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Acute Effects of Static Stretching on Peak Torque and Mean Power Output in National Collegiate Athletic Association Division I Women's Basketball Players

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Abstract. Egan, A.D., J.T. Cramer, L.L. Massey, and S.M. Marek. Acute effects of static stretching on peak torque and mean power output in National Collegiate Athletic Association Division I women's basketball players. *J. Strength Cond. Res. 20(4): 778–782. 2006.*—The purpose of this study was to examine the acute effects of static stretching on peak torque (PT) and mean power output (MP) during maximal, voluntary concentric isokinetic leg extensions at 60 and 300°·s^{-1} in National Collegiate Athletic Association Division I Women's Basketball players. Eleven members of a women's basketball team volunteered to perform maximal concentric isokinetic leg extensions at 60 and 300°·s^{-1} on a calibrated Biodex System 3 dynamometer. After the initial isokinetic testing, the dominant leg extensors were stretched using 1 unassisted and 3 assisted static stretching exercises. The poststretching isokinetic assessments were repeated at 5, 15, 30, and 45 minutes after the static stretching (post-5, post-15, post-30, and post-45). PT (N·m) and MP (W) were recorded by dynamometer software. The results indicated no stretching-related changes in PT (p = 0.161) or MP (p = 0.088) from pre- to poststretching for any of the testing intervals (post-5, post-15, post-30, and post-45). These findings indicated that the static stretching had no impact on PT or MP during maximal, voluntary concentric isokinetic muscle actions in collegiate women's basketball players. In conjunction with previous studies, these findings suggested that trained athletes may be less susceptible to the stretching-induced force deficit than untrained, nonathletes.

Key Words. stretching-induced force deficit, isokinetic, athletes, muscle strength, velocity

Introduction

Static stretching is often performed before exercise and athletic performance because it is widely believed that pre-exercise stretching will decrease the risk of injury (10, 11, 14, 23, 24, 27) and improve performance (25, 27, 28). Recent evidence, however, has suggested that a bout of stretching may actually cause acute decreases in muscle strength (1, 3, 6, 7, 12, 13, 18, 20–22), vertical jumping ability (4, 5, 19, 33), sprint speed (26), and balance and reaction times (2). In contrast, a few studies have observed no detrimental effects of stretching on maximal strength of the plantarflexors (17), 100-yd dash times (8), vertical jump kinetics (15), vertical jump performance (30), range of motion and foot speed while kicking a football (32), or tennis serve performance (16). However, despite some conflicting evidence regarding the acute effects of stretching before performance, limited evidence is available to suggest that preactivity stretching improves performance (25, 27, 28).

Several studies have examined the acute effects of stretching on performance in athletes (4, 8, 17, 19, 26, 30, 32, 33). While 4 of these studies have reported adverse effects of stretching on vertical jump performance (4, 19, 26, 33), others have reported no changes in athletic performance immediately after the stretching (8, 16, 30, 32). Unick et al. (30) reported no changes in vertical jumping ability after bouts of static or ballistic stretching in Women's National Collegiate Athletic Association (NCAA) Division III basketball players during their preseason conditioning. Based on these findings, Unick et al. (30) hypothesized that "A training effect which enhances neuromuscular recovery or other mechanisms could have resulted in a reduced effect from static stretching on the performance of the subjects used in this study" (p. 211). In addition, previous studies from our laboratory have reported stretching-induced decreases in peak torque (PT) in men (7, 18) and women (6, 18) as a result of both static and proprioceptive neuromuscular facilitation (PNF) stretching (18). However, relatively untrained, recreationally active college-aged participants were tested in these studies (6, 7, 18). If training status does contribute to the stretching-induced force deficit, the muscle strength and power output of well-conditioned athletes may not respond the same as that of untrained individuals to the static stretching protocol used in our previous studies (6, 7, 18). However, no previous studies have examined the effects of static stretching on isolated muscle strength and power output in athletes. Therefore, the purpose of this study was to examine the acute effects of static stretching on PT and mean power output (MP) during maximal, voluntary concentric isokinetic leg extensions at 60 and 300°·s^{-1} in NCAA Division I women's basketball players.

