Acute Effects of Dynamic Stretching, Static Stretching, and Light Aerobic Activity on Muscular Performance in Women

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Abstract

Curry, BS, Chengkalath, D, Crouch, GJ, Romance, M, and Manns, PJ. Acute effects of dynamic stretching, static stretching and light aerobic activity on muscular performance in women. *J Strength Cond Res* 23(6): 1811–1819, 2009—The purpose of this study was to compare three warm-up protocols—static stretching, dynamic stretching, and light aerobic activity—on selected measures of range of motion and power in untrained females and to investigate the sustained effects at 5 and 30 minutes after warm-up. A total of 24 healthy females (ages 23–29 years) attended one familiarization session and three test sessions on nonconsecutive days within 2 weeks. A within-subject design protocol with the testing investigators blinded to the subjects' warm-up was followed. Each session started with 5 minutes of light aerobic cycling followed by pretest baseline measures. Another 5 minutes of light aerobic cycling was completed and followed by one of the three randomly selected warm-up interventions (static stretching, dynamic stretching, or light aerobic activity). The following posttest outcome measures were collected 5 and 30 minutes following the intervention: modified Thomas test, countermovement jump, and isometric time to peak force knee extension measured by dynamometer. Analysis of the data revealed significant time effects on range of motion and countermovement jump changes. No significant differences ($p > 0.05$) were found between the warm-up conditions on any of the variables. The variation in responses to warm-up conditions emphasizes the unique nature of individual reactions to different warm-ups; however, there was a tendency for warm-ups with an active component to have beneficial effects. The data suggests dynamic stretching has greater applicability to enhance performance on power outcomes compared to static stretching.

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Introduction

A warm-up is a generally accepted and recommended method of preparing the body for strenuous activity. The role of a warm-up is to prime the body's cardiovascular, muscular and neural systems to meet the demands of a specific activity (22). Stretching exercises have traditionally formed an integral part of the warm-up (27) and it has been suggested that static stretching before activity promotes improvements in performance (24), and increases range of motion (ROM) (2). However, studies are now challenging the value of the conventional static stretching warm-up and its ability to improve physical performance (4,11,15,30). In the past, a direct positive relationship of using static stretching as a precursor to muscular performance had been assumed, despite a lack of evidence showing a clear connection (7).

Recent evidence reveals that repetitive or sustained bouts of static stretching may negatively impact acute power production and thus muscular performance (9,28,30). Acute static stretching may inhibit performance by reducing force production, balance, reaction time, sprint times, and power output (4,11,15,30). Consequently, some investigators have proposed that an alternative to static stretching be performed in a warm-up prior to activities requiring maximal power production (28,29).

In contrast to static stretching, dynamic stretching incorporates whole body movements (16) and involves actively and rhythmically contracting a muscle group through part of its functional ROM (28). This acts to elevate core body temperature, enhance motor unit excitability, improve kinaesthetic awareness, and maximize active ROMs (10). Dynamic stretching may include skipping, hopping, jumping, and rotation motions of the extremities, such as arm and leg swings (10,11,22). A proposed physiological rationale for replacing static stretching with dynamic stretching in a preperformance warm-up lies in mechanical (viscoelastic) and neuromuscular tissues changes (8). The acute effect of static stretching is an increase in muscle compliance (7), which increases the time to, and decreases the force of, myofibril contraction during muscular performance (9). Static stretching affects neural output by depressing reflex activity, further reducing muscle stiffness, muscle activation, and maximal force production (7,9). It is thought that dynamic stretching may enhance muscular performance by preserving muscle-tendon unit (MTU) stiffness (28).

To date, few studies have evaluated the effects of dynamic stretching on muscular performance. There are only a few comparisons between static stretching and dynamic stretching because the majority of studies found studying static stretching were compared to a control group only (4,15,21). However, two studies show that acutely, dynamic stretching enhances muscular performance of lower extremity power, when compared to a static stretching protocol (10,28). These studies investigated dynamic stretching in children and college age males. To our knowledge, only one other study has compared the effects of dynamic forms of stretching to static stretching protocols on muscular performance in women (26).

