ACUTE EFFECT OF LOW-INTENSITY ECCENTRIC EXERCISE ON ANGLE OF PEAK TORQUE IN SUBJECTS WITH DECREASED HAMSTRING FLEXIBILITY

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ABSTRACT

Background: Decreased hamstring flexibility and the angle of peak torque (APT) occurring at a shorter muscle length are considered risk factors for hamstring strain injury. Subjects with decreased hamstring flexibility have an APT that occurs at a shorter muscle length; hence, the susceptibility to hamstring strain injury could be associated with the APT occurring at a shorter muscle length. Low-intensity eccentric exercise (ECC-Ex) may reduce hamstring strain injury risk in the subjects with decreased hamstring flexibility by allowing the APT to occur at a longer muscle length. However, the acute effect of low-intensity ECC-Ex on the subjects with decreased hamstring flexibility has not been established.

Hypothesis/Purpose: The purpose of this study was to investigate the acute effect of low-intensity ECC-Ex on the peak torque, APT, and hip flexion angle in the subjects with decreased hamstring flexibility. The authors hypothesized that low-intensity ECC-Ex would shift the APT, allowing it to occur at a longer muscle length with a minimum decrease of peak torque and hip flexion angle in the subjects with decreased hamstring flexibility.

Study design: Case-control study

Methods: Twelve male college students were categorized into normal group [$n = 6$ (12 legs)] and decreased hamstring flexibility group [$n = 6$ (12 legs)] based on the median value of the baseline hip flexion angle (i.e., 80.8°) measured by passive straight leg raise test. Peak torque and APT during maximal voluntary eccentric knee flexion (via isokinetic dynamometer) and hip flexion angle were evaluated before and after the low-intensity ECC-Ex in both groups.

Results: Low-intensity ECC-Ex shifted the APT, causing it to occur at a longer muscle length in the decreased hamstring flexibility group. Low-intensity ECC-Ex increased the hip flexion angle and did not change the peak torque in both groups.

Conclusion: The results of the present study demonstrated that low-intensity ECC-Ex shifts the APT to occur at a longer muscle length and increases the hip flexion angle without a decrease in peak torque in the subjects with the decreased hamstring flexibility.

Level of Evidence: 3b

Keywords: Angle of peak torque, flexibility, hamstring strain injury, low-intensity eccentric exercise

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INTRODUCTION

The angle of peak torque (APT) has been identified as a risk factor for hamstring strain injury.^{1,2} APT occurring at a shorter muscle length may be associated with susceptibility to exercise-induced muscle damage,³ and the APT in an injured hamstring is observed at a shorter muscle length.⁴ Accordingly, APT occurring at a shorter muscle length is considered a hamstring strain injury and re-injury risk. Decreased hamstring flexibility (e.g., hip flexion angle) has been suggested to contribute to increased incidence of hamstring strain injury.^{5,6} The subjects with decreased hamstring flexibility have an APT that occurs at a shorter muscle length;⁷ therefore, shifting the APT to occur at a longer muscle length could be a significant factor for the prevention of hamstring strain injury in the subjects with decreased hamstring flexibility.

A single bout of high-intensity eccentric hamstring exercise (ECC-Ex) (e.g., the repeated Nordic hamstring exercise and maximum eccentric leg curl) shifts the APT to occur at a longer muscle length.^{3,8} However, high-intensity ECC-Ex could immediately decrease muscle strength and flexibility.⁹⁻¹¹ These negative changes immediately after the ECC-Ex depend on the ECC-Ex intensity.¹² Accordingly, low-intensity ECC-Ex could shift the APT to occur at a longer muscle length with a minimal decrease in muscle strength and flexibility. However, the acute effect of low-intensity ECC-Ex on the subjects with decreased hamstring flexibility has not been established.

The purpose of this study was to investigate the acute effect of low-intensity ECC-Ex on the peak torque, APT, and hip flexion angle in the subjects with decreased hamstring flexibility. The authors hypothesized that low-intensity ECC-Ex would shift the APT to occur at a longer muscle length with a minimum decrease in muscle strength and flexibility in the subjects with decreased hamstring flexibility.

