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Original Paper

The acute effect of two stretching techniques on isometric peak torque of the hamstring and quadriceps muscles

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Abstract

The purposes of this study were: 1) to determine the effect of two stretching techniques on isometric peak torque of the quadriceps femoris and hamstring muscles, and 2) to compare the effect of static stretching and the hold-relax stretching technique on isometric peak torque of these two muscle groups. Thirty healthy volunteer students (15 male and 15 female) were recruited to participate in this study. Isometric peak torque was measured using a Myoret RZ450 dynamometer (Kawasaki Heavy Industries, Ltd.) from the hamstring and quadriceps femoris muscle groups. Each subject participated in isometric peak torque measurements of hamstring and quadriceps femoris muscles under three conditions, without prior stretching, after static stretching, and after hold-relax stretching. Pairwise comparisons using Bonferroni adjustment for multiple comparisons revealed a significant difference ($p < 0.001$) between isometric peak torque without prior stretching and after static or hold-relax stretching for both knee extension and flexion. A significant difference was also found between isometric peak torque after static and hold-relax stretching for knee flexion ($p < 0.001$), but not for knee extension ($p > 0.05$). Previous studies have shown that even after a few weeks of stretching exercise, muscle peak torque improves significantly. However, the results of this study suggest that muscle stretching should not be performed immediately prior to a movement requiring maximal force output.

Key words: stretching, peak torque, hold-relax

Introduction

Athletes and nonathletes preparing for strenuous exercise are advised to perform stretching activities as part of the 'warm-up' (Arnheim et al., 2000). The main reasons cited for pre-exercise stretching are to improve flexibility (Shellock et al., 1985) and prevent sports-related injuries (Wilson et al., 1991). Some researchers have reported the effect of stretching on muscle peak torque, a major component of athletic success. Worrell et al. (1994) found an increase in hamstring peak torque after a three week static and contract-relax stretching program. Wilson et al. (1992) reported that initial concentric work on the bench press was significantly increased after an eight week stretching program. However, only two studies have attempted to establish the influence of stretching immediately prior to maximal performance, on muscle peak torque. DeVries (1963) found that stretching before a 100-yard run did not improve run time. Kokkonen et al. (1998) investigated whether a stretching program that included active and passive stretching of the muscles around the hip, thigh, and lower leg for 20 minutes would alter the performance of a one-repetition maximum lift (1RM). They reported that both knee-flexion and knee-extension force, measured by the 1RM, were significantly decreased after the stretching exercises. The elapsed time between the stretching program and commencement of exercise was, however, not a measured variable. Therefore, it is difficult to determine the exact effect of acute stretching on muscle peak torque. In addition, the stretching technique or techniques responsible for the adverse performance cannot be elucidated from the methodology.

Two stretching techniques recommended in the literature are static and Proprioceptive Neuromuscular Facilitation (PNF) stretching (Arnheim et al., 2000). Static stretching involves passively applying a stretch to the muscle and holding it in that position for a short period of time. It is the kind of stretching that individuals can easily perform on themselves. PNF stretching is composed of many different techniques and it's origin lies within the physical therapy profession (Voss et al., 1985). The hold-relax PNF stretching technique (HR) involves an isometric contraction of the agonist muscle followed by the application of passive stretch to the same muscle. Although this technique is usually performed on a person by a trained individual, it is possible to perform this technique on oneself. Interestingly, the authors of the PNF manual (Voss et al., 1985) state "That muscle responds with greater force after stretch has been superimposed is a fact of physiology". Certainly, the work of Kokonen et al. (1998) brings this statement into question, although one should remember that when stretching is utilized in PNF as a stimulus to force production, the subjects' subsequent muscle contraction is from the stretched position. Additionally, the stretching protocol employed in Kokonen's study was not a PNF technique.

The purposes of this study were: 1) to determine the effect of two stretching techniques on isometric peak torque of the quadriceps femoris and hamstring muscles, and 2) to compare the effect of static stretching and the hold-relax stretching technique on isometric peak torque of these two muscle groups.

Method

Thirty healthy volunteer students (15 male and 15 female) enrolled in an accredited physical therapy program at the Aino School of Health and Welfare Sciences, Osaka, Japan, were recruited to participate in this study. Prior to participation, all students were provided with an Informed Consent Form to read and sign, in accordance with the guidelines and approved by the Long Island University Institutional Review Board. Students were then screened for evidence of preexisting limitations to exercise (e. g., orthopedic or neurological disorder, uncontrolled asthma). Based upon this exclusion criterion, no potential volunteer was excluded. Study participants were all physically active but not specifically trained on the isometric dynamometer.