The purpose of this study was to compare three warm-up protocols: static stretching, dynamic stretching, and light aerobic activity on the performance of selected measures of ROM and power in untrained females and to investigate the enduring effects at 5 and 30 minutes after warm-up.

Methods

Experimental Approach to the Problem

A within-subject design protocol with the testing investigators blinded to the subjects' warm-up was followed. The order in which the subjects completed the protocols was randomized and counterbalanced. Repeated measures were used to compare the three warm-up protocols (static stretching, dynamic stretching, and light aerobic activity) on the affected muscles' capacity for maximum power production. The subjects were asked to avoid strength training or strenuous activities within 24 hours of the testing sessions. All session were separated by a minimum of 48 hours. Subjects were encouraged to continue their standard exercise practices during the testing period (e.g., activity, diet). Each subject maintained an activity log for the duration of their testing to help identify possible external confounding variables.

Subjects

Twenty-four recreationally active yet untrained (i.e., not currently training in jump/plyometric activities), healthy college age females (age, 26 ± 3 years; body mass, 61.5 ± 8.1 kg; height, 165.1 ± 8.8 cm) were recruited from the University of Alberta campus (Edmonton, Canada) and served as subjects for this study. Sample size required was estimated at 20 from the effect size of isokinetic torque measurements at 60° per second by the quadriceps following a static stretching protocol (power = 0.80 and alpha = 0.05) (18). University of Alberta Health Research Ethics Board approval was obtained; subjects provided written informed consent and answered the Physical Activity Readiness Questionnaire (20) prior to participation. Subjects were screened for and excluded if they presented with any history of ankle fracture, third-degree sprains or anterior cruciate ligament ruptures; lower extremity surgery or fractures in the past 3 years; current back symptoms or leg symptoms originating from the back; or pain in the lower extremity that inhibited normal level of activity.

Dependent Variables

A modified Thomas test from Harvey (13) was used to determine quadriceps flexibility. The subject was seated against the edge of a plinth and rolled onto her back while hugging both knees to her chest. While maintaining the left limb in the fully flexed position, the right limb was lowered toward the floor. The right knee was maximally flexed to the point of subject's maximum tolerance using gentle overpressure while maintaining neutral hips and pelvis. Knee flexion angle was measured by goniometry to determine passive quadriceps length. Test retest reliability was 0.91–0.94 for the Thomas test by Harvey (13).

A countermovement jump (CMJ) test was used as a measure of lower limb explosive power production. To complete this task, subjects stood 15 cm away from and perpendicular to the wall (17). Ink was placed on the tip of their middle finger. Subjects were allowed to step back with either foot while keeping the other foot in place. From this one-step preparatory position, the subjects were asked to step forward with the back leg and jump off of both feet. The subjects were instructed to make a mark on the wall at the highest point of their jump using their inked finger. Subjects completed three jumps in succession. The CMJ score was calculated by subtracting the standing reach height (m1) obtained during the familiarization session, from the highest jump height (m2) obtained. Test retest reliability was 0.980 for the countermovement jump test by Unick (26).

A KinCom isokinetic dynamometer (KinCom III, Chattecx, Chattanooga, TN, USA) was used to measure the time to peak force (TPF) of an isometric peak torque at 90° of flexion in the dominant knee extensors. All subjects used the right leg. The TPF was measured during the isometric muscle contraction of the knee extensors. Subjects completed two trials of TPF for each pre- and postintervention measures. Prior to testing, the KinCom was calibrated for force and velocity according to manufacturer's recommendations. During testing, waist and thigh straps were used to stabilize the subjects tested lower extremity. The dynamometer's rotational axis was aligned with the subject's lateral femoral epicondyle and the resistance pad positioned just proximal to the lateral malleolus of the ankle joint. The sequence of these tests remained consistent in order to keep any effects of the tests equal across all subjects and all sessions. Test-retest reliability was 0.95 for an isometric contraction of the leg on a KinCom machine by Brandenburg (6).

