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The Acute Effects of Antagonist Stretching on Agonist Movement Economy

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ABSTRACT

International Journal of Exercise Science 13(4): 1295-1304, 2020. Current research on the effects of stretching on movement performance varies. However, these studies focused on stretching agonist and antagonist muscle responsible for movement production. Few studies investigated the influence of antagonist stretching on exercise performance. The purpose of this study is to examine the acute effects of antagonist stretching on agonist movement economy. 14 participants (5 male, 9 females; 168.32 ± 7.63 cm stature; 65.00 ± 7.28 kg mass) completed baseline active ROM (AROM) and passive ROM (PROM) measurements. The experimental design required participants to complete two 5 min trials of seated hip abduction movement, one pre-stretching and one post-stretching (criterion $>15\%$ PROM). Each trial required participants to abduct (and adduct) both legs to 90% of AROM repeatedly for 5 min. The task was performed with no external resistance, only dependent upon the ability of agonist to perform the movement, while overcoming the resistance of the antagonist musculature. Principles of indirect calorimetry were used to calculate energy expenditure ($\text{kJ}\bullet\text{min}^{-1}$). Paired t-tests compared energy expenditure of the stretching and non-stretching trials. A greater PROM in post-stretching than pre-stretching was observed with an increase in PROM of $21.6\pm4.5°$ ($p<0.001$). There was also greater AROM in post- than pre-stretching with an increase in of $11.3\pm 9.2°$ ($p<0.001$). Less energy was expended during post- compared to pre-stretching exercise, with a decrease in EE of $0.66 \pm 1.17\text{kJ}\bullet\text{min}^{-1}$ ($p<0.05$). Increasing antagonist ROM by stretching resulted in a decrease in agonist energy expenditure and may be a viable mechanism to increase athletic performance.

KEY WORDS: Energy expenditure, indirect calorimetry, exercise performance, range of motion

INTRODUCTION

Stretching is very commonly used prior to an exercise bout. There are many different types of stretching, with the most common forms being static stretching, dynamic stretching, and proprioceptive neuromuscular stretching, all of which are believed to increase range of motion (ROM). This increase of range of motion is thought to be due to the decrease in musculotendinous unit (MTU) stiffness, and increase in muscle compliance, of the antagonist component as a consequence of stretching (3). This decrease in antagonist MTU stiffness allows for a greater production of force by the contractile (agonist) component (13). Contrarily, studies from Wolfe et al (18) and Hayes & Walker (1) suggest MTU tightness may lead to greater economy and increased performance. Similarly, Wilson et al (16) provided evidence that greater musculotendinous stiffness is directly related to greater force production for the isometric and concentric actions of a bench press movement. Although none of those studies investigated antagonist stretching alone, perhaps it is the combination of decreasing MTU stiffness of the antagonist component and maintaining MTU stiffness in the agonist component that allows for an increase in performance.

However, there is still a limited understanding of how stretching influences performance. Some studies show stretching to be beneficial to performance. A study by Yamaguchi et al (20) found dynamic stretching to acutely prolong time to exhaustion and increase total distance of endurance running. But other studies found stretching to be detrimental to performance. Kokkonen et al (2) found stretching the agonist prior to exercise negatively influences maximum strength performance of that muscle. Previous work found stretching prior to exercise increases time to complete a run and increased ground contact time in endurance runners (4). Paradisis et al (11) found static stretching to be detrimental to running and explosive performance and dynamic stretching to only impair explosive performance. Murphy et al. (8) found static stretching prior to exercise had no significant impact on performance of a countermovement jump, reaction time, and movement time tests.

The majority of research regarding stretching and human performance focuses on extrinsic outcomes, such as time to completion or total distance ran. Minimal studies have measured intrinsic factors of performance, such as energy expenditure. A study from Zourdos et al (21) found there was a significant increase in energy expenditure during a 30-minute run from pre- to post-stretching. However, other work found no significant change in energy expenditure from pre- to post-stretching when participants underwent a bout of aerobic running (6,10). This may be due to the decrease in MTU stiffness in both agonist and antagonist muscle groups.

