**Abstract**

This study investigated the effects of static stretching (SS) and dynamic stretching (DS) on vertical jump performance, using a randomized controlled cross-over design. A total of 11 physically active participants, aged 21 to 30, performed three stretching protocols: static stretching, dynamic stretching, and a no-stretch control (NS). Vertical jump height was measured pre- and post-stretch using a jump test. The results showed that dynamic stretching led to the greatest improvement in vertical jump height (mean increase of 4.00 cm), followed by static stretching (3.45 cm), while the control condition showed minimal improvement (1.91 cm). ANOVA revealed a significant difference between the dynamic and control conditions (p < 0.05), while the difference between static stretching and control was marginally significant (p = 0.102). These findings suggest that dynamic stretching may be the most effective warm-up strategy for improving vertical jump performance, providing valuable insights for athletes and coaches aiming to enhance explosive power

**Introduction**

Stretching is deemed to be a critical aspect of athletic preparation and performance, particularly in activities requiring explosive power, sudden changes in speed and direction. To help get blood moving through the muscle and also reduce the potential of injury. The ability to generate forceful movements through the body beginning in the lower, can be measured through vertical jump height, this provides some essential insights into an individual’s muscular strength, coordination, and motor control. Vertical jump performance is not only a valuable metric for athletes in sports like basketball, volleyball, but it also plays a significant role in everyday functional tasks, such as climbing stairs, lifting objects, and maintaining overall mobility.

Research has previously explored the effects of different stretching protocols on vertical jump performance, particularly the comparison between static stretching (SS) and dynamic stretching (DS). Static stretching typically involves holding a muscle in an elongated position for an extended period, usually between 10 to 30 seconds. This method has been shown to improve flexibility and increase range of motion, but recent studies suggest that it may have a negating effect on activities requiring explosive power. Conversely, dynamic stretching involves controlled, repetitive movements that mimic the activity to be performed. This type of stretching increases blood flow, enhances activation of tbe muscles, and has been shown to better prepare athletes for power-based movements.

For instance, Fletcher's (2010) study demonstrated that fast dynamic stretching had a more significant positive impact on vertical jump performance compared to slower dynamic stretching, suggesting that the velocity of stretching movements can influence performance outcomes. This highlights the importance of not only the type of stretching but also the intensity and speed at which it is performed. Similarly, Behm and colleagues (2021) emphasized the role of the stretch-shortening cycle (SSC) in enhancing dynamic performance, including jumping, by optimizing force production and energy efficiency during muscle contraction.

Furthermore, the use of ballistic stretching, a more aggressive form of dynamic stretching, has shown to be more effective than static stretching in improving jump performance, particularly in trained athletes. Bacurau et al. (2009) found that ballistic stretching led to greater improvements in flexibility and jump height in a group of trained runners. These findings support the notion that dynamic movements which replicate the intensity of the sport or activity may be superior for preparing the body for high-power outputs.

The inclusion of arm swings in dynamic movements has also been shown to significantly increase jump height by further optimizing the SSC, as noted by Gillen et al. (2022). Their research highlighted how the integration of upper body movements can contribute to overall performance, reinforcing the complexity of the neuromuscular interactions involved in vertical jumping.

Despite the wealth of research on stretching and its effects on performance, inconsistencies remain in the findings. Some studies suggest that static stretching may impair power output, while others highlight the benefits of dynamic stretching for activities requiring explosive strength. These discrepancies can be attributed to variations in study design, participant demographics, and stretching protocols. The results from this study further contribute to this body of knowledge, utilizing a randomized controlled cross-over design with participants aged 21 to 30.

Our findings show that dynamic stretching resulted in the greatest improvement in vertical jump performance, with an estimated mean difference of 4.00 cm in jump height, compared to 3.45 cm for static stretching and 1.91 cm for the control group. A significant difference was found between dynamic stretching and the control condition (p < 0.05), while the difference between static stretching and the control was marginally significant (p = 0.102). These results align with existing research suggesting that dynamic stretching better prepares the body for explosive activities by improving blood flow and neuromuscular activation.

This study addresses some of the inconsistencies in previous research by comparing the effects of static and dynamic stretching on vertical jump performance in adults with varying levels of athleticism. By providing robust statistical analysis, including ANOVA and post-hoc testing, we aim to offer definitive conclusions about the effectiveness of these stretching modalities. The findings are intended to inform athletes, coaches, and individuals seeking to optimize their physical performance and health in daily life.

