Inhibition of Maximal Voluntary Isometric Torque Production by Acute Stretching Is Joint-Angle Specific

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A lthough stretching exercises that enhance flexibility are regularly included in the training programs and pre-event warm-up activities of most athletes, research suggests that pre-exercise stretching could negatively impact the performance of skills for which success is related to maximal force output. Wilson, Murphy, and Pryor (1994) suggested that a stiff musculotendinous system allows for an improved force production by the contractile component and provided evidence to support this suggestion by demonstrating that concentric performance in the bench press was significantly related to musculotendinous stiffness. The findings of Wilson et al. (1994), coupled with the results of several studies (Magnusson, Simonsen, Aagaard, & Kjaer, 1996; Rosenbaum & Hennig, 1995; Taylor, Dalton, Seaber, & Garrett, 1990), indicating that the musculotendinous unit becomes less stiff as a result of acute stretching, lead Kokkonen, Nelson, & Cornwell (1998) to investigate the effect of acute stretching on knee extension and knee flexion one-repetition maximum (1RM) lifts. Kokkonen et al. (1998) reported that a regimen of acute stretching inhibited the one-repetition maximum lift (1RM) of both knee extension and knee flexion.

Kokkonen et al. (1998), however, could only speculate about the mechanisms responsible for this phenomenon. One speculated mechanism was derived from a Wilson et al. (1994) supposition that the lesser force production seen in more compliant musculotendinous systems was due to altered intramuscular length. Specifically, these researchers surmised that at a given magnitude of contraction, a compliant musculotendinous unit would go through a period of virtually unloaded shortening that would continue until the elastic components were stiffened sufficiently to transmit the generated force to the bone. Hence, a stiffer musculotendinous unit would produce force at a longer sarcomere length, thereby placing the contractile component at a more optimal point, in terms of force production, on the force-length curve.

Because Taylor et al. (1990) reported an increased tendon length and reduced tendon stiffness following stretching, it is possible that the stretching protocol imposed by Kokkonen et al. (1998) increased compliance in the tendons of the stretched muscle groups. In turn, this increased compliance might have been of sufficient magnitude to ensure that the muscle fibers operated over a less favorable range of the force-length curve in terms of force production. In other words, the more compliant tendon allowed for a shorter muscle length, thereby compelling the fibers to function more on the ascending limb rather than on the plateau region (optimal length range for force generation) of the curve.

If such a mechanism contributed to the findings of Kokkonen et al. (1998), it would ensure that any decrement in force would be more apparent at points in the range of motion where muscle fiber or sarcomere length closely corresponds to the ascending limb-plateau junction of the force-length curve. During knee extension, this would probably occur as the knee joint approaches full extension; that is, at knee joint angles closer to 180°. Therefore, the purpose of this study was to characterize the effects of an acute stretching regimen on maximal voluntary isometric knee-extension torque at five different knee joint angles. It was hypothesized that maximal voluntary isometric knee-extension torque at those angles close to 90° knee extension would be unaffected by acute stretch-
ing but maximal voluntary isometric knee-extension torque at the angles close to 180° would be reduced.

Methods

Participants

Thirty female and 25 male college students (Mage = 22 years, SD = 6), who were enrolled in professional physical education classes, participated in the study. Each individual declared themselves free of any history of knee problems and was unaware of both the findings of Kokkonen et al. (1998) and the study’s hypothesis. The study was approved by the appropriate institutional review board, and each participant gave both written and oral consent before engaging in the experiment.

Experimental Protocol

Each participant performed two bouts (baseline and poststretching) of maximal voluntary isometric knee extensions with the dominant leg. Isometric torque was measured with the participant seated on a Cybex II (Lumex, Inc., Bay Shore, NY) isokinetic device at five different knee angles (90°, 108°, 126°, 144°, and 162°). The two measurement bouts were separated by 10 min of passive, static stretching of the dominant quadriceps.

