Research Article

# Investigating the Immediate Effects of Static and Dynamic Stretching Exercises of Lower Extremities Muscles on Core Stability in Young Healthy Females

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## ABSTRACT

**Introduction:** This study investigates the immediate effects of warm-up exercises, specifically static and dynamic stretches for the lower extremities, on strength, endurance, flexibility, motor control, and core stability function in young, healthy females.

**Materials and Methods:** A total of 60 healthy, active women aged 19-30 years were randomly divided into three groups as follows: Static stretching (SS), dynamic stretching (DS), and a control group (CG), which received no exercises. Evaluation methods for core stability included strength, endurance, sit-and-reach, Y-balance, and bilateral squat tests. Meanwhile, these tests were conducted before and after the prescribed exercise protocols.

**Results:** Both the SS and DS groups experienced significant increases in all core stability components compared to their baseline values (P<0.05). Meanwhile, the analysis of variance/analysis of covariance indicated that immediately after performing the stretching exercises, the SS and DS groups exhibited significantly greater improvements in parameters, such as strength, endurance, flexibility, and balance tests (except for the posterior-medial direction) when compared to the CG (P<0.05). Regarding functional parameters after the exercises, there were no statistically significant differences between the study groups (P>0.05). In addition, dynamic exercises demonstrated a higher effectiveness than static exercises for most parameters (P<0.05).

**Conclusion:** Warm-up exercises, involving both static and dynamic stretches for lower limb muscles appear to have an immediate positive impact on core stability parameters. In sports that demand strong trunk muscles and balance, the dynamic protocol may be more effective.

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## Introduction

Stretching plays a crucial role in enhancing muscle flexibility, preventing muscle damage, and optimizing physical performance as part of a warm-up routine [1-3]. An effective pre-exercise warm-up regimen facilitates increased suppleness in muscles and tendons, promotes peripheral blood flow, elevates body temperature, and fosters coordinated movement [4].

Two common pre-activity stretching methods are static stretching (SS) and dynamic stretching (DS) [5]. SS involves athletes holding a muscle at its end range for a specific duration to increase muscle length [6]. However, the literature presents conflicting results regarding the effects of SS. While some studies suggest that SS before physical activity might reduce vertical jump height [7], sprint speed [8], and isokinetic muscle strength [9], it has been shown to positively impact the range of motion (ROM) [10]. Most research has concentrated on enhancing flexibility in both healthy and injured individuals, with limited investigation into its impact on sports performance [10, 11]. A study by Costa et al. reported improved performance with SS [11].

Due to the inconsistencies regarding the effects of SS, DS has gained popularity. DS involves controlled movements through a full ROM, often tailored to the specific demands of the sport [12]. Research indicates that DS may increase ROM [12], sprint performance [13, 14], power output [15], isokinetic muscle strength [16], and jump height [17-19]. However, one study suggested that DS may not be as effective as SS in improving flexibility, suggesting its inclusion in a warm-up routine for sport-specific purposes [20, 21]. Additionally, DS exercises have the potential to influence balance, agility, strength, and power [22, 23].

The core muscles encompass those in the lumbar and hip regions, with core stability being a critical factor in optimizing athletic performance and preventing injuries. As per the kinetic chain theory, core stability facilitates the efficient transfer of forces from the trunk and pelvis to the extremities during movement [24]. This, in turn, provides proximal stability for extremity movements through the activation of core muscles [25]. Achieving optimal core stability requires a combination of factors, including muscle strength, endurance, neuromuscular control, flexibility, and functional capacity [26-28].

Despite extensive research on stretching exercises before sports activities, there remains a lack of studies investigating the immediate effects of stretching exercises on core stability components through functional tests. This study fills this gap by examining the immediate impact of static and DS exercises as part of a warm-up routine on core stability, assessed through strength, endurance, flexibility, motor control, and functional tests.