Familiarization Session

Each subject attended four sessions on nonconsecutive days; one familiarization session followed by three testing sessions.

The familiarization session was designed to orient subjects to the stretching and treatment protocols. In this session, subjects were instructed in and performed the warm-up protocols (static stretching, dynamic stretching, and light aerobic activity) and were also instructed on the use and the administration of the 15-point Borg Scale of Perceived Exertion (5). Subjects further performed a trial on the cycle ergometer (Monark 818E, Monark, Sweden) to identify the appropriate target intensity (a rate of perceived exertion [RPE] of 10–11 on the Borg 15-point scale) for the light aerobic activity (5). Subjects were measured for standing vertical reach height (m). This task required each subject to stand 15 cm away from the wall while reaching up and making a mark with an inked middle finger (m1). Subjects performed CMJ tests, ROM measures, and KinCom dynamometer testing to familiarize themselves with these procedures.

Testing Sessions

All subjects were randomized for intervention order prior to the three testing sessions to limit the confounding effect of test learning on outcome. At each of the testing sessions, a 5-minute light aerobic cycling portion (RPE 10–11) was followed by pretesting of baseline outcome measures: a flexibility measure for quadriceps, a CMJ as a multiple joint explosive movement measure, and TPF as measured by the KinCom dynamometer. Following the pretest measures, each subject completed another 5-minute light aerobic cycling portion (RPE 10–11) with an additional 10 minutes of light aerobic activity, static stretching, or dynamic stretching. Testing sessions concluded with postintervention measures at 5 and 30 minutes after warm-up completion (Figure 1). Subjects sat quietly between the two posttests. Testers responsible for evaluating baseline and postintervention outcome measures were blinded to the intervention type (static stretching, dynamic stretching, or light aerobic activity) and each subject was tested by the same tester pairing to maintain blinding and consistency of test administration.

Light Aerobic Activity Protocol

The light aerobic activity protocol consisted only of light aerobic cycling. Subjects completed 5 minutes of light aerobic activity on a stationary cycle ergometer consistent with the other protocols, as well as an additional 10 minutes of cycling. Cycling intensity was measured by the subject's RPE according to the 15-point Borg Scale (5). The subjects cycled at a constant 70 rpm (21) with load adjusted to maintain an RPE of 10–11. Subjects were asked after the first minute and every 2 minutes thereafter to report their current RPE level. The test administrator adjusted the cycling load to sustain the RPE as described above.

