



ORIGINAL RESEARCH

The effect of kinesio taping versus stretching techniques on muscle soreness, and flexibility during recovery from nordic hamstring exercise



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KEYWORDS

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Summary The purpose of this study was to examine the effects of static stretching, proprioceptive neuromuscular facilitation (PNF) stretching, or kinesio taping (KT) on muscle soreness and flexibility during recovery from exercise. Sixty-five females were randomly assigned to four groups: PNF stretching (n = 15), static stretching (n = 16), KT (n = 17), and control (n = 17). All participants performed nordic hamstring exercise (5 sets of 8 repetitions). In all groups, hamstring flexibility at 24 h and 48 h was not changed from baseline (p > .05). The muscle soreness was measured higher at 48 h post-exercise compared with baseline in the control group (p = .04) and at 24 h post-exercise compared with baseline in the PNF group (p < .01). No significant differences were found for intervention groups compared with control group in all measurements (p > .05). The KT application and pre-exercise stretching have no contribute to flexibility at 24 h and 48 h after exercise, but may attenuate muscle soreness. © 2016 Elsevier Ltd. All rights reserved.

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Introduction

The health benefits of regular physical activity and sport have been well known, and exercise can reduce the risks associated with obesity, diabetes, cancer and cardiovascular diseases (Warburton et al., 2006). However, exercise can lead to muscle damage and fatigue. Exercise-induced muscle damage commonly associated with “delayed onset muscle soreness” (DOMS) may cause feelings of pain and stiffness in muscles several hours to days after unfamiliar predominantly eccentric exercise, such as downhill running (Cheung et al., 2003; Connolly et al., 2003). DOMS may impair physical performance and complicate activities of daily living by causing a decrease in joint range of motion (ROM), and muscle strength. Many different treatment strategies for alleviating DOMS have been used such as cryotherapy (Ascensao et al., 2011), stretching (McGrath et al., 2014), massage (Zainuddin et al., 2005), and anti-inflammatory drugs (Connolly et al., 2003).

Stretching before and after exercise or competition has traditionally been used to prevent injury, reduce soreness and improve athletic performance (Herbert et al., 2011). Static and proprioceptive neuromuscular facilitation (PNF) stretching are the most used techniques in clinical rehabilitation and athletic settings. Static stretching is to hold a muscle in elongated position for an extended period with a sustained force at the point of limitation (Young and Behm, 2002). The PNF stretching technique includes isometric contraction of the target muscle or muscle group in addition to static stretching. The PNF technique was developed by Knot and Voss and mainly used by physiotherapists in the rehabilitation of neurological and orthopedic diseases to restore functional range of motion and increase strength (Sharman et al., 2006). Some studies showed that PNF stretching technique is more effective than static stretching to increase muscle flexibility and performance (Funk et al., 2003; Rubini et al., 2007; Sharman et al., 2006; Yuktasir and Kaya, 2009). In PNF stretching technique, autogenic inhibition, reciprocal inhibition, stress relaxation, and the gate control theory are implemented to increase ROM (Sharman et al., 2006; Rowlands et al., 2003). Khamwong et al. (2011) reported that PNF stretching resulted in a lesser deficit of ROM and mechanical pain thresholds than the control group after eccentric exercise of the wrist extensors in healthy males. In contrast, McGrath et al. (2014) showed that post-exercise PNF stretching did not prevent DOMS.

Kinesio taping (KT) has been commonly applied for rehabilitation of musculoskeletal injuries and improve athletic performance. Kase et al. (2003) proposed the following mechanisms for the effectiveness of KT: (1) increasing proprioception, (2) correcting muscle function by strengthening of weakened muscles, (3) improving the circulation of blood and lymph by eliminating tissue fluid or bleeding beneath the skin by moving the muscle, and (4) decreasing pain through neurological suppression. Bae et al. (2014) demonstrated that KT application decreased muscle soreness following eccentric exercise of the biceps brachii muscle. In contrast, Shoger et al. (2000) reported that the KT did not reduce the pain associated with DOMS in the wrist flexors.