Maximal Voluntary Isometric Torque Measurement Protocol

Prior to each participant’s entry into the laboratory, the Cybex II was calibrated following company specifications. On entering the laboratory, each participant sat in an upright position and was secured to both the Cybex II and the chair to eliminate extraneous movements and maintain a constant hip joint angle. Following a quiet sitting period of 10 min, baseline maximal voluntary isometric torque measurements commenced. First, a gravity correction factor was determined with the leg at full extension and a movement speed at 0 rad·s⁻¹. The torque generated by the lever arm and hanging limb was subsequently added to the individual torque measurements. The participant then made the four maximal voluntary isometric torque measurements at each of the five knee angles, with a 30–60-s rest period between each contraction. The specific angle testing sequence for each participant was set in a random-balanced order. The participant completed all four measurements at a specific angle before changing the knee joint angle, and a minimum of 2 min elapsed before measurements were recorded at the next angle. On completing the baseline measurements, the participant was released from the testing apparatus to undergo the stretching program. Following the stretching program, the participant was again secured to the apparatus in the exact position used for the baseline tests, and the maximal voluntary isometric torque measurements were repeated using the same testing order and protocol used in the baseline tests. Knowledge of individual or overall performances was not provided until the end of the study.

Stretching Protocol

The stretching program consisted of two passive, static activities designed to stretch the quadriceps muscle group. Each individual performed a warm-up stretch before the two exercises. Participants performed each activity four times either unaided (warm-up) or assisted by one of the experimenters. To perform the assisted activities, the experimenter pushed the participant’s leg until the participant verbally acknowledged that the stretch was at the pain threshold. The experimenter would then hold the participant’s limb steady for 30 s. At the end of the stretch, the participant’s leg was returned to a neutral position for 20 s and then the stretch was repeated.

The warm-up stretch was outlined by Alter (1988) as Exercise #91. To perform this stretch, the person first stood upright with one hand placed against a surface for balance and flexed the knee to a 90° position. The individual then grasped the ankle of the flexed leg with the ipsilateral hand and raised the foot so that the heel was as close as possible to the buttocks. The first assisted exercise was Exercise #93 from Alter (1988). For this, the individual first lay down in a fully extended prone position. An experimenter would then flex the leg at the knee and slowly press the person’s heel into the buttocks. As the heel contacted the buttocks, the knee was then lifted up off the supporting surface. The second and last activity was a modification of Exercise #91. The participants stood with their backs to a bench that was approximately level with the buttocks. They would then rest the superior side of one foot on the bench by flexing at the knee joint. From this position, the experimenter would push backward on both the flexed knee and the corresponding shoulder.

Statistics

The isometric measurements for each angle were analyzed using paired t tests. The level of significance was set at $p < .05$ and was adjusted to cover for multiple comparisons ($p$ value divided by number of comparisons). Hence, for significance at the .05 level to occur, the $t$ score was actually tested at the $p < .01$ level (i.e., .05 divided by 5).

Results

The results of the maximal voluntary isometric torque measurements for all the knee joint angles of 90°, 108°, 126°, 144°, 162° are presented in Figure 1. Following the
Discussion

The purpose of the present investigation was to determine whether the inhibitory influence of acute muscle stretching on maximal voluntary strength performance was due, in part, to a stretching of the muscle tendon that subsequently placed the sarcomeres at a nonoptimal position on the force-length curve. It was hypothesized that if such a mechanism was present, then any force decrement would be more apparent at knee joint angles that were close to full extension. The main finding, that a significant decrease in maximal voluntary isometric torque was seen at a knee angle of 162°, suggests the working hypothesis was correct. It should be noted, however, that this study made no actual measurement of tendon length, tendon stiffness, or sarcomere length. Therefore, the possibility cannot be discounted that the significant decrease in maximal voluntary isometric torque a 162° knee extension was due to a mechanism other than the one presented in the hypothesis.

Moreover, it could be questioned whether the significant decrease in maximal voluntary isometric torque at 162° of knee extension is the sole or primary reason for the strength decrement reported by Kokkonen et al. (1998). While this study cannot answer this question directly, it is pointed out that in the Kokkonen et al. (1998) study, a successful lift was acknowledged only if the individual was able to achieve full extension. Moreover, it was noted that during the 1RM test, all failures to lift the next weight increment were due to an inability to complete rather than initiate the lift. Therefore, a loss of strength during the final degrees of the range of motion would greatly impact a 1RM performance.

Regardless of the aforementioned limitations, however, this study supports the supposition that a thorough bout of acute stretching can inhibit strength by placing sarcomeres at a less than optimal length much sooner in the full range of motion. It also suggests that any negative impact on performance by acute stretching is of a greater concern in those activities that require a joint to work in the terminal portion of its range of motion.

References


Authors’ Note

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