Isometric peak torque values were collected on a Myoret RZ450 dynamometer (Kawasaki Heavy Industries, Ltd.) from the hamstring and quadriceps femoris muscle groups. Calibration of the dynamometer was performed before each test session.

Each subject participated in three separate isometric peak torque measurement sessions. The order of sessions was randomly determined. The three test sessions were: 1) no prior stretching, 2) static stretching, and 3) hold-relax stretching. One-day intervals between test sessions were allocated. Subjects underwent an initial practice session at least one day before the first test session to familiarize themselves with the exercise protocol and instrumentation and to have any questions answered. During the practice session, maximal voluntary isometric contractions of the right knee joint were performed, consisting of both flexion and extension movements on the Myoret RZ450 dynamometer. Subjects were asked not to alter their diet or activity levels between tests and also to avoid any intensive lower extremity exercise.

1) The test session — no prior stretch

The subject sat upright in the dynamometer with hips and knees flexed at approximately 90 degrees of flexion. A restraining belt was strapped across the waist to minimize unwanted hip, pelvic girdle, and lower trunk movements. The axis of the lever arm was aligned with the axis of the right knee joint, and the padded cuff of the dynamometer arm was placed just proximal to the malleoli on the posterior surface of the lower leg. The right knee joint alignment with the fulcrum of the lever arm was checked, whereupon straps were applied to stabilize the hip and right lower limb. The subject's arms were positioned across the chest. Knee-flexion isometric peak torque was measured with the subject pressing maximally against a pad on the lever arm located posteriorly to the lower leg. The subject was instructed to perform two maximal isometric contractions and maintain each maximum effort for five seconds. A recovery period of ten seconds between contractions was strictly adhered to. The time periods were monitored directly on a second timer in full view of the participant and investigator. The higher value for peak torque of the two trials was recorded as the value of maximal flexion isometric strength. Five minutes after measurement of the knee-flexion isometric peak torque, knee-extension isometric peak torque was measured with the subject pressing maximally against a pad located on the lever arm anterior to the lower leg. The subject was asked to perform two maximal isometric contractions and maintain each maximum effort for five seconds, with a ten-second-recovery period between contractions. The higher value for peak torque of the two trials was recorded as the value of maximal extension isometric strength. This procedure has been shown to be a reliable method to measure isometric peak torque (Al-Abdulwahad, 1999).

2) The test session — static stretching

The right knee joint was aligned with the fulcrum of the dynamometer lever arm, and the lever arm adjusted so that the padded cuff of the dynamometer arm was just proximal to the malleoli. After preparation of the dynamometer, the subject was instructed to lie supine on a treatment plinth next to the dynamometer. The investigator provided static stretch for 30 seconds to the subject's right hamstring using the straight-leg-raise (SLR) procedure. At least 20 seconds is recommended as the duration of effective static stretching (Pope et al., 2000). The SLR procedure involves the investigator flexing the subject's right hip joint to 90 degrees with the knee bent and then passively extending the knee through the available range of motion to the point where limitation to further movement is felt. After static stretching, the subject quickly assumed the testing position on the dynamometer chair and the knee-flexion peak torque measurement protocol was implemented as described above for the non-stretching session. Using a stopwatch, the time was recorded between termination of the stretching procedure and termination of the isometric peak torque measurement.

After the measurement of knee flexion isometric peak torque, the subject was allowed to rest for five minutes. The subject was then instructed to assume a left side lying position on the plinth. The knee was flexed and the hip was extended passively by the investigator through the available range of motion, to the point where limitation was felt. The investigator held the static stretch to the subject's right quadriceps femoris muscle in this position for 30 seconds. After static stretching, the subject quickly assumed the testing position on the dynamometer chair and the knee-extension peak torque measurement protocol was implemented as described above for the non-stretching session. Using a stopwatch, the time was recorded between termination of the stretching procedure and termination of the isometric peak torque measurement.

