

Effect of Osteoporosis Prevention Exercise on Lower Limb Strength and Fall Risk: A One-Group Pretest–Posttest Study

I Komang Agus Pranata¹, I A Ratih Wulansari Manuaba², I Putu Prisa Jaya³, Komang Tri Adi Suparwati⁴

¹⁻⁴Physiotherapy Study Program, Faculty of Health Sciences, Universitas Bali Internasional, Denpasar, Bali, Indonesia

Corresponding author:

Name: I Komang Agus Pranata

E-mail: aguspranata2965@gmail.com

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Abstract

Background: Aging is associated with reduced lower limb muscle strength, impaired postural stability, and increased fall risk. This study evaluated Osteoporosis Prevention Exercise Series I as a low-impact exercise program for community-dwelling older women.

Objective: To evaluate the effect of Osteoporosis Prevention Exercise Series I on lower limb muscle strength and fall risk.

Methods: A one-group pretest–posttest study involved 50 community-dwelling older women recruited using total sampling. Participants performed the exercise program three times weekly for four weeks, with 40-minute sessions. Lower limb muscle strength was assessed using a Leg Dynamometer and fall risk using the Timed Up and Go Test (TUGT). Data were analyzed using the Wilcoxon Signed-Rank Test at $p < 0.05$.

Results: Lower limb muscle strength increased from 100.42 ± 22.20 kg to 130.76 ± 31.32 kg, with a mean improvement of 30.34 ± 9.12 kg ($p < 0.001$). TUGT time decreased from 18.30 ± 2.95 to 10.30 ± 2.24 seconds, with a mean reduction of 8.00 ± 0.71 seconds ($p < 0.001$).

Conclusion: Osteoporosis Prevention Exercise Series I was associated with improved lower limb muscle strength and reduced fall risk among community-dwelling older women. The absence of a control group limits causal inference and supports the need for controlled studies.

Keywords:

Aged; Accidental Falls; Exercise Therapy; Muscle Strength; Osteoporosis; Postural Balance

Introduction

Population ageing has become one of the most important demographic transitions worldwide, creating substantial challenges for healthcare systems, particularly in maintaining functional independence and preventing disability among older adults. Indonesia is the fourth most populous country in the world, with approximately 273 million inhabitants according to the 2020 population census.¹ Improvements in life expectancy, declining fertility rates, and advances in healthcare have contributed to a continuous increase in the proportion of older adults within the population.² Between 2019 and 2021, the number of older adults in Indonesia increased from 18 million (7.56%) to 25.9 million (9.70%) of the total population and is projected to reach approximately 48 million (15.77%) by 2035.³ Bali is among the provinces with the highest proportion of older adults, reflecting an accelerated demographic transition that is expected to increase the burden of age-related musculoskeletal disorders and mobility limitations.⁴ Consequently, preserving physical function and preventing mobility decline have become important priorities for healthcare professionals, including physiotherapists, in supporting healthy ageing and maintaining quality of life among community-dwelling older adults.⁵

Ageing is accompanied by progressive deterioration of multiple physiological systems, particularly the musculoskeletal and neuromuscular systems.⁶ Reductions in skeletal muscle mass, muscle strength, bone mineral density, tendon elasticity, joint mobility, and neuromuscular coordination collectively impair physical performance and postural stability.⁷ Among these changes, decreased lower limb muscle strength is considered one of the most important determinants of impaired mobility because the lower extremities are responsible for maintaining upright posture, transferring body weight, and supporting locomotion during daily activities.⁸ Progressive muscle weakness therefore contributes directly to impaired balance, reduced gait performance, diminished functional independence, and an increased likelihood of falls among older adults.⁹

Falls remain a major public health concern because they represent one of the leading causes of injury, disability, hospitalization, and mortality in the older population. According to the World Health Organization, approximately one-third of adults aged 65 years and older experience at least one fall annually, with the incidence increasing substantially in individuals aged over 70 years.¹⁰ Similar findings have been reported in Indonesia, where approximately 30% of community-dwelling older adults experience falls, with prevalence increasing further in advanced age.¹¹ Beyond physical injury, falls frequently result in fear of falling, restriction of daily activities, loss of independence, institutionalization, and increased healthcare expenditure, thereby placing considerable burdens on individuals, families, and healthcare systems.¹² Consequently, interventions targeting modifiable risk factors, particularly lower limb muscle strength and balance, are considered essential components of physiotherapy programmes for older adults.