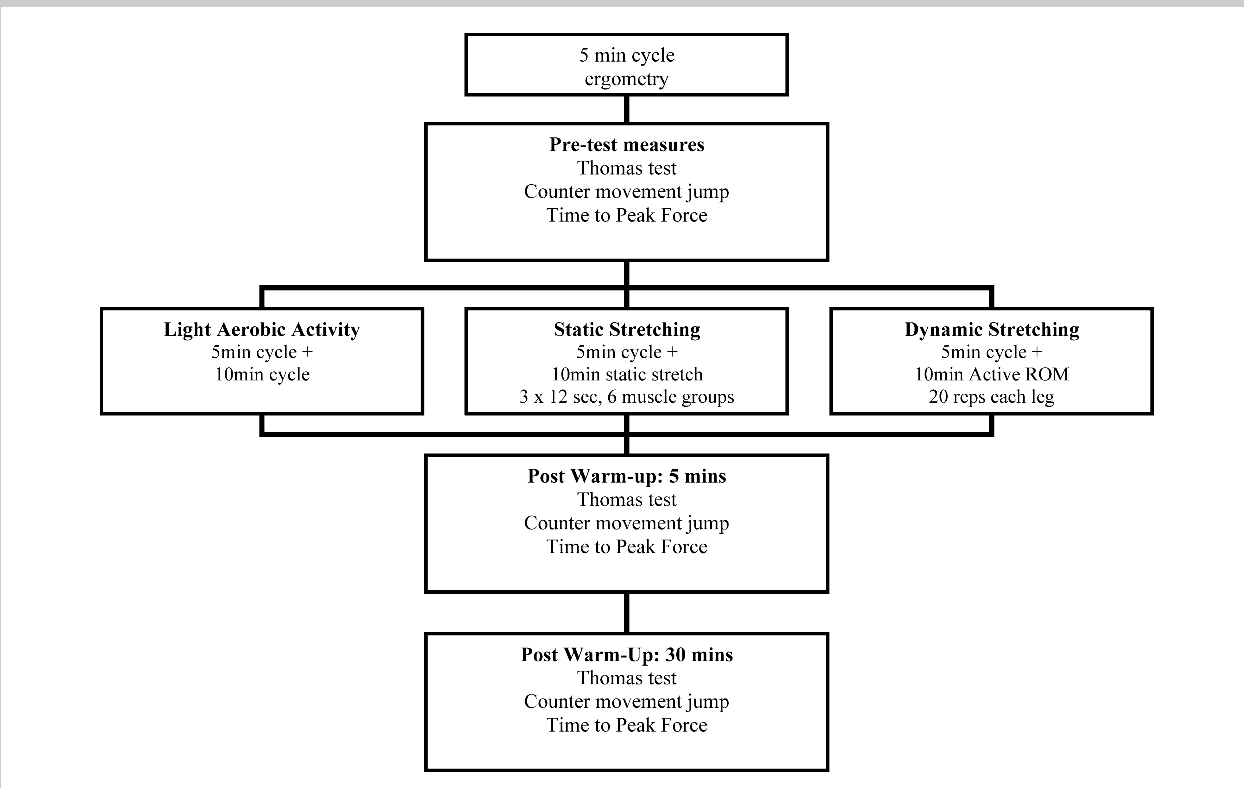

Figure 1. Summary of research design.

TABLE 1. Static stretching protocol.

Step	Description
1. Gluteal stretch	In one-leg-long sitting position, with the other leg bent, cross the ankle of the bent leg over the knee of the straight leg, drawing the knee of bent side to the contralateral shoulder.
2. Modified hurdler's stretch	In sitting with one leg straight forward, bend the opposite leg, resting ipsilateral foot on inside of the straight leg and reach forward.
3. Hip flexor stretch	In stride kneel position, keeping torso erect and pelvis neutral, lean forward from the hips.
4. Quadriceps stretch	From a standing position, keeping torso erect, bend one knee and bring heel up toward buttock; hold using ipsilateral hand.
5. Gastrocnemius stretch	In stride stand position, with back leg straight and forward leg slightly bent, lean forward with both hands against a wall.
6. Soleus stretch	In the same position as gastrocnemius stretch, however, keep both knees slightly bent.

Static Stretching Protocol

Subjects completed the 5-minute light aerobic activity warm-up at 10–11 RPE as in each of the other warm-up conditions. This was followed by a 10-minute stretching protocol for the following six muscle groups of the lower extremity: 1) gluteals, 2) hamstrings, 3) quadriceps, 4) hip flexors, 5) gastrocnemius, and 6) soleus. For consistency, all static stretches were performed in a preset order from the hip down.

TABLE 2. Dynamic stretching protocol.

Step	Description
1. Side leg swing	With body facing the wall, swing leg out to the side (abduct) and then swing leg back across midline (adduct) as far as possible with forward facing, neutral pelvis.
2. Forward leg swing	With body perpendicular to the wall, swing leg closest to the wall forward, keeping knee extended. On the backward return swing, allow thigh to extend as far back as possible at the hip joint.
3. Lateral side step (sideways moving jumping jacks)	Skip sideways in a jumping jack motion, bringing feet together, and then moving them apart. Arms swing out in concert with the legs.
4. Bilateral hops	Begin from a standing starting position and hop forward. On the first set, aim to move the feet as quickly as possible. On the second set, attempt to hop as high as possible.
5. High knees	Start by driving the right knee up while maintaining full extension of the left leg and foot. At the same time, drive left elbow forward and up, coming to approximately parallel position with the ground. The right arm is extended backwards at approximately 45°. As the right leg is returned to starting position, the left leg repeats same movements described.
6. Leg kick backs	From the same starting position as in the high knees, move forward and alternate kicking heel up to buttock. Minimize hip flexion and try to maintain vertical thighs.
7. Running cycles (ABCs)	For this exercise, a combination of high knees and kick backs in sequence is used. This activity mimics the complete running cycle.
8. Straight leg skipping	From a standing position with knees extended, hop forward on one leg. On ground contact, switch legs and hop forward with opposite leg.
9. Walking lunges	From a standing position, step out with one leg. Flex both knees as pelvis drops. When forward thigh reaches horizontal, bring back leg forward, step through and repeat from standing.

