Original Research

Effect of Single Set Dynamic and Static Stretching Exercise on Jump Height in College Age Recreational Athletes

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ABSTRACT

Int J Exerc Sci 3(4) : 214-224, 2010. This study examined the effects of single set dynamic and static stretching on vertical jump height and hip and knee range of motion in a sample of college age recreational males. Forty-two healthy, physically active males (aged 18-24) voluntarily participated in this investigation and were randomly assigned to one of three groups (1 set of 20 seconds dynamic stretch, 1 set of 20 second static stretch, or control). The knee and hip range of motion, sit and reach, and jump height were measured before and after the treatment condition. The same measures were performed on the control group that sat for 12 minutes. All subjects began with a five minute warm-up on a cycle ergometer. Following the warm-up period, subjects immediately began their stretching program. Results of the investigation showed significant changes from pre-to-post for all dependent measures ($p < 0.05$). A significant difference between groups was found for sit and reach in the SS + DS groups ($p < 0.05$). However, there were no significant differences between groups for jump height or knee and hip range of motion. The results of the present study suggest that static and dynamic stretching for 20 seconds prior to a vertical jump can improve vertical jump height and hip and knee range of motion in a sample of male college age recreational athletes. Future research is needed to investigate the effect of single set stretching exercise prior to activities requiring maximal force production that includes athletes and female subjects.

KEY WORDS: Flexibility, warm-up, stiffness, power, range of motion

INTRODUCTION

A pre-exercise warm-up consisting of aerobic activity has been widely accepted as an appropriate method to improve performance in competitive and non-competitive sports participants. In several studies where static stretching was performed just prior to jump performance, results indicated an increased range of motion about a joint in addition to decreased jumping performance (3, 6, 24). This has led some researchers to propose that static stretching be eliminated from pre-exercise warm-up for activities that require strength and power production (6, 16). In contrast, dynamic stretching does not appear to decrease power production, and in most cases, has shown improvements in power production relative to vertical jump and sprint performance (8, 21, 31).

In studies that demonstrated negative effects of static stretching on performance requiring strength and power production, several stretching exercises were performed for multiple sets (minimum of 3 sets) and durations of greater than 30 seconds (3, 6, 16). A recent review of the literature by Rubini et al. (25) stated that the static stretching protocols used in the literature showing significant performance decreases are excessive in the number of exercises performed and duration of the exercise. In addition, many of the studies showing significant performance decreases focus on a single muscle group (6, 16, 28). A recent study by McMillian et al. (21) showed increased vertical jump performance following a static stretching protocol for duration of less than 30 seconds that incorporated a single set of exercises for each muscle group involved in the activity. Siatras et al. (28) showed decreased knee extension isometric peak torque following a single stretch of the quadriceps for 30 seconds or greater, but no decreases in knee extension isometric peak torque were found following 20 seconds or less. The authors' of the study suggested that static stretching protocols of durations less than 20 seconds may not degrade maximal performance. The results are difficult to generalize to the recreational fitness participant because the subjects recruited were either athletes or accustomed to maximal effort activities.

Dynamic stretching has also been shown to increase performance prior to activities requiring maximal force production (8, 21, 31). The suggested mechanisms for improvements in power production following dynamic stretching are increased muscle temperature, increased range of motion, and postactivation potentiation (4, 10, 26). Based on previous literature, one proposed mechanism for improvements in power performance following dynamic stretching when compared to static stretching is due to differences in the viscoelastic properties (i.e. range of motion) of the muscle-tendon unit (21, 31). Observing the change in range of motion and power resulting from an acute dynamic stretching protocol prior to maximal vertical jump can provide possible explanations for the neuromuscular adaptations that occur with maximal muscular power exercise movements. To our knowledge, no study has examined the effects of an acute bout of dynamic or static stretching on range of motion and jump height in recreationally active college age males. By identifying the most beneficial type of stretching for a given exercise bout, coaches and trainers can utilize techniques to enhance range of motion as it relates to strength and power performance. Therefore, the purpose of this investigation was to determine the effect of single set dynamic compared to static stretching and control group on vertical jump height and hip and knee range of motion in a sample of college age recreationally active males. It was hypothesized that 1) dynamic stretching prior to a vertical jump will increase jump height compared to static or no stretch condition; and 2) Dynamic stretching and static stretching will increase range of motion compared to a no stretch condition.