METHODS

Participants

Twelve healthy male college students (mean age, 24.4 ± 2.4 years; mean body mass, 66.8 ± 6.9 kg) participated in this study. None of the participants had regularly performed any lower limb resistance

training in the past year, and they did not have a previous hamstring strain injury. This study was reviewed and approved by the institutional review board of the University of Tsukuba and was conducted in conformity with the principles of the Declaration of Helsinki. All the study procedures and potential risks were explained to the participants, and they provided written informed consent prior to participation in this study.

Experimental design

Hip flexion angle during the passive straight leg raise (PSLR) test was evaluated in both legs, and participants were categorized into two groups based on the median value of the baseline hip flexion angle (i.e., 80.8°): normal group [range, 81.7° – 96.7° ; $n = 6$ (12 legs)] and decreased hamstring flexibility group [range, 66.7° – 80.0° ; $n = 6$ (12 legs)].

Three days before the experiment, the participants were familiarized with the measurements for the peak torque, APT and hip flexion angle as well as the low-intensity ECC-Ex procedure. The positioning of the isokinetic dynamometer (Biodex System 4; Biodex Corp., Shirley, NY, USA) (e.g., seat position, lever arm angle, and height) for each participant was determined during the familiarization. Before the experiment, each participant performed a five-minute warm-up using a stationary bike (M3 INDOOR BIKE; Keiser Corp., Fresno, California, USA) at 50 W/60–70 rpm. All variables of interest were measured in both groups before and after the low-intensity ECC-Ex.

PROCEDURES

Hip flexion angle

The PSLR test was performed to measure the hip flexion angle. The participants were in the supine position on an examination bed, and the pelvis and thigh of the non-tested leg were secured using straps. One investigator raised the participant's leg, with the participant's knee kept passively extended, until the point at which the participant felt a strong but tolerable stretch, slightly before the occurrence of pain¹³ and another investigator measured the hip joint angle at this point by a goniometer. High test-retest reliability of PSLR test ((ICC) = 0.94) has been reported previously.¹³

Peak torque and angle of peak torque

The test protocol was adopted from a previous study.¹⁴ The participants were placed in the prone position on an isokinetic dynamometer with a neutral hip joint position (flexion angle, 0°), and the upper back region and pelvis were stabilized using Velcro straps. The rotation axis of the dynamometer lever arm was aligned with the lateral epicondyle of the knee. The ROM was set from a flexed position of 90° to 0° (full knee extension). Before the measurement, four submaximal and two maximal eccentric contractions were performed at an angular velocity of $60^\circ/\text{s}$ as a warm-up. After the warm-up, participants performed three maximal voluntary eccentric knee flexion at an angular velocity of $60^\circ/\text{s}$. The investigator verbally encouraged the participants to generate the maximum force for the whole range of motion. The peak torque and the APT of the trial with the highest value among three trials were used for subsequent statistical analysis.

Low-intensity ECC-Ex

In the present study, the stiff-leg deadlift (SLDL) without any added weight was used as the low-intensity hamstring ECC-Ex. The degree of muscle elongation during the ECC-Ex was a crucial factor for the shift of APT to a longer muscle length following the ECC-Ex.¹ SLDL was performed with slightly flexed knees and flexed torso;¹⁵ hence, SLDL could lengthen the hamstring to a longer muscle length.

Therefore, SLDL was adopted as a hamstring ECC-Ex in this study.

To perform the SLDL, the participants grasped a plastic bar with their hands spaced slightly wider than their shoulder width. While maintaining a neutral spine position and slightly flexed knees, the participants flexed their torso as far as possible over five seconds and subsequently returned to the start position over two seconds (Figure 1). The participants performed three sets of eight repetitions of this exercise, with a three-minute rest between sets.