## Materials and Methods

### Study participants

A total of 60 healthy female students (19-30 years old) who had a history of sports activity at the amateur level participated in this study. Volunteers with no history of vigorous activity in the past few days, acute or chronic back pain, trauma, back injury or surgery, and balance or central nervous system problems participated in this study. The participants (n=60) were randomly divided into 3 groups as follows: SS (n=20), DS (n=20), and CG (n=20). The anthropometric characteristics of each group are described in Table 1. Demographic characteristics were no different between the study groups.

### Study design

The study design is a randomized controlled trial, informed consent forms were obtained from all eligible participants. The parameters were assessed before and after interventions (SS, DS, and CG) to evaluate core stability. Each protocol consisted of a 5-min aerobic warm-up (using a stationary bike set at 70-75 rounds per min with 1 kg resistance), stretching exercises (excluding the CG protocol), and a 2-min rest. Core stability components were evaluated through strength testing, trunk endurance testing (extensor, flexor, and lateral flexor), the sit-and-reach test, the Y-balance assessment, and the bilateral squat test.

### Stretching interventions

#### SS protocol

The SS protocol comprises six exercises performed in either sitting or standing positions, focusing on the lower limb muscles (Table 2). The participants actively held each exercise for 30 s, without assistance, until they felt no discomfort. After a 5-s rest, they repeated the exercise for the opposite leg, followed by another 5-s rest before proceeding to the next exercise [29]. The SS protocol lasted 6 min (Figure 1).

#### DS protocol

The DS protocol consisted of six exercises, with muscle emphasis similar to that of the SS stretching protocol (Table 2). The participants performed each exercise over a distance of approximately 10 m (9.14 m). Following a 10-s

**Table 1.** Anthropometric characteristics of each group

| Groups | Mean±SD | | |
|---|---|---|---|
| | Age (y) | Height (cm) | Weight (kg) |
| SS | 24.50±2.64 | 163.80±4.64 | 65.25±5.0 |
| DS | 24.80±3.05 | 164.40±6.43 | 66.75±5.77 |
| CG | 24.15±3.17 | 165.15±5.29 | 63.15±5.27 |
| P | 0.78 | 0.74 | 0.11 |

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Abbreviations: SS: Static stretching; DS: Dynamic stretching; CG: Control group.

Notes: According to the analysis of variance, there is no significant difference in anthropometric characteristics between groups.

rest, they repeated the same exercise to return to the starting point, with another 10-s rest before moving on to the next exercise [29]. The DS protocol, like the SS protocol, lasted 6 min (Figure 2).

### Control group protocol

The participants in the control group (CG) sat without engaging in any exercises for 6 min [5, 14, 22].

## Core stability tests

Core muscle strength was assessed using a Barometer device. The subject assumed a supine position with hands beside the body, and the device was positioned near the posterior superior iliac spine. By performing a posterior pelvic tilt movement and maintaining the position for 3 to 5 s (Figure 3), the desired reading was recorded. The test was repeated three times with a 1-min interval, and the highest score achieved by the individual was recorded in mm of mercury (mm Hg) [30].

## Endurance test

### Trunk extensor endurance test

The participant began by lying prone on a table, with the pelvis, hips, and knees fixed to the table. The trunk and upper extremities extended beyond the table's surface at the same height as a chair. As the chair was removed, the participant held this position for as long as possible, with arms crossed over the chest. The duration they maintained the position was timed in seconds using a chronometer [31].

### Trunk flexor endurance test

The trunk flexor endurance test started with the participant in a sit-up position, trunk supported at 60 degrees of flexion, arms crossed over the chest, and feet secured by a belt. After the trunk support was removed, the participant maintained the position for as long as possible. The time they held the position was measured in seconds using a chronometer [31].

### Trunk lateral flexor endurance test

The participant began in a side-lying position on a table with knees extended, the top leg in front of the lower foot.