METHODS

Participants

Forty-two healthy, physically active males (aged 18-24) voluntarily participated in this investigation. The subjects were college students recruited from the University of Pittsburgh Department of Health and Physical Activity physical education classes, and recreational fitness participants throughout the semester. The subject's familiarity and skill level with jumping and stretching varied by their physical activity participation, which consisted of recreational sports such as basketball, racquetball, volleyball, soccer, weight training, and distance running. Subject characteristics are presented in Table 1.

Table 1. Descriptive Characteristics of Subjects.

Variable	Control (C)	Static Stretch (S)	Dynamic Stretch (D)
N	15	14	13
Age (y)	21 ± 2	21 ± 2	20 ± 2
Weight (kg)	83.30 ± 11.82	81.57 ± 13.73	73.90 ± 8.14
Height (cm)	179.11 ± 6.86	176.98 ± 7.89	176.62 ± 9.38
Body Fat (%)	12.43 ± 4.73	13.49 ± 4.14	9.36 ± 4.07*

Data are mean ± SD.
*$p < 0.05$

To be eligible to participate, subjects were: 1) healthy; 2) physically active defined as engaging in strength training (machine or free weights) or aerobic training a minimum of two but not greater than four days per week for a minimum of one year; and; 3) willing to participate in all testing sessions. Exclusion criteria for the study were: 1) responding yes to one or more questions on the Physical Activity Readiness Questionnaire; 2) presence of serious or unstable medical illness within the last 12 months; 3) any clinical, musculoskeletal or metabolic contraindications to exercise; 4) being treated for any serious psychological disorder or having treatment, hospitalization, and emergency room care within the previous six months; 5) currently taking performance enhancing substances 6) currently engaging in a plyometric and/or sprint training program, or flexibility training program performed longer than two minutes and/or greater than 3 days/week; and 7) unwilling to perform or participate in the prescribed program or testing sessions. All subjects were informed of the procedures, purposes and experimental risks of the study, and informed consent was obtained prior to the study. The protocol for this study was approved by the Institutional Review Board for the University of Pittsburgh.

Protocols

Experimental Approach to the Problem

The current study was a repeated measures design to investigate the effects of 20 seconds of static and dynamic stretching on vertical jump height and flexibility in a sample of college age recreational athletic males. The subjects participated in two sessions. The second session occurred within two weeks of the first session, and the time of sessions was within one hour of each other to prevent changes in power due to diurnal variations. During the first session subjects' height, body weight, and body composition were measured for each subject followed by the pretests. Anthropometrics were measured because studies have found them to be good predictors of power output in university male sample populations (7, 14, 27). The pretests were performed in the following order: sit and reach, hip and knee flexion range of motion with goniometer, and jump and reach test. Following pretesting, dynamic and static stretching protocols were performed, while subjects were not informed by the investigators of the expected effects of stretching on vertical jump or range of motion. Following the first session, the subjects were randomly assigned to one of three groups: 1) Control (C)- General warm-up with no stretch; 2) General warm-up and 20 second static stretch (SS); and 3) General warm-up and 20 second dynamic stretch (DS). During the second session, subjects performed a general warm-up followed by one of the three treatment groups followed by the posttests in the following order: sit and reach, hip and knee flexion range of motion, and vertical jump. The posttests were measured within 5 minutes of the pretests to prevent degradation of the acute effects of the stretching protocol.

The sit and reach test and hip and knee flexion range of motion with goniometer were measured in this study because they are reliable field and laboratory tests for changes in range of motion, and several studies have shown significant changes in range of motion with negative effects on jump performance following static stretching protocols (3, 6). In addition, the jump and reach test using a commercial Vertec device has demonstrated reliability using a male college age population (r = 0.906) (17). The average value of three trials was used for all dependent measures because it would better reflect daily performance of their recreational activities instead of performance at that given moment.

Procedures

Subjects reported individually for testing on two separate days within a 14-day period. The testing was performed at the same time on both days to prevent performance changes due to diurnal variations. On Day 1, subjects were provided an overview of the study and then completed the medical history forms to determine eligibility. Potential risks and benefits and underlying rationale for the investigation was explained to all subjects where upon written consent to participate were obtained. Next, pre-testing assessments (sit and reach, goniometry, and vertical jump), anthropometrics, and a practice orientation session were conducted. Following the orientation session, subjects were randomly assigned to one of the three treatment groups. On Day 2, a general warm-up and stretching treatment program was conducted followed by post-testing.