Methods

Experimental Approach to the Problem

This study was designed to extend previous findings (6, 7, 18, 30) by examining the acute effects of static stretching on isokinetic muscle strength and power output in nationally competitive NCAA Division I women's basketball players. To be consistent with our previous studies that have reported stretching-induced decreases in PT (6, 7) and MP (18) in untrained individuals, this study used the same static stretching protocol. In addition, we recorded PT and MP at relatively slow (60°·s^{-1}) and fast (300°·s^{-1}) angular velocities to test the hypothesis of Nelson et al. (21) that the acute effects of static stretching are velocity specific. Furthermore, PT and MP were tested at 5, 15, 30, and 45 minutes after the static stretching to examine the time course of the responses (13).

Subjects

Eleven women (mean age $\pm$ *SD* = 20.0 $\pm$ 1.1 years; height = 177.3 $\pm$ 8.6 cm; weight = 71.7 $\pm$ 10.0 kg) volunteered for this study. Subjects were recruited from a highly competitive NCAA Division I women's basketball team. This team was ranked 174th of 325 NCAA Division I teams and 3rd of 11 in the Southland Conference at the end of the 2003–2004 season. All subjects were free from any lower-body injuries as determined by a certified athletic trainer. All testing occurred within 2 weeks of the last game of the season. The study was approved by the University Institutional Review board for Human Subjects. In addition, 3–5 days before the experimental trial, each subject signed a written informed consent, completed a health history questionnaire, and attended a group familiarization trial conducted to orient the subjects with the testing equipment and protocol.

Isokinetic Testing

For the experimental trial, each participant began by completing a 5-minute warm-up at 50 W on a stationary cycle ergometer. The isokinetic testing was performed immediately before (pre) and after (post) the static stretching exercises at 5, 15, 30, and 45 minutes after stretching (post-5, post-15, post-30, and post-45). During the isokinetic testing, maximal voluntary concentric isokinetic PT and MP for extension of the dominant leg (based on kicking preference) were measured using a calibrated Biodex System 3 dynamometer (Biodex Medical Systems, Shirley, NY) at randomly ordered velocities of 60 and $300°\cdot s^{-1}$. Participants were seated upright in the dynamometer chair, with restraining straps over the pelvis, trunk, and thigh in accordance with the Biodex User's Guide (Biodex Pro Manual, Applications/Operations; Biodex Medical Systems). The input axis of the dynamometer was aligned with the axis of the knee. Three or 4 submaximal warm-up trials preceded 3 maximal muscle actions at both velocities. A 2-minute rest was allowed between testing at each velocity. The repetition resulting in the greatest amount of work was selected for analysis. Peak torque and MP were provided by the dynamometer software (Biodex System 3 Advantage Software; Biodex Medical Systems). For the selected repetition, PT (N·m) and MP (W) were reported as the maximal torque value and time-averaged integrated area under the angle-torque relationship, respectively.

Static Stretching Protocol

Each participant underwent 4 static stretching exercises designed to stretch the leg extensor muscles of the dominant thigh, according to the previously reported procedures of Cramer et al. (6, 7), Marek et al. (18), and Nelson et al. (20). Four repetitions of each stretching exercise were held for 30 seconds at a point of mild discomfort, but not pain, as acknowledged by the participant. Between each stretching repetition, the leg was returned to a neutral position for a 20-second rest period. The average duration of the stretching protocol was 16.8 $\pm$ 2.3 ($\pm$ *SD*) minutes, where the time under stretch was approximately 8 minutes.