**Table 2.** Stretching exercises

| Muscle | SS Protocol | DS Protocol |
|---|---|---|
| Quadriceps | Standing quadriceps stretch | Slow butt-kicks leg |
| Hamstrings | Sitting toe-touch stretch | Leg swing to the opposite hand |
| Gastrocnemius | Calf wall stretch | Tip-toe walking |
| Hip adductors | Butterfly (groin) stretch | Lateral low shuffle |
| Hip flexors | Hip flexor stretch | Forward lunge with opposite arm reach upward |
| Hip extensors | Supine knee flexion | Knee tuck |

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**Figure 1.** SS exercises

They supported their weight on their lower elbow and feet while lifting their hips off the mat. The participant held this position for as long as possible. The duration was timed in seconds using a chronometer. This test was performed on both sides, and an average value was calculated [31].

### Sit-and-reach test

The participants started in a seated position with their feet against a sit-and-reach box. They placed one hand on top of the other, palms down, with knees extended. They were instructed to lean forward along the measurement scale as far as possible without bending their knees, pausing for 2 seconds at their farthest point. The test was repeated three times, with a 1-min interval, and the greatest distance reached was measured in centimeters [32].

### Y-balance test

The Y-balance test assessed balance and control during a dynamic single-limb stance while reaching as far as possible in three directions as follows: Anterior, posteromedial, and posterolateral. The participants stood on one leg at the center of a platform (Figure 4). Their hands remained on their hips, and their feet maintained full contact with the support surface for a successful trial. The subjects underwent six practice trials on their dominant leg in each direction before completing three recorded trials. The results were averaged for each direction, normalized to leg length, and expressed as a percentage [33].

### Bilateral squat test

The bilateral squat test aimed to perform the maximum number of squats in 30 s. The participants began by sitting in an armless chair with hips and knees bent at 90 degrees. They stood up to full knee extension and then returned to a seated position, completing one repetition (Figure 5). Throughout the test, they kept their arms crossed over their chest, and the number of repetitions was recorded [34-43].

## Statistical analysis

We analyzed the data using the SPSS software, version 20. We assessed the normal distribution with the Shapiro-Wilk test (P>0.05). To ensure comparability among the three

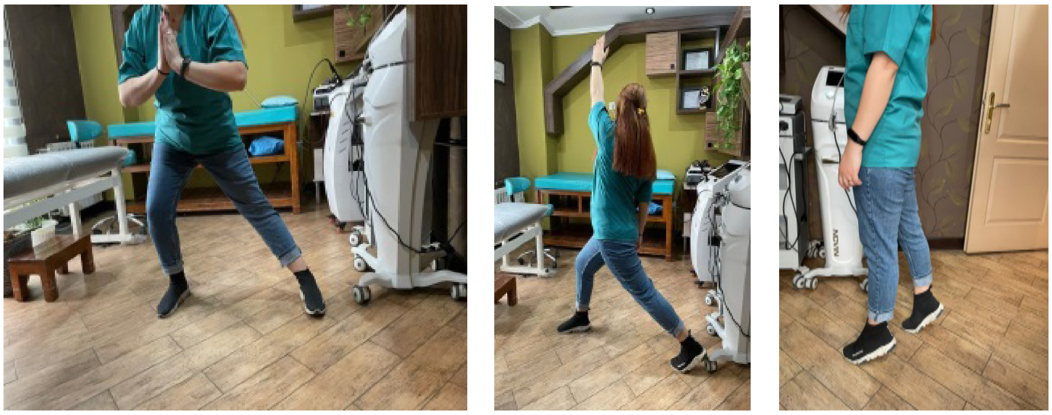

**Figure 2.** DS exercises

**Figure 3.** Strength test

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groups in terms of age, height, and weight, we conducted the one-way analysis of variance (P>0.05). To examine differences in dependent variables before and after each protocol, we used the paired t-tests. At the baseline, we compared the three groups using the one-way analysis of variance. After the protocol, we employed the one-way analysis of covariance/analysis of variance tests to compare the three groups.

These statistical analyses were conducted to assess the impact of interventions on core stability parameters and identify significant differences among the groups.