Hamstring, lower back, and gluteus maximus range of motion was measured using a sit and reach-testing device (Novel Flex Tester, Creative Health Products Inc., Plymouth, MI). Following a demonstration, three to five practice trials were allowed for investigators to provide feedback on technique. Subjects were asked to remove shoes, sit with legs extended and feet flat against the inside of the box. Subjects were instructed to cross one hand over the other and flex forward at the trunk while sliding hands across the top of the box (parallel to the thighs) until they could no longer extend the stretch. The final position was held for 2 seconds. Using three trials, the subject’s mean value was recorded as the flexibility score. A trial was discarded if the subject’s knees rose off the floor, or if they reached excessively with their hands, or rounded their upper or lower back (9). To examine the reliability of dependent measures, the type A Intra-class Correlation Coefficient using an absolute agreement definition was used to measure consistency of pretest and posttest measures in the control group. The control group was chosen because no "real" pretest to posttest change was expected. The sit and reach measurement had an average ICC of R = 0.991.

Following the sit and reach test, hamstring, gluteus maximus, and quadriceps range of motion were measured using a plastic goniometer (Baseline, Creative Health Products Inc., Plymouth, MI). The measurements were taken in degrees of motion on their dominant leg, which was defined as their kicking leg. All measurements were taken by the same examiner. A second examiner was used to passively move the subject's leg and to ensure stabilization of the pelvis during the tests to ensure reliability (22). The subjects were asked to lie supine on the medical exam table and were given verbal instruction to stay relaxed while the tester stretched their leg to their maximum range of motion without pain. Hamstring and quadriceps range of motion was measured using a passive straight leg raise and a passive knee flexion test and protocol established by Norkin and White (22). Markers were placed on the greater trochanter, lateral femoral epicondyle, and lateral malleolus as reference points to align the goniometer in the same position for each measurement (18). The end range of motion for both tests occurred when resistance was felt by the tester. The tester read the goniometer in degrees. Using the average of three trials for their dominant leg, a subject's mean value was recorded to the nearest degree. Goniometer measurements for the hip and knee had an average ICC of R = 0.691 and 0.781, respectively.

Subjects performed three consecutive countermovement jumps with arm swings for maximal height using a Vertec jumping apparatus (Power Systems, Knoxville, TN) and the countermovement jump technique described by Adams (1). Subjects stood with their dominant arm closest to the standard and extended upward as far as possible to measure reach height (15). The highest vane moved represented the height of the jump. Investigators measured the number of centimeters (to the nearest 0.5 inches) to the highest vane moved. The Vertec was zeroed prior to the beginning of the test based on the subjects reach height; therefore the highest vane touched during the test represented the recorded jump height. Subjects were allowed three to five practice jumps prior to the pre-test jumps. The subjects were given verbal instructions to jump as high as possible on the vertical jump device while touching or swatting the measurement vane at the highest point of the jump. A trial was discarded if the subject shuffled their feet, performed a knee dip beyond 90 degrees, took more than one arm swing, or performed more than one countermovement. The average of three jump heights was recorded as the score. Vertical jump had an average ICC of R = 0.966.

All treatment groups (control, static, and dynamic) began with a five minute warm-up on an upright cycle (Cybex, Medway, MA) at a speed of 70 revolutions per minute and a pedal resistance that elevated heart rate to 110 $\pm$ 5 beats per minute. This was done to raise muscle temperature prior to their treatment program. Following the warm-up period, subjects immediately began their stretching treatment program that lasted approximately 12 minutes. The control group remained seated for the 12 minutes. The stretching protocols consisted of 12 stretches for the lower and upper body, each performed for 20 seconds. A 10 second rest separated the right and left leg protocol. Timing of stretches and rest periods was monitored by the investigator. Each subject performed stretches independently, and were given verbal instructions "to stretch until they felt slight discomfort, but not to stretch to a range of motion that produces pain". Stretches addressed the major muscle groups required for vertical jumping such as the pectoralis major, deltoids, latissimus dorsi, hamstrings, quadriceps, gluteus maximus, hip flexors, and calves, and are recommended stretches to be used within a warm-up (2). Tables 2 and 3 provide a description of the static and dynamic stretching programs.