The hamstrings are reported to be one of the most commonly injured muscles in sports that involve sprinting, jumping, and kicking (Petersen and Holmich, 2005). Therefore, the aim of present study was to examine the effects of stretching techniques and KT application on hamstring muscle soreness and flexibility during the recovery from nordic hamstring exercise (NHE).

Methods

Participants

Female university students ($n = 65$) without a prior history of lower extremity injury or neurological disorder were recruited to participate in this study. Subject characteristics are shown in Table 1. Recruitment occurred through announcements publicizing the aims and inclusion/exclusion criteria of the study. All participants were healthy untrained without the habit of regular exercise. Participants were instructed to refrain from any form of unaccustomed physical exercise for at least 1 week prior to as well as during the study period and not to use any painkiller during the study period. Participants had no hamstring muscle soreness at the onset of the study. This study had been approved by the Ethics Committee of the University.

Procedures

Participants were randomly assigned to four groups: PNF stretching, static stretching, KT, and control. The randomization was performed by allowing the participant to pull a number out of a hat. Hamstring muscle soreness and flexibility were measured at baseline (before interventions and exercise), 24 and 48 h after NHE. Two participants from the PNF stretching group and one participant from the static stretching group did not complete post-tests. Stretching or KT application were implemented immediately before NHE. The control group performed NHE only during study period.

Muscle soreness

Muscle soreness was measured using pressure algometry (Baseline, USA). Intra-tester reliability with algometry has been shown to be fair to good ($r = 0.67$) for the measurement of the pressure pain threshold (Fischer, 1987). The investigator marked the measurement points with a skin pen over anatomical landmarks of lateral and medial parts of the hamstrings at 10 cm above the flexure of the knee when the participants lay prone with the knee approximately 90° flexed. The investigator applied a gradually increasing pressure perpendicularly against the skin over the marked point with a 1 cm² metal probe of the algometer. The participants were instructed to indicate when perceived “pain or discomfort” was experienced and the measurement ceased at that time. The pressure was recorded for the dominant leg (Fig. 1) (Aparicio et al., 2009). The dominant limb was determined as the one with which participants preferred kicking a ball.

Table 1 Subject characteristics and baseline values of groups.

Groups	PNF (n = 15)	Static (n = 16)	KT (n = 17)	Control (n = 17)	p
Age (yrs)	19.20 ± 1.01	19.37 ± 1.14	19.41 ± 0.87	19.17 ± 0.95	0.87
Height (cm)	165.46 ± 4.10	164.37 ± 6.81	164.76 ± 4.76	162.29 ± 5.70	0.38
Weight (kg)	58.00 ± 7.00	58.81 ± 6.10	54.17 ± 6.25	57.76 ± 11.73	0.37
Muscle soreness Medial side (Kg/cm ²)	7.82 ± 1.79	7.33 ± 1.12	6.82 ± 1.63	6.72 ± 1.38	0.54
Muscle soreness Lateral side (Kg/cm ²)	7.32 ± 0.95	7.04 ± 1.34	6.37 ± 1.40	5.55 ± 1.41	0.14
Flexibility (ROM)	79.11 ± 6.48	78.07 ± 5.06	79.24 ± 5.60	74.50 ± 8.39	0.13

Data are mean ± SD.

Flexibility

Hamstring flexibility was evaluated using passive straight-leg raises with a digital inclinometer (Baseline, USA). When the participant was in the supine position with legs straight, an investigator kept the nonstretched leg straight to avoid external rotation and fixed the pelvis to avoid the posterior pelvic tilt. The digital inclinometer was strapped over the distal tibia of the dominant leg. Another investigator lifted participant's dominant leg passively into hip flexion while the participant's knee was kept straight. The score was read from the inclinometer at the point of maximum hip flexion (Fig. 2) (Ayala and de Baranda Andujar, 2010).

