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SHORT REPORT **OPEN ACCESS**

ACUTE EFFECTS OF LIMITED-DURATION STATIC STRETCHING ON VERTICAL JUMP PERFORMANCE

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ABSTRACT

The purpose of this study was to examine the effects of 30- and 60-seconds of static stretching on vertical jump performance. In a balanced order, twenty-four university students (14 females and 10 males; $\bar{X} \pm$ SD; age = 21.4 $\pm$ 1.5 yrs, height = 1.72 $\pm$ 0.10 m, body weight = 67.3 $\pm$ 12.2 kg) completed no stretching, 30 seconds of static stretching, and 60 seconds of static stretching per muscle group following a warm-up, then completed three countermovement vertical jumps on a force plate. Data from the highest jump for each session was used for statistical analysis. Muscle groups stretched were the gluteals, hamstrings, and quadriceps. There was no difference across all three sessions in terms of vertical jump height, peak force, take-off velocity, and peak power (p > 0.05). The use of 30 seconds or 60 seconds of static stretching may not impair vertical jump performance. Inconsistent results in the literature regarding the acute effects of limited-duration static stretching on vertical jump performance may be due to the number of muscle groups stretched and their roles in vertical jumping.

Keywords: flexibility, force plates, kinematics, kinetics

INTRODUCTION

It is a generally accepted practice that a warm-up be performed prior to athletic performance with the intention of reducing the risk of injury as well as improving performance. A stretching program is often incorporated into this warm-up for similar reasons. However, the type of stretching program employed may have an immediate impact on the athlete's performance. Dynamic stretching has been shown to either have no effect or improve performance (1). Studies evaluating the impact of proprioceptive neuromuscular facilitation on performance have demonstrated either no effect (2,3) or a decrease in performance (4–6) while studies evaluating ballistic stretching have had mixed results (7–13). Static stretching has been shown to acutely impair a variety of athletic parameters (1,14,15). Moreover, these static stretching effects are not related to age, gender, or fitness level (16).

The most notable decrement in performance has occurred when measuring maximum force production (17). However, the time in which the athlete has to produce maximum force is limited in most sporting events. Therefore, the temporary decrease in maximum force production due to static stretching may not be the best indicator of the impact on performance. Power is the most important athletic parameter in most sporting events. Vertical jumping is an effective field test that can be used to assess an athlete's lower body power. When field testing, practitioners often record only the vertical jump height due to lack of equipment necessary to measure power and other performance variables. Vertical jump height is directly related to take-off velocity with faster take-off velocities equating to higher jump heights. The effect of static stretching on vertical jump performance remains unclear (17).

Due to the abundance of studies demonstrating the impairment in performance due to static stretching, some researchers and practitioners in the field have recommended discontinuing the use of static stretching immediately prior to competition or training for healthy individuals. This recommendation seems to be premature given the dose-dependent nature of this stretch-induced impairment. In several recent literature reviews, the authors concluded that the use of limited-duration static stretching volumes (i.e., < 45 s) may not be detrimental to maximal muscular performance (1,16,17). However, the number of studies using similar static stretching volumes is limited. Most research studies have used stretching volumes that often exceed those used by athletes as well as the general population. A small number of studies have used limited-duration static stretching to evaluate its effects on jumping performance and have reported conflicting results (18–20).

Performing static stretching using a volume of 30 seconds for three times per day over a four week period has been shown to improve range of motion (21). This limited volume of static stretching may facilitate positive changes in range of motion while not adversely affecting vertical jump performance. In addition, this volume of static stretching would represent a more practical application than what is used in most research studies. Two different review articles (16,17) concluded that static stretching volumes $\geq$ 60 seconds are likely to induce small to moderate reductions in performance. Therefore, the purpose of this investigation was to evaluate the acute effects of 30 seconds and 60 seconds of static stretching on vertical jump performance following a thorough warm-up.

METHODS

Twenty-four university students (14 females and 10 males; $\bar{X} \pm$ SD; age = 21.4 $\pm$ 1.5 yrs, height = 1.72 $\pm$ 0.10 m, body weight = 67.3 $\pm$ 12.2 kg) between 20 – 25 years of age participated in this study. Each participant was free from any condition that would impair their ability to jump with maximal effort and perform the requisite static stretching. All participants completed three sessions (Control, 30-second, and 60-second) in a randomized order with at least 48 hours and no more than 7 days separating successive sessions. During the first session, each participant filled out a health history questionnaire and informed consent. Training status was not documented for these participants since the static stretch-induced impairment in performance is not related to fitness level (16). Each participant was asked to refrain from strenuous exercise and static stretching for the 24 hours prior to each session. The University's Institutional Review

Board approved this study, the health history questionnaire, and the informed consent.