Physical inactivity further accelerates age-related deterioration in musculoskeletal function and functional mobility. Insufficient participation in regular physical exercise contributes to sarcopenia, impaired neuromuscular performance, reduced balance, and increased fall risk.¹³ Previous studies have shown that many Indonesian older adults rarely participate in structured exercise because of limited motivation, declining physical capacity, inadequate family support, and restricted access to appropriate exercise programmes.^{14,15} Preliminary observations conducted in Banjar Kuwum, Kuwum Village, Mengwi District also indicated that many older adults rarely engaged in regular exercise and demonstrated characteristics associated with increased fall risk. These findings highlight the need for exercise programmes that are safe, practical, inexpensive, and easily implemented within community settings.

One exercise programme specifically developed for older adults is Osteoporosis Prevention Exercise Series I, a standardized low-impact aerobic exercise programme developed by the Osteoporosis Research Group, Faculty of Medicine, Universitas Indonesia.¹⁶ The programme incorporates warm-up activities, stretching, rhythmic stepping, multidirectional weight shifting, coordinated upper and lower extremity movements, and light external resistance. These movement components are intended to stimulate weight-bearing activity, improve neuromuscular coordination, enhance lower limb muscle strength, improve postural control, and ultimately reduce fall risk while maintaining an exercise intensity appropriate for older adults.¹⁷ Previous studies have demonstrated that low-impact aerobic exercise can improve physical fitness, muscle strength, mobility, and functional performance among older adults.^{18,19} Nevertheless, these studies predominantly evaluated general low-impact exercise programmes rather than the standardized Osteoporosis Prevention Exercise Series I protocol, making direct comparison with this specific intervention difficult.

Despite the growing use of Osteoporosis Prevention Exercise Series I in community health programmes, an important research gap remains. Existing evidence has largely focused on general exercise interventions or has examined only a single functional outcome, such as muscle strength, balance, or physical fitness.^{18,19} To date, limited evidence has specifically evaluated the effectiveness of the standardized Osteoporosis Prevention Exercise Series I protocol in simultaneously improving lower limb muscle strength and reducing fall risk using objective outcome measures among community-dwelling older women.²⁰ Furthermore, evidence derived from Indonesian community settings, particularly in Bali, remains scarce. These limitations indicate that the effectiveness of this intervention within the target population has not been sufficiently established and justify further investigation.²¹

Therefore, this study aimed to evaluate the effect of Osteoporosis Prevention Exercise Series I on lower limb muscle strength and fall risk among community-dwelling older women in Banjar Kuwum, Kuwum Village, Mengwi District using a one-group pretest–posttest design. The findings are expected to provide additional evidence regarding the potential role of this standardized exercise programme as a practical physiotherapy intervention for improving lower limb function and reducing fall risk among community-dwelling older adults, while providing a scientific basis for future controlled intervention studies.

Methods

This study employed a pre-experimental one-group pretest–posttest design, in which all participants underwent baseline assessment before receiving the intervention and were reassessed after completion of the intervention without randomization or a comparison group. The study was conducted in Banjar Kuwum, Kuwum Village, Mengwi District, Badung Regency, Bali, Indonesia, between February and March 2026. The manuscript was prepared following the Transparent Reporting of Evaluations with Nonrandomized Designs (TREND) Statement to improve transparency and completeness in reporting nonrandomized intervention studies.

The target population consisted of community-dwelling older adults residing in Banjar Kuwum, Kuwum Village, Mengwi District. The accessible population comprised older adults who fulfilled the predetermined eligibility criteria during the study period. Participants were recruited using a total sampling technique to include all eligible individuals available at the study site. Based on an a priori sample size estimation using G*Power with a significance level of 0.05, statistical power of 80%, and a moderate expected intervention effect, the minimum required sample size was estimated to be fewer than the number of participants recruited.²² Therefore, the inclusion of 50 participants was considered adequate to detect statistically significant pre-post differences.²³ Inclusion criteria were female older adults aged 60 years or older who resided permanently in the study area and voluntarily agreed to participate by providing written informed consent. Exclusion criteria included inability to perform activities of daily living independently, use of walking aids, lower extremity pain or injury limiting movement, and neurological disorders affecting balance or mobility, including stroke and vestibular disorders. Participants were withdrawn if they sustained an injury during the intervention, voluntarily discontinued participation, or were absent from two consecutive exercise sessions. Fifty participants fulfilled all eligibility criteria and completed the study. Five additional eligible individuals were prepared as reserve participants in anticipation of possible withdrawal; however, no participant was lost to follow-up throughout the intervention period.

