The effects of static and ballistic stretching on delayed onset muscle soreness and creatine kinase

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The purpose of this study was to determine if static and ballistic stretching would induce significant amounts of delayed onset muscle soreness (DOMS) and increases in creatine kinase (CK). Twenty males were randomly assigned to a static (STATIC) or ballistic stretching (BALLISTIC) group. All performed three sets of 17 stretches during a 90-min period, the only group difference being that STATIC remained stationary during each 60-s stretch while BALLISTIC performed bouncing movements. Subjective ratings of DOMS (scale: 1–10) and serum CK levels were assessed before and every 24 hours post stretching, for 5 days. A repeated measures ANOVA revealed a significant main effect due to time (p < .05), with peak soreness occurring at 24 hours after (M = 2.8 ± 1.6). Surprisingly, a group effect (p < .05) demonstrated that DOMS was significantly greater for STATIC than for BALLISTIC. At 24 hours there was a 62% (p < .05) increase in CK for combined groups. These findings indicate that similar bouts of static and ballistic stretching induce significant increases in DOMS and CK in subjects unaccustomed to such exercise. Furthermore, static stretching induced significantly more DOMS than did ballistic.

Key words: delayed onset muscle soreness, static stretching, ballistic stretching, creatine kinase.

Delayed onset muscle soreness (DOMS) is a sensation experienced after unaccustomed exercise. It is usually first felt between 8 and 24 hours after the termination of exercise, peaks in intensity between 24 and 72 hours, and then decreases dramatically. After 5 days the soreness has usually disappeared (Armstrong, 1986; Ebbeling & Clarkson, 1989; Stauber, 1989).

DOMS is particularly prevalent after exercise involving unaccustomed eccentric, lengthening muscle actions and is associated with microtrauma to connective and/or contractile tissue (Armstrong, 1986; Ebbeling & Clarkson, 1989; Stauber, 1989). Although not as well documented, DOMS may also occur in response to isometric muscle action (Clarkson, Byrnes, McCormick, Turcotte, & White, 1986; Triffletti, Litchfield, Clarkson, & Byrnes, 1988) as well as bouncing-type movements, involving the stretch-shortening cycle (Komi, 1986).


Static stretching has also been recommended before and after a workout to prevent the onset of DOMS (De Vries, 1961), although these claims have not been substantiated (Burker & Schwane, 1989; High & Howley, 1989).

Ballistic, bouncing stretching is not recommended, although similar improvements in flexibility are seen in response to static and ballistic stretching (De Vries, 1962). One reason for cautioning against ballistic stretching is that it subsequently results in DOMS (De Vries, 1962); however, there appears to be no scientific evidence to substantiate this claim.

Therefore, the objectives of this study were to determine whether (a) similar bouts of unaccustomed static and ballistic stretching would induce significant amounts of DOMS, (b) whether ballistic stretching would cause significantly more DOMS than static stretching, and (c) whether serum creatine kinase (CK), a standard marker of muscle tissue disruption (Ebbeling & Clarkson, 1989), would be significantly elevated.
Method

Subjects

Twenty college-age males volunteered for this study. Subjects were screened using a medical health history and read and signed an informed consent consistent with the University's Policy for Human Research. Subjects were randomly assigned to a static (STATIC) or ballistic (BALLISTIC) stretch group. The respective means and ± standard deviations for physical characteristics of subjects were 20.7 ± 3.6 and 21.4 ± 4.0 for age (year); 177.0 ± 6.8 and 175.8 ± 6.9 for height (cm); 75.1 ± 7.5 and 73.2 ± 9.8 for weight (kg); 12.3 ± 4.6 and 11.8 ± 3.1 for percent body fat (Jackson & Pollock, 1982). t-tests revealed no significant (p > .05) differences between groups on any variable. All subjects were active, but none participated regularly in any type of stretching activity. Subjects were required to remain sedentary during the entire period of the experiment.