3) The test session — hold-relax stretching

The right knee joint was aligned with the fulcrum of the dynamometer lever arm, and the lever arm adjusted so that the padded cuff of the dynamometer arm was just proximal to the malleoli. After preparation of the dynamometer, the subject was instructed to lie supine on a treatment plinth next to the dynamometer. The investigator allowed subjects to bend the knee to ten degrees, at which point the investigator provided an immovable resistance to further knee flexion. The subject was then asked to flex the knee as strongly as possible for five seconds, all the while being resisted by the investigator. After isometric hamstring contraction, the subject was asked to relax as the investigator extended the knee and flexed the hip through the available range of motion to the point where limitation to further movement was felt. The investigator held the leg in this stretched position for ten seconds. This procedure of hamstring contraction and stretching was repeated twice more to total three times in all. After HR stretching, the subject quickly assumed the testing position on the dynamometer chair and the knee-flexion peak torque measurement protocol was implemented as described above for the no prior stretching session. Using a stopwatch, the time was recorded between termination of the contraction/stretching procedure and termination of the isometric peak torque measurement.

After the measurement of knee flexion isometric peak torque, the subject was allowed to rest for five minutes. The subject was then instructed to assume a left side lying position on the plinth. The investigator held the subject's hip in a position of maximal hip extension and maximal knee flexion. The subject was instructed to extend the knee as strongly as possible for five seconds against the immovable resistance provided by the investigator. After isometric contraction of the quadriceps muscle, the subject was asked to relax as the investigator flexed the knee and extended the hip through the available range of motion to the point where limitation to further movement was felt. The investigator held the leg in this stretched position for ten seconds. This procedure of quadriceps contraction and stretch was repeated twice more to total three times in all. After HR stretching, the subject quickly assumed the testing position on the dynamometer chair and the knee-extension peak torque measurement protocol was implemented as described above for the non-stretching session. Using a stopwatch, the time was recorded between termination of the contraction/stretching procedure and termination of the isometric peak torque measurement.

Data analysis

The data were analyzed with the SPSS 10.0 statistical package (SPSS, 1999). The alpha level was set at 0.05. Repeated Measures Analysis of Variance (RMANOVA) was used to identify differences in knee flexion and extension peak torque under the three conditions, namely, no stretching, static stretching, and hold-relax stretching. Post-hoc pairwise comparisons using Bonferroni adjustment for multiple comparisons were implemented to distinguish which groups were significantly different from each other.

Results

The mean age, height, and weight of the subjects are displayed in Table 1. Group means and standard deviations for knee extension peak torque by stretching method are presented in Table 2 and Fig. 1. Group means and standard deviations for knee flexion peak torque by stretching method are presented in Table 3 and Fig. 2 respectively.

Peak torque values were greatest for both knee extension and flexion when neither stretching procedure precedes the muscle contraction. In percentage terms, the mean SS and HR knee extension peak torques decreased by approximately 7.9 percent, and 9.5 percent, respectively, compared to the NS condition. Whereas the mean SS and HR knee

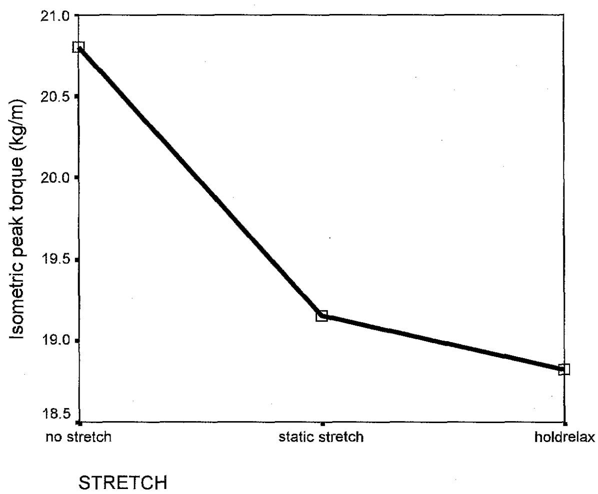

Fig. 1 Knee extension isometric peak torque by stretching method for all subjects (N=30)

Table 1 Mean (Standard deviation) of descriptive variables

Variables	All Participants (n=30)	Males (n=15)	Females (n=15)
Age (yr)	23.47 (2.69)	23.9 (3.0)	23.0 (2.3)
Height (m)	1.62 (0.06)	1.73 (0.49)	1.58 (0.53)
Weight (kg)	62.6 (20.61)	75.6 (22.3)	49.6 (4.6)

Table 2 Mean (Standard deviation) of knee extension peak torque (kg/m)

Variables	All Participants (n=30)	Males (n=15)	Females (n=15)
No prior stretch (NS)	20.8 (8.47)	28.1 (4.69)	13.5 (3.54)
Static stretch (SS)	19.15 (7.95)	25.78 (2.69)	12.53 (3.45)
Hold-relax stretch (HR)	18.83 (7.71)	25.07 (5.18)	12.59 (3.58)