The independent variable was Osteoporosis Prevention Exercise Series I, whereas the dependent variables were lower limb muscle strength and fall risk. Osteoporosis Prevention Exercise Series I is a standardized low-impact aerobic exercise programme developed by the Osteoporosis Research Group, Faculty of Medicine, Universitas Indonesia.²⁴ Although the original intervention manual was published in 1999, it remains the official standardized protocol implemented in community-based osteoporosis prevention programmes in Indonesia and therefore serves as the primary reference for intervention procedures. The intervention consisted of opening activities, warm-up, stretching, Core Movement I, Core Movement II, and cool-down exercises performed at light-to-moderate intensity three times weekly for four consecutive weeks. Each session lasted approximately 40 minutes, comprising 5 minutes of warm-up, 5 minutes of stretching, 10 minutes of Core Movement I, 10 minutes of Core Movement II, and 10 minutes of cool-down. Additional resistance was provided using light dumbbells weighing 300–1000 g or 600 mL water bottles. Floor exercises included in the original protocol were excluded because they primarily target trunk and upper extremity musculature rather than the lower limb muscles investigated in this study.

The intervention was delivered in a community setting under the direct supervision of the research team. Participant attendance was recorded at every exercise session using an attendance register, while adherence to the intervention protocol was monitored through continuous direct observation during each session. No modifications to the intervention protocol were implemented throughout the study period. The intervention was administered by physiotherapists and researchers who had received standardized training regarding the implementation of Osteoporosis Prevention Exercise Series I before data collection commenced.

Lower limb muscle strength was assessed using a Leg Dynamometer, with measurements recorded in kilograms to the nearest 0.5 kg. Three consecutive measurements were performed, and the highest value was recorded as the final score. Previous studies have demonstrated good validity (0.86), reliability (0.91), sensitivity (0.91), and specificity (0.88) of the instrument for assessing lower limb muscle strength in older adults.²⁵ 15–18 During testing, participants stood barefoot on the dynamometer platform with the handle adjusted according to individual height. Participants maintained approximately 45° of knee flexion while keeping the trunk upright before performing maximal lower limb extension following a standardized verbal instruction.²⁶

Fall risk was assessed using the Timed Up and Go Test (TUGT), which measures the time required for participants to stand from a chair, walk three metres, turn around, return to the chair, and sit down. The TUGT reflects functional mobility, gait performance, dynamic balance, and lower limb muscle strength.²⁷ Previous studies have demonstrated excellent validity, high intra-rater and inter-rater reliability, and good diagnostic accuracy for identifying older adults at increased risk of falls.^{27–30}

Before the intervention, participants underwent baseline assessment consisting of demographic characteristics, body mass index, vital signs, lower limb muscle strength, and fall risk evaluation. Eligible participants subsequently completed Osteoporosis Prevention Exercise Series I according to the standardized intervention protocol for four weeks. Upon completion of the final exercise

session, all outcome measures were reassessed using identical instruments, procedures, assessors, and testing environments to minimize measurement variability. Figure 1 illustrates the participant flow from eligibility assessment through baseline assessment, implementation of the osteoporosis prevention exercise intervention, post-intervention assessment, and final inclusion in the statistical analysis.

