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ORIGINAL RESEARCH OPEN ACCESS

STATIC AND DYNAMIC STRETCHING AND ITS EFFECTS ON HAMSTRING FLEXIBILITY, HORIZONTAL JUMP, VERTICAL JUMP, AND A 50 METER SPRINT

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ABSTRACT

Preactivity stretching is commonly performed by active individuals as part of their warm-up routine. While both static and dynamic stretching are techniques utilized by the everyday exerciser, it has been questioned as to whether these types of stretching protocols can be harmful or beneficial to anaerobic exercise performance. The current literature on stretching has also been biased toward athletes. Therefore, the purpose of this study was to investigate whether three weeks of either static or dynamic hamstring stretching affects range of motion (ROM) and anaerobic exercise performance in recreationally active individuals. Twenty-two healthy college-aged students were randomly divided into three groups; static stretching (n=9), dynamic stretching (n=8), or no-stretch control (n=5). Participants completed three weeks of the stretching protocol with measurements taken before and after the stretching regimen. ROM of the hamstrings were measured via the sit and reach test and the active knee extension test (AKET) while three variables of anaerobic performance (horizontal jump, vertical jump, and 50 meter sprint) were analyzed. Statistical analysis showed no significant differences ($p<0.05$) between groups for the horizontal jump ($p=0.261$), vertical jump ($p=0.983$), or the 50 meter sprint ($p=0.899$). Furthermore, three weeks of either static or dynamic hamstring stretching did not improve ROM in our active volunteers. Therefore, based on the current investigation, neither static nor dynamic stretching appears to impact anaerobic exercise performance.

Keywords: static; dynamic; stretching; vertical jump; horizontal jump

INTRODUCTION

Flexibility is one of the five health-related components of physical fitness (1). For individuals who engage in exercise on a regular basis, stretching is a vital part to any training program. Static and dynamic stretching are two of the more common techniques used by individuals to improve range of motion (ROM). Static stretching has been shown to be effective in increasing muscle length by taking the muscle to its end range and maintaining that position for a specific amount of time (5). Static stretching increases the muscle length without regard for the specific movements of the subsequent exercise program (5). On the other hand, dynamic stretching increases both body and muscle temperature (6), stimulates the nervous system (17), decreases the inhibition of antagonist muscles, and increases post-activation of power (10). Dynamic stretching is more appealing to the everyday exerciser as it mimics the movements that the individual will be doing in their ensuing program (10).

In either case, stretching increases the force and/or rate of muscle contraction by increasing the compliance of the muscle and reducing the energy needed to move the limb (13). Unfortunately, previous studies have been conflicting on whether or not both types of stretching actually improve anaerobic muscular performance (3, 4, 7, 8, 11, 12, 15, 17).

Anaerobic leg power can be measured by performance on a 50 meter sprint, vertical jump, and horizontal jump. Hayes and Walker (2007) found that there were no significant changes in sprint performance when completing a static or dynamic stretching protocol in long distance runners (8). This is in agreement with Bazett-Jones *et al.* (2008), who found that there was no change in 50 meter sprint time or vertical jump height with static stretching (3). However, both of these studies are in contrast with Winchester et al. (2008), who found that static stretching does impair sprinting performance in track and field athletes (15).

The vertical jump is widely used and accepted as a test of maximal leg power (10). Nonetheless, while Jaggers *et al.* (2008) measured an increase in vertical jump performance from an increase in power production of the leg extensors following dynamic stretching (10), Bazett-Jones *et al.* (2009) failed to find a significant increase in vertical jump height with chronic static stretching of the hamstrings (3).

Lastly, the horizontal jump has not been widely studied, even though greater hamstring activity has been found during a horizontal jump versus a vertical jump (7). The horizontal jump has been studied less with respect to stretching protocols, possibly due to a lack of exercise specificity when compared with the vertical jump in exercise regimens.

