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Article Title: The Effectiveness of Kinesio Taping in Recovering from Delayed Onset Muscle Soreness: A Cross-Over Study

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The Effectiveness of Kinesio Taping in Recovering from Delayed Onset Muscle Soreness: A Cross-Over Study

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Abstract

Context: Kinesio taping (KT) is a popular taping technique used in the recovery process; however, in the relevant literature, there is no real consensus on its efficacy. **Objective:** To investigate whether rectus femoris KT application after DOMS enhances recovery of muscle soreness, edema, and physical performance. **Participants:** Twenty-two healthy amateur male athletes participated in this study. **Design:** Randomized, crossover study. **Setting:** Human Performance Laboratory of the University. **Interventions:** Participants performed an exercise protocol inducing DOMS. They accomplished two distinct trials, with or without KT. The washout period between trials was 6 wk. For the KT condition, KT inhibition technique was used and applied immediately after exercise bilaterally on rectus femoris. **Main Outcome Measures:** Range of motion, muscle soreness, and edema were measured at baseline, 30 min, 24, 48, and 72 h post-exercise. Dynamic balance, sprint, and horizontal jump were evaluated at similar time frame except for 30 min post-exercise. **Results:** The findings showed that there were no significant differences between the KT group (KTG) and control group (CG) for all the outcome variables ($p > 0.05$). Muscle soreness returned to baseline values 72 h post-exercise only within the KTG ($p > 0.05$). Although the horizontal jump performance decreased substantially from baseline to 24 and 48 h post-exercise only within the CG ($p < 0.05$), the performance increased significantly from 24 to 72 h post-exercise within the KTG ($p < 0.05$). Balance increased significantly from baseline to 48 h post-exercise ($p < 0.05$) in both groups. Balance also increased significantly from baseline to 72 h post-exercise only within the KTG ($p < 0.05$). The effect size of soreness which is our primary outcome was large in both groups ($r > 0.5$). **Conclusions:** KT is favorable in the recovery of muscle soreness after DOMS. KT has beneficial effects on horizontal jump performance and dynamic balance.

Keywords: recovery, pain, edema, physical performance, Kinesio tape

Introduction

Unaccustomed physical activity with high intensity and eccentric contractions may cause muscle damage that may present itself as delayed onset muscle soreness (DOMS).^{1,2} Indeed, DOMS is accepted as a type I muscle strain.³ Stiffness, soreness, and tenderness of muscles are symptoms associated with DOMS.³ These symptoms generally appear within the first 24 h post-exercise,^{3,4} peak 24 to 72 h post-exercise,^{1,3,4} and disappear from 5 to 7 d post-exercise.^{3,4} Recovery techniques may help to expedite the process.³ There are many causes for the psychological discomfort associated with DOMS, including muscle spasm, connective tissue and muscle damages, accumulation of metabolites, an increase in creatine kinase activity and other inflammatory markers.^{3,5} In addition to the muscle soreness, the structural changes in muscle and connective tissue due to DOMS may impair muscle functions and joints' mechanical properties.³ Consequently, muscle soreness and structural changes in soft tissues cause a decrease in the joints' range of motion (ROM), a swelling of muscles, and limited functional movements.⁶ Moreover, many researchers showed that DOMS is associated with a substantial decline in strength and power.^{1,3,4,6} In conclusion, DOMS adversely affects physical performance by reducing muscle function and ROM with a concomitant increase in psychological discomforts, such as muscle soreness.

Elastic taping is known to be a popular recovery method.^{2,6} The Kinesio taping (KT) is a type of elastic taping which stretches up to 140% of its original length.⁷ Many studies showed that KT would have beneficial effects on soreness by ameliorating muscle function,⁶ inhibiting muscle activity⁴, increasing blood and lymph circulation,^{6,8,9} and leading to neurological inhibition.^{4,10}

There are few studies that have investigated the potential effects of KT on DOMS, which remained under-researched.^{2,4,6,10,11} According to the relevant published studies, to date, there was