Static stretching

With the participant in the supine position with legs straight an investigator held the nonstretched leg in position. Another investigator held the participant's dominant leg and passively moved the tibia to the terminal position of knee extension, defined as the point at which the participant complained of a feeling of discomfort or tightness in the hamstring muscles. The static stretching was performed for 30 s with 30-s rest periods between stretches and repeated 5 times.

PNF stretching

The contract-relax agonist-contract (CRAC) method of PNF stretching was used for the current study (Rowlands et al.,

2003). The participant lay in a supine position on the examination table while an investigator firmly stabilized the nonstretched leg. Another investigator took the dominant leg passively to the terminal position of knee extension, defined as the point at which the participant complained of a feeling of discomfort or tightness in the hamstrings. The participant was asked to perform a maximal voluntary isometric contraction of the hamstrings (antagonist muscles) for 10 s, followed by 5 s relaxation. Then the participant contracted the quadriceps femoris (agonist muscles) and the first investigator moved the leg to a new end point (mild discomfort and without pain), which was held for 10 s. This stretching technique was repeated 3 times.



Figure 1 Measurement of muscle soreness.



Figure 2 Measurement of hamstring flexibility.

Taping

Standard two-inch (5-cm) Kinesio Tex tape (Kinesio Holding Company, Albuquerque, NM) was used for all applications. The participants taped with facilitation technique by a certified physiotherapist. Kinesio tape was applied to the hamstrings from origin to insertion (proximal to distal) in a Y shape with tension of approximately 30%. The participants were positioned with the knee in extension and the hip flexed to place a stretch on the hamstrings in supine lying position. The base of the tape was attached to the skin over the ischial tuberosity. After stabilizing base of the tape, KT was removed from the paper backing to the base of 'Y' tails and placed on the skin. The 'Y' tails were applied to the skin over the medial and lateral epicondyle of the tibia (Fig. 3) (Kase et al., 2003).

Exercise protocol

In the present study, the exercise protocol of Mendiguchia et al. (2013) was used. NHE involves eccentric contractions and is known to result in muscle soreness (Mendiguchia et al., 2013). The participant had to kneel on the floor with the upper body vertical and straight while a partner applied pressure to the heels in order to the feet kept contact with the floor throughout the movement. Subsequently, the participants slowly covered their upper

body towards the floor (knee extension) whilst trying to resist falling by contracting the hamstring muscles (knee flexion). The elbow joints were kept flexed with hands close to the shoulders as long as possible and the elbow joints would be extended only at the final stages of the movement to buffer the fall. The participants performed 5 sets of 8 repetitions NHE movements, with 5 s interval between each fall, which included the time to return to the starting position, and a 2 min interval between each set (Mendiguchia et al., 2013). All participants received strong verbal encouragement to resist the planned fall by contracting the hamstring muscles (Fig. 4).

Statistic analysis

Data were analyzed using SPSS (Version 16.0, SPSS Inc, Chicago, IL). Subject characteristics were calculated for each measurement time (Table 1). Normality of the dependent variables was checked using the Kolmogorov Smirnov test. One-way ANOVA was used to determine baseline differences and subject characteristics among groups. A 4×3 (group \times time) mixed ANOVA were assessed at each measurement time (baseline, 24 h and 48 h after exercise) for four group. The Bonferroni Test for multiple comparisons was applied to determine differences between the groups. All results are shown as the mean \pm SD. Significance was set at $p < .05$.

Results

Subject characteristics of groups are presented in Table 1. There were no differences in subject characteristics and the baseline values between groups ($p > .05$) (Table 1). Means and standard deviations (Mean \pm SD) of all measurements are presented in Table 2. Repeated-measures ANOVA showed that no differences were observed ($p > .05$) between baseline, 24 h and 48 h in hamstring flexibility in all groups. The muscle soreness was measured



Figure 3 KT application on hamstring muscles.



Figure 4 Nordic hamstring exercise.

Table 2 Muscle soreness and flexibility values of all groups.