Table 3 Mean (Standard deviation) of knee flexion peak torque (kg/m)

Variables	All Participants (n=30)	Males (n=15)	Females (n=15)
No prior stretch (NS)	8.21 (3.71)	11.24 (2.82)	5.19 (0.99)
Static stretch (SS)	7.24 (3.53)	9.85 (3.17)	4.62 (1.03)
Hold-relax stretch (HR)	6.77 (3.51)	9.34 (3.24)	4.19 (0.93)

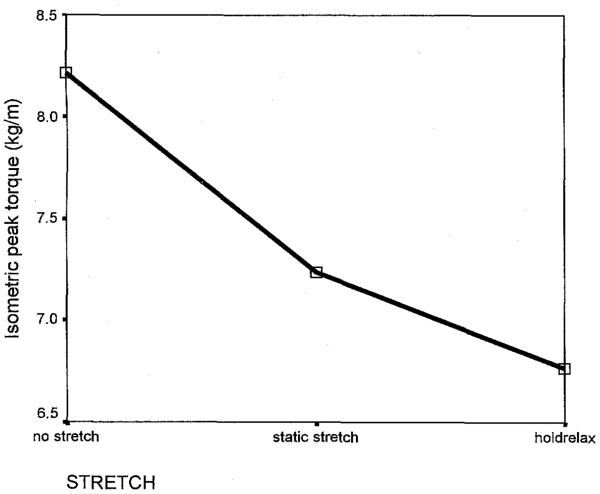

Fig. 2 Knee flexion isometric peak torque by stretching method for all subjects (N=30)

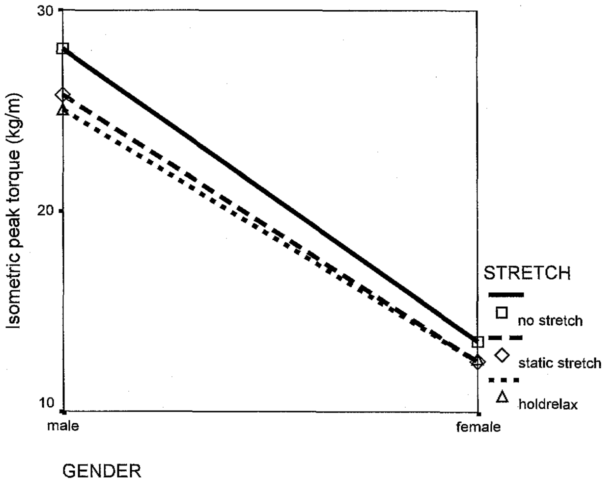

Fig. 3 Knee extension isometric peak torque by gender

flexion peak torques decreased by approximately 11.8 percent and 17.5 percent respectively compared to the NS condition.

The RMANOVA procedure revealed a significant main effect for both knee extension and flexion peak torque ($p < 0.001$). Between subject effects for gender were also significant for both knee extension and flexion peak torque ($p < 0.001$). Pairwise comparisons using Bonferroni adjustment for multiple comparisons revealed a significant difference ($p < 0.001$) between NS and SS or HR for both knee extension and flexion. A significant difference was also found between SS and HR peak torque for knee flexion ($p < 0.001$), but not for knee extension ($p > 0.05$).

A significant disordinal interaction (Fig. 3) was noted for group by gender for knee extension ($p < 0.001$) and a significant ordinal interaction (Fig. 4) for knee flexion peak torque ($p < 0.05$). Univariate ANOVA with pairwise comparisons using Bonferroni adjustment for multiple comparisons revealed a significant difference ($p < 0.001$) for males between NS and SS or HR for knee extension. No significant difference ($p > 0.05$) was found for males between SS and HR peak torque for knee extension. A significant difference for females was found between NS and SS ($p < 0.05$), and between NS and HR ($p = 0.001$) for knee extension. No significant difference ($p > 0.05$) was noted for females between SS and HR peak torque for knee extension. A significant difference was observed for males between NS and SS ($p = 0.001$), and between NS and HR ($p < 0.001$) for knee flexion. No significant difference was found for males between SS and HR peak torque for knee flexion ($p > 0.05$). A significant difference for females was found not only between NS and SS ($p < 0.05$), and between NS and HR ($p = 0.001$) for knee flexion, but also between SS and HR ($p < 0.001$).