no consensus on how to apply KT. KT cutting methods, amount of stretch in the tape, and application techniques may vary.^{2,4,6,10,11} For example, Boobphachart et al² used the KT facilitation technique before the exercise protocol on rectus femoris, vastus medialis, and vastus lateralis muscles by stretching it up to 125% of its original length. They found out that elastic tape application on quadriceps femoris recovered muscle strength and reduced muscle soreness after 72 h post-intensive exercise. They proposed that the reduction in muscle soreness might be due to blood and lymphatic flow enhancement, and these two physiologic responses along with increased stimulation of skin mechanoreceptors caused by increased sensory feedback in the taped area might improve muscle strength.² Similarly, Tajik et al¹¹ applied KT before fatigue protocol, on the same muscles and direction. However, we should note that the tension applied was different (stretched to 40% of initial length). They showed that KT application did not have any significant effects on balance just after fatigue intervention. However, the KT group had better scores in dynamic balance compared to the CG. They postulated that KT enhances fatigued muscles' proprioception which may decrease the joint error, and thereby positively affects balance.¹¹ Lee et al⁶ applied tape perpendicularly to the biceps brachii muscle after an intensive exercise. They demonstrated that KT is an effective method in the recovery of biceps brachii muscle thickness and strength after 72 h post-DOMS protocol. According to them, KT accelerates the recovery of muscle thickness by stimulating γ -motor neurons. Furthermore, KT, by lifting the skin, facilitates the removal of waste products and the increase of oxygen supply to the muscle and thereby may induce a recovery of muscle strength.⁶ Bae et al^{4,6} who used maximally lengthened Y-shaped KT on biceps brachii muscle and Lee et al⁶ showed that KT decreases soreness significantly from 24 to 72 h after an exercise inducing DOMS. Both authors indicated that increased metabolic activity due to muscle contraction reduces soreness.^{4,6} In addition, applying stretched KT in muscles pulls

them and causes stimulation of GTO which induces neurologic suppression resulting in pain reduction.⁴ In contrast to the findings of studies reported above, including Lee et al’s findings,⁶ in a crossover study conducted by Ozmen et al,¹⁰ KT was found out to be useless in the recovery of DOMS and short sprint performance 48 h post-exercise. However, the same study showed that KT maintained flexibility. They applied from origin to insertion of quadriceps femoris muscle a Y-shaped KT with 25% tension on the tails immediately before the exercise protocol. Ozmen stated that beneficial effects of KT, such as increase blood and lymphatic circulation, and stimulation of cutaneous mechanoreceptors might improve flexibility.¹⁰

When we examined the relevant studies in the literature, we noticed that the KT inhibition technique was not used on rectus femoris muscle. The present study aims to investigate whether the application of rectus femoris KT inhibition technique after DOMS enhances recovery of muscle soreness, edema, and physical performance. Thus, we hypothesized that the perception of soreness, level of edema, and athletic performance would be similar in KTG and CG after an exercise inducing DOMS.

Methods

Participants: In this study, a priori sample size was calculated using statistical power analysis by PASS 2005 software (NCSS, Kaysville, UT, USA). The power analysis indicated that 20 participants were needed for 80% power and 0.05 type 1 error (under the assumptions lower limit = 0, upper limit = 10, true difference = 0.5, standard deviation = 0.6, alpha = 0.05 and beta = 0.20). In case of a potential dropout, the estimated number of participants was increased by 30%. As a result, the final sample size was calculated as 26. Participants were randomly assigned into two groups by simple randomization technique (14 in the KTG and 12 in the CG). While there were 26 participants at the beginning of this study, only 22 of them (Mean±SD: age, 21.36±1.68

y; body height, 178.14 ± 6.57 cm; body weight, 79.43 ± 10.07 kg; BMI, 25.03 ± 2.85 kg/m²; sport age, 5.73 ± 3.27 y) completed the whole study as planned (see figure 1). All the participants were recreational athletes (i.e. they were participating in sports activities to be healthy and/or to have fun), and they were attending aerobic based activities at least two sessions per week. They were informed to abstain from doing any lower body strength training or unaccustomed physical exercise at least one week before the beginning of this study. Participants who had any neuromuscular, cardiorespiratory, neurologic diseases, or underwent any musculoskeletal injuries over the last six months were excluded from this study. The participants were also advised not to consume alcohol, take nutritional supplements, participate in physical activities, and call on other recovery techniques, such as analgesic drugs and cryotherapy, throughout this study. Moreover, they were asked to maintain their usual nutritional and water intake over the course of this study. Both written and verbal information was given to all participants, and their written informed consent was requested. The ethical approval for this study was obtained from the Eastern Mediterranean University Health Subcommittee in February 2018 (approval number: 2018/53-04).