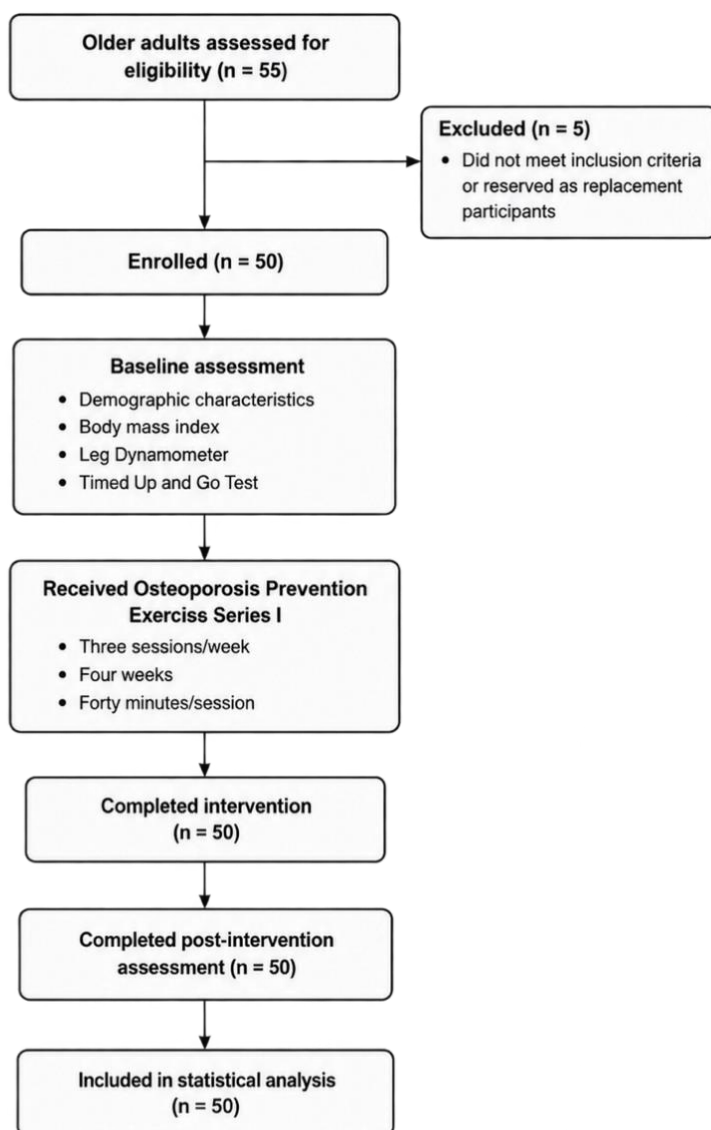


Figure 1. Study Flow and Intervention Process

The participant flow demonstrates that all eligible participants completed every stage of the study without withdrawal, ensuring complete pre-intervention and post-intervention datasets for statistical analysis.

Data were analysed using IBM SPSS Statistics version 22.0. Descriptive statistics were used to summarize participant characteristics. Normality was assessed using the Shapiro–Wilk test, whereas homogeneity of variance was evaluated using Levene's test. Because at least one paired dataset was not normally distributed, differences between pre-intervention and post-intervention measurements were analysed using the Wilcoxon Signed-Rank Test, with statistical significance established at $p < 0.05$. In accordance with international reporting standards, all statistical probabilities previously expressed as $p = 0.000$ were reported as $p < 0.001$.

The study protocol was approved by the Health Research Ethics Committee of Universitas Bali Internasional, and written informed consent was obtained from all participants before enrolment. All research procedures were conducted in accordance with the ethical principles outlined in the Declaration of Helsinki. Because the official ethical approval number was unavailable during manuscript preparation, it should be inserted before final publication.

Results

A total of 55 older adults were initially assessed for eligibility. Following application of the predefined inclusion and exclusion criteria, 50 participants fulfilled the eligibility requirements and were enrolled in the study. All participants completed the four-week Osteoporosis Prevention Exercise Series I programme and underwent both pre-intervention and post-intervention assessments. No participant withdrew during the study period; therefore, complete datasets were available for statistical analysis. These findings indicate excellent participant retention and complete follow-up throughout the intervention period.

The baseline characteristics of the study participants were analysed to describe the demographic and anthropometric profile of the study population. These characteristics provide important contextual information for interpreting the intervention outcomes presented in subsequent analyses.

Table 1. Characteristics of the Study Participants (n = 50)

Characteristic	Category	n	%
Age	60–74 years	39	78
	75–90 years	11	22
Sex	Female	50	100
Occupation	Housewife	30	60
	Farmer	10	20
	Trader	5	10
	Retired	2	4
	Private employee	1	2
	Tailor	1	2
	Self-employed	1	2
Body mass index	Underweight	3	6
	Normal	25	50
	Overweight	22	44

Abbreviation: BMI, body mass index.

As presented in Table 1, most participants were aged 60–74 years (78%), while 22% were aged between 75 and 90 years. Because only women fulfilled the study eligibility criteria, all participants were female. Housewives represented the largest occupational group (60%), followed by farmers (20%) and traders (10%). Regarding nutritional status, half of the participants had a normal body mass index, whereas 44% were classified as overweight and only 6% were underweight. Overall, the study population consisted predominantly of relatively young older women with generally adequate nutritional status, providing an appropriate population for evaluating community-based exercise interventions.

