



THE EFFECT OF BODY-WEIGHT SQUAT EXERCISE ON INCREASING LOWER-LIMB MUSCLE STRENGTH AND REDUCING THE RISK OF FALLS IN ELDERLY WOMEN

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ABSTRACT

The decline in estrogen levels among elderly women leads to increased bone fragility and joint degeneration, making them more susceptible to osteoporosis and osteoarthritis. One of the most serious consequences of reduced musculoskeletal function in older women is an increased vulnerability to falls. Therefore, to improve the quality of life of elderly women, it is essential to implement exercise programs that are easy to remember, simple to perform, safe, and feasible to conduct independently at home. This study aimed to determine the effectiveness of body-weight squat exercises in improving lower limb muscle strength and reducing the risk of falls among elderly women. This study employed an experimental design using a randomized controlled trial with a pre-test and post-test control group design. A total of 30 elderly women participated as samples and were randomly assigned into two groups: the intervention group and the control group. Participants in the intervention group performed body-weight squat exercises for four weeks, with a training frequency of four times per week. Outcome measures included lower limb muscle strength, assessed using the Five Times Sit-to-Stand Test (FTSTS), and fall risk, assessed using the Timed Up and Go Test (TUG). Measurements were taken before and after the intervention. The study was conducted in Mengwi District, Badung Regency, Bali, from July to September 2025. Data were analyzed using SPSS, based on the pre-test and post-test measurements. The statistical analyses employed were the Paired Sample T-Test and the Independent Sample T-Test. The results demonstrated a significant increase in lower limb muscle strength ($p = 0.000$) and a significant reduction in fall risk ($p = 0.000$) in the intervention group, as analyzed using the Paired Sample T-Test. Performing body-weight squat exercises four times per week for four consecutive weeks effectively increases lower limb muscle strength, as measured by the FTSTS test, and reduces the risk of falls, as measured by the TUG test, among elderly women in Gulingan Village, Mengwi District.

Keywords: body-weight squat; elderly women; fall risk; muscle strength

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INTRODUCTION

Falls represent a serious health concern among the elderly population, often leading to severe or life-threatening injuries. More than one-third of the global population aged 65 years and older experiences at least one fall each year. The incidence of falls increases to approximately 50% annually among individuals over the age of 75. Falls are a major cause of disability and even mortality among older adults. After experiencing a first fall, older individuals have a 66% likelihood of recurrent falls within one year. Recurrent falls are twice as common and more dangerous among older adults residing in long-term care facilities. The higher incidence of falls in this population significantly increases the risk of developing serious complications (Ariyanti et al., 2023).

The risk of injury and mortality resulting from falls increases with advancing age. Falls are also the most common cause of hospital admission among older adults related to trauma. The primary reasons for hospitalization following a fall include traumatic brain injury (TBI) and orthopedic injuries such as fractures of the hip, forearm, and upper arm. The consequences of such falls may lead to long-term disability and, in severe cases, death (Cifu et al., 2018). The risk of falls among

older adults can be attributed to both intrinsic and extrinsic factors. Extrinsic factors are related to environmental conditions, whereas intrinsic factors are associated with the individual's health status.

Musculoskeletal disorders are a major cause of gait and balance impairments in older adults, leading to slowed movement, instability, and a reduced ability to anticipate slips or trips. These impairments, combined with delayed motor responses, increase the likelihood of falls among the elderly. The musculoskeletal factor therefore plays a significant role in contributing to fall risk in older adults (Sartika et al., 2023)

Elderly women who have entered the menopausal phase experience hormonal changes, particularly a decline in estrogen levels, accompanied by reduced physical activity. These changes contribute to a decrease in muscle strength and a reduction in bone mineral density (Vina Devi Kurniawati & Widarti, 2023). A decrease in lower extremity muscle strength can lead to slower and stiffer body movements, shorter steps, and reduced ability of the feet to provide stable support. As a result, individuals become more prone to instability while standing and experience delayed postural responses, making it more difficult to recover balance and prevent a fall when disturbances occur (Hartinah et al., 2019).