Surprisingly, there have been limited studies investigating how stretching the antagonistic (opposite) musculature prior to performance effects the performance of the agonistic muscles. Sandberg et al (14) found stretching the antagonist muscles prior to performance produced a greater vertical jump height. Contrarily, Miranda et al (5) found stretching the pectoralis muscles in between sets of a seated row exercise led to an increase in the amount of repetitions performed in this movement. A similar study by Paz et al (12) found that PNF stretching of the pectoralis muscles prior to a seated row exercise led to a greater number of repetitions performed and a greater overall work output. More recently, Serefoglu et al (15) found that a static stretching bout of the antagonist musculature had no effect on the agonist concentric and isokinetic peak torque values as well as electromyographic amplitudes. In a similar finding, Muir et al (7) found static stretching of the calf muscles had no influence on peak torque values at 10° of ankle dorsiflexion. However, there is no current research focusing on stretching a specific antagonist muscle or group of muscles and then measuring the economy of a movement utilizing the agonist musculature. Movement economy may play a significant role in athletic and recreational exercise performance. When an individual requires less energy to perform a given movement they are able to allocate more energy resources to increasing other training variables, including intensity and volume. This may lead to the individual being able to push harder during training and see greater improvements in performance over time.

Therefore, the purpose of this study is to examine the acute effects of antagonist stretching on agonist movement economy. This will be done through a leg abduction movement task. We hypothesize stretching the hip adductor muscles (antagonist) will lead to an increase in hip abduction movement (agonist) economy. By specifically stretching the antagonist muscles there would be a decrease in antagonist MTU stiffness while still maintaining agonist MTU stiffness. We then believe the agonist muscles would need to produce less energy to complete the leg abduction task, ultimately leading to an increase in movement economy.

METHODS

Participants

Fourteen recreationally active participants (5 male, 9 female; 168.32 ± 7.63 cm stature; 65.00 ± 7.28 kg mass) participated in this study. Criteria for participant recruitment and study protocol were reviewed and approved by the Pacific University Institutional Review Board. All participants provided written informed consent prior to involvement in the study. Participants must have been safely able to perform the abduction exercise for 4 minutes continuously without pain or aggravation of previous injuries, answered "no" to every question on a Physical Activity Readiness Questionnaire (PAR-Q), be at least 18 years of age, not pregnant, sufficiently fluent in the English language to read and review the informed consent document, and have no known allergies to adhesive bandages. This research was carried out fully in accordance to the ethical standards of The International Journal of Exercise Science (9).

Protocol

Baseline Measures: Resting energy expenditure (EE) was measured by having the participant sit upright in a comfortable position for five minutes while being monitored by a metabolic cart (Viasys SensorMedics Vmax 229 Metabolic Cart, Yorba Linda, CA, USA). This allows for measurement of VO_2 consumption and VCO_2 production. Participants then completed baseline measures of agonist maximum active range of motion (AROM) and maximum passive range of motion (PROM). Max AROM and PROM were measured using the hand-controlled leg stretching apparatus and cross referenced using an image analysis app (Angle – Video Goniometer) (Figure 1). Max PROM was achieved when participant manually utilized the stretching apparatus until self-assessed moderate discomfort (5 out of 10 on a pain index scale).

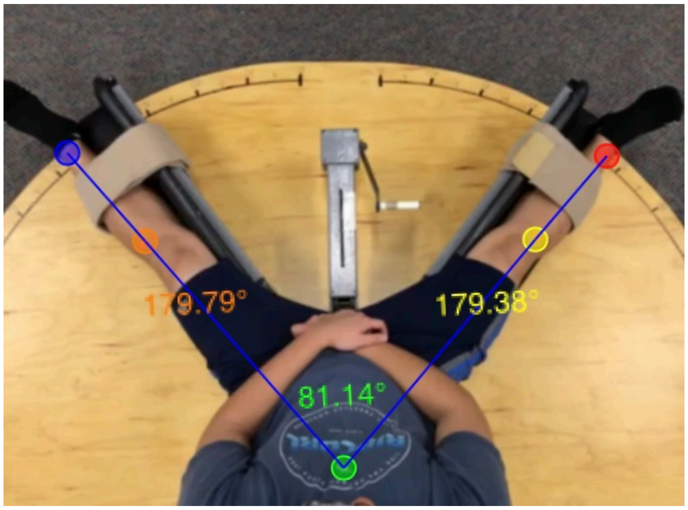

Figure 1. Photo of the Angle-Video Goniometer Application.

