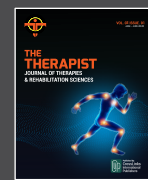




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Original Article



Detrimental Effect of Prolonged Lower Limb Static Stretching on Dynamic Balance in Older Adults with Knee Osteoarthritis

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ABSTRACT

Due to the fast aging of the world's population, physiological alterations associated with age that impair postural control and boost the risk of falls are becoming more common. Falls are a major public health concern among the elderly, and knee osteoarthritis (OA). **Objectives:** To investigate the short-term effects of a multi-muscle lower limb stretching regimen on the balance performance of older adults with knee OA. **Methods:** Twenty-nine individuals with OA, aged 60 to 75 years, participated in a quasi-experimental study. Participants were divided into two groups: a control group (n=15) that performed placebo stretches and an intervention group (n=14) that underwent static stretching for five minutes each, targeting the hamstring, tensor fasciae latae, and calf muscles. The Fullerton Advanced Balance (FAB) scale, the Timed Up and Go (TUG) test, the Functional Reach (FR) test, and knee range of motion (ROM) were used to assess mobility and balance outcomes both before and after the intervention. **Results:** Reduced FAB and FR scores and longer TUG times after stretching were indicative of a statistically significant loss in dynamic balance in the intervention group. The control population, on the other hand, showed no discernible changes in any of the balance metrics. The intervention group's knee range of motion improved somewhat, but this difference was not statistically significant. **Conclusions:** A single session of prolonged static stretching of lower limb muscles can acutely impair dynamic balance in older adults with knee OA. Immediate rest following such exercises is recommended to reduce the potential risk of falls in this vulnerable population.

INTRODUCTION

Aging is a complex and inevitable biological process, though its progression can be moderated with appropriate care to achieve a long, healthy life. The older adult population is growing significantly in modern societies, making evidence-based understanding of their issues crucial for planning and decision-making [1]. The demographic shift is substantial; the global population over 60 years is projected to rise from 11% in 2000 to 22% by 2050, with the most rapid increases occurring in low-to

middle-income countries [2]. Iran exemplifies this trend, where the population is currently young but is expected to see 33% of its citizens over the age of 65 by 2050, posing a considerable future societal burden [3]. The aging process is accompanied by various physiological alterations, including changes to cognitive function and postural control systems. The efficacy of the visual, vestibular, and somatosensory systems, which are integral to balance, diminishes with age [4]. A higher likelihood of falling, which



is defined as an abrupt, unintentional change in position that results in a descent, is a crucial effect of these changes [5]. With over one-third of adults over 65 experiencing a fall each year, falls are a serious health problem and the sixth highest cause of death among the elderly in the US [6]. Environmental risks, problems with gait and balance, and functional deficiencies in the integration of sensory and motor information required for postural control are some of the multifactorial causes [7]. For older adults, maintaining an upright posture and controlling the body's center of mass within its base of support, known as balance, becomes increasingly difficult [8]. Age-related reductions in neural and muscle fibers further contribute to instability, jeopardizing simple daily activities [9]. Stretching the muscles of the lower extremity is a common intervention aimed at improving joint range of motion and balance. However, its acute effects on dynamic balance, the ability to maintain postural stability during movement, can be paradoxical. Prolonged static stretching may temporarily reduce muscle stiffness and alter proprioceptive feedback, leading to delayed neuromuscular responses and decreased balance control. A study by Min-Jung-Han et al. found that five minutes of plantar flexor stretching significantly increased postural sway in the elderly, indicating a temporary impairment in static balance [10]. These findings suggest that stretching may also influence dynamic balance by affecting coordinated movement and reaction time during mobility tasks such as walking or standing transitions. Studies consistently report increased postural sway and a higher risk of instability in this population [11]. These challenges are often exacerbated by comorbid conditions such as knee osteoarthritis (OA), a degenerative joint disease prevalent in approximately 10% of men and 18% of women over 60. Knee OA is characterized by pain, stiffness, and reduced range of motion, and individuals with this condition demonstrate greater impairments in both static and dynamic balance compared to their healthy peers [12]. Given that daily exercise regimens for older adults frequently include stretching, it is vital to understand its immediate impact on balance, particularly in a fragile population already at risk due to conditions like knee OA. This study aims to examine the short-term effects of a multi-muscle lower limb stretching regimen on the balance performance of older adults with knee OA.