Statistical analyses

Two-way analysis of variance (ANOVA) with repeated measurements was used to identify the time (before or after) $\times$ group (normal or decreased hamstring flexibility) interaction. When a significant interaction or main effect was identified, a post hoc *t*-test with Bonferroni correction was performed. All data were reported as the mean $\pm$ standard deviation (SD). Statistical significance was set at $p < 0.05$ and, where possible, Cohen's *d* was reported for the effect size (ES) of the comparisons, with the levels of effect being deemed small ($d = 0.2$), medium ($d = 0.5$), or large ($d = 0.8$), as recommended by Cohen.¹⁶

RESULTS

In this study, a small APT indicates that the peak torque occurred at a longer muscle length.

Figure 1. The stiff-leg deadlift procedure: While maintaining a neutral spine position and slightly flexed knees, the participants flexed their torso as far as possible for 5 seconds and subsequently returned to the start position for 2 seconds.

Table 1. Variables of interest before and after the low-intensity stiff-leg deadlift in normal and decreased hamstring flexibility groups.

	Normal group				Decreased hamstring flexibility group			
	Before	After	<i>p</i>	ES (<i>d</i>)	Before	After	<i>p</i>	ES (<i>d</i>)
Peak torque, Nm	89.5 ± 19.2	82.4 ± 19.2	0.16	0.4	84.3 ± 29.7	78.7 ± 19.1	0.39	0.2
Angle of peak torque, °	24.1 ± 10.0	28.4 ± 15.2	0.35	0.3	32.1 ± 21.0	21.6 ± 11.0*	0.03	0.6
Hip flexion angle, °	89.6 ± 5.9	98.5 ± 4.9*	0.00*	1.6	71.9 ± 3.9	79.2 ± 5.4*	0.00	1.5

Data are expressed as mean ± SD. Significant difference vs. before, * $p < 0.05$.

Figure 2. Angle of peak torque before and immediately after the low-intensity stiff legged dead lift in the normal and decreased hamstring flexibility group. Results are shown as mean ± SD.

Table 1 shows the variables of interest before and after the low-intensity ECC-Ex in both groups. A significant interaction effect (time × group) for APT ($F = 5.435$, $p = 0.03$) was observed. The post hoc *t*-test indicated that low-intensity SLDL shifted the APT to a longer muscle length significantly in the decreased hamstring flexibility group (normal, $24.1 \pm 10.0^\circ$ to $28.4 \pm 15.2^\circ$, $p = 0.35$; decreased hamstring flexibility, $32.1 \pm 21.0^\circ$ to $21.6 \pm 11.0^\circ$, $p = 0.03$) (Figure 2). No significant interaction or main effect was observed for the peak torque (normal, 89.5 ± 19.2 to 82.4 ± 19.2 Nm; decreased hamstring flexibility, 84.3 ± 29.7 to 78.7 ± 19.1 Nm). No significant interaction effect for hip flexion angle was observed; however, the main effect for the time showed significance (hip flexion angle: $F = 57.819$, $p < 0.01$). The post hoc *t*-test indicated that low-intensity SLDL

increased the hip flexion angle significantly in both groups (normal, $89.6 \pm 5.9^\circ$ to $98.5 \pm 4.9^\circ$, $p < 0.01$; decreased hamstring flexibility, $71.9 \pm 3.9^\circ$ to $79.2 \pm 5.4^\circ$, $p < 0.01$).

DISCUSSION

In this study, the acute effects of low-intensity SLDL on the peak torque, APT, and hip flexion angle in the subject with decreased hamstring flexibility were investigated. The main outcomes are summarized as follows: first, low-intensity eccentric exercise (SLDL) shifted the APT to occur at a significantly longer muscle length in the decreased hamstring flexibility group, and second, low-intensity SLDL increased the hip flexion angle significantly (measured by PSLR) but did not change the peak torque in both groups. These results suggest that low-intensity SLDL could improve the APT and hip flexion angle without a decrement in peak torque in the decreased hamstring flexibility group.

To the authors' knowledge, this is the first study to demonstrate a shift of APT to occur at a longer muscle length following ECC-Ex in the subjects with decreased hamstring flexibility. Decreased hamstring flexibility is considered a risk factor for hamstring strain injury.^{5,6,17} According to Alonso et al. (2009), the subjects with decreased hamstring flexibility has an APT that occurs at a shorter muscle length.⁷ APT occurring at a shorter muscle length could result in severe muscle damage following ECC-Ex;^{3,8} thus, susceptibility of the subjects with decreased hamstring flexibility to hamstring strain injury could be associated with APT occurring at a shorter muscle length. In this study, low-intensity SLDL shifted the APT to a longer muscle length in the subjects with decreased hamstring flexibility.