During the Control session, each participant performed a five-minute warm-up by pedaling continuously against 50 Watts of resistance at 50 rpm on a cycle ergometer (Monark Ergomedic 828E). Seat height was set to allow for approximately a 5-10° bend in the extended knee. The same seat height was used for each session. Following the warm-up, each participant rested for 7 minutes. This time period represents the time it takes to give instructions and have the participants stretch during the 60-second session. Participants were allowed to sit or stand during this rest period. Next, each participant performed three maximal effort vertical jumps on a force plate (type 9260AA6, Kistler, Amherst, NY) with one minute rest between successive jumps. For each jump, participants were instructed to keep their hands on their hips and jump as high as possible. Each jump was a countermovement jump with no attempt to control the depth of the downward movement. The procedure for the vertical jumps was the same for all three sessions. All participants were familiar with the countermovement vertical jumping prior to participating in this study.

During the 30-second session, each participant performed the same warm-up procedure as the Control session. The warm-up was followed by a one-minute rest period and three static stretches. The first stretch performed was the side quadriceps stretch. With the participant lying on one side and leaning on the ipsilateral elbow for balance, the contralateral knee was flexed and grasped the same ankle of the flexed knee to pull it towards their buttocks. Each stretch was held for 30 seconds. The opposite side was stretched immediately following the completion of the 30 seconds. The second stretch was the sitting toe touch. This stretch was performed with the person seated upright on the floor with their legs fully extended. The participant leaned forward and attempted to touch their toes with both hands without flexing their knees. After 30 seconds of rest, the gluteal stretch was performed. During this stretch, each participant was seated upright on the floor with one leg fully extended. The other leg was flexed at the knee and crossed over the extended leg. The flexed knee was pulled to the opposite shoulder. The opposite side was stretch immediately following the completion of stretching the ipsilateral side. After all three stretches were performed, each participant rested for 3 minutes prior to performing the vertical jumps. Participants were instructed to hold each stretch at a point in their range of motion that would maximize discomfort but not cause pain. The total time spent stretching was approximately 3 minutes. Therefore, the duration of time from the end of the warm-up until the first vertical jump was approximately 7 minutes.

The 60-second session was performed in the same manner as the 30-second session except each stretch was performed twice (i.e., two sets of 30 seconds). Immediately following the conclusion of the last stretch, each participant performed the three vertical jumps. The total time spent stretching for this session was 6 minutes. Therefore, the duration of time from the end of the warm-up until the first vertical jump was the same for all three sessions (i.e., ~7 minutes).

Vertical ground reaction force data was sampled at 250 Hz and recorded using Bioware version 5.2 (Kistler). Data was stored on a flash drive and analyzed offline. The sampling rate was chosen due to the limited storage capacity of the flash drive. Previous research has shown that using sampling rates as low as 200 Hz does not adversely impact the reliability or validity of jump performance measurements (22). Take-off velocity was calculated using the impulse-momentum relationship. Vertical jump height was the maximal displacement of the participant's center of mass. It was calculated using $d = (v^2_f - v^2_i)/2a$, where d is the maximal displacement of the participant's center of mass, v^2_f is the square of the take-off velocity, v^2_i is the square of the initial velocity, and a is the acceleration due to gravity (9.81 m/s^2). Peak force and peak power were also recorded. Only the dependent measures from the best vertical jump height produced during each session was recorded for statistical analysis. Differences in vertical jump height, peak force, take-off velocity, and peak power across all three sessions were statistically assessed using separate Repeated-Measures Analysis of Variance (RMANOVA) using SPSS (version 22, IBM Corporation, Armonk, NY). The statistical power calculated *a priori* for this study was 86% and was based on the results of a previous static stretching study (23). The alpha level was set to 0.05. Results are reported as means ± standard deviations.

RESULTS

The results of the RMANOVAs revealed no significant differences across the three sessions for any of the dependent variables ($p>0.05$). Table 1 lists the means and standard deviations for vertical jump height, peak force, take-off velocity, and peak power for each session.

Table 1. Vertical jump height, peak force, take-off velocity, and peak power for each session.