METHODS

This research was designed as a quasi-experimental study, aimed at evaluating the effects of lower limb stretching exercises on balance and knee range of motion (ROM) in older adults with knee osteoarthritis. The trial was conducted at a center for community-dwelling older adults, located within a private clinic in Ghaemshahr, Iran, for six

months following official approval of the research synopsis (July to December 2024). The sample size was calculated a priori using Open Epi version 3.3 for comparing two independent means. The calculation was based on the Fullerton Advanced Balance (FAB) scale as the primary outcome. The expected mean $\pm$ SD scores were 10.8 ± 2.0 for the control group and 8.8 ± 2.0 for the intervention group, derived from a pilot study conducted by the authors (unpublished data). This represented an expected mean difference of 2.0 points. Using a two-sided significance level (α) of 0.05, a power ($1-\beta$) of 80%, and an allocation ratio of 1, the formula for the sample size per group was: $n \text{ per group} = (2 * (Z_{\alpha/2} + Z_{\beta})^2 * SD^2) / (\text{Mean}_1 - \text{Mean}_2)^2$. Where $Z_{\alpha/2} = 1.96$ (for $\alpha=0.05$) and $Z_{\beta} = 0.84$ (for $\beta=0.20$). This calculation yielded a minimum of 14 participants per group. To account for a potential 10% attrition rate, we aimed to recruit 31 participants. However, due to time constraints and eligibility criteria, a final sample of 29 participants was enrolled. Participants were first recruited through a non-probabilistic, convenience sampling method from community-dwelling older adults attending the clinic. Following eligibility screening according to inclusion and exclusion criteria, individuals were assigned to either the control or intervention groups using a non-randomized allocation procedure based on scheduling availability. No random number generation or allocation concealment was employed. This approach allowed for practical recruitment while ensuring comparable baseline characteristics between groups to minimize selection bias. A total of 29 older adults aged 60–75 years with knee osteoarthritis were enrolled. All participants were included in the final analysis, and for the lone participant who dropped out, baseline observation was carried forward (BOCF) to impute missing post-intervention data. The intervention group received targeted lower limb stretching exercises, whereas the control group received placebo stretching in similar positions without actual stretching. Functional balance tests and knee ROM assessments were conducted before and after the interventions. Participants aged 60–75 years were included if they exhibited at least three of the following features: morning stiffness lasting less than 30 minutes, crepitus, tenderness in the knee joint, swelling in the knee joint, and no sensation of warmth on palpation. Exclusion criteria included a history of rheumatologic or myopathic conditions, fracture or trauma to the knee meniscus or ligaments, use of systemic or intra-articular corticosteroids in the past three months, use of NSAIDs in the past two months, cognitive impairment preventing questionnaire completion, cardiovascular diseases or diabetes, conditions affecting balance, or severe visual or auditory impairment. Demographic data, including age, height, weight, and BMI, were recorded using a data

collection form. After obtaining written informed consent, participants were assigned to intervention or control groups. In the intervention group, three key muscle groups underwent static stretching, each held for five minutes to the point of mild discomfort, followed by a five-minute rest between stretches. The hamstring group included the semitendinosus, semimembranosus, and biceps femoris, stretched in a straight leg raise (SLR) position with the participant supine and the therapist raising the leg until discomfort was noted. The gastrocnemius and soleus muscles were stretched with the participant lying supine and the knee extended, while the therapist applied dorsiflexion at the ankle until mild discomfort was felt. The tensor fascia lata was stretched in the Ober test position, with the participant lying in side-lying position and the upper leg guided into adduction until mild discomfort was noted. Three standardized balance assessment tools were used: The Fullerton Advanced Balance (FAB) test, the Timed Up and Go (TUG) test, and the Functional Reach (FR) test. The FAB test assesses multiple aspects of balance and mobility in higher-functioning older adults and contains 10 items, each scored from 0 to 4, with a total of 40 points, where scores below 25 indicate a high fall risk. Participants were also instructed to rise from a chair, walk three meters, turn 180 degrees, return, and sit for the TUG test, which measures dynamic and static balance, gait, and directional change ability. The FR test measured the distance participants could reach forward while standing without losing balance, assessing postural control. All data were analyzed using SPSS version 20. Normality was evaluated using the Kolmogorov-Smirnov test, and comparisons between and within groups were made using independent t-tests and paired t-tests, respectively, with $p < 0.05$ deemed statistically significant. Frequency and percentage were used to report descriptive data. The instruments used for data collection included data collection forms, a tape measure, and a digital weighing scale. A pilot study was not conducted for this research. All participants provided written informed consent before enrollment. Confidentiality of participant data was maintained through coding and secure storage. Ethical approval was obtained from the Iran University Ethical Review Board, and the estimated budget for the study was approximately 30,000 Rs. Active knee flexion and extension ROM were measured using a standard 12-inch universal goniometer (Baseline®) with 1° increments. The measurement protocol followed established anatomical landmarks to ensure reliability. Participants were positioned in a supine position for measurements. The goniometer's axis was positioned above the femur's lateral epicondyle, with the moving arm lining up with the lateral malleolus and the stationary arm with the greater