Exercise Task: Participants were instructed to produce leg abduction and adduction movements to each tick of a metronome within set barriers. A seated leg abduction task was chosen because it is a novel task the participants would not be practicing consistently. This means amount of time spent training or practicing the movement would not influence our results. Also, for this movement the exercise and stretching tasks could be completed on the same piece of equipment. This is beneficial because the exercise of the abductors and stretching of the adductors could occur with the participant in the same position, creating an opportunity for direct antagonist stretching (Figure 3). The participants were instructed to keep their back flat against the back rest, limited the forward movement of the torso to prevent momentum from being utilized to abduct the legs. During exercise, the metronome was set to 55 beats per minute (bpm). Keeping leg movements within the barriers to a set rhythm (55bpm) was used to keep work, and work rate, constant. Barriers were set at 90% of max AROM and 30° less than this value (15° less on both legs). The reason for this was, according the previously stated hypothesis, the adductors would be placing a fairly large amount of resistance the abductors would need to overcome. The stretching could then decrease this resistance enough for us to measure through EE. The exercise task lasted for five minutes. During the task, EE, heart rate (HR), and rate of perceived exertion (RPE) were assessed. Measuring of agonistic AROM and PROM followed exercise in the same manner as baseline measures. This exact task was repeated once more after the stretching protocol. This was used to compare the same work done before and after stretching. During the five minutes of EE collection for the baseline, pre-, and post-exercise, only the last two minutes of VO_2 and VCO_2 measures were used and analyzed. This was to ensure EE was analyzed in steady state. Steady state EE was crossed referenced with a heart rate monitor (Polar H10 Heart Rate Sensor, Kempele, Finland). The average VO_2 and VCO_2 from the last two minutes of the five-minute EE collection was used to convert the oxygen and carbon dioxide uptake (L/min) to EE ($kJ \bullet min^{-1}$) using the Weir Equation ($EE = [3.9 * (VO_2) + 1.1 * (VCO_2)] * 4.184$) (19). This was done for both pre- and post-exercise conditions.

Stretching Protocol: The stretching protocol occurred after the initial exercise task. The stretching routine consisted of 5-30 minutes of stretching utilizing the stretching apparatus, with each static stretch being held for one minute, allowing the legs to return to a resting position after each minute (Figure 2). PROM was assessed after five sets of static stretching. The criterion for continuation was a 15% increase in agonist PROM. If target PROM was not achieved, additional stretching was implemented until criterion was met. Upon completion of stretching, the measuring of agonist AROM and PROM followed in the same manner. The final exercise task then ensued with the exact same ROM requirements as the baseline task.

Statistical Analysis

A paired two-sample t-test (α=.05) was used to compare AROM, PROM, and EE of stretching and non-stretching conditions. Effect size analysis via Cohen's d was also utilized. This analysis was ran using the Microsoft Office Excel Analysis Toolpak Application.