All stretches were performed unilaterally, alternating legs between each stretch so that both lower extremities were stretched. Each stretch was held for 12 seconds and repeated 3 times. Subjects were instructed to stretch to the point of maximum tolerance. Each muscle received 12 seconds of rest while the opposite limb was stretched. The protocol is detailed in Table 1.

Dynamic Stretching Protocol

Subjects completed the 5-minute light aerobic activity warm up as utilized in the other protocols prior to completing the dynamic stretching protocol. Dynamic stretching consisted of 10 minutes of controlled movement through the active ROM for each of the six lower-extremity muscle groups. Modifying the active dynamic stretching protocol used by Fletcher and Jones (11), subjects completed the nine movements described below for two sets of 10 repetitions on each leg reciprocally, with a walk back recovery between sets. The protocol is detailed in Table 2.

Statistical Analyses

The peak values of ROM, CMJ, and TPF, measures were used from the trials in each pretest, 5-minute, and 30-minute posttesting sessions. The effects of different protocols on the dependent variables were determined using two-way repeated measures analysis of variance. Any significant F ratios were followed by Bonferroni's post-hoc analysis. Statistical significance was set at an alpha level of $p \leq 0.05$. Statistical analysis was carried out using SPSS 12.0.

Results

A total of 23 recreationally active college aged females voluntarily completed the study. One subject dropped out of the study on the first testing day due to knee pain. Table 3 displays the mean ROM, CMJ, and TPF for the subjects. There were no statistical differences among the three warm-up conditions for any of the variables.

Range of Motion

There was no significant interaction effect between the three interventions across time ($F[4, 88] = 0.60, p = 0.66$). Evidence of physiological changes from the warm-up conditions was demonstrated by a significant linear main effect of time on ROM ($F[2, 44] = 26.61$, $p < 0.0001$). All three warm-up conditions improved similarly in ROM from pretest to 5 minutes after and then declined from 5 minutes to 30 minutes after intervention testing ($p < 0.0001$; Table 3).

Power (CMJ and TPF)

There was a significant quadratic interaction effect of time and warm-up conditions for the changes in CMJ height ($F[4, 88] = 6.28$, $p < 0.0001$; power = 99%). In addition, the changes over time were significant ($F[2, 44] = 78.57$, $p < 0.0001$; Figure 2). Post-hoc analysis of the 5 minutes to 30 minutes after ($p < 0.0001$) and pretest to 30 minutes after intervention test ($p < 0.0001$) both showed a significant decrease in performance in all warm-up conditions.

Table 3. Measurements for the dynamic stretching, static stretching, and light aerobic activity protocols.*

	Dynamic stretching			Static stretching			Light aerobic activity		
	Pretest	5 minutes posttest	30 minutes posttest	Pretest	5 minutes posttest	30 minutes posttest	Pretest	5 minutes posttest	30 minutes posttest
Countermovement jump (cm)	41.5 (6.5)	42.3 (6.1)	39.8 (6.1)†‡	42.0 (6.7)	40.8 (6.4)	39.8 (6.5)†‡	42.2 (6.5)	40.9 (7.6)	40.5 (5.9)†‡
Time to peak force (seconds)	1.1 (0.6)	0.8 (0.4)	0.8 (0.5)	0.9 (0.5)	0.9 (0.5)	1.0 (0.5)	1.0 (0.4)	0.9 (0.5)	1.0 (0.5)
Range of motion (degrees)	123.0 (19.7)	130.9 (14.4)§	126.4 (17.3)	121.6 (21.2)	128.1 (14.5)§	125.5 (17.6)	124.6 (18.1)	129.5 (16.7)§	127.6 (17.7)

*Data are mean ± *SD*. Significant interactive effect of time and condition were seen for countermovement jump.
†Significant main effect of time from pretest to 30 minutes.
‡Significant main effect of time from 5 minutes to 30 minutes.
§Significant main effect of time from pretest to 5 minutes.