Each participant performed an unassisted stretching exercise followed by 3 assisted stretching exercises. For the unassisted stretching exercise, the participant stood upright with 1 hand against a wall for balance. The participant flexed the dominant leg to a knee joint angle of 90°. The ankle of the flexed leg was grasped by the ipsilateral hand, and the foot was raised so that the heel of the dominant foot approached the buttocks. After the unassisted stretching exercise, the remaining stretching exercises were completed with the assistance of an investigator. The first assisted stretching exercise was performed with the participant prone on a padded table with the legs fully extended. The dominant leg was flexed at the knee joint and slowly pressed down so that the participant's heel approached the buttocks. If the heel was able to contact the buttocks, the knee was gently lifted off the supporting surface, causing a slight hyperextension at the hip joint, to complete the stretch. To perform the second assisted stretching exercise, the participant stood with her back to a table and rested the dorsal surface of her dominant foot on the table by flexing the leg at the knee joint. From this position, the dominant leg extensors were stretched by gently pushing back on both the knee of the flexed leg and the corresponding shoulder. The final assisted stretching exercise began with the participant lying supine along the edge of the padded table with the dominant leg hanging off the table. The dominant leg was flexed at the knee, and the thigh was slightly hyperextended at the hip by gently pressing down on the knee. After the static stretching exercises, the isokinetic testing protocol was repeated at post-5, post-15, post-30, and post-45 minutes after the stretching.

Reliability

Previous test–retest reliability from our laboratory indicated that, for 10 women (mean age $\pm$ *SD* = 23.0 $\pm$ 3.33 years; height = 160.0 $\pm$ 9.6 cm; weight = 62.8 $\pm$ 10.3 kg) measured 48 hours apart, the intraclass correlation coefficients (ICCs) for PT were 0.90 at $60°\cdot s^{-1}$ and 0.95 at $300°\cdot s^{-1}$, and the *SEM* values were 4.21 N·m at $60°\cdot s^{-1}$ and 2.91 N·m at $300°\cdot s^{-1}$. For MP, the ICCs were 0.96 at $60°\cdot s^{-1}$ and 0.88 at $300°\cdot s^{-1}$, and the *SEM* values were 2.82 W at $60°\cdot s^{-1}$ and 4.64 W at $300°\cdot s^{-1}$. There were no significant differences (p = 0.099–0.353) between the mean values for test vs. retest for PT or MP at either velocity. Based on the recommendations of Weir (31), model 3,1 was used to calculate the ICC and *SEM* values.

Statistical Analyses

For each participant, the PT and MP values were normalized to their respective prestretching values (% prestretching) before statistical treatment. Two separate two-way repeated measure analyses of variance (ANOVAs) (time [pre- vs. post-5 vs. post-15 vs. post-30 vs. post-45] $\times$ velocity [$60°\cdot s^{-1}$ vs. $300°\cdot s^{-1}$]) were used to analyze the PT and MP data. When appropriate, follow-up analyses included one-way repeated-measures ANOVAs and Bonferroni-corrected dependent-samples *t*-tests. In addition, for statistically significant findings, the strength of association (effect size) was estimated with the partial eta squared (η^2) statistic (29). An alpha of $p \leq 0.05$ was considered statistically significant for all comparisons. All statistical analyses were performed with SPSS software (version 11.5; SPSS, Inc., Chicago, IL).

TABLE 1. Peak torque (N·m) and mean power output (W) during the prestretching and post-5, post-15, post-30, and post-45 isokinetic tests.

	Prestretching		Poststretching							
			Post-5		Post-15		Post-30		Post-45	
	$60°\cdot s^{-1}$	$300°\cdot s^{-1}$	$60°\cdot s^{-1}$	$300°\cdot s^{-1}$	$60°\cdot s^{-1}$	$300°\cdot s^{-1}$	$60°\cdot s^{-1}$	$300°\cdot s^{-1}$	$60°\cdot s^{-1}$	$300°\cdot s^{-1}$
Peak torque (N·m)										
Mean	180.2	99.6	174.5	104.7	179.5	102.6	173.7	111.6	182.4	107.1
SEM	11.9	3.8	12.5	5.5	11.7	5.0	13.6	7.4	11.2	5.3
Mean power output (W)										
Mean	104.7	181.0	98.8	192.0	106.2	211.9	108.5	201.0	112.5	201.3
SEM	8.3	23.9	8.8	27.3	8.1	29.1	9.0	25.5	8.0	22.1