While the current literature on stretching is conflicting it is also biased toward athletes. Therefore, the aim of this study was to determine how both chronic static and dynamic stretching affects anaerobic exercise performance for the everyday exerciser. We hypothesized that neither static nor dynamic stretching would negatively affect anaerobic exercise performance in our population.

METHODS

Participants

Twenty-two active college-aged students participated in this study. To be included, participants must have been regular exercisers (recreationally active 3-4 times per week). Participants were divided into one of three groups; static stretching (n=9), dynamic stretching (n=8), or no-stretch control (n=5). All participants completed an informed consent and Physical Health and Medical History Questionnaire prior to participation. This study was done in compliance with the Federal Requirements for Protection of Human Subjects and was approved by the West Chester University of Pennsylvania

Human Subjects Committee Institutional Review Board.

Experimental Design

Prior to the stretching protocol, pre-tests were performed. Each participant was tested for hamstring flexibility using three different instruments, sit-and-reach test (Homemade Device; West Chester, PA, **Figure 1**) and the active knee extension test (AKET) using both a goniometer (Invacare Corporation; Elyria, OH) and an inclinometer (Baseline® AcuAngle Inclinometer; Elmsford, NY, U.S. PAT 2194335, 2-D Functions) for both legs. Next, pre-testing for anaerobic exercise performance was completed. Three trials of the horizontal jump test and vertical jump were completed. Lastly, one trial of the 50 meter sprint was performed. The order of testing for each participant was the same during post-testing. Following pre-test data collection, participants were randomly assigned to one of the three stretching protocols (control, static, and dynamic).

Figure 1. Sit and reach box used for hamstring flexibility.

For three consecutive weeks, three times per week, participants came into the Human Performance Laboratory at West Chester University of Pennsylvania for the stretching protocol. All participants came in for one session per day for a total of nine sessions. The same investigator led each specific stretching session. In addition, the same researcher collected pre and post-test measurements on each participant.

Stretching Protocols

Stretching exercises for the static and dynamic groups were performed following a five-minute walking warm-up. The control group also completed the five-minute warm-up, prior to the participants sitting, while the other groups performed their stretches. The investigator demonstrated the stretches during these sessions with the same investigator demonstrating each time. Both the static and dynamic stretching group performed hamstring and quadriceps stretches. Each stretch was held for 30 seconds, switching between legs before repeating the stretch a total of four times. Static stretching of the hamstring was done by having the participants sit with one leg out in front, while the other leg was bent and the foot was at the side of the outstretched leg. The quadriceps were stretched by using a standing stretch (**Figure 2**). Participants were informed to hold all stretches at a point of mild discomfort. For the dynamic hamstring stretch the participants contracted the hip flexor with the knee being extended and flexing the hip joint. The leg was swung anteriorly. For the quadriceps, the hamstring was intentionally contracted and the knee flexed so that the participant's heel touched the buttock (**Figure 3**).

Figure 2. Static hamstring stretch (left) and static quadriceps stretch (right).

Figure 3. Dynamic hamstring stretch; participant contracted the hip flexor with the knee being extended and flexing the hip joint. The leg was swung up anteriorly (left). Dynamic quadriceps stretch; the hamstring muscles were intentionally contracted and the knee flexed so that the participants heel touched the buttock (right).

Hamstring Flexibility

Hamstring flexibility was assessed by the sit-and-reach test and the active knee extension test (AKET) using both a goniometer and an inclinometer. For the sit and reach test, participants reached with both hands, one on top of each other, as far as they could along the sit and reach box three times. The individual's legs were completely extended. The average of three attempts was recorded.

Hamstring flexibility was completed using the AKET. The participants laid supine on the floor. The leg that was not being tested was bent at the knee and hip with the foot flat on the floor. The other leg was brought to a 90 degree angle at the hip, as the knee was bent. The subject then actively

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extended the knee until there was tightness or pain that restricted further extension of the knee. Active ROM in knee extension was measured first via a goniometer and second via an inclinometer. This was then repeated for the other leg to determine the bilateral difference in flexibility of the hamstrings. Knee extension was measured three times and averaged for both legs and both devices.