Before testing the study hypothesis, normality and homogeneity analyses were performed to determine the appropriate statistical procedure for comparing pre-intervention and post-intervention outcomes. The results of these preliminary analyses are presented in Table 2.

Table 2. Results of Normality and Homogeneity Testing

Variable	Mean $\pm$ SD	Shapiro–Wilk (p)	Levene's Test (p)
Leg Dynamometer (Pre)	100.42 $\pm$ 22.20	0.145	
Leg Dynamometer (Post)	130.76 $\pm$ 31.32	<0.001	0.483
TUGT (Pre)	18.30 $\pm$ 2.95	0.001	
TUGT (Post)	10.30 $\pm$ 2.24	<0.001	

Abbreviations: SD, standard deviation; TUGT, Timed Up and Go Test.

The Shapiro–Wilk test demonstrated that only the pre-intervention Leg Dynamometer measurements were normally distributed ($p = 0.145$), whereas post-intervention Leg Dynamometer measurements and both TUGT assessments were not normally distributed ($p < 0.05$). Homogeneity testing using Levene's test indicated homogeneous variance between measurements ($p = 0.483$). Because the assumption of normality was not satisfied for all paired observations, differences between pre-intervention and post-intervention measurements were analysed using the non-parametric Wilcoxon Signed-Rank Test.

The primary objective of this study was to evaluate changes in lower limb muscle strength and fall risk following Osteoporosis Prevention Exercise Series I. Comparisons between pre-intervention and post-intervention measurements are presented in Table 3.

Table 3. Changes in Lower Limb Muscle Strength and Fall Risk Following Osteoporosis Prevention Exercise Series I

Variable	Pre-intervention Mean $\pm$ SD	Post-intervention Mean $\pm$ SD	Mean Difference $\pm$ SD	p-value
Leg Dynamometer (kg)	100.42 $\pm$ 22.20	130.76 $\pm$ 31.32	30.34 $\pm$ 9.12	<0.001
TUGT (seconds)	18.30 $\pm$ 2.95	10.30 $\pm$ 2.24	8.00 $\pm$ 0.71	<0.001

Abbreviations: SD, standard deviation; TUGT, Timed Up and Go Test.

As shown in Table 3, lower limb muscle strength increased substantially following completion of the intervention. Mean Leg Dynamometer values increased from 100.42 $\pm$ 22.20 kg before the intervention to 130.76 $\pm$ 31.32 kg after four weeks of exercise, corresponding to a mean improvement of 30.34 $\pm$ 9.12 kg. Statistical analysis using the Wilcoxon Signed-Rank Test demonstrated that this improvement was statistically significant ($p < 0.001$), indicating that participants exhibited greater lower limb muscle strength following participation in the exercise programme.

A comparable improvement was observed in fall risk as measured by the TUGT. Mean TUGT completion time decreased from 18.30 $\pm$ 2.95 seconds before the intervention to 10.30 $\pm$ 2.24 seconds after the intervention, representing a mean reduction of 8.00 $\pm$ 0.71 seconds. The decrease in TUGT time was also statistically significant ($p < 0.001$), suggesting improved functional mobility and dynamic balance following completion of Osteoporosis Prevention Exercise Series I.

Overall, the intervention was associated with statistically significant improvements in both primary study outcomes. Participants demonstrated increased lower limb muscle strength together with reduced TUGT completion time after four weeks of exercise. Because the study employed a pre-experimental one-group pretest–posttest design without a comparison group, these findings indicate significant changes following the intervention and should be interpreted as evidence of improvement within the study population rather than definitive evidence of a causal relationship.

Discussion

The present study demonstrated that four weeks of Osteoporosis Prevention Exercise Series I was associated with significant improvements in lower limb muscle strength and reductions in fall risk among community-dwelling older women. Participants exhibited a significant increase in Leg Dynamometer scores together with a significant reduction in Timed Up and Go Test (TUGT) completion time following the intervention. These findings indicate that the exercise programme may improve physical function by enhancing lower extremity muscle performance and functional mobility. Nevertheless, because the study employed a pre-experimental one-group pretest–posttest design without a comparison group, the observed improvements should be interpreted as changes associated with the intervention rather than definitive evidence of causality.