trochanter. All ROM measures were carried out by the same skilled physiotherapist, who was blind to group assignment. Each motion was measured twice to increase reliability, and the average value was analyzed. The intra-rater reliability of this method was established in a pilot study ($n=10$) before the main trial, showing an Intraclass Correlation Coefficient (ICC) of 0.92 for knee flexion, indicating excellent reliability.

RESULTS

A summary of the subjects' demographic information is provided. A one-sample Kolmogorov-Smirnov test was used to determine whether the data was normal. For intra-group comparisons, the paired T-test was used, and for inter-group comparisons, the T-test. Significant values are denoted by an asterisk (*) in this chapter, and a p-value of less than 0.05 was deemed statistically significant. Prior to the interventions, the two groups' age, height, weight, and BMI were all well matched (Table 1).

Table 1: Demographic Characteristics

Variables	Intervention Group	Control Group	p-Value
Age (Years)	67.07	67.26	0.098
Height (cm)	162.07	158.13	0.679
Weight (kg)	70.85	62.73	0.751
BMI (kg/m ²)	26.86	24.84	0.387

Mean values of balance tests and knee ROM, pre- and post-trial in the intervention group (* statically significant ($p\text{-value} \leq 0.05$)). The study summarizes the results of intra-group comparisons in group 1 and shows that FAB and FR scores decreased, and TUG score increased significantly following the stretching exercises. ROM increased in this group, although it was not statistically significant (Table 2).

Table 2: Gender of Participants

Variables	Gender	Frequency
Group 1	Male	6
	Female	8
Group 2	Male	5
	Female	10

Results indicate the intra-group comparisons in group 2. Based on this table, none of the balance tests and knee ROM showed statistically significant change after placebo stretch (Table 3).

Table 3: Balance Tests and Knee ROM, Pre- and Post-Trial in the Intervention Group

Variables	Pre-intervention	Post-intervention	p-Value
ROM	123.28 ± 5.71	124.14 ± 4.95	0.082
FAB	34.21 ± 3.78	31.35 ± 4.87	0.0002*
TUG	12.28 ± 1.63	14.14 ± 1.51	0.001*
FR	20.35 ± 4.16	16.92 ± 4.14	0.0001*

The study demonstrates the pre-post changes of values in

each group. According to the findings, all the tests, except ROM, show significant between-group differences (Table 4).

Table 4: Balance Tests and Knee ROM, Pre- and Post-Trial in the Control Group

Variables	Pre-intervention (Mean $\pm$ SD)	Post-intervention (Mean $\pm$ SD)	p-Value
ROM	125.53 $\pm$ 5.66	125.66 $\pm$ 5.38	0.550
FAB	32.60 $\pm$ 3.78	32.66 $\pm$ 4.87	0.709
TUG	12.06 $\pm$ 1.63	12.20 $\pm$ 1.51	0.685
FR	17.53 $\pm$ 4.16	18.06 $\pm$ 4.14	0.088

*Statically Significant (p -values ≤ 0.05)

The between-group analysis revealed significant differences in the change scores for dynamic balance measures. The intervention group showed a significantly greater decline in FAB score (Mean Difference [MD] = -2.92, 95% CI: -4.17 to -1.67, $p = 0.0001$, Cohen's $d = -1.85$), a significantly greater increase in TUG time (MD = 1.72, 95% CI: 0.67 to 2.77, $p = 0.002$, Cohen's $d = 1.27$), and a significantly greater decrease in FR distance (MD = -3.95, 95% CI: -5.34 to -2.57, $p = 0.0001$, Cohen's $d = -2.20$) compared to the control group (Table 5).