Considering this phenomenon, it is important for elderly women to engage in exercise programs aimed at reducing the risk of falls. Such exercise programs should involve simple, easy-to-remember, and safe movements suitable for older adults. One of the simple exercise programs that can be applied is the body-weight squat. Research conducted by Kurniawati demonstrated that body-weight squat exercises significantly improve lower limb muscle strength in elderly women, emphasizing that strong lower limb muscles are essential for maintaining postural balance (Vina Devi Kurniawati & Widarti, 2023). In contrast, a study conducted by Fujita reported that body-weight squat exercises had only a minimal effect on balance among older adults. This outcome was attributed to the fact that all study participants were individuals who were unable to perform activities of daily living, such as dressing, eating, and other routine tasks (Fujita et al., 2016). A similar finding was reported in a study conducted by Liu et al. (2025), which examined the effects of body-weight resistance training on balance and fear of falling. The study revealed a significant improvement in lower limb strength; however, the results did not show a significant reduction in fear of falling (FES-I) and did not demonstrate significant effects on psychological or self-confidence aspects (Liu et al., 2025). Based on the aforementioned findings, there is still limited research examining the effects of body-weight squat exercises on fall risk among elderly women. Therefore, this study aims to investigate the effectiveness of body-weight squat training in assessing fall risk and the level of functional independence in elderly women.

METHOD

This study is an experimental research employing a randomized controlled trial (RCT) design with a pre-test and post-test control group approach. The purpose of this study is to determine the effectiveness of body-weight squat exercises in improving lower limb muscle strength and reducing fall risk among elderly women. The study will be conducted in Mengwi District, Badung Regency, Bali, from July to September 2025. The selection of research participants is based on inclusion and exclusion criteria. The inclusion criteria are as follows: (a) women aged 60 years or older; (b) having a Five Times Sit-to-Stand Test (FTSTS) score greater than 13 seconds; (c) having a Timed Up and Go (TUG) score greater than 10 seconds and less than 20 seconds; (d) able to communicate effectively; (e) having a normal or overweight body mass index (BMI); and (f) able to walk independently without assistive devices. The exclusion criteria include: (a) a history of bone fracture; (b) musculoskeletal injury; (c) a history of neurological disorders; (d) uncontrolled cardiovascular disease; (e) current stroke condition; (f) alteration of the Q-angle in one or both knee joints; and (g) unwillingness to sign the informed consent form. The drop-out criteria are as follows:

(a) participants who are absent three times or more during the intervention period; (b) deterioration in the participant’s health condition during the study; and (c) voluntary withdrawal from the study.

Participant recruitment will be carried out using a simple random sampling technique. Subsequently, random selection will be performed by the researcher to achieve the required sample size based on statistical calculation, followed by random allocation to divide participants into two groups. Group 1 (intervention group) will receive body-weight squat exercises which was conducted over a period of four weeks with an exercise frequency of four sessions per week, whereas Group 2 (control group) will perform daily activity exercises. The selection of research subjects was carried out using a simple random sampling technique, followed by random selection. The number of participants for this research is 15 elderly women per group. Thus, the total number of participants for both groups is 30 elderly women.

The study procedure begins with obtaining official permission from the Gulingan Village administration in Mengwi District. The researcher will then explain the purpose and procedures of the study to participants and obtain their written informed consent indicating their willingness to participate until the end of the study. A pre-test assessment will be conducted for both groups, measuring lower limb muscle strength using the Five Times Sit-to-Stand Test (FTSTS) and fall risk using the Timed Up and Go Test (TUG). Both tests will be repeated after the intervention as a post-test evaluation. This study was conducted over a period of four weeks, with an exercise frequency of four sessions per week. This study has fulfilled all ethical and legal requirements and has received an ethical eligibility certificate from the Research Ethics Committee, Faculty of Medicine, Udayana University, with approval number 1914/UN14.2.2.VII.14/LT/2025.

RESULT

The following section presents the research data as follows: Table 1 describes the characteristics of the participants, including age, body weight, height, body mass index (BMI), FTSTS pre-test scores, and TUG post-test scores. Table 2 presents the results of the paired sample *t*-test comparing the mean differences in lower limb muscle strength measured by the FTSTS test before and after the intervention in both the treatment and control groups. The findings indicate a significant improvement in lower limb muscle strength within the treatment group.