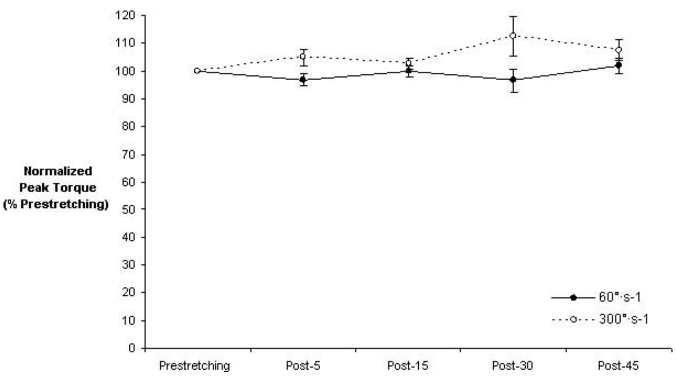

FIGURE 1. Isokinetic peak torque (expressed as a percentage of the prestretching value) at 60 (solid line) and $300°\cdot s^{-1}$ (dashed line) during the prestretching and post-5, post-15, post-30, and post-45 isokinetic tests. Values as mean ± *SEM*.

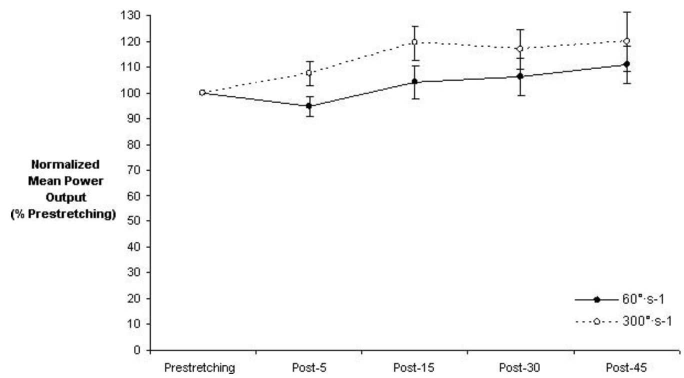

FIGURE 2. Isokinetic mean power output (expressed as a percentage of the prestretching value) at 60 (solid line) and $300°\cdot s^{-1}$ (dashed line) during the prestretching and post-5, post-15, post-30, and post-45 isokinetic tests. Values as mean ± *SEM*.

RESULTS

Table 1 shows the mean and *SEM* values for PT and MP before normalization. For PT, there was no time × velocity interaction ($p = 0.275$), no main effect for time ($p = 0.161$), but a significant main effect for velocity ($p = 0.026$; $\eta^2 = 0.405$). The marginal mean for normalized PT (collapsed across time) at $300°\cdot s^{-1}$was greater than $60°\cdot s^{-1}$ (Figure 1). For MP, there was no time × velocity interaction ($p = 0.301$), no main effect for time ($p = 0.088$), but a significant main effect for velocity ($p = 0.002$; $\eta^2 = 0.618$). The marginal mean for normalized MP (collapsed across time) at $300°\cdot s^{-1}$ was greater than $60°\cdot s^{-1}$ (Figure 2).

DISCUSSION

It has been suggested that stretching before exercise or athletic events can decrease the risk of injury (10, 11, 14, 23, 24, 27) and improve performance (25, 27, 28). Recent evidence, however, has indicated that an acute bout of stretching may cause transient decreases in isolated muscle strength (1, 3, 6, 7, 12, 13, 18, 20–22), vertical jumping ability (4, 5, 19, 33), sprint speed (26), and balance and reaction times (2). In contrast, several studies have observed no detrimental effects of stretching on maximal voluntary strength of the plantarflexors (17), 100-yd dash times (8), vertical jump kinetics (15), vertical jump performance (30), range of motion and foot speed while kicking a football (32), or tennis serve performance (16). Furthermore, at least 8 studies have examined the acute effects of stretching on performance in athletes (4, 8, 16, 19, 26, 30, 32, 33). Four have reported adverse effects of stretching on vertical jump performance (4, 19, 26, 33), whereas the other 4 have reported no adverse effects of stretching on athletic performance (8, 17, 30, 32). The results of this study extended the previous findings (4, 8, 16, 19, 26, 30, 32, 33) and indicated that the static stretching did not adversely affect isokinetic PT or MP at 60 or $300°\cdot s^{-1}$ during the 5-, 15-, 30-, or 45-minute poststretching intervals in NCAA Division I women's basketball players.

