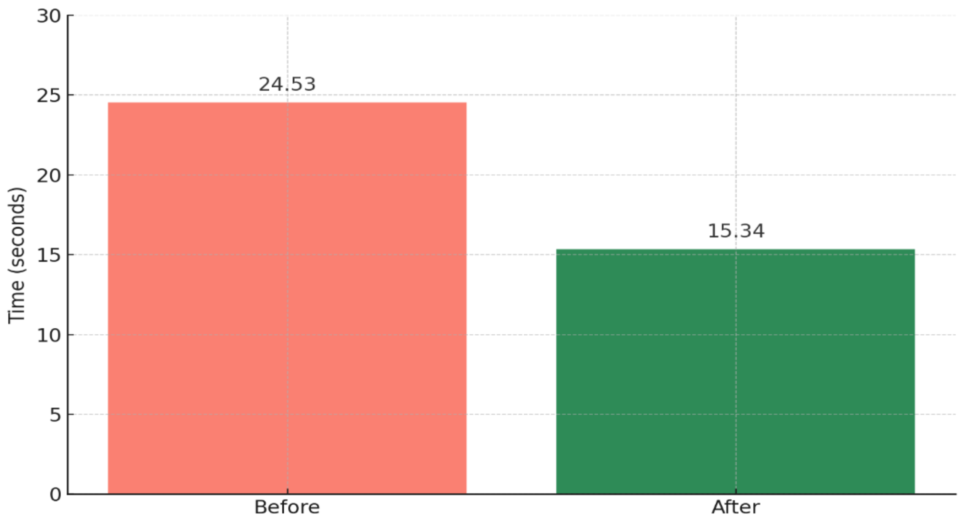

Figure 1. TUG results before and after treatment

The findings indicate a substantial reduction in the average Timed Up and Go (TUG) score, with a decrease of 9.19 seconds following the exercise intervention. This improvement reflects a significant enhancement in participants' dynamic balance and overall mobility. Specifically, the mean TUG time decreased from 24.53 seconds to 15.34 seconds, indicating a shift from a high fall-risk category to a level associated with greater stability and functional mobility. The Berg Balance Test (BBT), which evaluates an individual's ability to maintain balance during both static and dynamic tasks, was also employed in this study. The maximum possible score on the BBT is 56, representing optimal balance performance.

Table 3. Differences in Berg Balance Test scores based on gender before and after the exercise intervention

Balance Type	Time	Male (Mean±SD)	Female (Mean±SD)
Static	Pre Test	39.55 ± 2.946	41.15 ±2.907
	Post Test	47.5 ±3.663	51.3 ± 3.278
Dynamic	Pre Test	36 ± 2.406	37.85 ± 3.376
	Post Test	40.4 ± 2.415	42.05 ± 2.282

As shown in Table 3, static and dynamic balance scores measured using the Berg Balance Scale (BBS) showed differences between pre- and post-intervention measurements in male and female participants. In static balance, the average score of female participants changed from 41.15 in the initial measurement to 51.30 in the final measurement, while the average score of male participants changed from 39.55 to 47.50. In dynamic balance, the average score for female participants changed from 37.85 to 42.05, while the average score for male participants changed from 36.00 to 40.40. All static and dynamic balance scores based on gender before and after the intervention are presented in detail in Table 3.