Horizontal Jump Test

Following the hamstring flexibility tests, participants were tested for horizontal jump distance, vertical jump height, and their 50 meter sprint time. Standing behind a clearly marked line on the floor, participants jumped from a two-foot take-off as far as they could horizontally and landed with both feet. The use of an arm swing was allowed. The distance was measured from the takeoff line to the back of the subject's heels. Participants jumped three times and the average horizontal distance was calculated and recorded.

Vertical Jump Test

Vertical jump height was measured with a Vertec (Gill Athletics). The participants reached up as far as they could with their dominant hand with both feet flat on the ground. This was considered their standing reach value and the Vertec was adjusted so that their fingertips touched the bottom rung. The participants then jumped vertically as high as they could, from a two feet take off to determine their vertical jump height. The non-dominant hand was at the participant's side. Participants jumped three times and the average vertical height distance was calculated and recorded.

Sprint Test

For the 50 meter sprint, participants started behind a marked starting line. The investigator said ready, set, and go. The participants ran 50 meters as fast as they could, while a stopwatch was used to time them. The 50 meter sprint was only completed once and the time was recorded.

Statistical Analysis

All results are presented as means ± standard error of mean (SEM). SPSS version 21.0 was used for all analyses (SPSS Inc., Chicago, IL, USA). The data was analyzed using repeated-measures ANOVA, with a Bonferroni's post hoc test. Differences between each group (no-stretch control, static, and dynamic) and among testing sessions (pre and post) were investigated. The level of statistical significance was set at $p<0.05$.

RESULTS

Participant Demographics

Participant demographics are displayed in **Table 1**. Weight and body mass index (BMI) were higher in the no-stretch control group only because two out of the five control subjects weighed significantly more than the rest of the participants.

Flexibility

Sit and Reach Test

Two measures of hamstring flexibility were analyzed in all three experimental groups': pre and post-stretching. For the sit and reach test, pre-tests showed there were no significant differences in hamstring/lower back flexibility between groups. Static stretching slightly increased hamstring flexibility from pre to post-test (26.82 cm vs. 28.33 cm; 5.5% improvement) while the dynamic stretching group saw a decrease in hamstring flexibility (38.95 cm vs. 34.19 cm; 13% decline) pre to post-test (**Figure 4**). However, neither of these results were statistically significant.

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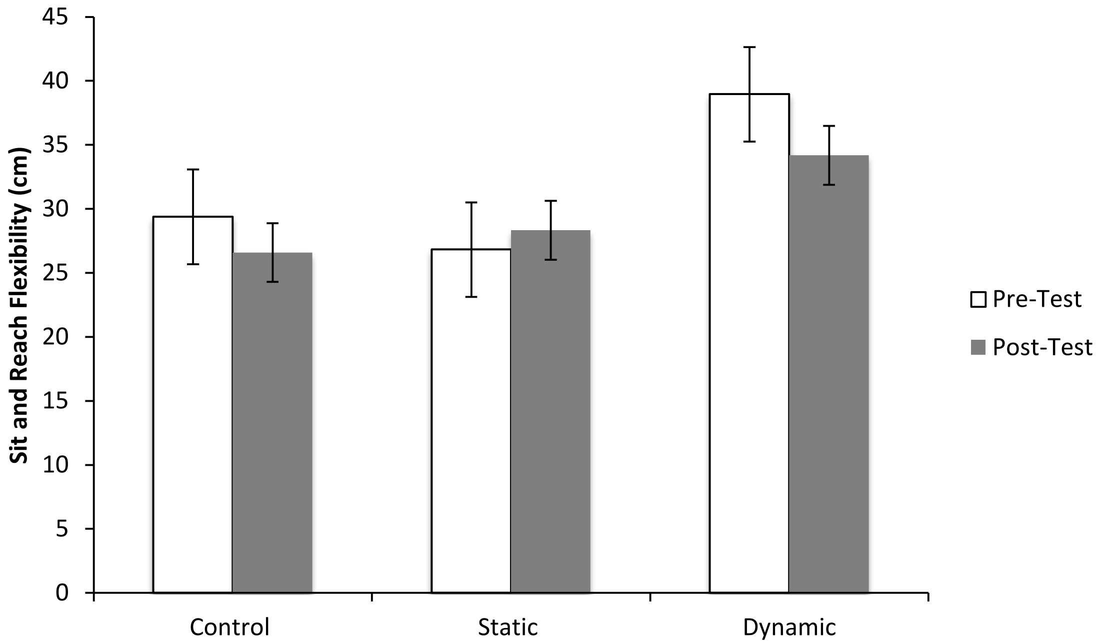
***Table 1** – Participant Demographics*