## Results

Table 3 presents the Mean±SD values of the study variables for the three groups before and after each protocol. The findings indicate that both the SS and DS groups exhibited a significant improvement in all core stability components compared to their baseline values (P<0.05). In the CG, statistically significant changes were observed only in terms of the sit and reach test, Y-balance test, and bilateral squat test (P<0.05).

The results of the analysis of variance/analysis of covariance revealed a significant increase in ST, trunk flexor endurance test, TEET (trunk extensor endurance test), trunk lateral flexor endurance test, sit-and-reach test, and Y-balance test (except for the posteromedial direction) immediately after the stretching exercises in both the SS and DS groups when compared to the CG (P<0.05). No statistically significant difference was found in the bilateral squat test among the study groups (P>0.05). Additionally, the DS group displayed

**Figure 4.** Y-balance test

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**Figure 5.** Bilateral squat test

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higher mean values for all tests (except for the trunk flexor endurance test, trunk lateral flexor endurance test, and sit-and-reach test) compared to the SS group (P<0.05).

## Discussion

The objective of this study was to assess the immediate effects of warm-up exercises, including static and DS, on core stability components in healthy and active women. The findings indicate that both static and DS groups exhibited significant improvements in all core stability components, including strength, endurance, flexibility, motor control, and function, compared to their baseline values. Specifically, SS and DS led to significant enhancements in strength, endurance, flexibility, and balance (except for the posteromedial direction) immediately after the stretching exercises, when compared to CG.

SS, involving prolonged muscle lengthening, has been a common part of warm-up routines. However, its immediate impact on core stability is not straightforward, with some studies suggesting a temporary reduction in muscle strength.

**Table 3.** Mean±SD of variants before and after intervention

| Variables | SS Protocol | | | DS Protocol | | | CG Protocol | | |
|---|---|---|---|---|---|---|---|---|---|
| | Mean±SD | | P | Mean±SD | | P | Mean±SD | | P |
| | Before | After | | Before | After | | Before | After | |
| ST (mm Hg) | 118.50±16.39 | 134.70±13.94 | <0.001 | 126.50±17.02 | 151.75±14.62 | <0.001 | 118.50± 15.22 | 119±13.63 | 0.61 |
| TFET (s) | 27.10±1.29 | 31.85±2.18 | <0.001 | 28.10±1.41 | 33.70±2.36 | <0.001 | 28.20 ±1.85 | 28.70±2.15 | 0.09 |
| TEET (s) | 32.60±4.89 | 35.90±4.10 | <0.001 | 31.90±2.57 | 37.95±2.75 | <0.001 | 31.60±5.44 | 31.85±4.95 | 0.41 |
| TLFET (s) | 37.45±4.31 | 41.65±4.40 | <0.001 | 35.45±4.06 | 41.50±3.39 | <0.001 | 37.10±3.26 | 37.55±3.59 | 0.64 |
| SRT (cm) | 28.45±4.03 | 31.95±3.74 | <0.001 | 30.75±3.67 | 31.30±3.37 | <0.001 | 28.30±2.36 | 29.05±2.35 | 0.012 |
| YBT-Ant (%) | 0.92±0.03 | 0.97±0.04 | <0.001 | 0.92±0.04 | 1.0±0.06 | <0.001 | 0.90±0.05 | 0.91±0.05 | 0.05 |
| YBT-PL (%) | 0.82±0.03 | 0.84±0.03 | <0.001 | 0.82±0.04 | 0.87±0.04 | <0.001 | 0.82±0.04 | 0.83±0.04 | 0.006 |
| YBT-PM (%) | 0.79±0.04 | 0.81±0.04 | <0.001 | 0.78±0.04 | 0.83±0.04 | <0.001 | 0.77±0.04 | 0.79±0.04 | <0.001 |
| BST (n) | 22.75±1.80 | 24.05±1.96 | <0.001 | 23.40±1.57 | 24.15±1.42 | 0.005 | 22.35±2.23 | 22.95±2.16 | 0.019 |

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Abbreviations: SS: Static stretching; DS: Dynamic stretching; CG: Control group; TFET: Trunk flexor endurance test; TLFET: Trunk lateral flexor endurance test; SRT: Sit-and-reach test; YBT: Y-balance test; Ant: Anterior; PL: Posterolateral; PM: Posteromedial; BST: Bilateral squat test; TEET: Trunk extensor endurance test; ST: Strength.