Table 3 presents the results of the independent sample comparison of post-intervention lower limb muscle strength scores between the treatment and control groups, showing a statistically significant difference between groups ($p = 0.000$). Table 4 displays the results of the paired sample *t*-test comparing the mean differences in fall risk, as measured by the TUG test, before and after the intervention in both groups. The findings reveal a significant reduction in fall risk within the treatment group. Finally, Table 5 presents the results of the independent sample comparison of post-intervention fall risk scores between the treatment and control groups. The results demonstrate a statistically significant difference between groups ($p = 0.000$).

Table 1.

Sample Characteristics Data

Characteristics	Intervention Group		Control Group	
	Mean	Standard Deviation	Mean	Standard Deviation
Age	63,26	1,162	62,66	1,39
Weight	53	5,62	53,92	4,08
Height	153,36	5,59	154,44	4,80
Body Mass Index	22,49	1,49	22,61	1,43
FTSTS Test (Pre – Test)	14,47	0,68	14,70	0,74
TUG Test (Pre – Test)	14,39	0,61	13,85	0,47

Table 2.
Mean Improvement in Lower Limb Muscle Strength Before and After Exercise

Groups	Mean Before Intervention	Mean After Intervention	Mean Difference	Standard Deviation	p*
Intervention Group	14,47	12,12	2,34	0,52	0,000
Control Group	14,70	14,66	0,04	0,12	0,334

(*) Paired Sample T-test

Table 3.
Increase in Lower Limb Muscle Strength After Exercise in the Treatment and Control Groups

Groups	n	Mean	Standard Deviation	p
Post – test Intervention Group	15	2,34	0,66	0,000
Control Group	15	0,03	0,69	

(*) Independent Sample T-test after intervention

Table 4.
Mean Decrease in Fall Risk Before and After Exercise

Groups	Mean Before Intervention	Mean After Intervention	Mean Difference	Standard Deviation	p*
Intervention Group	14,39	12,20	2,18	0,77	0,000
Control Group	13,86	13,85	0,01	0,04	0,423

(*) Paired Sample T-test

Table 5.
Decrease in Fall Risk After Exercise in the Treatment and Control Groups

Groups	n	Mean	Standard Deviation	p
Post – test Intervention Group	15	2,18	0,67	0,000
Control Group	15	0,01	0,45	

(*) Uji Independent Sample T-test Sesudah Latihan

DISCUSSION

The results of this study indicate that performing body-weight squat exercises four times per week over a period of four weeks among elderly women led to a significant increase in lower limb muscle strength and a significant reduction in fall risk. These findings support the concept that resistance exercises without external loads can serve as an effective intervention to enhance muscle function and postural stability in older adults. The improvement in muscle strength is attributed to rapid neuromuscular adaptations, including increased motor unit recruitment, enhanced muscle activation synchronization, and greater intramuscular coordination efficiency. Such adaptations typically occur during the early weeks of training, prior to morphological changes such as muscle hypertrophy. This explains why a relatively short duration of four weeks was sufficient to produce a meaningful improvement in lower limb muscle strength.

The aging process in women is accompanied by complex physiological changes that affect the musculoskeletal, nervous, and hormonal systems. One of the most prominent changes is the decline in muscle mass and strength, known as sarcopenia. Sarcopenia is characterized by a reduction in the number of type II (fast-twitch) muscle fibers, a decrease in muscle fiber size (atrophy), and diminished neuromuscular capacity due to a loss of alpha motor neurons in the spinal cord (Cho et al., 2022). This condition leads to a decrease in the muscle's ability to generate force and power, particularly in the lower extremities.