Group	Age (years)	Gender (Male/ Female)	Height (m)	Weight (kg)	BMI
Control (n=5)	21.4 ± 0.68	4 /1	1.79 ± 0.06	90.26 ± 8.27*	28.11 ± 1.86*
Static (n=9)	21.4 ± 0.29	5 /4	1.71 ± 0.02	69.00 ± 2.11	23.71 ± 0.40
Dynamic (n=8)	21.0 ± 0.33	5 /3	1.74 ± 0.03	73.71 ± 4.15	24.66 ± 0.83

Data represents means ± SEM. * Significantly different from stretching groups.

Figure 4. Sit and reach flexibility pre and post-test for the three experimental stretching groups. Values are means ± SEM.



Active Knee Extension Test (AKET)

The AKET was performed in all three experimental groups' pre and post-stretching and two different devices were used to measure ROM. The goniometer found that left hamstring ROM increased by 3.9 degrees, while ROM of the right hamstring only increased by 0.8 degrees following a static stretching program. Interestingly, ROM improvements were reversed with static stretching using an inclinometer. Left and right leg hamstring ROM increased by 0.6 degrees and 2.6 degrees, respectively (**Table 2**).

Conversely, goniometer measurements of left and right leg hamstring ROM increased by 5.3 degrees and 4.6 degrees, respectively following the dynamic stretching program. The inclinometer only measured slight improvements in hamstring ROM with dynamic stretching; 3.0 and 1.4 degrees (left and right hamstring) (**Table 2**). Even though there was an increase in hamstring flexibility for the inclinometer and goniometer tests, they were not statistically significant.

Table 2. *Hamstring Range of Motion via the Active Knee Extension Test (AKET) using both a Goniometer and Inclinometer*

	Control	Static	Dynamic
Goniometer Left Leg			
Pre	8.4 ± 2.08	14.7 ± 3.69	10.1 ± 2.15
Post	8.4 ± 3.86	10.8 ± 3.09	4.9 ± 2.31
Difference	0.0	-3.9	-5.2
Goniometer Right Leg			
Pre	14.0 ± 1.92	10.4 ± 2.57	12.0 ± 1.58
Post	10.8 ± 3.51	9.7 ± 2.87	7.4 ± 2.62
Difference	-3.2	-0.70	-4.6
Inclinometer Left Leg			
Pre	6.4 ± 4.41	6.6 ± 1.96	7.1 ± 2.19
Post	6.0 ± 2.09	6.0 ± 1.37	4.1 ± 1.37
Difference	-0.4	-0.6	-3.0
Inclinometer Right Leg			
Pre	7.8 ± 3.77	9.7 ± 2.53	6.9 ± 1.29
Post	7.6 ± 1.60	7.1 ± 2.58	5.5 ± 1.28
Difference	-0.2	-2.6	-1.4

Values shown are in degrees. Lower degree means more flexibility in the leg, which is closer to 180 degrees. Data represents means ± SEM. Differences shown are Post vs. Pre.