Measure	Control	30 Second	60 Second
Vertical Jump Height (m)	0.27 (0.08)	0.26 (0.08)	0.26 (0.08)
Peak Force (N)	830.71 (294.79)	826.70 (323.99)	829.14 (326.89)
Take-off Velocity (m/s)	2.27 (0.33)	2.25 (0.33)	2.24 (0.34)
Peak Power (W)	3099.04 (1044.09)	3168.22 (1120.39)	3076.04 (1017.23)

*Mean (SD)

DISCUSSION

The purpose of this study was to evaluate the effects of two different limited-duration static stretching protocols following a thorough warm-up on vertical jump performance. Previous research has shown conflicting results when evaluating the effects of limited-duration static stretching on power performance. The results of this investigation show that performing either stretching protocol (30 seconds or 60 seconds) following a warm-up had no effect on vertical jump performance. Kay and Blazevich (17) and Simic et al. (16) suggest that performing static stretches using short durations (≤ 30 s) would not adversely affect muscle performance while longer-duration stretches (≥ 60 s) would likely induce a small to moderate impairment in performance. The current study's results appear to be partially in agreement with these systematic reviews.

One possible explanation for the differences or lack of differences observed in the current study and previous studies is the training status of the participants. The current study's participants' varied in their training status from sedentary to athletic. In a literature review, Behm and Chaouachi (1) concluded that there was no difference in studies that used trained or untrained individuals when studying the acute effects of static stretching on performance. Simic et al. (16) also concluded that training status as well as gender and age did not influence static stretching-induced strength deficits. Therefore, it is unlikely that the difference between the current study's results and previous studies are due to training differences of the participants.

The current study's finding that there was no effect of 30 seconds of static stretching on vertical jump performance is consistent with the majority of previous studies using similar stretching volumes (14,19,24). However, Hough, Ross, & Howatson (7) demonstrated a 4.2% decrease in static vertical jump height following 30 seconds of static stretching for the plantar flexors, hip extensors, hamstrings, hip flexors, and quadriceps femoris. Fletcher and Monte-Colombo (25) also demonstrated a statistically significant ~3.8% decrease in countermovement vertical jump height due to 30 seconds (2 sets of 15 s) of static stretching for the hamstrings, quadriceps, abductors, adductors, gluteus maximus, hip flexors, gastrocnemius, and solei. The current study only stretched three muscle groups (gluteals, hamstrings, and quadriceps). Hubley and Wells (26) determined that the hip, knee, and ankle extensors contribute 28%, 49%, and 23%, respectively, of the work done to perform a countermovement vertical jump with no arm swing. While the current study manipulated less musculature that contributes to the vertical jump performance, Curry et al. (19) stretched the hip extensors, hip flexors, knee extensors, and ankle extensors for a static stretching volume of 36 seconds (3 sets of 12 seconds) and reported no effect when assessing vertical jump height within five minutes of stretching. Therefore, it seems that statically stretching more than just the hip, knee, and ankle flexors may have a greater impact on the impairment of vertical jump performance. Future research may want to explore the effect of stretching various muscle groups to better understand this potential adverse impact on performance.

The lack of significant differences between the Control session and the 60 second session was unexpected since Kay and Blazevich (17) reported that static stretching durations ≥ 60 s would likely cause a small to moderate reduction in performance. Simic et al. (16) stated that static stretching duration of 46 – 90 s could possibly impair performance by 2.5%. The percent change in the current study for the 60 second session was <1%. A few studies investigating 60 seconds of static stretching volume have found similar results (24,27,28). However, Pearce et al. (29) showed a statistically significant 7.7% decrease in vertical jump height after the participants completed 60 seconds (2 sets of 30 s) of static stretching for the hamstrings, gastrocnemius, gluteals, hip flexors, and quadriceps. The stretching of additional muscle groups may have been the deciding factor in terms of performance impairment. Studies using larger stretching volumes have been able to demonstrate statistically significant impairments in vertical jump performance when stretching fewer muscle groups (24,30,31).

In conclusion, it appears that the use of 30 second volume of static stretching followed by a thorough warm-up may not impair vertical jump performance. The use of 60 second volume of static stretching per muscle group may impair performance depending upon the number of muscle groups being stretched. Future research is needed to evaluate the relationship of this limited-duration static stretching volume and the magnitude of musculature being stretched and the impairment in muscular power events.

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