Measurements	Groups	Baseline	24 h	48 h	p
Muscle soreness Medial side (Kg/cm ²)	PNF	7.82 ± 1.79	6.60 ± 2.09 ^a	7.41 ± 1.88	0.003
	Static	7.33 ± 1.12	7.32 ± 1.37	6.86 ± 1.65	0.24
	KT	6.82 ± 1.63	6.82 ± 1.63	6.52 ± 1.85	0.70
	Control	6.72 ± 1.38	6.67 ± 1.76	6.37 ± 1.93	0.60
Muscle soreness Lateral side (Kg/cm ²)	PNF	7.32 ± 0.95	6.20 ± 2.01	6.67 ± 1.57	0.08
	Static	7.04 ± 1.34	6.82 ± 1.32	6.07 ± 1.91	0.09
	KT	6.37 ± 1.40	6.56 ± 1.16	5.89 ± 1.82	0.27
	Control	6.63 ± 1.14	6.40 ± 1.24	5.55 ± 1.41 ^a	0.01
Flexibility (ROM)	PNF	79.11 ± 6.48	77.46 ± 8.07	76.96 ± 9.39	0.36
	Static	78.07 ± 5.06	77.96 ± 5.37	75.06 ± 8.45	0.22
	KT	79.24 ± 5.60	73.20 ± 9.79	76.22 ± 8.72	0.07
	Control	74.50 ± 8.39	73.20 ± 9.79	72.45 ± 12.87	0.34

Data are mean ± SD.

^a Different from baseline.

higher at 48 h post-exercise compared with baseline in the lateral side of the hamstrings in the control group ($p = .04$) and at 24 h post-exercise compared with baseline in the medial side of the hamstrings in the PNF group ($p < .01$). No significant differences were found for intervention groups compared with control group in all measurements ($p > .05$).

Discussion

The results of the present study showed that KT application, PNF and static stretching attenuated muscle soreness in the lateral side of hamstrings at 48 h post-exercise compared with baseline. However, the intervention groups did not contribute to recovery after exercise compared with control group. Pre-exercise PNF stretching did not alleviate muscle soreness in the medial side of the hamstrings up to 24 h post-exercise from baseline. Mendiguchia et al. (2013) showed that the lateral hamstring muscle (biceps femoris) was particularly damaged after NHE using magnetic resonance imaging observations. Similarly, in the present study, muscle soreness in lateral side of the hamstrings was significantly higher in the control group compared with baseline. It has been proposed that repeated stretching diminishes the tension on the muscle-tendon unit. This visco-elastic behavior of the muscle tendon unit may reduce the level of muscle damage induced by eccentric exercise (Cheung et al., 2003). McHugh et al. (1999) reported that passive hamstring stiffness was associated with the severity of muscle damage measured by strength loss, pain, and muscle tenderness. The stretching techniques that can decrease passive stiffness might contribute to reduce the severity of muscle damage. Khamwong et al. (2011) reported that PNF stretching demonstrated a lesser deficit in pressure pain threshold than control after eccentric exercise of the wrist extensors in healthy males. The authors observed that the pain pressure threshold decreased immediately and 1–4 days post-exercise in the PNF group, but did not return to the pre-exercise level by day 5 post-exercise in the control group. On the other hand, Lund et al. (1998) found that static stretching of quadriceps femoris before eccentric

exercise did not decrease DOMS in seven healthy females. The stretching protocol was performed for 3 times of 30 s duration with a pause of 30 s in between each stretch. There was no control group. Johansson et al. (1999) demonstrated that static stretching at 20 s for four repetitions did not prevent the muscular soreness before 10 sets of 10 maximal isokinetic eccentric exercise for knee flexion when comparing stretched and nonstretched legs in ten females. In the present study, the hamstrings was stretched for 5 times of 30 s duration with a rest of 30 s in between each stretch. The effects of stretching on properties of the muscle-tendon unit depend on various factors including the stretching techniques used, time to stretch, holding duration, time to rest, and the time gap between intervention and measurement (Weerapong et al., 2004). It has been reported that lower stretching repetitions did not provide the changes in viscoelastic properties of muscle (Weerapong et al., 2004). McNair et al. (2001) observed no changes in musculotendinous stiffness of the plantar flexors after either four 15-s or two 30-s static stretching.

