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Research Quarterly for Exercise and Sport; Dec 2001; 72, 4; Health Module
pg. 415

Acute Ballistic Muscle Stretching Inhibits Maximal Strength Performance
Arnold G Nelson and Joke Kokkonen

Key words: concentric contraction, flexibility, strength loss, warm up

In the December 1998 issue of Research Quarterly for Exercise and Sport, we presented data showing that acute static stretching of the hip, thigh, and calf muscles before the performance of a one-repetition maximum lift (IRM) resulted in a decreased IRM for both knee flexion and knee extension (Kokkonen, Nelson, & Cornwell, 1998). Since then, we have had the opportunity to engage in dialogue with many individuals who were interested in discussing the implications and mechanisms that accompanied our finding. The foremost question has dealt with the type of stretching activity used in the study. Because static stretching was used, many people asked if the negative impact of stretching was present following ballistic stretching. Unfortunately, we could not answer this question with any precision. In the Kokkonen et al. (1998) study, the issue of ballistic stretching had been avoided, because most exercise physiology textbooks recommend against doing ballistic stretching (see deVries & Housh, 1994; Foss & Keteyian, 1998; Plowman & Smith, 1997; Powers & Howley, 2001; Robergs & Roberts, 1997). The basis behind these recommendations is that ballistic stretching increases the chance of muscle injury, because the athlete is trying to lengthen the muscle while the myotatic reflex is contract-

Submitted: April 4, 2000
Accepted: March 27, 2001

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Method

Participants

Participants in the study consisted of 11 female and 11 male college students enrolled in professional physical education classes who were not engaged in any regular or organized stretching or weight lifting activity. Descriptive characteristics of the participants are tabulated in Table 1. None of the individuals were aware of the results of the previous study (Kokkonen et al., 1998). Moreover, when asked, “Yes or no, is stretching before doing a 1RM test beneficial?” all the individuals replied, “yes.” Approval from the appropriate institutional review board and both written and oral consents from each individual were obtained before the experiment commenced.

Experimental Protocol

The experimental protocol followed the exact protocol used by Kokkonen et al. (1998). Each participant did a 1RM prone-knee flexion and a 1RM seated knee extension on 2 successive days. On each day, one of two treatments preceded the pair of flexion and extension 1RM lifts. The two treatments were either 10 min of quiet sitting (NS), or 20 min of active and passive ballistic stretching of the hip, thigh, and calf muscle groups (ST). NS and ST were assigned at random so that half the participants did NS on the first testing day, and the other half performed ST on the first testing day. To ascertain whether alterations in joint range of motion occurred following either NS or ST, each participant did a sit-and-reach test on an Acuflex I sit-and-reach box (Novel Products, Rockton, IL) before and after each treatment. Thus, when the participants entered the laboratory on each testing day, they did the following activities in order: Sit-and-Reach Test #1, NS or ST, Sit-and-Reach Test #2, knee-flexion 1RM, 10–15-min rest, knee-extension 1RM.

Stretching Protocol

The ST stretching program consisted of five different ballistic stretching activities designed to stretch all the major muscles involved in knee flexion and extension. Again, the activities used were the same ones used by Kokkonen et al. (1998). A sit-and-reach was the first stretching exercise. The participants sat on the floor with their legs extended and then lowered their head toward their knees. The second activity was the lotus stretch. Here, the participants first sat on the floor in the lotus position, with the soles of their feet touching, and then lowered their head to the floor. For the third activity, the heel cord stretch was performed. To do this, the participants first stood with one foot flat on the floor and the other foot placed on a block so that the ball of the foot was 10 cm above the heel. The participants would then lean forward until they achieved maximum dorsiflexion and felt noticeable tension in their calf. The fourth exercise was a standing half lotus. While standing with one foot flat on the floor, the participants placed the opposite leg in a lotus position on a table. They would then alternate lowering their head toward either the foot or the knee of the leg resting on the table. The fifth and final exercise was a quadriceps stretch. The participants stood with their back to a pommel horse and then placed the dorsal surface of one foot on the pommel horse by flexing at the knee joint. From this position, the participants would lean backward.