Anaerobic Exercise Performance

Horizontal Jump

There were no statistically significant differences between experimental groups (control, static, and dynamic) for the horizontal jump. From pre to post-test, static stretching improved horizontal jump distance from 170.41 cm to 174.71 cm, while jump distance declined with dynamic stretching from 190.98 cm to 186.32 cm. Both groups saw an ~2.5% change in horizontal jump distance following three weeks of stretching, however, neither of the changes were considered statistically significant (*p*=0.261, **Figure 5**).

Vertical Jump

There were no statistically significant differences between experimental groups (control, static, and dynamic) and pre to post-test for the vertical jump (*p*=0.983, **Figure 6**). Vertical jump height increased slightly in the static group while the vertical jump height remained the same pre to post test in the dynamic stretching group.

50 Meter Sprint

Similar to the vertical jump, there were no statistically significant differences between experimental groups (control, static, and dynamic) and pre to post-test for the 50 meter sprint (*p*=0.899, **Figure 7**). It should be noted that one participant in the control group had to be eliminated because of an injury during the sprint, limiting the control group to an n=4.

Figure 5. Horizontal jump distance (cm) pre and post-test for the three experimental stretching groups. Values are means ± SEM.

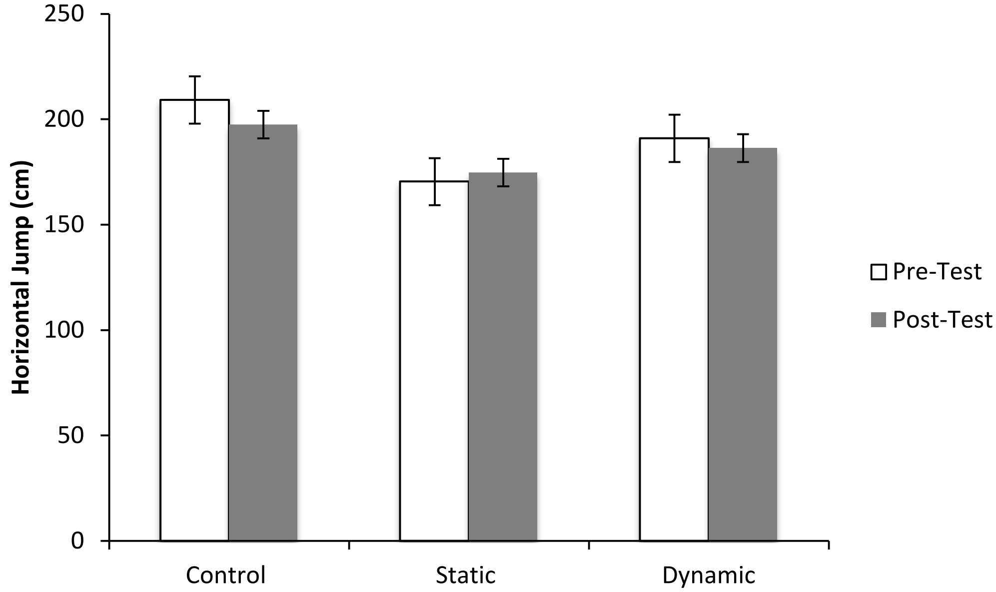


Figure 6. Vertical jump height (cm) pre and post-test for the three experimental stretching groups. Values are means ± SEM.