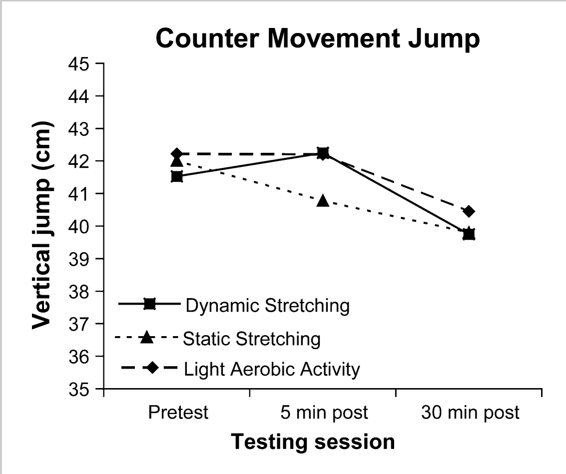

Figure 2. Comparison of changes, from pretest to 5 minutes and 30 minutes after test, in CMJ (cm) for dynamic stretching, static stretching, and light aerobic activity conditions.

There was no significant interaction effect of time and warm-up conditions for the changes in TPF (F [4, 88] = 1.54, p = 0.19; power = 55%). The changes of the three warm-up conditions suggested a trend over time (F [2, 44] = 2.86, p = 0.061; power = 46%; Figure 3). The TPF improved by 27% in the dynamic stretching warm-up intervention, and 10% in the light aerobic activity intervention from pre-test to 5 minutes after intervention testing. The static stretching warm-up condition did not change mean TPF between these two testing sessions.

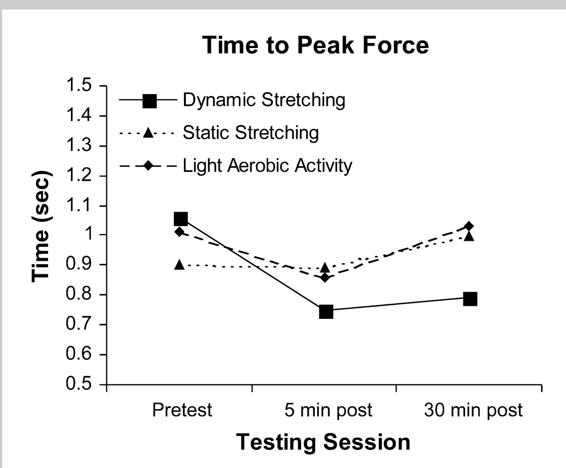

Figure 3. Comparison of changes, from pretest to 5 minutes and 30 minutes after test, in time (sec) to peak force for dynamic stretching, static stretching, and light aerobic activity conditions.

Discussion

The purpose of this study was to compare three warm-up protocols: static stretching, dynamic stretching, and light aerobic activity on the performance of ROM and power production and to investigate the sustained effects at 5 and 30 minutes after warm-up. There were no significant differences between warm-ups on any of the variables. Significant results of time were seen for all warm-up conditions in ROM and CMJ. A pattern was seen in the power variables (CMJ and TPF) showing a possible important difference between static stretching and dynamic stretching from pre-test to 5 minutes after testing. For these power variables, dynamic stretching resulted in improved scores, while the static stretching produced a decrement in performance.