Each participant did all five stretches three times unassisted and three times assisted. They completed the three repetitions (unassisted or assisted) of a specific exercise before doing another exercise. After performing the five exercises unassisted, participants did the exercises again in the same order but with assistance from an investigator. For each of the unassisted exercises, the participant would assume the appropriate position and then lean or lower as far as possible, placing the musculature on stretch. Within 2 s after feeling the stretch, the person would begin to bob up and down about once per second for a total of 15 s. After the 15 s of bobbing, the person would relax for 15 s and then repeat the activity two more times with a 15-s recovery period between each 15 s of stretching. Each participant was requested to keep the joint angular displacements of each bob at approximately 2–5°, with the desired amount of displacement displayed by the experimenter before commencing the activity. Participants performed the assisted activities in the same manner and for the same length of time as the unassisted; however, for the assisted condition an experimenter would push the person until the participant verbally acknowledged that the stretch was at the pain threshold. The experimenter would then immediately move the participant’s joint back and forth once each second through approximately 2–5° of angular displacement for 15 s. The stretching exercises

<table>
<thead>
<tr>
<th>Table 1. Participants’ descriptive characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>--------</td>
</tr>
<tr>
<td>Age (years)</td>
</tr>
<tr>
<td>Height (cm)</td>
</tr>
<tr>
<td>Weight (kg)</td>
</tr>
<tr>
<td>Sit-and-reach (cm)</td>
</tr>
<tr>
<td>Knee-flexion 1RM (N)</td>
</tr>
<tr>
<td>Knee-extension 1RM (N)</td>
</tr>
</tbody>
</table>

Note. \(M = \) mean; \(SE = \) standard error.

\(^a\)Values are the average of both pre-NS (no stretching) and pre-ST (stretching) measures.

\(^b\)Values represent measurements made under control (NS) conditions.
were usually completed in 20 min. Following the stretching bout, the participant would relax for 10 min before repeating the sit-and-reach test.

**One Repetition Maximum Protocol**

The knee-flexion 1RM was done in the prone position using the same Nautilus knee-flexion machine (Nautilus, Ocala, FL) and protocol in the (Kokkonen et al., 1998) study. Before the test, the participants would move the device unweighted until their legs were straight. Lines marking this position were placed on both the stationary and moving parts of the machine, and subsequent lifts were not deemed complete until these marks were in alignment. The initial weight was set at 134 N (30 lb.) for women. The weight was then increased to 223 N (50 lb.), followed by 267 N (60 lb.), and 312 N (70 lb.). After the participant lifted 312 N successfully, the weight was increased in 22 N (5 lb.) increments until the participant failed to complete a lift. At this point, the load was decreased by 11 N (2.5 lb.), and the participant performed a final attempt. For the men, the initial weight was 223 N (50 lb.). The weight was then increased to 356 N (80 lb.), followed by 445 N (100 lb.), and 490 N (110 lb.). After 490 N, the weight was incremented by 45 N (10 lb.) until 623 N (140 lb.) was reached. After 623 N, the weight was incremented by 22 N (5 lb.) until the participant failed to complete a lift. The load was then decreased by 11 N (2.5 lb.), and the participant performed a final attempt. For both the women and men, a 1-min rest was instituted among all lifts.

The knee-extension 1RM test followed a protocol similar to the knee extension. The test, however, was done in a seated position on a Nautilus knee-extension machine using the same machine as in Kokkonen et al. (1998) study. The initial four weights for the women were 223 N (50 lb.), 356 N (80 lb.), 445 N (100 lb.), and 490 N (110 lb.). After 490 N, the incremental increases were set at 22 N (5 lb.). The men first lifted, in order, 356 N (80 lb.), 554 (120 lb.), 668 N (150 lb.), and 757 N (170 lb.). After 757 N, the weight was incremented by 45 N (10 lb.) up to 979 N (229 lb.), and then successive increments of 22 N (5 lb.) were applied. For all 1RM tests, the participants were not unaware of the progression outlined above, nor were they allowed to visually detect the load for each lift. Knowledge of individual or overall performances was not provided until the end of the study.

**Statistics**

The 1RM measurements and the sit-and-reach tests were analyzed using paired t tests. The level of significance was set at $p < .05$.

**Results**

Changes in flexibility due to the ST and NS treatments were substantiated through the sit-and-reach tests. The ST exercises altered sit-and-reach performance such that the poststretching sit-and-reach scores were significantly, $t(21) = 8.11$, $p < .05$, $\omega^2 = .75$, increased 9% over the initial sit-and-reach scores (see Table 2). The NS did not have a significant effect on sit-and-reach performance, $t(21) = 1.06$, $p > .05$.

Results of the knee-flexion 1RM and the knee-extension 1RM are presented in Table 3. Following the ST treatment, the average knee-flexion 1RM was significantly less, $t(21) = 7.11$, $p < .05$ $\omega^2 = .69$, than the NS average knee-flexion 1RM (average decline = 7.5%). Likewise, the ST program had a negative influence on knee-extension 1RM. The knee-extension 1RM following ST was on average a significant, $t(21) = 7.85$, $p < .05$ $\omega^2 = .73$, 5.6% less than the 1RM following NS.