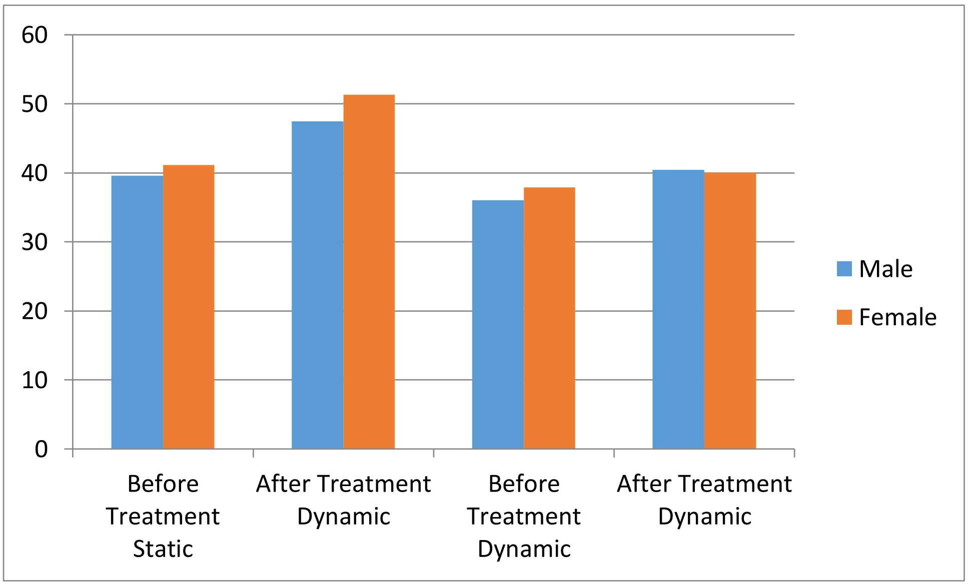

Figure 2. TUG results before and after treatment

The paired-sample t-test showed a significant difference in TUG scores between the pre-test and post-test ($t = 29.776$; $p < 0.001$). The mixed-design ANOVA on BBS scores showed a main effect of time ($F(1, 38) = 232.557$; $p < 0.001$), a main effect of gender ($F(1, 38) = 5.227$; $p = 0.028$), and no interaction between time and gender ($p = 0.912$).

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Statistical Analysis

Overview:

Statistical tests were conducted to compare numerical differences between pre-test and post-test scores and to examine the effects of time and gender on BBS outcomes. The statistical outputs are presented in Tables A and B.

Table 4. Paired-Sample t-test for TUG

Statistical Test	Variable	n	Test Value	p-value	Description (Objective)
Paired-sample t-test	TUG (Pre vs Post)	40	t(39) = 29.776	p < 0.001	The test shows a statistically significant numerical difference between pre-test and post-test values.

Extended Numerical Description:

Table A displays the comparison of TUG scores between pre-test and post-test. The pre-test mean was 24.53 seconds, and the post-test mean was 15.34 seconds. The paired-sample t-test yielded a test statistic of t(39) = 29.776 with p < 0.001, indicating a significant numerical difference between the two measurement points. This table reports the statistical outcomes without interpreting their functional meaning.

Table 5. Mixed-design ANOVA for BBS

Effect Tested	Statistical Value	p-value	Description (Objective)
Time	F(1, 38) = 232.557	p < 0.001	Numerical difference between pre-test and post-test BBS scores.
Gender	F(1, 38) = 5.227	p = 0.028	Numerical difference between male and female BBS scores.
Time × Gender	–	p = 0.912	No statistically significant interaction between the two factors.

Table 5 summarizes the mixed-design ANOVA results for the Berg Balance Scale (BBS). The analysis shows a main effect of time, indicating that the statistical model detected a numerical difference between the pre-test and post-test scores across participants. The main effect of gender also shows a numerical difference in overall BBS scores between male and female participants. Meanwhile, the interaction effect, with a p-value of 0.912, indicates that the numerical changes from pre-test to post-test were similar for both genders. These results present the statistical outputs of the model and describe the observed differences without providing functional or clinical interpretation.

DISCUSSION

This study achieved its primary objective by conceptually demonstrating that a combined approach involving core stability and paired walking exercises can contribute to improvements in static and dynamic balance among older adults. The results reinforce theoretical perspectives that view balance as the outcome of integrated interactions between the musculoskeletal, neuromuscular, and sensory systems, all of which undergo age-related decline and require coordinated stimulation. By incorporating two complementary exercise modalities within a single structured program, this study supports the growing consensus that interventions addressing multiple physiological systems simultaneously offer more robust benefits than single-component training, particularly for older adults who often experience multifactorial balance impairments.

The main findings of this study indicate measurable improvements in balance performance across all intervention groups, reflected in increased Berg Balance Scale scores and reduced Timed Up and Go times. These outcomes are consistent with previous research, which has shown that structured balance-focused exercises can enhance postural control and functional mobility in older adults (Fauziah et al., 2021; Ghasemabad et al., 2022; Kusumadewi et al., 2023). Imama and Prasetyo (2025) similarly reported improvements in functional balance following programs that target trunk stability and coordinated stepping. The consistency between this study and prior findings suggests that multimodal training reinforces various components of the balance system simultaneously, offering physiological advantages that extend beyond isolated approaches commonly used in community settings.