Previous studies from our laboratory using the same stretching volume, intensity, and rest period duration after the stretching bout (or longer) (18) have reported stretching-induced decreases in isokinetic strength in men (7, 18) and women (6, 18). In addition, we have observed acute decreases in PT and MP as a result of both static and PNF stretching (18). The primary difference, however, between this study and our previous studies (6, 7, 18) was the training status of the participants. Relatively untrained, recreationally active college-aged participants were tested previously (6, 7, 18), whereas well-conditioned NCAA Division I women's basketball players were tested in this study. Therefore, these results suggested that the acute effects of static stretching may be related to training status, affecting untrained individuals, but not trained athletes.

Conflicting evidence exists regarding the acute effects of stretching on performance in athletes. Stretching-induced decreases in vertical jump performance have been reported in women's NCAA Division I tennis, rowing, volleyball, and track and field athletes (4) and men's track and field, football, and field hockey athletes with 1 season of experience (33), but the delimitations of their training status and training phase (in- vs. off-season) were not specified. Church et al. (4) showed decreases in vertical jump performance after PNF stretching, but not static stretching; however, these findings may have been confounded by muscle fatigue, because the PNF procedure involved 60 seconds of isometric contractions for each of 6 separate stretching exercises. Young and Elliott (33) reported drop jump deficits after static stretching, but not PNF stretching, and no stretching-related changes in squat jump performance. In addition, McNeal and Sands (19) reported stretching-induced decreases in flight time, but no changes in ground contact time, during the drop jump in 13-year-old competitive gymnasts, and Siatras et al. (26) found stretching-induced decreases in vault approach sprint speed in 9-year-old elite competitive gymnasts. Other studies, however, have shown no acute effects of stretching on performance in athletes during the 100-yd dash (8), tennis serve (16), football kicking (32), and vertical jump (30). Unick et al. (30) reported no changes in vertical jumping ability after bouts of static or ballistic stretching in NCAA Division III women's basketball players during their preseason conditioning. The results of this study supported those of Unick et al. (30) and indicated no stretching-related changes in PT or MP in NCAA women's basketball players within 2 weeks after the last game of the season. Therefore, these findings, in conjunction with those of Unick et al. (30), suggest that the sport-specific conditioning for collegiate women's basketball players may provide the chronic training adaptations necessary to avoid any adverse effects of stretching on performance. However, this may not be the case for young gymnasts (19, 26) or other athletes during different phases of conditioning (4, 33).

Two mechanisms have been proposed to explain the stretching-induced force deficit: (a) mechanical factors associated with decreases in musculotendinous stiffness that may alter the shape of the length–tension relationship (5–7, 12, 13, 20, 21) and (b) neural factors caused by decreases in muscle activation (1, 3, 6, 7, 13, 22). For example, using the formula of Duchateau (9), Fowles et al. (13) calculated that 60% of the reduction in strength immediately after 30 minutes of intense stretching was caused by decreases in motor unit activation, whereas 40% was caused by intrinsic mechanical alterations in the muscle. After 15 minutes of recovery from the stretching, however, most of the remaining strength deficit was attributed to changes in the length–tension relationship and plastic deformation of the connective tissues (13). Furthermore, Nelson et al. (20) suggested that the stretching-induced increases in musculotendinous compliance allowed the sarcomeres to shorten farther and at a faster rate, which resulted in the contractile components operating at less optimal points on the length–tension relationship and decreased sarcomere force production caused by the force–velocity relationship. In this study, however, we observed no stretching-induced decreases in strength (PT) or power (MP), which suggested that the length–tension relationship was not altered. It is possible that the chronic musculotendinous adaptations associated with the resistance training, flexibility training, and cardiovascular conditioning of the basketball players throughout their season minimized the acute impact of the static stretching on the length–tension relationship.