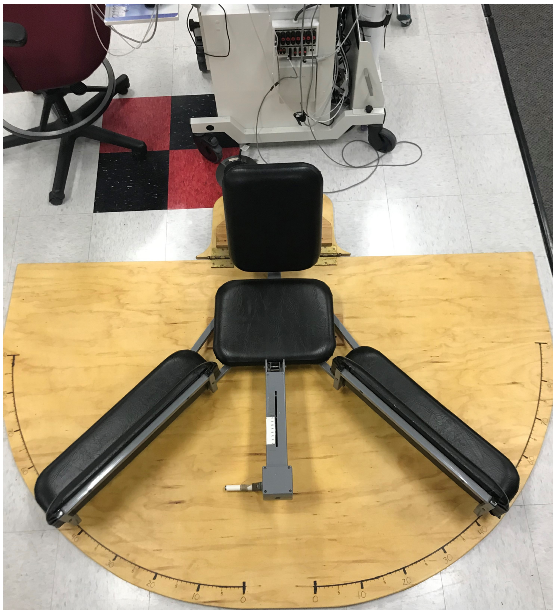

Figure 2. Hand-Controlled Leg Stretching Apparatus

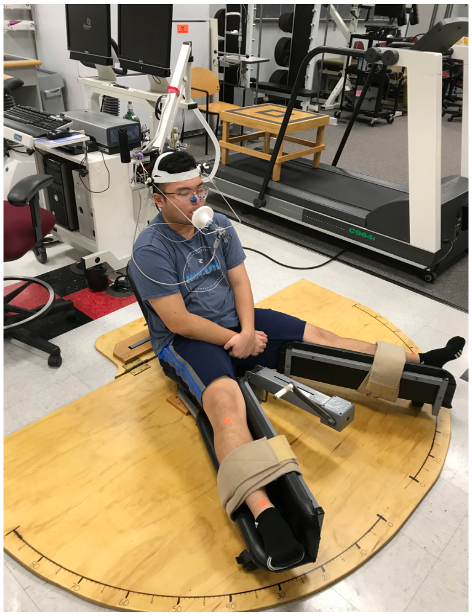

Figure 3. Participant performing the movement task using the stretching apparatus and metabolic cart.

RESULTS

Participants demonstrated a significant increase in both AROM and PROM from pre- to post-stretching. Stretching responses revealed a greater PROM in post-stretching than that of pre-stretching with an average increase in PROM of 21.6±4.5° ($p<0.001$, d=1.30) (Figure 4). This was expected due to criterion for continuation. Stretching responses also revealed a greater AROM in post-stretching than that of pre-stretching, with an average increase in AROM of 11.3± 9.2° ($p<0.001$, d=0.75) (Figure 5). Interestingly, less energy was expended in the post-stretching condition when compared to the pre-stretching condition with an average decrease in EE of 0.66 ± 1.17$\text{kJ}\bullet\text{min}^{-1}$ (6.1% decrease) ($p<0.05$, d=.32) (Figure 6). No effect of sex was found on the difference in EE pre/post stretching, difference in PROM pre/post stretching, and difference in AROM pre/post stretching (p>0.05).

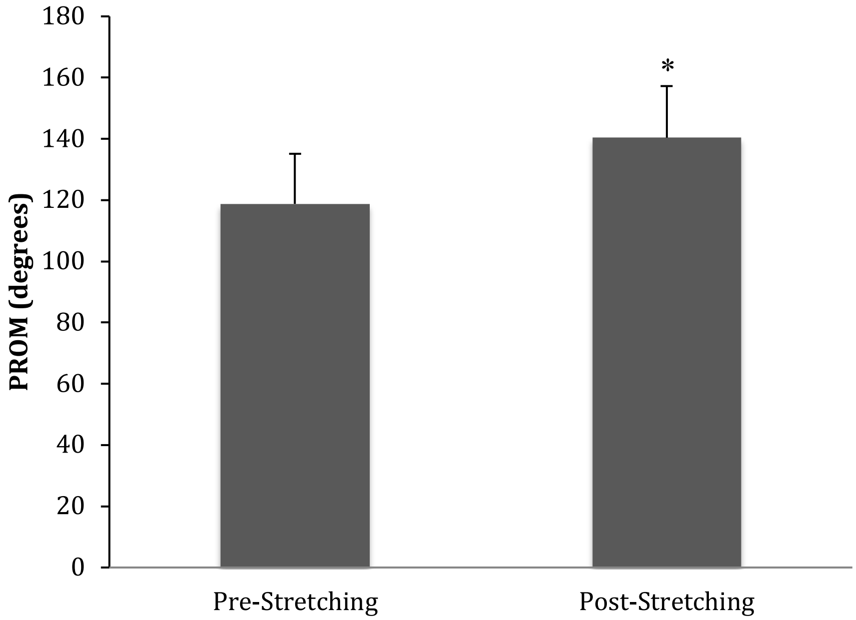

Figure 4. Measure of passive range of motion (PROM) in degrees from pre- to post-stretching protocol. PROM significantly increased post-stretching. *P<.05