For the static stretching protocols, subjects stretched the specified muscle of the right leg and held it for 20 seconds. Following 10 seconds of rest, the same stretch was repeated for the left leg. For dynamic stretching protocols, the procedure was performed according to Yamaguchi and Ishii (31), however, total stretch time for each leg was for 20 seconds (approximately 10 repetitions). The procedure was performed on the right leg first followed by the left leg with a rest period of 10 seconds.

Anthropometrics
Height in centimeters (cm) and weight in kilograms (kg) were measured with a standard medical beam stadiometer scale (Sensormedics, Yorba Linda, CA). Subjects were instructed not to exercise the day of testing and to abstain from eating three hours prior to the test (9). Measures were taken on the right side of the body at the chest, abdomen, and thigh sites using a Lange skinfold caliper and standardized procedures established by American College of Sports Medicine (ACSM) (9). The same investigator performed all measures to maintain inter-test and intra-test reliability. Percent body fat was determined by skin fold method using the equations by Jackson and Pollock (13).

Statistical Analysis
Data analysis was performed using SPSS 15.0 for Windows statistical software. A sample size of forty-two subjects (15 control, 14 SS, and 13 DS) was used with a statistical power ranging from 0.227- 0.759 to detect a 10% change in mean jump height and range of motion. A repeated measures analysis of variance was conducted to determine between and within differences in stretch groups. A Bonferroni *post-hoc* analysis was performed for significance for the stretch groups using an adjusted alpha of $p < 0.17$. Descriptive data for subject characteristics and experimental variables were expressed as means and standard deviations. One-way analysis of variance was conducted to detect group differences in anthropometrics and all dependent variables measured during pre-assessments. Statistical significance was set at $\alpha = 0.05$.

RESULTS

Subject characteristics are presented in Table 1. Results of the analysis of variance on anthropometrics and all dependent variables at pre-test showed no significant differences between treatment groups with the exception of body fat. The dynamic group had a significantly lower body fat compared to the static or control groups. Since a non-significant correlation was determined between percent body fat and jump height (r = - 0.300), percent body fat was not used as a covariate in the main analysis.

Table 2. Dependent Variables.

Variable	Test	C	SS	DS
Jump height	Pre	61.68 ± 7.91	59.57 ± 7.41	63.39 ± 8.58
(cm)	Post	61.57 ± 8.10	60.63 ± 7.07	64.66 ± 9.85
ROM Hip	Pre	66.67 ± 8.62	66.24 ± 8.08	66.16 ± 9.58
(degrees)	Post	68.00 ± 6.43	69.39 ± 5.47	70.14 ± 9.10
ROM Knee	Pre	131.99 ± 6.74	132.43 ± 5.09	135.05 ± 6.46
(degrees)	Post	133.09 ± 4.95	134.66 ± 5.88*	135.31 ± 5.39
Sit and Reach †	Pre	24.61 ± 10.51	23.96 ± 9.02	23.64 ± 11.11
(cm)	Post	24.73 ± 10.68	26.28 ± 8.69*	25.62 ± 11.33*

Data are mean ± SD. * Significant change from pre to post; $p < 0.017$. † Significant time x treatment interaction; $p < 0.05$. C = Control, SS = Static Stretch, DS = Dynamic Stretch

Pre-and post-test means (based on the average of three trials) for each dependent variable based on stretch condition are presented in Table 2. Non-significant changes from pre- to post-test occurred in vertical jump height for both the SS and DS groups (*p > .017), with no significant differences observed between treatment groups. The SS and DS groups increased mean vertical jump height by 1.8% and 2%, respectively. Therefore, trends were in the expected direction for the dynamic stretch group. Of the thirteen subjects in the dynamic stretching group, nine subjects increased vertical jump height, and four subjects decreased vertical jump height

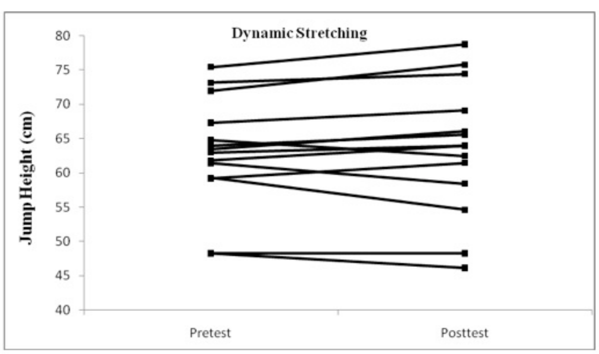

Figure 1. Changes in mean jump height for all subjects in dynamic stretching group.