It has also been suggested that the stretching-induced force deficit is attributed to neural factors (1, 3, 6, 7, 13, 18, 22). As mentioned earlier, Fowles et al. (13) indicated that most of the force loss that was observed within 15 minutes after the stretching was caused by an impaired ability to activate all available motor units. Previous studies have reported acute stretching-induced decreases in muscle activation using both surface electromyography (EMG) (1, 3, 7) and the twitch interpolation technique (3, 13, 22). In fact, in a previous study from our laboratory (7), stretching-induced decreases in PT and EMG amplitude were observed in both the stretched and unstretched (contralateral) leg extensor muscles, which may have been caused by a central nervous system inhibitory mechanism. However, the lack of change in PT and MP in this study suggested that the static stretching did not elicit any acute neural impairments. Again, it is possible that the chronic neural adaptations elicited by the sport-specific training program of the basketball players in this study minimized the acute impact of the static stretching on the nervous system. Future studies are needed, however, to investigate the influences of chronic training adaptations and the mode of training (resistance, flexibility, or cardiovascular) on the acute musculotendinous and neuromuscular responses to static stretching.

Recently, Nelson et al. (20) reported stretching-induced decreases in PT at 60 and $90°\cdot s^{-1}$, but no changes at 150, 210, or $270°\cdot s^{-1}$ during maximal, concentric isokinetic leg extension muscle actions. The authors suggested that the stretching-induced force deficit was velocity specific, affecting the high torque conditions at the slower velocities (60 and $90\cdot s^{-1}$), but not the lower torque conditions at the faster velocities (150, 210, and $270°\cdot s^{-1}$). Subsequent studies, however, have shown decreases in PT at 60, 240, and $300\cdot s^{-1}$ during leg extension muscle actions (6, 7, 18) and at 30 and $270°\cdot s^{-1}$ during forearm flexion muscle actions (12), which collectively showed that the decreases in PT as a result of static stretching may not be as velocity specific as originally suggested by Nelson et al. (20). The results of this study indicated that the normalized values for PT and MP at $300°\cdot s^{-1}$ were greater than $60°\cdot s^{-1}$ (Figures 1 and 2) for each testing period (prestretching, post-5, post-15, post-30, and post-45), which tentatively suggested that PT and MP at $300°\cdot s^{-1}$ responded differently to the static stretching exercises than PT and MP at $60°\cdot s^{-1}$. However, because there were no changes in PT or MP from pre- to post-stretching at 60 or $300°\cdot s^{-1}$, these findings do not provide any conclusive evidence regarding the velocity-specific nature of the stretching-induced force deficit. Future studies are needed to examine the effects of static stretching on muscle strength and power output during a wide range of isokinetic velocities in athletes and nonathletes.

PRACTICAL APPLICATIONS

The main findings of this study indicated that static stretching did not adversely affect isokinetic PT or MP at 60 or $300°\cdot s^{-1}$ during any of the poststretching intervals (post-5, post-15, post-30, and post-45) in NCAA Division I women's basketball players. These results were consistent with Unick et al. (30), who showed no effects of static or ballistic stretching on vertical jump performance in NCAA Division III women's basketball players. Therefore, the results of this study, in conjunction with those of Unick et al. (30), suggest that trained collegiate athletes may be less susceptible to the stretching-induced force deficit than untrained nonathletes. However, this may not be the case for young gymnasts (19, 26) or other athletes during different phases of conditioning (4, 33). Future studies are needed to study the influences of chronic, sport-specific training adaptations on the acute musculotendinous and neuromuscular responses to static stretching. These findings may be useful for strength and conditioning practitioners and allied health professionals who regularly incorporate flexibility exercises before competition for collegiate women's basketball players.

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