Procedures: This study was conducted in a randomized crossover design, involving a KT intervention trial and a non-KT control trial with a 6-week interval (washout) between the trials. While 14 of the participants started this study in the KTG, the rest began the study in the CG. Six weeks later, they crossed over to the other group. Each trial lasted five days. To discard the potential effects of learning, the first day at least 48 h prior testing was reserved for a familiarization session about the different tests. An exercise protocol inducing DOMS was held on the second day. The results related to the evaluation of edema, pain intensity, and ROM were measured for each group at baseline, 30 min, 24h, 48h, and 72h post-exercise. Meanwhile, the outcome variables related to the assessments of balance, speed, and explosive power were taken

at similar time frame except there was no measurement at 30 min post-exercise. Physical performance tests and DOMS induction were conducted at the same time of day (2 pm) to avoid fluctuations in physiological responses due to differences in circadian rhythm. They also were conducted indoors in the Human Performance Laboratory of the University, which allowed for climate and testing surfaces to remain more consistent. Verbal encouragement was given to the participants during the physical performance tests to ensure they were giving their best. All measurements were performed by the same researcher.

Exercise protocol inducing DOMS: To generate DOMS, we used the drop jump that is an eccentric exercise. Participants successively performed five sets of twenty drop jumps from a 0.6 m high box with 10 s intervals between each jump. The rest between sets were 2 min.¹²

Taping Application: The 5-cm width Kinesio tape (KINESIO® TEX GOLD™) applied to the participants had a feature of being stretched to 140% of its original length. Moreover, due to its latex-free, cotton, hypoallergenic, and porous characteristics, comfortable wear over a 3-5 days period was possible. Its water-resistant fabric insulated from moisture and allowed the participants to bathe as usual.⁷ Body hair may prevent the tape from adhering directly to the skin. To avoid such a case, the skin was shaved. Moreover, the skin was cleaned with rubbing alcohol before applying the Kinesio tape. Similar to the study conducted by Vercelli et al,¹³ a certified physiotherapist applied KT inhibition technique to the rectus femoris from the insertion to origin with light tension (15%-25% of available tension), to inhibit muscle tension. We preferred to use this taping technique which may prevent muscle spasm, a reason of DOMS. To be clear, the tape was cut in a Y-shape. While the rectus femoris was held in the stretching position, it was surrounded bilaterally with the tails.¹³ The tape was applied immediately after the DOMS inducing exercise.

Outcome Measures:

Demographic and anthropometric evaluation: On day one, all demographic and anthropometric assessments were done. Chronological and training ages were asked. Body height was measured with a tape measure. Body weight was measured by a scale. Body mass index was calculated by using the following formula: weight (kg)/height (m)².

Perceived soreness: A visual analogue scale (VAS) ranging from 0 ("no pain") to 10 ("unbearable/worst pain") was used to assess pain level.^{14,15}

Range of Motion: The flexibility of quadriceps femoris muscle was measured by using a goniometer.¹⁰ The dominant knee ROM was measured by using a goniometer, and the measure was taken while the participant laid prone and held his knee at full flexion. The goniometer was positioned so that the goniometer axis stayed still over the lateral epicondyle of the femur. The stationary goniometer arm was aligned parallel to the longitudinal axis of the femur, aligned with the greater trochanter, while the mobile arm was placed parallel to the longitudinal axis of the fibula, aligned with the lateral malleolus.¹⁶

Level of edema: The level of edema was detected by measuring the circumference of the middle of rectus femoris. As the described in the study of Sellwood et al,¹⁴ we palpated for the anterior superior iliac spine (ASIS) and the superior margin of the patella (SMP), and then marked with a pen to record the length of the femur by using a tape measure. Next, we found the mid-point between the ASIS and SMP by using a tape measure again and marked with a pen.

Sprint performance: Sprint measurements were conducted using photocells placed at 0 and 20 m (Newtest Oy 2007-2010, FIN-90220 Oulu, Finland). The participants stood 1 m behind the starting line, started on a verbal signal, and then ran to complete the 20-m distance as fast as

they could.¹⁰ All of them completed three runs. They rested one min between each run. The mean sprint time was retained for the analyses.

Horizontal jump performance: The horizontal jump performance was assessed by using the double leg hop test. The participants started in a standing position with their toes just behind the starting line. They began the jumping movement by swinging their arms and bending their knees to provide maximal forward drive. Subjects were asked to jump as far forward as possible and land on two feet. The jump-length measurement was determined using a metric tape measure, from the takeoff line to the nearest point of landing contact (i.e. the back of the heels).¹⁷ Each subject completed three attempts. The rest between attempts was one min. The mean of the three jump distances was taken.