We also aim to further investigate the effects of static and dynamic stretching on vertical jump performance using a randomized controlled cross-over design. By comparing the two stretching modalities in adults with varying levels of athleticism, this study seeks to address some of the inconsistencies found in previous research and provide more definitive conclusions. The findings of this study are intended to inform not only athletes but also individuals seeking to optimize their physical performance and health in daily life.

**Methods**

**Study Design**

This study employed a randomized controlled cross-over design to compare the effects of static stretching (SS), dynamic stretching (DS), and a no-stretch control (NS) on vertical jump performance. Each participant was randomly assigned to one of three groups, which participated in all three conditions (static, dynamic, control) across three testing sessions. The cross-over design ensured that each participant acted as their own control, minimizing individual variability in jump performance.

To minimize external variables such as fatigue, ambient temperature, and participant routines, testing was conducted on consecutive days in a controlled indoor environment, with sessions scheduled at the same time of day.

**Participants**

The sample consisted of 11 participants aged 21 to 30, all of whom were physically active and engaged in regular physical activity. Participants were recruited from the local community through word-of-mouth. Prior to the experiment, each participant completed a health screening questionnaire to ensure they had no injuries preventing vertical jumping. Informed consent was obtained from all participants.

**Experimental Protocol**

**1. Warm-Up**  
Each participant began with a standardized three-minute warm-up, either on a rowing ergometer (approximately 500 meters) or by performing light aerobic activities such as jogging shuttles. The warm-up was designed to elevate heart rate without inducing fatigue.

**2. Pre-Stretch Vertical Jump Test**  
Participants performed three vertical jumps using a vertical jump test. The test involves the individual taking a paused jump to remove any momentum from the movement, then marking the highest point. The highest jump was recorded as the pre-stretch baseline measurement. The participants were instructed to stand to the side with feet together, raise one arm overhead, and perform a maximal jump with a pause at the bottom of the jump to ensure no momentum contributes towards the effort. The difference between the standing reach height and the highest point reached during the jump was used to calculate vertical jump height.

**3. Stretching Protocols**  
Participants were assigned one of the following stretching protocols for each session:

* **Static Stretching (SS)**: Participants performed static stretches targeting the major leg muscles (hamstrings, quadriceps, and calves). Each stretch was held for 30 seconds without bouncing, and the total stretching duration was three minutes.
* **Dynamic Stretching (DS)**: Participants performed dynamic stretches that targeted the same muscle groups. These included knee grabs, glute stretches, and calf pumps, repeated for three minutes.
* **No Stretch (NS)**: Participants in the control condition rested passively for three minutes without any stretching activity.

**4. Post-Stretch Vertical Jump Test**  
After the completion of the stretching protocols, participants performed three more vertical jumps. The highest jump was recorded as the post-stretch measurement. This was repeated for each session (static, dynamic, and control).

**Equipment and Procedures**

* **Marker and Measuring Tape:** Used to measure vertical jump height. Participants reached up with one hand to set the baseline reach height, and performed their jumps. All three attempts were marked down, with the highest displacement during the jump being recorded
* **Rowing Ergometer**: Used for the standardized warm-up (approx. 500 meters in three minutes) or an alternative light aerobic warm-up such as jogging shuttles was allowed.
* **Ambient Temperature Control**: Temperature and humidity were recorded each day to ensure consistency in environmental conditions during testing.

**Data Collection and Analysis**

Jump height differences were calculated by subtracting pre-stretch jump height from post-stretch jump height. Data were collected and organized in a CSV file and analysed using R Statistical Software (v4.2.3). Descriptive statistics, including mean, median, standard deviation, and range, were calculated for each stretching condition.

The normality of the data was assessed using the Shapiro-Wilk test, and a repeated measures ANOVA was conducted to compare the effects of SS, DS, and NS on vertical jump performance. Post-hoc analysis with Tukey’s HSD was used to further explore significant findings. Effect size (η²) and confidence intervals (CI) were reported where relevant.

**Key Considerations**

* **Minimizing Fatigue**: Testing sessions were conducted on consecutive days with sufficient rest between jump attempts to minimize fatigue.
* **Consistency of Conditions**: All tests were conducted indoors under controlled environmental conditions, and participants were instructed to maintain consistent sleep, nutrition, and activity patterns throughout the experiment.