(Figure 1). Of the fourteen subjects in the static stretching group, nine subjects increased vertical jump height, and five subjects decreased vertical jump height (Figure 2). Furthermore, the effect size for the interaction (eta squared = 0.105) would be described as medium (5). However, statistical power for the interaction was 0.425.

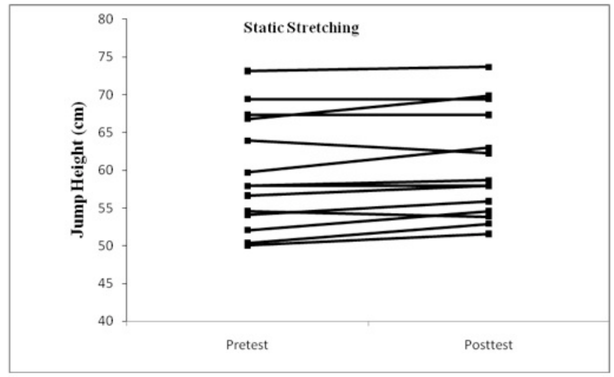

Figure 2. Changes in mean jump height for all subjects in static stretching group.

Non-significant changes from pre- to post-test were observed in hip range of motion for the DS and SS group (*p >.017), with no significant differences observed between treatment groups. Significant changes from pre- to post-test were observed in knee range of motion for the SS group only (*p =.010), with no significant differences observed between treatment groups. The SS and DS groups increased hip range of motion by 4.7% and 6%, and the SS and DS groups increased knee range of motion by 1.7% and 0.02%, respectively. Results showed a significant time and time x treatment interaction (*p < 0.05) for the sit and reach measurement. The SS group (p = 0.004) and DS group (p = 0.011) significantly increased sit and reach distance when compared to the control group (p > 0.017). The SS and DS groups increased sit and reach measurement by 9.7% and 8.4%. Figure 4 shows changes in mean sit and reach from pretest to posttest by treatment group. The effect size for the interaction (eta squared = 0.031) would be described as small (5). Statistical power for the interaction for knee and hip range of motion and sit and reach was 0.227, 0.137, and 0.759, respectively.

DISCUSSION

The purpose of this investigation was to determine the effect of 20 seconds of single set dynamic and static stretching on vertical jump height and range of motion in a sample of college age recreationally active males. Results revealed non-significant improvements in jump height following a single set of static (SS) stretching exercises for duration of 20 seconds. These results are consistent with the findings of McMillian et al. (21) that showed non-significant increases in jump height following single set of static stretching exercises. In contrast to previous studies that have shown significant increases in power activities following DS in comparison to SS, our results showed no significant differences between DS and SS for jump height (21, 31). The discrepancy between the results of previous studies and those of the present study may be attributed to several factors including protocol selection, measurement instrumentation, and skill level of the subjects.

The first factor may be related to the duration of the stretching protocol. The current study used a single set of 20 seconds, whereas, previous studies used single and multiple sets of greater than 20 seconds (16, 21, 24, 31). It has been shown that time under stretch may cause peak torque (defined as the highest force that will rotate an object about an axis) reductions following static stretching (28). Siatras et al. (28) recently determined that a static stretch of the quadriceps muscle for 30 and 60 seconds reduced peak torque compared to a no stretch condition. Whereas a static stretch of 10 and 20 seconds did not reduce peak torque compared to a no stretch condition. Such stretch induced deficits have been attributed to an increase in the muscle tendon unit length, stretch tolerance, and a decrease in muscle stiffness (19, 20, 28). Therefore, changes to a muscle's stiffness relate to a viscoelastic response to a stretch, and may be considered time dependent (11, 12). While static stretching may decrease muscle stiffness, it also appears to contribute to a decreased ability to produce force. One proposed mechanism for decreased force production following static stretching suggests that a more compliant muscle-tendon unit will produce an unfavorable change in the force-length curve (16, 30). It is possible that the short duration of force applied with the current static stretching protocol may not have been of sufficient duration, resulting in a minimal change in muscle length. The increased range of motion shown following both stretching protocols in this study was less than previous studies showing decrements following static stretching (3, 6, 16). In addition, the time lag between the stretch protocols and measurement of jump height was not adequately controlled, which may have influenced range of motion and consequent force decrements due to the possibility that range of motion improvements may have been lost during transition times greater than six minutes (29).