The demographic characteristics of the participants provide important context for interpreting the study findings. Most participants were between 60 and 74 years of age, representing the younger segment of the older adult population, while all

participants were women. Progressive ageing is accompanied by reductions in skeletal muscle mass, motor unit number, bone mineral density, tendon elasticity, and neuromuscular efficiency, all of which contribute to declining physical performance and impaired postural stability.^{7,9,31} Furthermore, postmenopausal reductions in estrogen accelerate musculoskeletal deterioration and increase susceptibility to sarcopenia, osteoporosis, and balance impairment, making older women particularly vulnerable to functional decline.^{32,33} Consequently, interventions that improve muscle strength and mobility are especially relevant in this population.

The significant improvement in lower limb muscle strength observed following the intervention is consistent with the physiological principles underlying exercise adaptation. Osteoporosis Prevention Exercise Series I incorporates repetitive weight-bearing activities, multidirectional stepping, coordinated limb movements, and light external resistance that stimulate the major lower extremity muscle groups, including the quadriceps, hamstrings, gastrocnemius, soleus, and tibialis anterior.²⁴ Repeated activation of these muscles promotes neuromuscular adaptation through increased motor unit recruitment, improved synchronization of muscle activation, and enhanced intermuscular coordination, thereby increasing force production despite the relatively limited hypertrophic response expected during a short intervention period.^{34,35} These findings are consistent with previous studies reporting that low-impact aerobic exercise improves muscle strength, physical fitness, and functional capacity among older adults.^{18,19,36}

The improvement in muscle strength observed after four weeks of exercise is likely attributable primarily to neural adaptation rather than structural muscle hypertrophy. Early increases in muscular strength are generally associated with improved motor unit recruitment, increased firing frequency, reduced antagonist coactivation, and more efficient neuromuscular coordination before measurable increases in muscle mass occur.^{37,38} Repeated practice of coordinated lower extremity movements during the intervention may also have improved movement efficiency, enabling participants to generate greater muscular force during post-intervention testing. This physiological explanation is supported by the magnitude and direction of change observed in Leg Dynamometer measurements.

A significant reduction in TUGT completion time was also observed following the intervention, indicating improved functional mobility and reduced fall risk. The TUGT is a comprehensive functional assessment that reflects lower limb muscle strength, dynamic balance, gait performance, turning ability, and transitional movements.²⁷ Improvements in TUGT performance therefore suggest that the intervention influenced multiple physiological systems simultaneously rather than improving muscle strength alone. The multidirectional stepping, rhythmic gait patterns, repeated weight shifting, and postural transitions incorporated within Osteoporosis Prevention Exercise Series I continuously challenge the musculoskeletal, proprioceptive, vestibular, and central nervous systems, thereby facilitating improvements in postural control and movement coordination.^{39,40} Such adaptations are essential for maintaining balance during daily functional activities and reducing the likelihood of falls among older adults.

The relationship between improved lower limb muscle strength and reduced fall risk should also be considered when interpreting the findings. Lower extremity muscle weakness has consistently been identified as one of the strongest predictors of impaired balance, decreased gait stability, delayed protective responses, and increased fall incidence among community-dwelling older adults.^{41–43} Stronger lower limb muscles improve the ability to control the body's centre of mass, absorb external perturbations, and generate rapid corrective movements when balance is disturbed. Consequently, the significant reduction in TUGT completion time observed in this study is likely mediated, at least in part, by improvements in lower limb muscle strength achieved during the intervention. However, because balance is a multifactorial construct, contributions from enhanced proprioception, improved neuromuscular coordination, and increased movement confidence should also be considered.

Several methodological limitations should be acknowledged when interpreting these findings. First, the absence of a control group limits internal validity because improvements may have been influenced by external factors unrelated to the intervention. Potential history effects cannot be excluded if participants experienced changes in lifestyle or health status during the study period. Likewise, maturation effects may have contributed to changes over time independent of the intervention. Repeated administration of the same outcome measures may also have introduced testing effects, whereby participants became more familiar with the assessment procedures. In addition, the supervised nature of the intervention may have produced a Hawthorne effect, whereby participants improved their performance because they were aware that they were being observed. Finally, regression to the mean should also be considered, particularly in participants with relatively poor baseline performance. These inherent limitations reduce the ability to establish definitive causal relationships despite statistically significant improvements observed after the intervention.