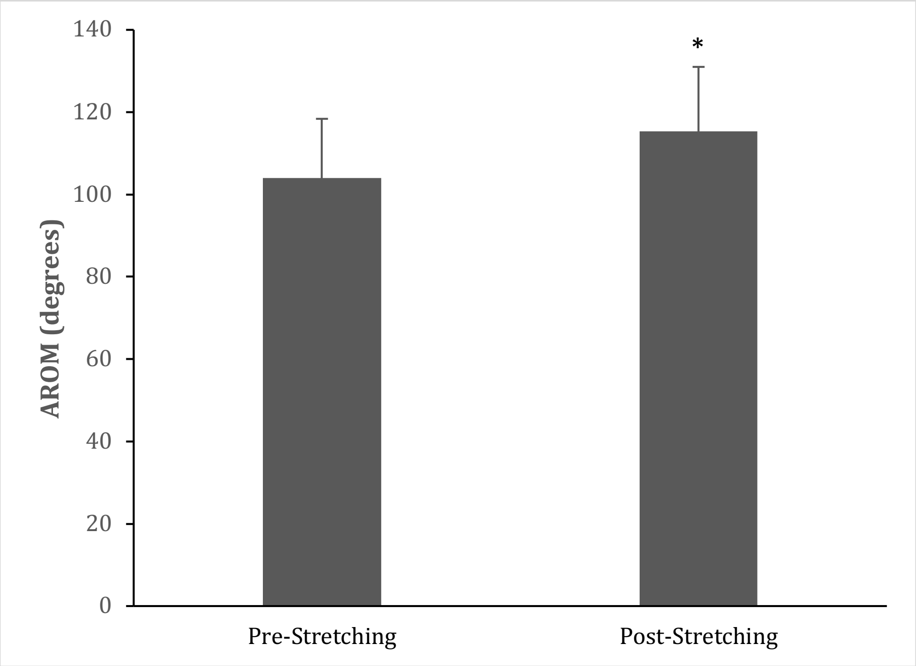

Figure 5. Measure of active range of motion (AROM) in degrees from pre- to post-stretching protocol. PROM significantly increased post-stretching. *P<.05

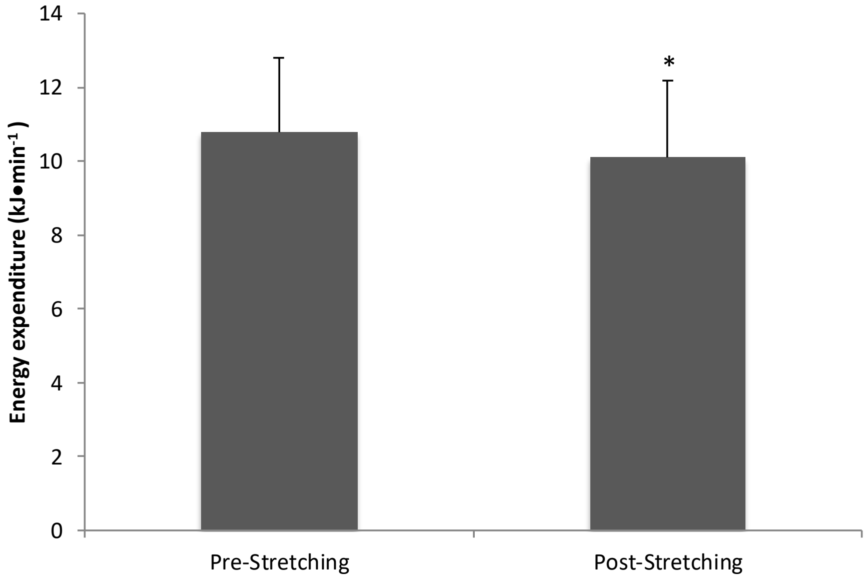

Figure 6. Measure of Energy Expenditure (EE) in kJ•min-1 during movement
task from pre- to post-stretching protocol. EE significantly decreased post-stretching. *P<.05