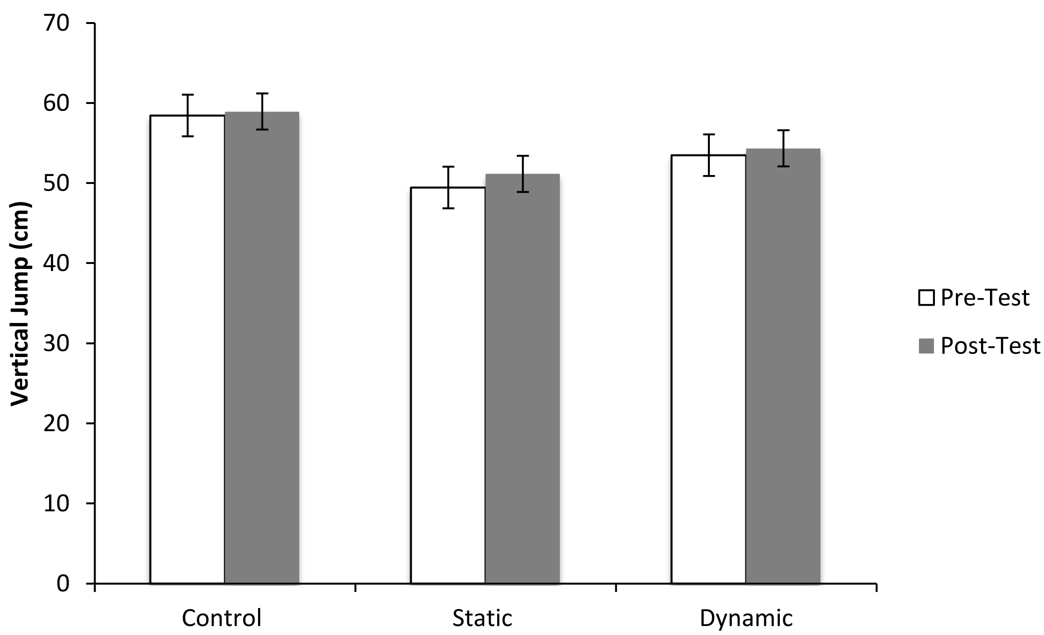
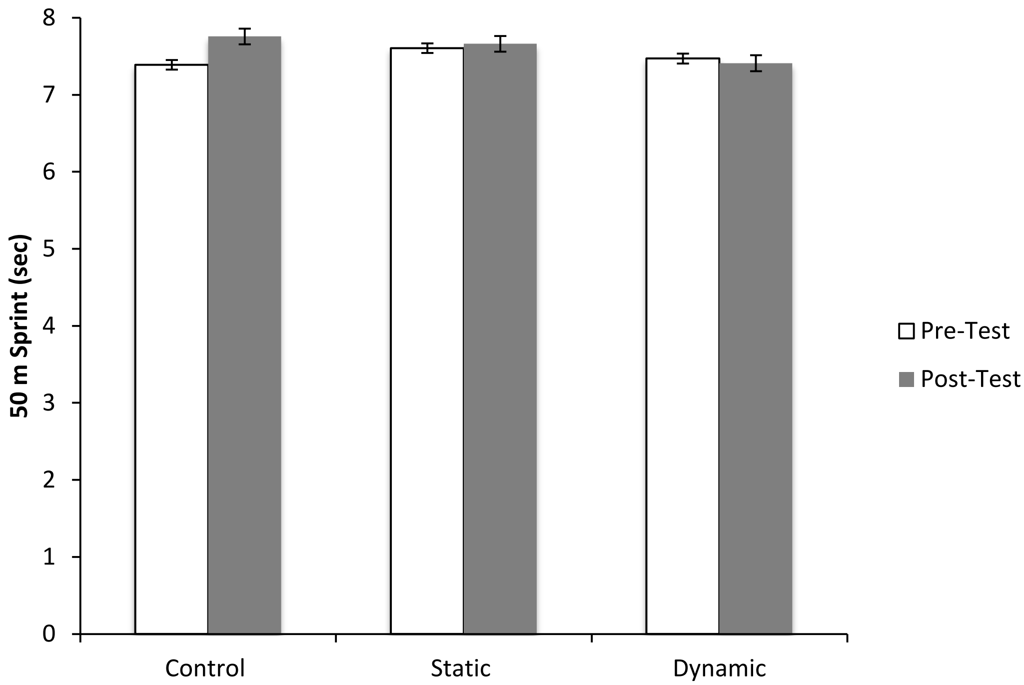


Figure 7. 50 meter sprint times pre and post-test for the three experimental stretching groups. Values are means ± SEM.