Dynamic balance: We used a computer-based balance device (PK200WL, Prokin TecnoBody) like the one used by Birinci et al.¹⁸ However, the disequilibrium assessment was chosen to test dynamic balance on bipedal stance for 30-s (see figures 2 and 3). In this test, the subject sees some gates that come against, and the aim is to enter into those gates and to maintain the board as firm as possible. Four difficulty levels are available in the test (monoaxial, easy, medium, and hard). As the participants were recreational athletes, an easy base was chosen. This test provides us with the distance medium error (DME) which shows the participants' ability to move themselves correctly into the gates. If the participants moved away from the gates, the DME (%) would be high.¹⁹ Subjects were asked to complete three attempts, interspersed by one min intervals. The mean of the three attempts was recorded.

Statistical analysis: All statistical analysis was performed by using IBM SPSS 22 Package. Before statistical tests were used, we checked potential outliers and missing data. Normal distribution assumptions of the data were checked with Shapiro-Wilk test. As $p < .05$ data were

not normally distributed, we used non-parametric tests. The Friedman test was used to detect significant differences within the group. Meanwhile, for multiple comparisons within the group, we used the post-hoc DUNN test. The Mann-Whitney U test was used to detect significant differences between groups. Statistical significance was set at $p < 0.05$.

The " $r = z / \sqrt{nx2}$ " formula is used to determine the effect size of the changes over time in the KTG and CG. Effect sizes were interpreted as small ($r \leq 0.1$), moderate ($r = 0.3$), and large ($r \geq 0.5$).²⁰

Results

The characteristics of the participants were displayed in Table 1.

The results related to the evaluation of edema, pain intensity, and ROM, were displayed in Table 2. Meanwhile, the outcome variables related to the assessments of balance, speed, and explosive power were shown in Table 3.

CG muscle soreness remained substantially elevated 30 min, 24 h, and 48 h post-exercise compared to baseline [respectively, $p = 0.00$, CI = 1.7 (0.10-6.6); $p = 0.00$, CI = 1.9 (0.10-5.4); $p = 0.00$, CI = 2.7 (-0.3-9.2)]. In the meantime, muscle soreness remained also significantly elevated 24 and 48 h post-exercise compared to baseline within the KTG [respectively $p = 0.00$, CI = 2.8 (0.2-6.2); $p = 0.00$, CI = 2.8 (0.1-6.4)]. Even if muscle soreness remained significantly elevated 30 min post-exercise compared to baseline ($p = 0.01$) within KTG, CI was 1.7 (-0.3-4.3). Muscle soreness remained substantially elevated 72 h post-exercise compared to baseline ($p = 0.00$) within the CG but CI was 1.5 (-0.8-6.7). On the other side, it returned to baseline values 72 h post-exercise within the KTG. Although there was a significant drop in muscle soreness from 24 to 72 h post-exercise ($p = 0.01$) within the KTG, CI was -1.8 (-5.6-1.9). Otherwise, there was a

significant increase in muscle soreness from 30 min to 24 h post-exercise in the KTG ($p = 0.03$) but IC was found 1.7 (-1.5–6.5).

Meanwhile, as shown in Table 2, there was a significant increase in the level of edema from baseline to 48 h post-exercise in both groups ($p = 0.00$ in control group and $p = 0.01$ in KTG). However, from baseline to 48 h post-exercise, CI was 0.8 (-0.4–2.4) in KTG and 0.53 (-4.3–2.6) in CG.

No significant time effect was found in the knee flexion ROM among the KTG ($p > 0.05$).

In both groups, speed decreased significantly only from baseline to 24 h post-exercise ($p = 0.02$ in CG and $p = 0.04$ in KTG), but IC was 0.01 (-0.3–5) in KTG and 0.1 (-0.1–0.7) in CG.

There were substantial decreases in the horizontal jump performance from baseline to 24 and 48 h post-exercise (respectively $p = 0.04$ and $p = 0.00$) within the CG. However, IC values were respectively -7 (-46–10) and -7.7 (-26–2). In addition, there was a significant increase in the horizontal jump performance from 24 to 72 h post-exercise within the KTG ($p = 0.00$); however, IC was 1.5 (-2.2–6.1).

The distance medium error in the disequilibrium assessment decreased significantly from baseline to 48 h post-exercise in both groups ($p = 0.03$ in CG and $p = 0.02$ in KTG) but IC was -0.9 (-4.1–0.5) in CG and -0.6 (-1.8–0.8) in KTG.

There were no difference between the groups at all times, at any parameters ($p > 0.05$). In addition, the effect size of our primary outcome (i.e. soreness) was found large in both groups ($r = 0.72$ in both groups). Apart from the effect size of KT balance value which is large ($r = 0.53$), all other parameters' effect size were moderate in both groups ($0.1 < r < 0.5$).