Core stability training plays an important role in improving static balance by enhancing postural alignment, trunk control, and segmental stability. Strengthening core musculature increases intra-abdominal pressure, provides greater support for the spine and pelvis, and improves the distribution of body weight, all of which contribute to the maintenance of upright posture (De Blaiser et al., 2018; Sadeghi et al., 2020). Since ageing

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is associated with diminished postural reflexes, decreased lower-limb strength, and slower neuromuscular responses, older adults often experience difficulty maintaining stable positions. The core-focused exercises used in this study may help compensate for these age-related deficits by improving neuromuscular coordination that is essential for maintaining static balance.

Paired walking training complements these benefits by improving dynamic balance through the optimization of sensorimotor integration. Walking with controlled patterns requires coordinated activation of visual, vestibular, and somatosensory systems to adjust body position appropriately during movement. Prior research has shown that structured walking programs can improve gait stability, enhance proprioceptive feedback, and promote efficient step coordination in older adults (Kim et al., 2019; Joo et al., 2022). When combined with core stability training, paired walking provides a dual mechanism—strengthening the trunk while refining movement accuracy, which supports improvements in both static and dynamic balance. This combination is particularly effective for addressing the functional challenges faced by older adults living in community environments.

Gender-related findings in this study showed that female participants tended to achieve higher balance scores than male participants at both measurement points, a pattern that aligns with earlier evidence suggesting that older women generally demonstrate greater flexibility, better postural adaptation, and higher adherence to exercise programs (Shiryaeva et al., 2020; Wu et al., 2021; Imama & Prasetyo, 2025). However, the absence of a significant interaction effect between gender and exercise type indicates that both men and women benefited similarly from the intervention, with differences reflecting baseline characteristics rather than differences in responsiveness. An additional noteworthy pattern is that participants with lower initial balance scores showed larger numerical improvements, reinforcing earlier findings that older adults with poorer baseline function tend to respond strongly to moderate-duration structured balance training (Szafraniec et al., 2018; Melani et al., 2021).

The novelty of this study lies in integrating core stability and paired walking into a single structured program implemented in a rural community setting that had never received systematic balance training before. This model offers a practical, low-cost option that can be replicated within community-based health programs, particularly in regions where older adults have limited access to formal exercise facilities. The exercises used in this study are simple, do not require specialized equipment, and can be delivered effectively by community health workers, elderly health-post cadres, or trained volunteers. These characteristics make the intervention suitable for routine implementation in existing community activities such as group exercise sessions, elderly health posts, and home-visit programs, thereby supporting broader fall-prevention initiatives and promoting functional independence in older adults.

Despite its contributions, this study has several limitations that must be acknowledged. The sample was drawn from a single rural area, which limits the generalizability of the results to older adults living in different geographic, cultural, or socioeconomic contexts. External factors known to influence balance, such as nutritional intake, daily physical activity, medication use, and environmental conditions, were not controlled, which may have affected individual responses to the intervention. In addition, the study did not include very old adults, who may exhibit different physiological responses and require modified intervention strategies. These limitations highlight the need for caution when applying these findings to broader populations.

Future research should involve larger and more diverse samples, incorporate control of key external variables that influence balance outcomes, and include long-term follow-up assessments to evaluate the sustainability of intervention effects over time. Longitudinal designs and multi-site community trials are also recommended to ensure that combined

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core stability and paired walking programs can be adapted effectively across different health-service settings.

CONCLUSION

This study demonstrates that the combined use of core stability and paired walking exercises produces measurable improvements in both static and dynamic balance among older adults, as reflected in higher Berg Balance Scale (BBS) scores and lower Timed Up and Go (TUG) times. The primary novelty of this research lies in implementing an integrated balance-training model in a rural Indonesian community that previously lacked access to structured exercise programs. The intervention proved feasible as a simple, affordable, and scalable community-based approach that can be adopted in settings with limited resources. By presenting empirical evidence on the effectiveness of combining two complementary modalities within a single regimen, this study contributes to the advancement of multimodal balance-training research and provides a scientific foundation for strengthening community-level fall-prevention policies that support functional independence and quality of life in older adults.

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