Range of motion was measured to determine if subjects were stretching with sufficient intensity. Static stretching, dynamic stretching, and the light aerobic activity warm-ups all showed a similar and statistically significant increase in ROM. This is important in demonstrating the effectiveness of using a warm-up to create a physiological change. It also identifies a positive effect of utilizing some kind of warm-up prior to performance. All three warm-up protocols maintained that positive change in ROM for a minimum of 30 minutes. However, there are possible limitations with using a static ROM measure and correlating that to performance. The available ROM in a static compared to dynamic environment is dependent on neurological factors as much as muscular factors. If increased available ROM during activity is important for performance, then a measure needs to be devised to effectively record this dynamic ROM. In this study, it can only be accurately stated that ROM was increased for static movements.

The CMJ was chosen as a performance measure because of its use in other studies and its reported correlation to other performance measures (7,14,17,29). The visual analysis of interaction between warm-up conditions across time shows that the dynamic stretching warm-up condition improved CMJ performance slightly while the static stretching and light aerobic activity warm-up conditions decreased CMJ performance from the pre-test to 5-minute intervention testing. This is consistent with previous studies that found a decrease in vertical jump after warm-ups involving static stretching (10,29). There was a substantial variation in direction of performance change by the untrained subjects, which may have lead to the nonsignificant finding.

No significant changes were observed for the TPF dependent variable. However, from pretest to 5 minutes after test, there was a 27% decrease in TPF for the dynamic stretching protocol and a 10% reduction in TPF following the light aerobic activity protocol. The calculated power for this variable was 55%, which may not have been sufficient to find a significant difference between the warm-up conditions. The improvement in TPF introduces that dynamic stretching in a warm-up may allow for more rapid application of force during the performance that follows.

Faster application of force is a valuable practical finding given the critical nature of time in competitive environments. The difference between pretest and the 5-minute posttest for dynamic stretching was on average 0.3 seconds faster. Many athletic events are decided by differences of hundredths of a second. The decrease in TPF is consistent with the nonsignificant change following dynamic stretching seen in CMJ at 5 minutes after testing. While these results are not confirmed statistically as differences between warm-up conditions, dynamic stretching may have a positive outcome on power events. Two of the proposed theories to explain this improvement in power output are an elevation in muscle temperature and postactivation potentiation (PAP) (1,23). This study did not measure muscle temperature, stiffness, or PAP. The results of other research measuring the effects of these components on muscular performance can be compared to our results to look for similarities. The faster TPF is consistent with the increased rate of force production found by Abbate et al. (1) following PAP. In a review of PAP, it was also noted that repeated contractions form a potentiation response (23). The cycling component in each warm-up protocol may have produced a small PAP effect as well as elevated muscle temperature. This may have masked the significance of the potential differences between protocols. It was thought that the light aerobic activity protocol would enable us to separate the effects of warm-up from the effect of stretching. The results may indicate that the contribution of each component was not distinct enough.

A serious consideration in human-subject research is the difficulty in standardizing and controlling all study aspects. This study was more rigorous than many comparable studies on the basis of its randomization, blinding of testers, and maintenance of the same tester for all sessions with each subject. Thorough attempts to standardize the protocols were made and multiple practice instruction sessions were used prior to the start of testing. At the midpoint of the study, the research group met to review procedures and findings, allowing further narrowing of testing differences and increased standardization.

This study is important because of its unique commitment to replicating the kind of warm-up that would be typical of recreational athletes prior to performance. Equally important is the 5-minute rest between warm-up and testing, which is similar to event breaks such as final instructions from the coach and pregame introductions. Some athletes in a team sport may be required to sit on the bench for extended periods following pregame warm-up before their opportunity to perform. The design element of a 30-minute posttest is also intended to accurately replicate potential performance conditions and identify the sustaining effect a warm-up may have.

Dynamic stretching and static stretching were chosen in this study due to rising popularity as a pre-event warm-up for the former and due to historical popularity for the latter. Both of these warm-ups can be conducted in a self-stretch fashion, requiring no assistance to complete and could further be accomplished in a timeframe that would more closely simulate preperformance preparation. There is evidence in the literature that stretching bouts of 10–15 seconds may demonstrate similar improvements in flexibility when compared to longer duration stretches of 30 seconds or greater (26). These shorter stretching bouts would more likely be applied in the above preperformance preparation.