Discussion

This study aimed to investigate the effectiveness of rectus femoris KT application on muscle soreness, edema, and athletic performance in recovery from a DOMS inducing exercise in young male recreational athletes. The results of our study showed that significant changes occurred in variables, such as muscle soreness, explosive power (i.e. horizontal jump), and balance, in both groups. However, unlike the CG, recovery of muscle soreness occurred 72 h post-exercise compared to baseline in the KTG. Although significant drops in the horizontal jump performance occurred from baseline to 24 and 48 h post-exercise in CG, no significant changes were identified in the KTG. In fact, a substantial increase in the horizontal jump performance happened from 24 to 72 h post-exercise in the KTG. While balance performance increased significantly in both groups from baseline to 48 h post-exercise, balance performance increased significantly from baseline to 72 h post-exercise only within the KTG.

There are different methods inducing DOMS (e.g. plyometric exercise, isokinetic dynamometry, running based-exercises, cycling, free weight exercises, squat, drop jump, match or training).^{1,4} The drop jump protocol was used as a method in the present study. Many studies related to DOMS showed that muscle soreness tended to increase within 24 h post-exercise, peaked at 48 h post-exercise, and started to decrease 72 h post-exercise.^{1,3,4,6,10,15} The results of our study are in line with the literature.^{1,4,6,10,15} Muscle soreness began 30 min post-exercise, gradually increased over time, and peaked at 48 h post-exercise in both groups. While muscle soreness returned to its baseline value 72 h post-exercise in the KTG, it remained significantly elevated 72 h post-exercise compared to baseline in the CG. Many studies in the literature investigated the potential effects of KT on the level of tenderness after a high intensive exercise.^{2,4,6,10} Few of the published studies, like the present study, were about the lower extremity. Ozmen et al¹⁰ who

applied Y-shaped KT on quadriceps femoris muscle from origin to insertion demonstrated that muscle soreness increased 48 h post-exercise compared to baseline in the KTG. No changes were found in the inter-groups. Therefore, they concluded that KT was not an efficient method to reduce muscle pain.¹⁰ Likewise, Boobphachart et al² who used KT facilitation technique on superficial muscles of the quadriceps femoris found out that muscle soreness remained elevated 72 h post-exercise compared to baseline in the elastic taping group. However, muscle soreness was lower at 72 h post-exercise in the KTG compared to the placebo group.² In addition, studies about the effects of KT on upper extremity DOMS showed that soreness did not diminish 48 or 72 h post-exercise compared to baseline, however, soreness decreased 72 h post-exercise compared to 24 h in KTG.^{4,6} Unlike our study, other studies used different KT techniques or application tension. Except us, in none of the published studies, KT provided a recovery in muscle soreness from baseline to 72 h post-exercise. Several explanations are put forward to explain the favorable effects of KT on muscle soreness. First of all, the accumulation of lymphatic fluids may cause increased pressure on tissue that may consequently cause pain. KT enhances lymphatic circulation in the application area by lifting the skin away from the tissue beneath. This lifting action can help to relieve pressure on nociceptors directly under the skin and to remove the accumulated metabolites. Thus, it could decrease muscle soreness quicker in the early period of DOMS.² Second of all, the alteration of muscle soreness could be attributed to the gate control theory. KT increases the afferent stimulus to large diameter nerve fibers, and therefore, the afferent input received by thin diameter nerve fibers, such as nociceptors is reduced, and less pain is felt.²¹ Thirdly, KT triggers the Golgi tendon organ (GTO) by pulling the muscles, which causes inhibition of the contraction which is called autogenic inhibition.⁴ Fourthly, KT is thought to increase blood circulation and muscle temperature by stimulating the vasomotor reflex. This increased metabolism may decrease

pain.⁴ KT stimulates the cutaneous fusimotor reflex which in turn generates muscle contraction. Lymphatic and blood circulation is increased when muscle contraction occurs.⁴ In the present study, the recovery of muscle soreness occurred 72 h post-exercise when KT inhibition technique and paper off tension were applied. This finding could be attributed to the increased blood and lymphatic circulation generated by the cutaneous fusimotor and vasomotor reflexes, which in turn increased the removal of metabolites and increased muscle oxygenation. As KT was applied along the muscle from insertion to the origin, the proprioceptors which are sensitive to changes in muscle length are thought to be stimulated and thereby generating inhibition of muscle which could also explain the recovery of muscle soreness.