DISCUSSION

The present study examined chronic static and dynamic stretching on anaerobic exercise performance in the everyday exerciser. The results from this study demonstrate that neither static nor dynamic stretching negatively affect anaerobic leg power.

While we unfortunately did not see a significant increase in ROM from our stretching protocols, previous research has shown that this protocol length is enough to see flexibility improvements. Worrell et al. (1994) had a three-week stretching protocol with five days of stretching and saw a statistically significant increase in hamstring flexibility (16). In addition, Davis et al. (2005) used a four week stretching protocol with stretching sessions three days /week, but only repeating the stretches once per session (5). They measured the knee extension angle of the individual to determine hamstring flexibility, where they saw an increase in hamstring length following the stretching protocol. We choose three stretching sessions a week for three-weeks, as this is more realistic of what the general population currently performs (2). In addition, having the participants repeat the stretches four times at each session would help to increase hamstring length compared to the control group. Most of the individuals in this study exercised at least three times a week. Therefore, it could be assumed that our participants were already at their ideal flexibility or optimal length (14) and that is why we failed to see a significant improvement in hamstring ROM. Future studies should either 1) include more participants in each stretching group , 2) extend the stretching protocols to see a measurable increase in hamstring flexibility or 3) utilize an active but older population to measure significant improvements in flexibility with the current protocol.

The goniometer and the inclinometer were used to determine if these devices are comparable in measuring hamstring flexibility. There was not a significant difference between these two measuring devices and the degree of hamstring flexibility of our participants. Nonetheless, it should be noted that these two devices cannot be used interchangeably.

To our knowledge, there has never been a study that has examined the effect of chronic static and dynamic stretching on horizontal jump distance. This study found that neither stretching protocol significantly affected the horizontal jump distance. While the mechanism is unknown, muscular power could be increased, but the muscles may not able to convert the elastic potential energy (16) into the horizontal jump distance. This is because the dynamic stretching protocol was not completed just prior to testing, therefore, the participant could not benefit from the increased muscle temperature that the stretching would cause. In research that has looked at hamstring activation during horizontal jump, it has been found that the hamstrings are more activated in this type of jump compared to a vertical jump (7). Therefore, the jump distance would be more affected by an increase in flexibility and a decrease in muscle stiffness, as this would negatively affect muscular power (12).

With regards to the vertical jump, our study confirms what previous research has found. Following a six week flexibility program, Bazett-Jones *et al.* (2008) found that static stretching neither benefits nor harms vertical jump performance (3). Similarly, our study supports the results found by Jaggers *et al.* (2008), which found that even though jump power may be increased following a dynamic stretching protocol, it does not play a role in vertical jump performance (10). Likewise, the 50 meter sprint was neither positively nor negatively affected by either a static or dynamic stretching protocol. Hayes and Walker (2007), as in our study, found that both a static and dynamic stretching protocol did not affect sprint time from pre to post-test (8). Muscle power is generated by greater storage of elastic energy. In order to increase elastic energy there needs to be an increase in eccentric lower-limb stiffness (9). In this study, while hamstring flexibility increased slightly, it did not negatively affect the sprint time, as it probably did not disturb the eccentric contraction phase of running. The lack of significant findings in this study agrees with our hypothesis that neither stretching protocol would affect anaerobic exercise performance in our everyday exercisers.

CONCLUSION

In summary, the literature on chronic stretching and its role on anaerobic exercise performance have been mixed. The results from this study demonstrate that neither static nor dynamic stretching affects anaerobic exercise performance for the everyday exerciser. Performance in high intensity interval training, a 5-mile run, or a pick-up game of basketball will not be negatively influenced by static stretching prior to the exercise nor will dynamic stretching pre exercise necessarily improve performance. The important thing to note is that it is crucial to stretch in a manner that you enjoy both pre and post workout to increase range of motion of the hamstring muscles.

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