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Acute Effects of Stretching Are Not Evident in the Kinematics of the Vertical Jump

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ABSTRACT

The acute effect of stretching on the kinematics of the vertical jump was investigated in a sample of 20 young adults. Sagittal plane videography (60 Hz) was used to measure the kinematics of vertical jumps after 2 warm-up routines, control and stretching. Subjects were tested on 2 occasions with warm-up routine randomized. There were no significant changes in vertical velocity, knee angle, or the durations of the eccentric and concentric phases as a result of stretching despite good statistical power for the tests. Fifty-five percent of the subjects had lower vertical velocities (−7.5%) after stretching, while 45 percent of the subjects had no change (10%) or higher vertical (35%) velocities (2.4%) after stretching. Stretching prior to stretch-shortening cycle activities like the vertical jump results in small decreases in performance in some subjects, but the nonsignificant biomechanical changes suggest that neuromuscular inhibition may be the mechanism rather than changes in muscle stiffness.

Key Words: warm-up, static stretch, flexibility, stretch-shortening cycle

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Introduction

Stretching during the warm-up has become a traditional practice in preparing for exercise or athletic events (3). It is believed that stretching is effective in improving performance. This practice may be contraindicated in some activities because there is little scientific evidence to support the performance benefits of stretching (8, 12, 14). Recent research has begun to demonstrate that stretching prior to physical activity decreases performance. This effect has been observed in studies of animal models (1, 18) and studies of human isometric strength expression (2, 7, 16, 23) and dynamic movement (6, 10, 20).

The mechanism of this decrease in performance is controversial and may be due to short-term decreases in activation, muscle stiffness, and reflex sensitivity (2, 5, 20, 25). The study by Nelson et al. (20) demonstrated that stretching prior to static jumps (SJ) and countermovement jumps (CMJ) significantly decreased performance in both by 4%. The similar decrease in the SJ and CMJ following stretching suggests that stretching did not affect the stiffness or storage and utilization elastic energy in the leg musculature.

A study of the changes in the biomechanics of CMJ resulting from stretching might provide information on the mechanism of the acute inhibition of performance typically seen after stretching. The purpose of this study was to measure acute changes in kinematic variables related to stretch-shortening cycle (SSC) muscle actions as a result of stretching during warm-up. Specifically, we were interested in the overall response of a variety of physically active adults rather than specific athletic subgroups. Previous studies have used homogeneous groups studied on a single day, so it was desirable to document the effect of stretching on a more generalizable sample displaying a wider range of biomechanical performance.

Methods

Twenty active young adult volunteers gave informed consent to participate in the study. The sample included 10 males and 10 females with a mean (*SD*) age of 23.7 (4.5) years. The mean (*SD*) heights and masses of the males and females were 1.76 (0.04) m, 85.7 (9.7) kg, and 1.64 (0.05) m, 62.4 (5.2) kg, respectively. The sample was selected to be as heterogeneous as possible ranging from intercollegiate athletes to moderately active young adults. Subjects were informed that the study dealt with the effects of 2 warm-up routines on vertical jump performance and were verbally encouraged to jump as vigorously as possible in both conditions.

The experimental protocol consisted of 2 tests sessions scheduled a week apart. This allowed testing to be conducted at a similar time of day, with similar subject activity prior to testing, and also insured that jumping biomechanics had not changed (9). Sagittal plane video (60 Hz) of three CMJ's with hand on hips for each subject were collected after 1 of 2 warm-up routines, control (C) and stretching (S). The order of the warm-up routines was randomly selected for each subject. All routines began with the taping of 13-mm-diameter retroreflective markers to the fifth metatarsal, lateral malleolus, lateral epicondyle of the femur, greater trochanter, and the acromion process.

After marker placement the subjects rode a Lifecycle (Irvine, CA) at resistance setting 1 (80 rpm) for 3 minutes and then performed 3 practice vertical jumps. In the S routine subjects performed 3 sets of stretching exercises, with each exercise held for 3 15-second repetitions. The stretches included a seated bilateral hamstring stretch, standing unilateral quadricep stretches, and standing unilateral calf stretches. Quadricep and calf stretches were performed one leg at a time. Stretching was supervised by a certified athletic trainer with subjects subjectively selecting the holding point of each static stretch at the point ''just before discomfort'' (13). In the C routine the subjects sat and rested for 10 minutes. The timing of both routines was 10 minutes and was modeled after a recent study (16).

Videotapes of all the subject's jumps were digitized from 5 frames before the countermovment to 5 frames after take-off with the Peak Motus 4.3 videography system (Peak Performance Technologies, Englewood, CO). Kinematic data were smoothed with a digital filter with optimal cutoff frequencies selected by the technique of Jackson (11). The kinematics of a 4-segment rigid body model were calculated, and anthropometric data (22) were used to calculate the whole body center of gravity.