Edema limits mobility which is a significant bio-motor ability in sports. Inflammation due to micro tears occurring in muscle fibers or connective tissue damage is likely to be present particularly after the eccentric exercises inducing DOMS.^{4,6} Accordingly, the likelihood of muscle spasticity and swelling grows, and therefore, routine daily activities are adversely affected.⁴ As shown in the study conducted by Pop et al⁹, using their own KT method with %10 tension had positive effects on the level of edema. In fact, KT reduced by 55% lymphedema after mastectomy. Pop et al⁹ showed that direction of the tapes' application (i.e. from the most distant part of the edema limb to the proximal part) has an effect on the reduction of the volume of lymphedema.⁹ Likewise, ultrasound muscle thickness measurements conducted by Lee et al⁶ after an exercise inducing DOMS showed that perpendicular KT application was an effective method to decrease the level of edema. They suggested that stimulation of γ -motor neurons by KT caused a reduction of edema.⁶ In contrast, the results of another study which used KT facilitation technique indicated that KT application after DOMS did not attenuate muscle swelling.² In the present study, we used the inhibition technique. However, KT application did not prevent the development of edema.

Different KT modality used to prevent edema might be the reason for explaining the discrepancy in the literature. We could also hypothesize that the amount of edema generated after DOMS is not as much as lymphedema, which might be the underlying reason why KT application was less beneficial in the recovery of edema in the current study.

Decreased flexibility is a relevant risk factor for musculoskeletal injuries. Various studies showed that acute KT application improved the shoulder joint ROM in overhead athletes²² and healthy sedentary people,²³ and the ankle joint ROM in duathletes.²⁴ However, we should note that there is inconsistency in the literature about the potential effects of KT application on ROM after an exercise. Although Marban et al²⁴ showed that I-shaped KT application with %10 tension did not affect ankle ROM in duathletes after an exercise, Eom et al²⁵ who used the same KT application technique that we also used, indicated that KT had beneficial effects in university students. Moreover, Boobphachart et al² concluded that KT application was not effective in the recovery of ROM immediately and 24 h post-exercise inducing DOMS. However, ROM returned to baseline values 48 h post-exercise. They evoked that lifting the skin in the taped area reduces the loading of the underlying fascia or connective tissue, and the circulation and cutaneous mechanoreceptors stimulation may affect the range of motion.² In the present study, no significant effect over time was observed for ROM in the KTG. In the meantime, even though edema persisted, we noticed that ROM did not diminish in the KTG. We applied the KT inhibition technique on rectus femoris muscle while it was stretched. We thought that the maintenance or improvement of ROM could be due to the neurologic suppression generated by the stimulation of GTO. In addition, KT improves blood and lymphatic circulation which may also improve flexibility.¹⁰

The proprioceptive system which is essential for balance is affected adversely by inflammatory substances or metabolites.¹¹ Although the way about how KT affected balance was

not yet fully understood, a study demonstrated that KT induced changes in the skin surface, dermis, and epidermis which could support physiological pathways enhancing balance.²⁶ According to Bischoff et al⁸, the development of proprioceptive skills might also be due to this fact. Non-elite soccer players' balance decreased after a protocol inducing fatigue in both CG and KTG. However, the decrease in the KTG was significantly lower than the CG. Tajik et al¹¹ attributed these results to the plausible effects of KT in mitigating the adverse effects of fatigue on balance. To be more precise, KT improves blood flow and thereby oxygen supply to the tissues. Consequently, this situation helps the removal of metabolites.¹¹ In our study, we noticed that a substantial decrease of distance medium error still occurred from baseline to 72 h post-exercise only in the KTG. The same physiologic mechanism underlined by Tajik et al¹¹ may explain why KT had beneficial effects on balance in the present study.

DOMS induced by unaccustomed physical activities reduced explosive power.¹⁵ In a study conducted by Aktas et al⁷, the single leg hop test performance increased significantly and progressed the best in the group using both quadriceps muscle technique and patellar mechanical correction technique (KT) compared to the brace group and the brace plus KT group. They postulated that the favourable effects of KT on performance were assignable to an increase of circulation and a tactile input enhancement which modulates the excitability of the central nervous system resulting in an increase of motor unit firing.⁷ We used the double leg hop test to assess the horizontal jump performance, and similarly to Aktas et al⁷, we found out that performance did not decrease in any time frame compared to baseline and increased significantly from 24 to 72 h post-exercise only in the KTG. Applying KT on rectus femoris which are known to generate power to thrust the body forward²⁷ may increase the skin mechanoreceptors stimulation. The improvement of explosive power may be explained by two following different reasons: the mechanoreceptors

stimulation firstly provides information about joint position and movement to decrease joint error, and secondly increases motor unit firing which is a physiologic mechanism argued above by Aktas et al⁷.