The exercises chosen for the dynamic stretching protocol were designed to provide general preparation for the muscles of the lower extremity without specific focus on increased jump performance. Coaches and trainers, however, have promoted the concept of specificity in dynamic warm-ups (16,22). This specificity of the dynamic stretching exercises in a warm-up may be the critical factor allowing for improved vertical jump performance found by other authors in their respective dynamic stretching protocols (10,29). In contrast, this study used movements that were more generalized for lower extremity activity preparation. This lack of specificity between the dynamic stretching protocol and the tested jump may have diminished the possible power improvements in performance.

For static stretching, subjects in this study were instructed to self-stretch to the point of discomfort, as opposed to investigator assisted stretching as reported in other studies (3,12,15,18,29,30). This was done to accurately simulate the preperformance warm-up condition, which is more likely to be a self-stretch event. As with dynamic stretching, the goal was general lower extremity muscle preparation and not specific improved vertical jump preparation.

Gender differences may account for some or all of the differences demonstrated between this study and other studies. At the time this study was conducted, there were no other studies focusing on just females. Currently, to our knowledge, Unick et al. (26) is the only other group to use this population. Unick et al. (26) went into a detailed discussion comparing the possible gender-based mechanisms that may have caused the differences between the females of their study and the male subjects from Young and Elliot (30) to demonstrate the varied responses to vertical jump performance. The discussion centres on gender based differences in MTU stiffness and muscle thickness, with males demonstrating increased muscle stiffness and thickness compared to females (26). These differences in viscoelastic properties may be the cause of the incompatible effects of stretching between the genders and further investigations in this area may elucidate physiological properties of the MTU, which are responsible for these differences. It is important that females continue to be included in subject sampling to determine if there are any differences in warm-up response based on gender.

A significant difference between this study and the study conducted by Unick et al. (26) is the subjects' training status. In this study, the subjects were not highly experienced with jumping or plyometric training programs. They were a group of recreationally trained active women as opposed to highly trained athletes versed in advanced methodologies. The dynamic stretching process is not widely used by recreational athletes; therefore, the comfort levels between this study's subjects were very different. Because it was a new motor skill, many of the movements involved in dynamic stretching require increased motor coordination and control leading to increased level of exertion. Although all subjects were put through a complete familiarization session in an attempt to reduce this effect, it may not have been sufficient. An indicator of this was the informal inquiry of RPE according to the Borg scale following completion of the dynamic stretching protocol. The responses ranged from 11–17. The elevated physiological stress for those who responded with 17 may correlate with decreased ability to execute performance measures. Although this RPE was not a formal part of the gathered data, the elevated level of effort was consistent with Faigenbaum et al. (10), who used two training sessions before randomizing and testing subjects. In that study, they randomly assessed heart rate during the protocols finding greater than 40 beats per minute difference between dynamic and static protocols. Having an extended period of training specific to the dynamic stretching exercises may reduce this difference and demonstrate more clearly the true effect that dynamic stretching may have in a warm-up.

In reviewing the trends between responders and non-responders, those who were previously power trained (e.g., tumbling/gymnastics) were more likely to be responders whereas the non-power-trained (e.g., joggers) were more likely to be nonresponders.

Much of the difficulty with elucidating the effects of various warm-up protocols in power performance is rooted in the myriad of stretching protocols available to investigators. These warm-up modalities include but are not limited to static stretching, ballistic stretching, dynamic stretching, and PNF stretching, among others. Each study typically uses a unique program, with its own defined application of stretching or warm-up parameters. This availability of multiple forms of stretching and the methods in which they are studied only adds to the often contradictory and confusing information on the benefits or decrements that these modalities confer upon performance measures, such as vertical jump.

Practical Applications

The findings of this study support the inclusion of warm-ups that have a dynamic component, such as dynamic stretching. The pattern of improvement seen immediately following dynamic stretching could suggest its applicability to power performance in untrained females. With further training, greater improvements in power outcomes may be possible. This research study supports the validity of pursuing this line of investigation.

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