Stretching Protocols

After a 5-min warm-up of marching in place, both the STATIC and BALLISTIC groups performed three identical sets of 17 stretches. The only difference between the two groups was that during static stretching, subjects remained stationary during each 60-s stretch, while during ballistic stretching, subjects performed bouncing movements in time to a metronome (60 bounces/min). The stretches were selected from two popular texts (Alter, 1988; Anderson, 1980). A criterion for selection was that the stretches were easy and safe for a beginner to perform. Approximately two stretches were used for each muscle group being monitored for DOMS. However, it was not always possible to isolate the stretch to a particular area; for example, stretching the hamstrings also appeared to involve the gastrocnemius, soleus, and gluteal muscles. To standardize procedures, each group performed the stretches in synchronisation with a pre-recorded video. The entire session, including instructions, took 90 min.

Measurement of Delayed Onset Muscle Soreness

A 10-point scale was used to assess soreness (1 = no soreness, 10 = unbearable soreness) before stretching and then at 24, 48, 72, 96, and 120 hours after. Subjects rated DOMS in nine separate muscular sites: (a) the back of the lower leg, (b) the back of the thigh, (c) the front of the thigh, (d) the lower back and the buttocks, (e) the waist and abdominals, (f) the upper back, (h) the shoulders, (i) the front and back of the upper arm, and (j) the front and back of the lower arm. A daily mean soreness score was computed. This involved summing all soreness scores reported at each time period and then dividing this by the number of areas.

Measurement of Creatine Kinase

Blood samples were drawn from an antecubital vein before stretching and then at 24, 48, 72, 96, and 120 hours after. The blood (5 ml) was allowed to clot at room temperature for 10 min and then centrifuged. Serum was separated and frozen at -20°C for subsequent analysis of CK. Total CK was determined spectrophotometrically, at 30°C, using a commercially available kit (Sigma Diagnostics, St. Louis, 47-UV). All CK samples were run in duplicate. If there was a difference of >5%, the sample was rerun. The mean of the two values that were within 5% of each other was recorded.

Heart Rate and Ratings of Local Perceived Exertion

A goal of the present study was to compare DOMS and CK in response to similar bouts of static and ballistic stretching. In addition to using the same stretching exercises, we thought it was necessary to ascertain that subjective feelings of effort in the muscles and/or joints (Pandolf, 1982) being stretched were alike between groups. Following each stretch, subjects were asked to record local perceived exertion (RPE-local) in the muscles that had been stretched, using Borg's 6-20 scale (Borg, 1970). Because each stretch was repeated three times, the mean of the three scores for the 17 stretches was computed. We were also concerned that the overall metabolic cost was comparable and therefore monitored heart rate (HR) as an approximate indicator. HR was monitored during each stretch via telemetry (Heartwatch, Lafayette Instrument, Lafayette, IN). The mean of the three heart rates for each of the 17 stretches was computed.

Statistical Analysis

Repeated measures ANOVAs were used to analyze mean DOMS scores (2 x 6), serum CK (2 x 6), HR, and RPE-local (2 x 17). A Tukey post-hoc test was used to test significant effects. The level of significance was set at p < .05 and values are reported as M ± SD. The sphericity assumption was addressed using the three-step testing procedure outlined by Greenhouse and Geisser (1959).

Results

One subject in the STATIC group had baseline CK levels above the normal range; therefore, his results were excluded from the analysis.

Delayed Onset Muscle Soreness

There was a small but significant time effect for soreness perception, F (5, 85) = 45.3, p < .05. Post-hoc...
testing revealed that soreness scores were significantly (p < .05) elevated over baseline at 24 hours (2.8 ± 1.6) and 48 hours (2.4 ± 1.8) after exercise. There was also a significant group effect, F(1, 17) = 6.0, p < .05, with soreness perception being consistently higher for the STATIC (2.1 ± 1.4) than for the BALLISTIC (1.6 ± 1.0) group (see Figure 1, Table 1). There was no significant interaction effect.

**Creatine Kinase**

Initial CK values were similar for STATIC (84.6 ± 21.6 U/L) and BALLISTIC groups (79.8 ± 28.8 U/L). An ANOVA revealed a significant time effect, F(5, 85) = 6.6, p < .05. Post-hoc testing demonstrated that CK was significantly elevated for both groups (p < .05) over baseline levels (82.0 ± 25.1 U/L) at 24 hours (133.2 ± 64.4 U/L). There was also a significant interaction, F(5, 85) = 2.7, p < .05. However, when the conservative Greenhouse–Geisser correction was made, the interaction was not significant (see Figure 2, Table 1).