Sprint is a complex sports task with different phases.²⁸ During running, the highest power is generated by the ankle plantar flexors for the complete stride cycle compared to other lower extremity joints. One of the main functions of knee extensors is to maintain the center of mass height while running. However, the contribution of knee extensors is negligible during the stance phase of the stride cycle.²⁷ Instead, Y-shaped facilitation KT technique with paper-off tension applied on quadriceps muscle improved the 30 yd sprint performance in a study.²⁹ However, same KT cut and technique with 120% tension had no effect on 10 m sprint performance in another study.³⁰ Likewise, Y-shaped facilitation KT technique applied to male athletes' gluteal muscles and young healthy adult women's quadriceps femoris muscle did not have an effect on their 20 m sprint performance after an exhaustive exercise protocol.^{10,28} In the present study, KT application resulted in similar sprint time as the CG compared with baseline. We thought that the underlying reason why KT application did not improve sprint performance in the present study was due to the minimal contribution of the quadriceps muscle group during this complex task.

Finally, there are some limitations in this study. First, the sample size is small. Secondly, the findings of this study should only be applied to young recreational athletes.

Conclusions

In conclusion, muscle soreness returned to baseline values 72 h post-exercise only within the KTG. Balance improved from baseline to 72 h post-exercise only in the KTG. KT had a favorable effect on horizontal jump performance from 24 to 72 h post-exercise only in the KTG.

KTG and CG had similar results related to the mid-belly circumference of quadriceps, sprint performance, and ROM.

Implications for Practice, Education, and Future Research

The findings obtained in the present study suggest that KT could be applied after an unaccustomed or eccentric physical exercise to reduce muscle soreness. The application of KT can be worthy of recommendation to improve performance during training based on explosive power or balance.

Further studies are needed to find out whether the effects of KT differ in professional athletes and athletes with chronic symptoms accompanying knee problems due to the rectus femoris weakness. Furthermore, additional research is needed to find out the most convenient KT application technique for recovery.

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Conflict of Interest:

None; the authors confirm that there is no financial and personal relationship with other people or organizations that could inappropriately influence (bias) the present study.

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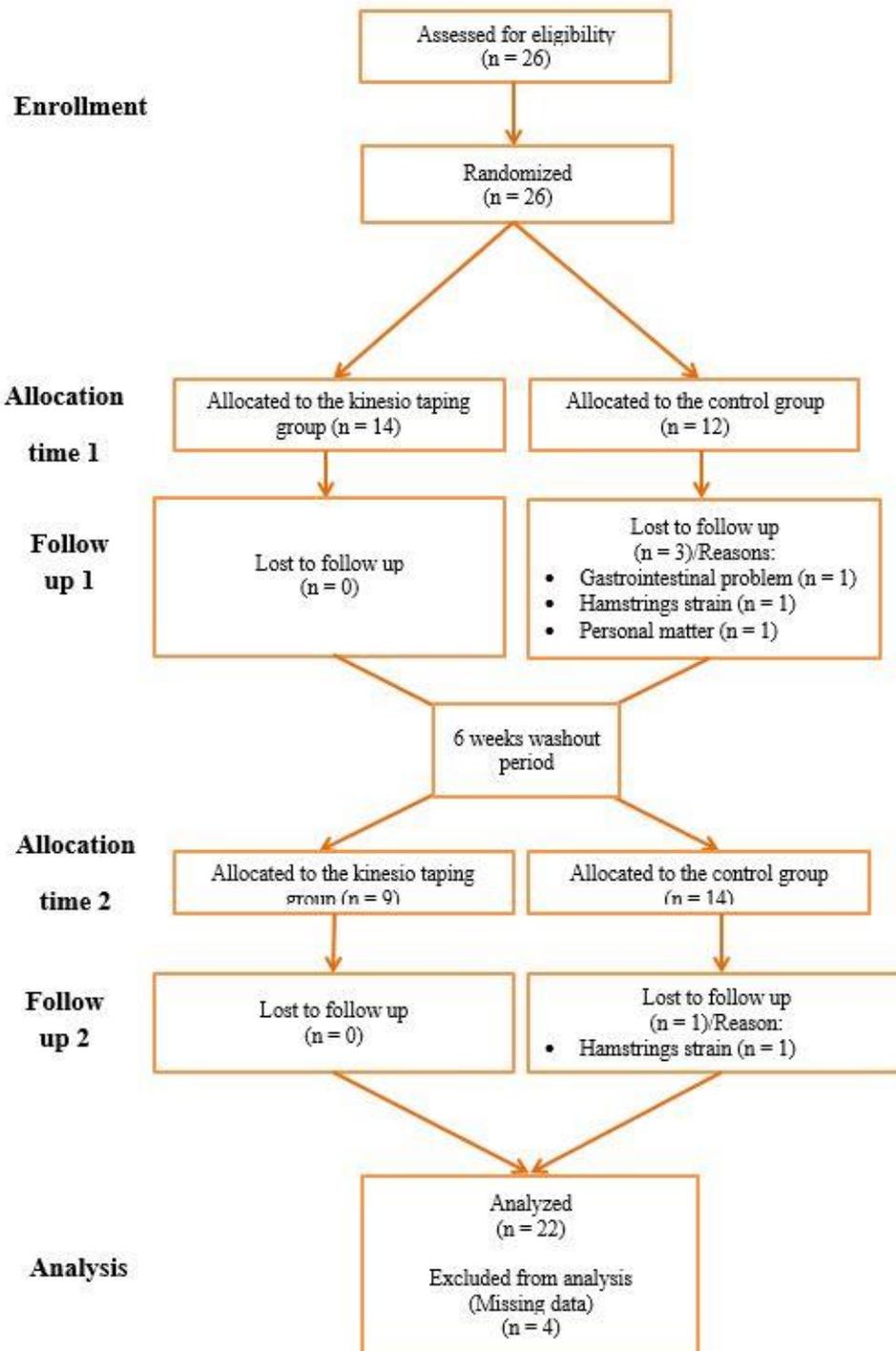