Several biomechanical variables have been used to document the potential benefit of stored elastic energy in SSC movements (4). The dependent variables selected were the peak vertical velocity of the center of mass prior to take-off (V_P), deepest knee flexion (θ_K), and the durations of the eccentric and concentric phases (t_E and t_C) of the jump. These variables were selected to document an overall measure of performance (V_P) and several linear and angular measures (θ_K, t_E, t_C) related to the SSC in vertical jumping. If stretching were to decrease muscle-tendon unit (MTU) stiffness, it is likely that the duration of the concentric and eccentric phases would increase and deepest knee flexion would decrease. These kinematic variables have also been observed to be quite consistent within subjects (15) so that small changes as a result of stretching might be detectable. The durations of the eccentric and concentric phases were operationally defined relative to motion of the body center of mass from initial downward movement (at least 7 mm) to the lowest position, and from the lowest position to take-off.

The mean of the dependent variables from the three jumps of each subject in each warm-up condition (S and C) were calculated for statistical analysis. The effect of stretching on the 4 dependent variables was examined by a MANOVA with repeated measures, and significance was accepted at the 0.05 level. Main effects of individual dependent variables were examined by dependent *t*-tests.

Table 1. Mean (*SD*) kinematic variables in the vertical jump.*

	Control	Stretching	Difference
V_P (m/s)	2.36 (0.18)	2.29 ± (0.26)	−0.07 (0.20)
t_E (s)	0.546 (0.163)	0.548 (0.222)	0.002 (0.159)
t_C (s)	0.295 (0.058)	0.293 ± (0.074)	0.002 (0.051)
θ_K (deg)	81.7 (10.8)	81.4 ± (15.3)	−0.4 (9.5)

* Peak vertical velocity = V_P, duration of eccentric phase = t_E, duration of concentric phase = t_C, smallest knee angle = θ_K, difference = stretching − control.

Results

The MANOVA demonstrated a nonsignificant ($F_{1,19}$ = 1.39, p = 0.25) effect of stretching on the dependent variables. The mean kinematic data are reported in Table 1. A dependent *t*-test showed that the S routine resulted in a (t_{19} = −1.59, p = 0.13) trend of reduced mean peak vertical velocity (3%) of the center of mass (V_P) compared to the C routine. The effect of the S routine was not uniform across subjects with 55% of the subjects having a mean decrease in V_P (−7.5%) after stretching. The remaining subjects had no change (10%) or an increase (35%) in V_P after stretching (+2.4%). The changes in V_P, however, were uniform across jumping ability, indicating that stretching had similar effects on both the better and poorer jumpers.

This nonsignificant mean decrease (−3%) in performance after stretching is consistent with the usually small (4–8%) decreases in performance observed after stretching in studies of human muscular performance (5, 16, 20, 23). A previous study has shown that extensive stretching (14 stretches) creates significant decreases in strength that persist for up to 60 minutes (7).

Discussion

The overall nonsignificant effect of stretching on mean change V_P in the present study could be due to the more heterogeneous sample, individual differences in stretching intensity, and greater intrasubject variability in CMJ performance on different days. Previous studies of the acute effects of stretching performed all tests in a single session, risking learning, sequence, and fatigue effects in order to obtain control over day-to-day variations in performance. It should be noted that this small and mixed response is likely the effect that can be expected in the real world with self-administered stretching prior to physical activity. The small effect of stretching on performance in the present study may be physically significant because of a reverse placebo effect. Most all of our subjects would have expected to perform better after stretching because the adverse effects of stretching in warm-up are not known in the general public.

There were nonsignificant differences in kinematic variables related to coordination and muscle stiffness in SSC activities (t_E, t_C, and θ_K) as a result of the S routine. Statistical power was strong (>0.85) for detecting a 5% difference in all dependent variables except for t_E. The duration of the eccentric phase (t_E) was much more variable than the other kinematic variables and created the low statistical power.

If stretching were to decrease the stiffness of the muscles of the lower extremity, jumpers could be expected to have lower angles of knee flexion and elongated durations of eccentric and concentric action. The present study demonstrated that these subjects did not significantly change jumping kinematics that would be consistent with changes in stiffness of the leg musculature. Studies of the acute effect of stretching on MTU stiffness have been conflicting (14) and suffer from methodological problems (17). These observations combined with recent studies of the acute neural inhibition from stretching (2, 26) suggest that changes in muscle stiffness immediately following stretching is not primarily responsible for decreased performance. Future studies should combine electromyogram, kinematic, and kinetic data in an attempt to determine the mechanism of the detrimental effects of stretching on muscular performance.

Generalized muscle activity in warm-up, however, is very important to increase muscle temperature that has been shown to decrease MTU stiffness, increasing the maximum strain and stress the MTU can resist before injury (21, 24). Research that has examined both stretching and active warm-up in combination demonstrates that the decrease in MTU stiffness is primarily related to increased muscle temperature and not the effect of stretching (19, 23). More research on the acute effect of stretching on the MTU and dynamic athletic performance is clearly needed.

Practical Applications

Stretching in the warm-up for dynamic physical activity may be counterproductive to CMJ performance for most physically active young people. Most of the subjects in the present study (55%) decreased jumping performance by 7.5% following stretching although the group mean difference (−3%) was not significant. There were no differences in the biomechanics of the jumping performances that would indicate that stretching decreased the stiffness of the muscles. Stretching in the warm-up for sports using vertical jumps is likely to result in a small decrease in performance for most jumpers and further research into the mechanism of this decrease is needed.

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