A second factor may be related to the instrument used for measurement of jump height. Several studies directly measured force using a force plate or contact mat. However, the present study measured jump height with a Vertec jumping device. A Vertec jumping device used for a jump and reach test is considered a reliable instrument (r = 0.93 to 0.99) for male adult populations (23). However, there is considerable subject and tester error associated with the device (17). Several factors influence the jump height measurement such as the ability of the subject to contact the vanes at the peak of the jump, which is also influenced by the shoulder range of motion of the subject. Failure of the subject to contact the vanes at the peak of the jump can result in underestimation of the jump height. Many of the subjects that participated in the current study were inexperienced at jumping and shoulder flexibility was not measured prior to the study. In addition, there may have been error in the ability of the examiner to accurately and efficiently count the vanes following the jump.

In the present study, dynamic stretch slightly improved post-tests of vertical jump height. In previous studies, muscular peak power performance following dynamic stretching increases compared to no stretching or static stretching routines when major lower body muscle groups were dynamically stretched for 1-3 sets of 30 seconds with total stretching duration lasting between five and 10 minutes (8, 21, 31). Yamaguchi et al. (31) reported dynamic stretching of hip and knee flexors and extensors for five minutes (5 exercises of 1 x 30 seconds) resulting in greater leg extension power when compared to static stretching and non-stretching. McMillian et al. (21) reported that dynamic stretching of major muscle groups for eight minutes (8 exercises of 1 x 20-30 seconds) demonstrated higher 5-step jump performance compared to a static stretch and no stretch condition. The mechanisms associated with improvements in jump height following dynamic stretching is an increase in muscle spindle activity due to repeated stretch (i.e. dynamic stretch) causing an agonist muscle to increase length and contract with greater force (12). Stretching progression from short to full range movements allows for greater recruitment and faster contraction of type II muscle fibers at the time of the event (10, 26). In the present study, reasons for lack of significance in jump height between dynamic and static stretching groups were unclear. Subjects selected for the study were not permitted to have trained with plyometrics (defined as exercise outside their normal recreational exercise) or stretching exercise within the previous six months so many were considered novice level with regards to previous stretching and jumping experience. Therefore, the influence of the stretch on the compliance of the muscle tendon unit may not have been used effectively due to the lack of skill with jumping of many of the subjects. The current study was the first to measure range of motion changes following dynamic stretching. Range of motion measurements can provide information in regards to viscoelastic changes in the muscle tendon unit following stretching (11). The range of motion increased significantly in the dynamic stretching group from pre to post, but it is possible that the increase in range of motion was not sufficient to significantly improve jump height. Future studies need to examine range of motion changes following dynamic stretching to determine if a maximal range of motion exists for improvements in vertical jump. Other explanations include subjects being post-tested two weeks following their pre-test may have experienced a learning effect and low statistical power due to small sample size.

Results of the present study suggest that incorporating single set dynamic or static stretching of muscle groups of the lower and upper body for 20 seconds into a warm-up can slightly improve vertical jump performance in recreationally active males. However, the results of the study identify several concerns that the practitioner should be aware of when incorporating stretching into a pre-exercise warm-up, especially when increased power performance is the goal. The practitioner needs to consider the impact of the time between the stretching protocol and the event, and the desired effect on the muscle-tendon unit (i.e. change in range of motion). The results of this study suggest that a dynamic and static stretch duration of 20 seconds can significantly improve range of motion with slight improvements in jump height in male recreational athletes when the activity is performed within 5 minutes after the stretch. However, from the present results it is difficult to advise the implementation of static stretching for 20 seconds prior to jumping activities without further examining the issue of stretch duration and the impact of the rest period between the stretch and jump activity on range of motion. Future research is needed to investigate the impact of duration of dynamic and static stretching of single set stretch routines on power performance and range of motion in recreational and competitive male and female athletic sample populations. This research will provide physical educators, athletic trainers, physical therapists, exercise physiologists, and strength and conditioning specialists' valuable information in selecting appropriate stretching modalities within a warm-up to enhance performance. In addition, it will provide the recreational fitness participant with safe and beneficial stretching programs to improve range of motion and improve performance within their sport activities.

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