**Heart Rate and Local Perceived Exertion**

There was no significant difference between STATIC and BALLISTIC in heart rate (p > .25) or RPE.

**Table 1. Time after exercise, in hours**

<table>
<thead>
<tr>
<th>Groups</th>
<th>PRE</th>
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<th>72</th>
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</table>

**Figure 1. Soreness ratings (M ± SD) for STATIC and BALLISTIC subjects across time.**

**Figure 2. Creatine kinase levels (M ± SD) for STATIC and BALLISTIC subjects across time.**

**Discussion**

One purpose of this study was to determine if a bout of static and/or ballistic stretching, of a similar intensity and duration, would induce significant amounts of DOMS and increases in serum CK. The results indicated that both types of stretching resulted in a significant increase (p < .05) in DOMS, which peaked at 24 hours after stretching. Surprisingly, static stretching resulted in significantly higher levels of DOMS than did ballistic stretching (see Figure 1).

The popular literature is replete with contraindications concerning ballistic stretching, suggesting that ballistic movements place an individual at greater risk for incurring injury and DOMS (Alter, 1988; Anderson, 1980; Beaulieu, 1981; De Vries, 1962; Etnyre & Lee, 1987). In contrast, static stretching is recommended as a palliative, although these claims have not been substantiated (Burkholder & Schwane, 1989; High & Howley, 1989; Komi, 1986; McGlynn, Laughlin, & Rowe, 1979). In favor of ballistic stretching is the fact that it increases flexibility as much as (De Vries, 1962; Etnyre & Lee, 1987; Hartley-O'Brien, 1980; Holt, Travis, & Okita, 1970; Sady, Wortman, & Blanke, 1982) or more effectively than static stretching (Weber & Kraus, 1949). It also mimics segments of many motor patterns (Hardy & Jones, 1986) such as the initiation of a jump (Komi, 1986), thus providing specificity of training. It is conceivable that recommendations contraindicating ballistic stretching are unwarranted.

The time course and the extent of DOMS in the present study are similar to previous reports (Armstrong, 1986; Ebbeling & Clarkson, 1989). Donnelly, McCormick,
Maughan, Whiting, and Clarkson (1988) observed mean soreness scores of approximately 2.3 on a 1–10 scale, 24 hours after 30 min of downhill running. Clarkson et al. (1986) had subjects perform eccentric exercise with the upper extremity using pulley weights and reported small but significant increases, on a 1–10 scale, in forearm extensors (approximately 3) and wrist flexors (approximately 4) 24 hours after exercise.

The small (62%) but significant elevations in CK observed at 24 hours (see Figure 2) are consistent with previous reports (Clarkson et al., 1986; Tiidus & Ianuzzo, 1983; Triffletti et al., 1988) where CK values were also significantly elevated at 24 hours after negatively biased exercise in association with DOMS. Although CK is frequently used as an indirect marker of muscle damage, the mechanism for the increase in circulating levels is unclear (Armstrong, 1986; Ebbeling & Clarkson, 1989; Stauber, 1989). Furthermore, increases in CK do not correlate with the intensity of DOMS (Ebbeling & Clarkson, 1989).

The sensation of DOMS is associated with microtrauma to connective and/or contractile tissue (Armstrong, 1986; Ebbeling & Clarkson, 1989; Stauber, 1989). However, after one bout of unaccustomed eccentricity, muscle is more resistant to damage, suggesting a rapid training effect (Clarkson & Tremblay, 1988). Few studies have investigated the role of unaccustomed stretching in the production of DOMS and associated changes, as well as possible adaptations. It is suggested that future studies examine responses to various stretching techniques, possibly using more vigorous stretches and focusing on fewer muscle groups such as the hamstrings and quadriceps muscles.

References


Tiidus, P. M., & Ianuzzo, C. D. (1983). Effects of intensity and duration of muscular exercise on delayed soreness and