This result suggests that low-intensity SLDL could be useful in preventing hamstring strain injury in the subjects with decreased hamstring flexibility. However, it should be noted that in the normal group APT shifted to shorter muscle length after the low-intensity SLDL, though the difference was not statistically significant. This result suggests that single bout of low-intensity SLDL might increase the susceptibility of the subjects with normal hamstring flexibility to hamstring strain injury. Accordingly, the impact of hamstring flexibility should be considered when the low-intensity SLDL is conducted prior to exercise.

High-intensity ECC-Ex could result in changes that impart muscle damage, such as decreased muscle strength and flexibility;⁹⁻¹¹ therefore, high-intensity ECC-Ex may not be suitable to perform before intense physical activity. Moreover, the present study also showed no change in muscle strength in either group and increased flexibility in both groups following the low-intensity SLDL. Thus, low-intensity SLDL could be useful as a warm-up exercise in the athletes with decreased hamstring flexibility before intense physical activity.

Various warm-up exercises are performed to prevent muscular injury before intense physical activity.^{18,19} Static stretching has been used as a warm-up exercise for the prevention of hamstring strain injury by increasing flexibility.¹⁸ However, an acute bout of static stretching could cause the immediate decrease in eccentric muscle strength^{20,21} and does not shift the APT during eccentric contraction to a longer muscle length.²²⁻²⁴ By contrast, low-intensity SLDL shifted the APT during eccentric contraction to a longer muscle length and increased the hip flexion angle without a decrease in peak torque during eccentric contraction in the decreased hamstring flexibility group, making it a potentially useful preventive warm-up exercise as compared to static stretching.

Methodological considerations and limitations

There are two major techniques to evaluate the hamstring flexibility such as the PSLR test and active knee extension (AKE) test. The AKE test is considered to be superior to the PSLR test to evaluate the flexibility without compensatory movement of the

pelvis. However, previous authors have reported that decreased hip flexion angle could be a risk factor for hamstring strain injury.⁶ Thus, PSLR test is considered to be related to the hamstring strain injury; therefore, PSLR test was utilized in the present study.

In this study, participants were categorized into normal group and decreased hamstring flexibility group based on the median value of the baseline hip flexion angle. As a result, the average of normal and decreased hamstring flexibility group was 90° and 72°, respectively. Ayala et al. (2013) has reported that based on the value of PSLR test hamstring flexibility was classified as normal hamstring flexibility ($\geq 80^\circ$), limited hamstring flexibility ($< 80^\circ$).²⁵ Considering this classification, categorization of the present study was considered relatively adequate.

In the present study, a standardized ECC-Ex intensity was not adopted and the influence of ECC-Ex intensity difference on the change in peak torque, APT, and hip flexion angle was not investigated. Therefore, the optimal intensity to improve the APT and hip flexion angle without decreasing peak torque was not established in this study. However, SLDL without any added weight was utilized in the present study as this exercise could be easily performed in various clinical fields. This exercise could be useful in improving the APT and hip flexion angle for athletes with decreased hamstring flexibility; thus, the present findings showed clinical relevance.

CONCLUSION

The results of the current study indicate that low-intensity SLDL significantly shifted the APT to occur at a longer muscle length and increased flexibility without decreasing the muscle strength in subjects with decreased hamstring flexibility. While warm-up exercises have been used to prepare for and improve performance, recently, prevention program (e.g., FIFA 11 +) has been incorporated into the warm-up.²⁶ Thus, the present findings suggest that low-intensity SLDL might be useful to shift the APT in individuals with decreased hamstring flexibility without disturbing the preparation for performance. Furthermore, low-intensity SLDL was performed using a plastic bar only, thus, low-intensity SLDL could be easily performed by various athletic populations and varied environments.

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