Nevertheless, this reduction might not be significant, especially when incorporated into a comprehensive warm-up routine.

DS, characterized by controlled movements resembling the required ROM for specific activities, has gained popularity as a warm-up strategy. DS can enhance blood flow, increase muscle temperature, and activate neuromuscular pathways, which could positively contribute to core stability by enhancing neuromuscular control and coordination.

Our study revealed that dynamic exercises were more effective than static ones in improving strength, extensor endurance, and motor control parameters. The effect size, as measured by Cohen's d, indicated a moderate effect size, which is consistent with previous research showing that a moderate-intensity active warm-up can significantly enhance short-term performance across various movements.

In terms of flexibility, both static and DS significantly increased flexibility compared to the CG, with no statistically significant difference between the two stretching methods. These results align with previous findings suggesting that both static and dynamic protocols can enhance flexibility.

We also observed a significant improvement in motor control (Y-balance test) after DS exercises, which is consistent with previous research highlighting the positive impact of DS on balance. The improved performance might be attributed to increased muscle temperature, nervous system stimulation, and enhanced nerve conduction.

Regarding the functional parameter (bilateral squat test), no significant differences were observed among the three protocols. This functional test was administered at the end of the study, possibly leading to fatigue in participants. Fatigue can affect muscle performance and, consequently, the outcomes of functional tests. Future studies should consider the potential influence of fatigue on results [44-48].

Our findings are in line with some studies that reported no significant differences in certain performance measures between static and DS protocols. However, other research has indicated that DS can have a more positive impact on certain activities, such as sprinting and vertical jumps.

The immediate effects of stretching on muscle strength and viscoelasticity are complex, involving neural and mechanical factors. SS on resting muscles can temporarily decrease strength due to disruptions in neural signaling and mechanical changes in stretched muscles. DS, on the other hand, increases muscle and body temperature, potentially explaining the improvements observed in various parameters.

## Conclusion

This study demonstrated that warm-up exercises incorporating both static and DS can immediately enhance all core stability components, encompassing trunk strength, trunk endurance, back flexibility, motor control, and function. Furthermore, DS methods appear to be particularly effective for activities demanding robust trunk muscle strength and balance. While function parameters displayed significant changes following both static and DS exercises, no significant differences were observed among the study groups based on the results.

## Ethical Considerations

With a strong emphasis on ethical considerations, this research prioritizes informed consent, confidentiality, and risk assessment to safeguard the well-being and rights of the participants. The study contributes to the scientific understanding of the impact of stretching but also underscores the ethical responsibilities involved in conducting research with human participants, especially within the context of exercise science and its implications for well-being.

### Study limitations

The limitations of this study include the absence of a combined stretching group and the lack of follow-up to assess the durability of the exercises. Future research could explore the effects of stretching exercises on core stability with combined groups and long-term follow-up assessments.

### Compliance with ethical guidelines

This study was approved by the Ethics Committee of Tehran University of Medical Sciences (TUMS) (Code: IR.TUMS.FNM.REC.1401.032).

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### Authors' contributions

Conceptualization and supervision: Siamak Bashardoust Tajali, and Zinat Ashnagar; Methodology: Siamak Bashardoust Tajali, Zinat Ashnagar, and Elaheh Mehdizadeh Harikandei; Data collection: Elaheh Mehdizadeh Harikandei, and Fatemeh Manafi Havigh; Data analysis: Elaheh Mehdizadeh Harikandei, and Siamak Bashardoust Tajali; Investigation and writing: Elaheh Mehdizadeh Harikandei, Siamak Bashardoust Tajali, and Zinat Ashnagar.

## Conflict of interest

The authors declared no conflict of interest.

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