Several additional limitations should also be considered. The study included only community-dwelling older women from a single geographical area, limiting generalizability to older men and other populations. Although the sample size was adequate for the study objectives, recruitment from a single community may reduce external validity. Furthermore, daily physical activity, nutritional intake, medication use, sleep quality, and chronic comorbidities were not monitored throughout the intervention period and therefore may have influenced the observed outcomes. No long-term follow-up assessment was performed, making it impossible to determine whether the improvements were sustained after completion of the intervention. Future studies should employ randomized controlled trial designs with larger and more diverse populations, longer intervention periods, follow-up assessments, and more comprehensive control of potential confounding variables to strengthen causal inference and improve external validity.

The present findings nevertheless provide clinically meaningful evidence supporting the implementation of Osteoporosis Prevention Exercise Series I as a community-based physiotherapy programme for older adults. The intervention requires relatively simple equipment, can be delivered in community settings at low cost, and simultaneously targets lower limb muscle strength and functional mobility, both of which are key determinants of fall risk. Although confirmation through controlled trials remains necessary, the results suggest that this standardized exercise programme may represent a practical strategy for promoting healthy ageing and reducing mobility-related functional decline among community-dwelling older women.

Conclusion

This study demonstrated that Osteoporosis Prevention Exercise Series I was associated with significant improvements in lower limb muscle strength and reductions in fall risk among community-dwelling older women after four weeks of intervention. Participants exhibited significant increases in Leg Dynamometer measurements together with significant reductions in Timed Up and Go Test completion time, indicating improvements in muscle performance and functional mobility following participation in the exercise programme.

These findings suggest that Osteoporosis Prevention Exercise Series I has the potential to serve as a practical community-based physiotherapy intervention for maintaining lower limb function and supporting fall prevention programmes among older adults. However, because this study employed a pre-experimental one-group pretest–posttest design without a comparison group, the findings should be interpreted as evidence of significant improvement following the intervention rather than definitive proof of a causal

relationship. Future controlled studies involving larger and more diverse populations are required to confirm the effectiveness of this intervention and strengthen the generalizability of the findings.

Study Limitations

Several limitations should be acknowledged when interpreting the findings of this study. First, the absence of a control group limits the ability to establish causal relationships between the intervention and the observed improvements. Consequently, potential threats to internal validity, including history effects, maturation effects, testing effects, Hawthorne effect, and regression to the mean, cannot be completely excluded.

Second, the study included only community-dwelling older women from a single community, thereby limiting the generalizability of the findings to other populations, including older men and older adults from different geographical or cultural settings. Third, although all eligible participants were recruited using total sampling, the relatively limited sample size may reduce external validity.

Finally, several factors that may influence lower limb muscle strength and fall risk, including habitual physical activity, nutritional intake, medication use, sleep quality, and chronic comorbidities, were not monitored throughout the intervention period. In addition, no follow-up assessment was conducted after completion of the intervention; therefore, the long-term sustainability of the observed improvements remains unknown.

Clinical Implications

The findings of this study suggest that Osteoporosis Prevention Exercise Series I may represent a feasible and practical physiotherapy intervention for community-dwelling older adults. The programme requires minimal equipment, can be implemented in community settings at relatively low cost, and combines weight-bearing activities with coordinated lower extremity movements that target both muscle strength and functional mobility.

These characteristics make the programme suitable for implementation in community health centres, integrated health service posts for older adults, community exercise groups, and primary healthcare facilities as part of fall prevention and healthy ageing programmes. Although additional evidence from randomized controlled trials is required, the present findings provide preliminary support for incorporating Osteoporosis Prevention Exercise Series I into community-based physiotherapy services for older adults.

Author Contribution

I Komang Agus Pranata: Conceptualization, Methodology, Investigation, Data Curation, Formal Analysis, Writing Original Draft Preparation.

I A Ratih Wulansari Manuaba: Supervision, Validation, Writing Review and Editing.

I Putu Prisa Jaya: Supervision, Methodology, Writing Review and Editing.

Komang Tri Adi Suparwati: Supervision, Methodology, Writing Review and Editing.

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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 Health Research Ethics Committee of Universitas Bali Internasional. Written informed consent was obtained from all participants prior to enrollment.

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