**Discussion**

It was the purpose of the present investigation to determine the effect of acute ballistic muscle stretching on maximal strength performance. The main finding was that a significant decrease in 1RM performance for both knee flexion and knee extension occurred following an acute ballistic stretching treatment. These results are similar to the

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**Table 2. The effects of ballistic stretching on sit-and-reach test**

<table>
<thead>
<tr>
<th>Group</th>
<th>Pre M</th>
<th>SE</th>
<th>Post M</th>
<th>SE</th>
<th>Mean difference M</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>NS (cm)</td>
<td>38.0</td>
<td>1.2</td>
<td>38.1</td>
<td>1.2</td>
<td>0.1</td>
<td>0.2</td>
</tr>
<tr>
<td>ST (cm)</td>
<td>38.5</td>
<td>1.2</td>
<td>42.0</td>
<td>1.0</td>
<td>3.5</td>
<td>0.4</td>
</tr>
</tbody>
</table>

Note. M = mean; SE = standard error; NS = no stretching; ST = stretching. 'Significant difference, $p < .05$.

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**Table 3. The effects of ballistic stretching on knee-flexion and knee-extension 1RM**

<table>
<thead>
<tr>
<th>Type of lift</th>
<th>NS</th>
<th>SE</th>
<th>ST</th>
<th>SE</th>
<th>Mean difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee flexion (N)</td>
<td>595</td>
<td>39</td>
<td>552</td>
<td>37</td>
<td>43</td>
</tr>
<tr>
<td>Knee extension (N)</td>
<td>917</td>
<td>60</td>
<td>869</td>
<td>58</td>
<td>48</td>
</tr>
</tbody>
</table>

Note. NS = no stretching; ST = stretching; M = mean; SE = standard error. 'Significant difference, $p < .05$. |
effect of static stretching reported by others (Fowles, Sale, & MacDougall, 2000; Kokkonen et al., 1998; Nelson, Allen, Cornwall, & Kokkonen, 2001). Therefore, it appears that regimens of acute static or ballistic stretching can inhibit the maximal strength of the knee flexors and extensors.

Unfortunately, this study does not provide any further insights into the mechanisms behind the stretch-induced strength decrement. The ST treatment might have influenced maximal strength through either mechanical (i.e., a reduction in either the passive or active stiffness of the musculotendinous unit), or neurological (i.e., autogenic inhibition of a muscle) mechanisms. As pointed out by Kokkonen et al. (1998), Wilson, Murphy, and Pryor (1994) suggested that a stiff musculotendinous system allows for an improved force production by the contractile component. They provided evidence to support this suggestion by showing that concentric performance in the bench press was significantly related to musculotendinous stiffness. Moreover, the results of several studies (Magnusson, Simonsen, Aagaard, & Kjaer, 1996; Rosenbaum & Hennig, 1995; Taylor et al., 1990) indicated that the musculotendinous unit becomes less stiff as a result of acute stretching. In addition, Magnusson, Aagaard, Simonsen, and Bojesen-Moller (1998) showed no difference between static and ballistic stretching on flexibility, joint range of motion, and resistance to stretch. Therefore, the mechanical explanation for the loss of strength cannot be discounted and might even be the same for both stretching techniques.

Several researchers (Thigpen, Moritani, Thiebaud, & Hargis, 1985; Vujnovich, & Dawson, 1994; Avela, Kyrolainen, & Komi, 1999) reported that the Hoffman reflex (H reflex) remained depressed after doing static stretching. This depressed H reflex supports the neurological explanation for stretch-induced compromise in force production. As Plowman and Smith (1997) pointed out, static and ballistic stretching activities use different neurological mechanisms to produce the autogenic inhibition. Ballistic stretching uses the myotatic reflex, and static stretching uses the inverse myotatic reflex. Because static and ballistic stretching use different neurological mechanisms to produce the autogenic inhibition, it had been hoped that this study would provide clues to the role of neurological factors in inducing the strength decrement. Because the relative force decrements seen between the two studies are similar (static knee-flexion decline = 7.3% vs. ballistic knee-flexion decline = 7.5%; static knee-extension decline = 8.1% vs. ballistic knee-extension decline = 5.6%), no new insights into the neurological factors were manifest. Recent work by Fowles et al. (2000), however, suggested that both neurological and mechanical factors could be present. Fowles et al. found that a poststretching force decrement persisted in the plantar flexors for 60 min. Their data indicated that the strength decrement was a result of impaired activation (neurological factors) and contractile force (mechanical factors) during the early phase (0–15 s poststretch) and impaired contractile force throughout the duration of the deficit.

In conclusion, this study iterates that maximal knee-flexion and extension 1RM can be reduced by engaging in a thorough bout of acute stretching. Further, it suggests that this force decrement is independent of the type of stretching activity. Unfortunately, further work is required to establish the exact mechanism or mechanisms responsible for this relationship, and, until more mechanistic information is obtained, it is suggested that intense stretching of muscles should not be undertaken just before any event in which success is related to maximal strength output.

References


**Authors’ Note**

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