DISCUSSION

The purpose of the present study was to examine the acute effects of antagonist stretching on agonist movement economy. The results indicated both AROM and PROM significantly increased after stretching, as expected. Heart rate and energy expenditures of participants also decreased significantly from pre- to post-stretching. This supports the previous hypothesis, which stated stretching the antagonist musculature increases agonist movement economy. This was supported in the present study when participants expended less energy during an abduction exercise after completing a stretching protocol targeting the adductors, when compared to no stretching at all. A possible explanation for these results may be due to a decrease in passive resistance torque caused by static stretching, as found by Konrad et al (3). Statically stretching the antagonist musculature alone may have decreased its MTU stiffness and increased its passive muscle compliance without affecting the agonist musculature. By doing so, there may have been less tension created by the antagonist muscle that the agonist muscle had to overcome, decreasing the energy requirements for the movement.
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These findings are similar to those of Miranda et al (5) and Paz et al (12) who found stretching the antagonist musculature positively influenced the performance of the agonist musculature during a seated row exercise. As well as a study by Sandberg et al (14) who found antagonist stretching had a positive influence on vertical jump performance. However, there are also some studies with conflicting evidence, specifically regarding the influence of antagonist stretching on agonist peak torque values. These results were seen in studies by both Muir et al. (7) and Serefoglu et al (15). As previously mentioned, there are a multitude of studies that have investigated the acute effects of static stretching on running and cycling economy (1, 6, 10, 17, 18, 21) however, due to these studies stretching the entire lower body musculature, they are unable to contribute to the body of knowledge regarding antagonist stretching and agonist performance.

This study supports the hypothesis that stretching, specifically the antagonist musculature, increases movement economy. However, there still is very little literature on antagonist stretching alone. With the literature on the effects of stretching on movement economy varying in its support, it is still difficult to determine whether stretching is beneficial or detrimental to movement economy. It would be beneficial for more future research to focus on stretching the antagonist musculature alone and analyzing its effects on agonist movement economy. Though most studies, along with the present study, focused on lower extremity movements, it would also be beneficial to analyze the possible effects antagonist stretching would have on upper extremity movements. This study, as well as the other studies, indicated stretching to have acute effects on movement economy through a cross-sectional design. To determine whether the effects of stretching could lead to chronic adaptations, a longitudinal study on this topic would be advantageous.

There are limitations of this study that should be mentioned. The sample size of 14 is relatively small and was made up of both male and female participants. Therefore, sex differences in the variables measured were difficult to analyze. A power analysis was also not performed prior to the beginning of this study. A significant amount of variation was observed when comparing differences in EE pre- and post-stretching. The participants were recreationally active and not competitive or elite level athletes, whom the results from this study may be more applicable to. However, because a novel task was used we believe the results from this study may also be further discussed in an athletic setting. The novelty of the movement allowed practice to be controlled for. This task could also be tightly regulated in a laboratory setting at the expense of lacking functionality.

The results from this study also have practical applications that can be applied to athletes and coaches who participate in recreational and competitive activities, specifically those which require large amounts of ROM. These results may be beneficial to athletes, especially those who require high amounts of ROM. For example, gymnastics, combat sports, and dance all have movements that require large amounts of ROM. Being able to move and exercise while producing less energy would be a tremendous benefit to many different athletes. This could allow more work to be done per unit of energy and allow athletes to push harder during training, leading greater physiological adaptations in the future. Athletes are often performing movements at the greater end of their ROM. Therefore, as this study demonstrated, it could potentially be advantageous to stretch the antagonist muscles of their prime movements to allow for greater movement economy. With this study being one of a select few on this topic, more research on the influence of stretching the antagonist musculature on agonist movement economy is needed.

ACKNOWLEDGEMENTS

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