Table 5: Between-group comparison of change scores (post-intervention - Pre-intervention)

Variables	Intervention Group Change	Control Group Change	Between-Group Mean Difference (95% CI)	p-Value	Cohen's d
ROM	0.86 $\pm$ 1.70	0.20 $\pm$ 1.26	0.66 (-0.48, 1.79)	.246	0.44
FAB	-2.85 $\pm$ 2.14	0.07 $\pm$ 0.96	-2.92 (-4.17, -1.67)	.0001*	-1.85
TUG	1.85 $\pm$ 1.51	0.13 $\pm$ 1.24	1.72 (0.67, 2.77)	.002*	1.27
FR	-3.42 $\pm$ 2.34	0.53 $\pm$ 1.12	-3.95 (-5.34, -2.57)	.0001*	—

DISCUSSION

This study sought to investigate the immediate effects of 5-minute static stretching of multiple lower limb muscle groups (hamstrings, calf muscles, and tensor fascia latae) on balance performance and knee ROM in older adults with knee osteoarthritis (OA). Our results demonstrated a significant deterioration in dynamic balance, as reflected in decreased scores in the Functional Reach (FR) and Fullerton Advanced Balance (FAB) tests, and a significant increase in TUG time, indicating reduced dynamic balance and mobility immediately after stretching. Meanwhile, increases in knee ROM were observed in the intervention group but were not statistically significant. The decline in balance aligns with prior research suggesting that prolonged static stretching can reduce neuromuscular performance. Behm et al. found that 45-second static stretches repeated over the hamstring, quadriceps, and calf muscles led to decreased dynamic balance [13]. Similarly, Nagano et al. reported increased postural sway after 3-minute static stretching of calf muscles [14]. In contrast, shorter-duration stretches (~15–30 seconds)

have sometimes improved balance and strength, possibly by enhancing muscle spindle sensitivity and neural activation [15]. Previous studies observed increased power and strength following brief proprioceptive neuromuscular facilitation and static stretching in younger subjects [16]. Static stretching reduces muscle-tendon unit (MTU) stiffness, which may enhance flexibility but compromise reactive balance. Toninelli demonstrated that prolonged stretching decreases stretch reflex sensitivity and H-reflex amplitude, indicating reduced neuromuscular excitability [17]. This neuromuscular suppression can lead to delayed corrective responses during balance tasks. Cramer et al. also reported reductions in EMG activity and power output following static stretching, further supporting a neural basis for post-stretch performance declines [13]. The discrepancy may be due to our inclusion of additional muscle groups (hamstrings and tensor fascia latae), potentially inducing broader neuromuscular disruption. Moreover, our sample consisted of older adults with knee OA, who are already at a baseline disadvantage in balance due to joint degeneration and proprioceptive decline. Oba et al. recently evaluated five sets of 1-minute static calf stretches in older adults and found increased center-of-pressure velocity post-stretch, indicating potential instability, despite improvements in joint range and lean limits [18]. These findings further suggest that static stretching, even of moderate duration, can acutely affect dynamic postural control in aging populations. Regarding knee ROM, the improvements observed in our intervention group were not statistically significant. This is unsurprising given the single-session design. Most prior studies reporting significant ROM gains used multi-week stretching protocols. Pourahmadi et al. implemented a 6-week program of static hamstring stretches and found significant ROM improvements in older adults [19]. These findings indicate that duration and frequency are critical factors in achieving significant flexibility gains. Furthermore, structural and physiological differences between younger and older populations may impact outcomes. With aging, skeletal muscles undergo fibrosis, fat infiltration, and loss of contractile tissue, reducing elasticity and adaptability [20]. Wilson et al. showed that while young adults gained dorsiflexion ROM after three consecutive days of stretching, the improvements diminished within days of cessation [21]. Such results suggest that acute flexibility gains are both minimal and short-lived, especially in aged populations with musculoskeletal impairments. From a clinical standpoint, our findings suggest caution in recommending long-duration static stretching immediately before functional activities like balance or gait training in older adults with knee OA. Instead, short-duration or dynamic stretching, or

stretching at the end of training sessions, may offer flexibility benefits without compromising immediate balance and mobility. Additionally, separating stretching and balance training by a recovery interval might allow neuromuscular performance to normalize post-stretch.

CONCLUSIONS

The present study showed that applying stretch over the lower limbs of older adults with chronic knee OA reduces their balance status, but may not affect their knee ROMs. Therefore, it is highly suggested that the elderly have a rest just after stretching exercise in order to prevent falling. Lack of follow-up: Only one session of intervention due to the unavailability of subjects.

Authors Contribution

Conceptualization: MRG

Methodology: MDBC

Formal analysis: SU

Writing review and editing: ML, STZ

All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

All the authors declare no conflict of interest.

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