The KT method has been applied to increase muscle strength and ROM and to decrease pain by many investigators in recent years (Aktas and Baltaci, 2011; Gonzalez-Iglesias et al., 2009; Yoshida and Kahanov 2007). However, there are limited studies examining the effects of KT application on DOMS. Lee et al. (2015) reported that KT application decreased pain after DOMS-inducing biceps brachii exercise. They suggested that KT facilitated recovery by lifting of the skin and muscle fascia due to its elastic nature. Bae et al. (2014) measured muscle soreness at 24, 48, and 72 h after biceps brachii eccentric exercise. The KT application over biceps brachii muscle decreased significantly in scores of visual analog scale at 24 h after inducement of DOMS. Nosaka (1999) applied eccentric exercise with a modified arm curl machine to the biceps muscles of 12 males; the KT on biceps muscle contributed to the recovery from DOMS. The researchers suggested that the KT expanded interstitial space between the skin and the muscle, decreased the pressure on subcutaneous nociceptors and increased circulation. In this way, fluid exchange enhances between tissue layers (Kase et al., 2003; Kahanov, 2007) and may assist muscle recovery

after exercise and lower the pain from DOMS. In addition, it was documented that the effect of KT application was maintained until 72 h (Kase et al., 2003; Slupik et al., 2006). To our knowledge, only one study showed that KT application did not reduce the pain associated with DOMS in the wrist flexors (Shoger et al., 2000).

In the present study, KT application and pre-exercise PNF and static stretching did not maintain hamstring flexibility during recovery at 24 h and 48 h after eccentric exercise. Chen et al. (2013) compared effects of PNF stretching + static stretching and KT application + static stretching on hamstring muscles in nine healthy males. The researchers observed a significant increase in hamstring flexibility immediately after stretching. Also, these effects were maintained immediately after a bout of maximal isokinetic hamstring exercise. We tested the acute effects of stretching exercises on hamstring flexibility. Previous studies reported that PNF and static stretching were effective at enhancing flexibility in short term (Chen et al., 2013; Sharman et al., 2006; Weerapong et al., 2004), but this gain was maintained for up to 24 h (De Weijer et al., 2003). In the present study, if flexibility was measured immediately after NHE, it could have been observed with significant improvement. In contrast to the results of our study, Khamwong et al. (2011) demonstrated that the PNF stretching significantly led to a lesser deficit in wrist extension ROM than that of the control group on days 1–6 after eccentric exercise of the wrist extensors in healthy subjects. The researchers applied PNF stretching (hold-relax with agonist contraction) for 10 times with 7 s isometric contraction (antagonist muscle) to each subject. In our study, PNF stretching was repeated 3 times. A possible explanation is that knee extension ROM was not maintained at 24 h and 48 h after NHE because our number of repetitions in stretching were lower than study of the Khamwong et al. (2011).

Some limitations of the present study should be noted. The participants in the present study were healthy untrained females and responses to stretching and KT application in recovery from exercise-induced muscle damage may be different in trained athletes. In addition, another limitation of this study was that we did not evaluate muscle strength during recovery. Exercise-induced muscle damage may lead to the loss of muscle strength. In addition, the researchers who performed the measurements were not blinded. Absence of blinding may potentially cause an expectancy bias. The sample size might be considered as rather small in the present study. However, previous studies reported similar sample sizes (Bae et al., 2014; Chen et al., 2013; Khamwong et al., 2011; McGrath et al., 2014).

Conclusion

KT application and pre-exercise PNF and static stretching have no contribute to flexibility during recovery at 24 h and 48 h after exercise, but may attenuate muscle soreness. KT application and stretching prior to exercise or competition should be considered by exercise trainers and athletes. Future studies may evaluate different strategies or therapeutic applications to prevent and to manage muscle soreness.

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