The body-weight squat is a form of functional exercise that engages the major muscles of the lower limbs, including the quadriceps, hamstrings, gluteus maximus, as well as the stabilizing muscles of the pelvis and ankles. In this study, the squat movement refers to the action of standing up from a

seated position (sit-to-stand), which is highly relevant to the functional abilities of older adults. Therefore, the strength gains produced by this exercise directly contribute to improvements in functional capacity and postural control. These findings are consistent with the meta-analysis conducted by Zeng et al. (2023), which reported that chair-stand and squat-based exercise patterns have a significant effect on enhancing lower limb muscle strength and daily functional performance among the elderly (Zeng et al., 2023). With the improved ability to perform postural transitions efficiently, the risk of losing balance and experiencing falls is consequently reduced.

In addition to improving muscle strength, body-weight squat exercises also have a positive impact on dynamic balance control. The squat movement requires coordination between the neuromuscular and proprioceptive systems, both of which play a crucial role in maintaining body stability. According to Montero-Odasso et al. (2022) in the World Guidelines for Falls Prevention and Management for Older Adults, physical exercise programs that focus on strength and balance are key strategies for reducing fall risk, particularly among elderly women, who tend to experience a faster decline in muscle mass (sarcopenia) and bone density compared to men (Montero-Odasso et al., 2022). These findings are also consistent with the systematic review conducted by Martins et al. (2022), which reported that resistance training performed two to four times per week can enhance lower limb muscle strength and improve functional performance measures such as the Timed Up and Go (TUG) and 30-Second Chair Stand Test among older adults (Martins et al., 2022).

Although the intervention in this study lasted only four weeks, a significant improvement was achieved due to the high training frequency (four times per week), which facilitated rapid neuromuscular adaptations. This finding is consistent with the meta-analysis conducted by Zhu et al. (2025), which demonstrated that higher-frequency exercise doses are correlated with greater increases in muscle strength and more substantial reductions in fall risk among older adults. More frequent exercise stimulation enhances afferent and efferent neural activation, improves synchronization of muscle contractions, and increases muscle perfusion and metabolism. These adaptations accelerate the process of motor learning and enhance intermuscular coordination, resulting in faster gains in muscle strength (Zhu et al., 2025). The study by Sadaqa et al. (2023) also supports this finding, indicating that regular lower limb strengthening and balance exercises significantly improve muscle strength and reduce the incidence of falls among older adults (Sadaqa et al., 2023). Thus, it can be concluded that a short training duration can still be effective if the frequency and intensity of exercise are appropriately adjusted to the individual's capacity.

From a safety and clinical application perspective, body-weight squat exercises are simple, inexpensive, and require no specialized equipment. This makes them ideal for implementation in community-based or home-based fall prevention programs. A study by da Silva Capanema et al. (2024) demonstrated that home-based exercise programs involving simple movements such as squats have high adherence rates, low dropout levels, and lead to significant improvements in the functional abilities of older adults (Capanema et al., 2024). Nevertheless, the implementation of this exercise requires supervision during the initial stages to ensure proper technique, such as maintaining the knees behind the toes and keeping the back in a neutral position. Correcting biomechanical errors is essential to maximize the benefits while minimizing the risk of injury, as highlighted by Papadakis et al. (2024) in their biomechanical analysis of the squat movement among older adults (Papadakis et al., 2024).

The findings of this study also have practical implications for physiotherapists and public health practitioners. The body-weight squat program can be incorporated as part of a routine exercise intervention for elderly women, either individually or in groups, to help maintain functional independence and prevent falls. However, it is important to note that strength training should be combined with balance and flexibility exercises to achieve more comprehensive effects on postural stability. Furthermore, future research with longer intervention durations and larger sample sizes is

needed to evaluate the long-term sustainability of the exercise's effects on reducing the actual incidence of falls.

Overall, the results of this study confirm that body-weight squat exercises are a simple yet effective intervention for improving lower limb muscle strength and reducing fall risk among elderly women. This form of exercise aligns with global fall prevention guidelines and can be integrated into community-based exercise programs with minimal supervision. Broad implementation of this program is expected to enhance independence and improve the quality of life of older adults within the community.

CONCLUSION

Based on the data analysis conducted, it can be concluded that performing body-weight squat exercises four times per week for a duration of four weeks effectively increases lower limb muscle strength, as measured by the Five Times Sit-to-Stand Test (FTSTS), and reduces fall risk, as measured by the Timed Up and Go Test (TUG), among elderly women.

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