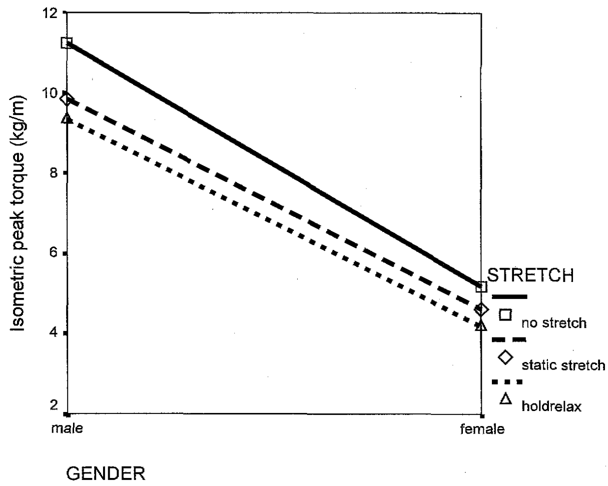

Fig. 4 Knee flexion isometric peak torque by gender

The means and standard deviations of the time from the termination of the stretching procedure to the completion of the isometric peak torque measurements were 42 seconds (5.1 seconds) for SS and 43 seconds (3.9 seconds) for HR.

Discussion

The purpose of this study was to determine the effect of two stretching techniques on muscle isometric peak torque and also to compare the two stretching techniques. This was achieved by measuring isometric peak torque of two antagonistic muscles surrounding the knee under three conditions: no prior stretching, after static stretching, and after hold-relax stretching. The main finding was that measured against isometric peak torque with no prior stretching, both stretching methods produced a significant reduction in the isometric peak torque of the two muscle groups studied. Hypotheses one through four are therefore rejected.

Comparing the two stretching techniques for knee extension, no significant difference in quadriceps isometric peak torque was noted between the two stretching techniques. The same was not true for knee flexion, where hamstring isometric peak torque was found to decrease significantly more after the HR stretch than after SS. Therefore, the fifth hypothesis is supported and the sixth hypothesis is rejected.

The findings of this study were in agreement with the work of Kokkonen et al. (1998) and DeVries (1963). The magnitudes of strength deficits reported after the static stretch protocol for hamstrings (7.3%) and quadriceps (8.1%) in Kokkonen's study are comparable to our static stretch deficits for hamstrings (11.8%) and quadriceps (7.9%).

The significant effect of gender was expected as muscle strength disparity between the sexes is well recognized and therefore was not a primary consideration. Nevertheless, it is noted (Tables 2 and 3) that the male mean peak torque values for both quadriceps and hamstrings were approximately double those of the females. The significant interaction between gender and the stretching variable points to a difference not only between the sexes, but also in the way their performance varied among the three stretching groups. This was an unexpected finding. The females actually did marginally worse after SS than after HR in knee extension, although this result 'washed out' when the male and female scores were pooled. In knee flexion for females and in flexion and extension for males, HR stretching reduced maximal isometric peak torque more than SS, although only in female knee flexion was this difference significant.

It is impossible to draw a general conclusion from this study as to whether the PNF hold-relax technique will reduce maximal muscle strength more than static stretching. For some unknown reason, the two muscles studied performed differently under the two stretching conditions between the sexes.

The mean times from the cessation of stretch to the completion of the measurement of peak torque were well within the target of one minute that had been hoped for (42 seconds for SS and 43 seconds for HR). The rationale for this stringency was that it appeared from the 'warm-up' literature that the effects of stretching are time-dependent and also because one often sees athletes stretching immediately prior to maximal effort. The small standard deviations, 5.1 seconds for SS and 3.9 seconds for HR, attest to the fact that with small variances in time between stretching and strength testing among the study participants, any time effects would affect everyone uniformly.

Conclusion

Both stretching techniques performed just prior to maximal isometric muscle contraction significantly decreased the muscle peak torque of the two muscles studied. No difference in quadriceps isometric peak torque was noted between the two stretching techniques. Hamstring isometric peak torque was found to decrease significantly more after the HR stretch than after SS for females but not for males.

Undoubtedly, flexibility is a prerequisite to normal movement and athletic activities, especially in those sports that rely on extremes of joint range of motion for superior performance (Shellock et al., 1985). Studies have shown that even after a few weeks of stretching exercises, muscle peak torque improves significantly (Worrell et al., 1994; Wilson et al., 1992). However, the results of this study supported by the findings of Kokonen et al. (1998), suggest that muscle stretching should not be performed immediately prior to a movement requiring maximal force output.

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