Figure 1. Consort flow diagram showing the flow of participants through each stage of the randomized crossover trial.

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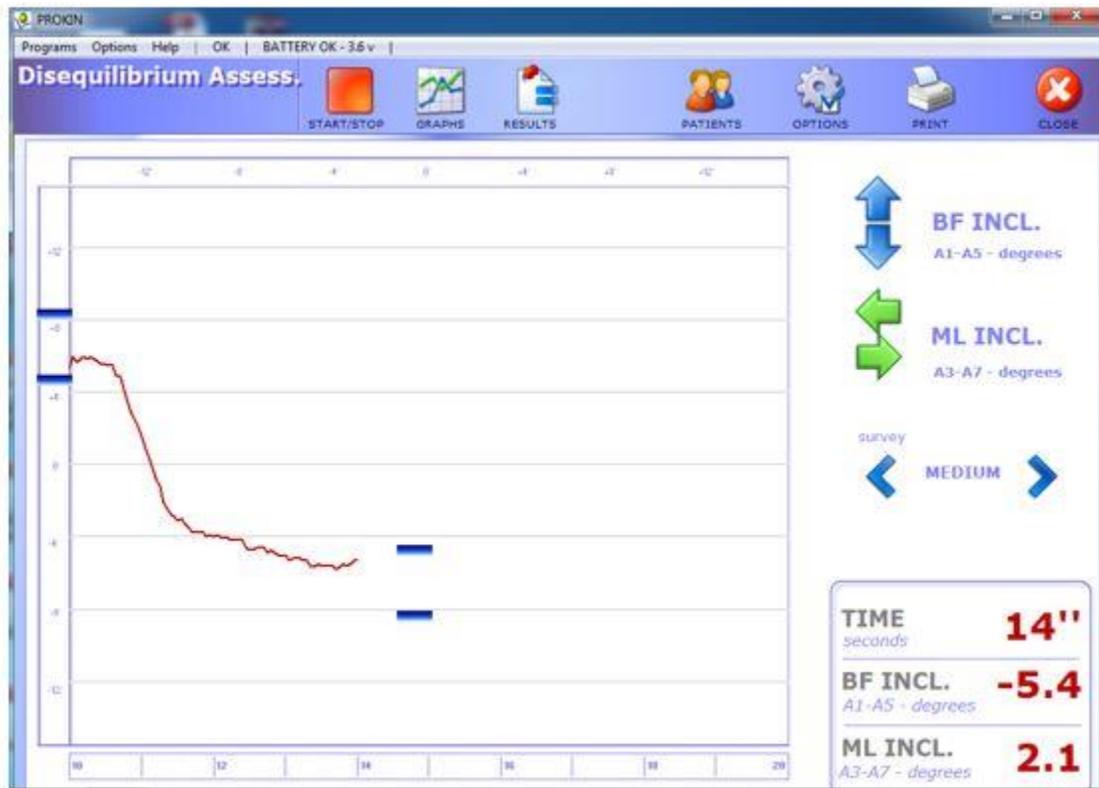


Figure 2. Dynamic balance test (disequilibrium assessment)

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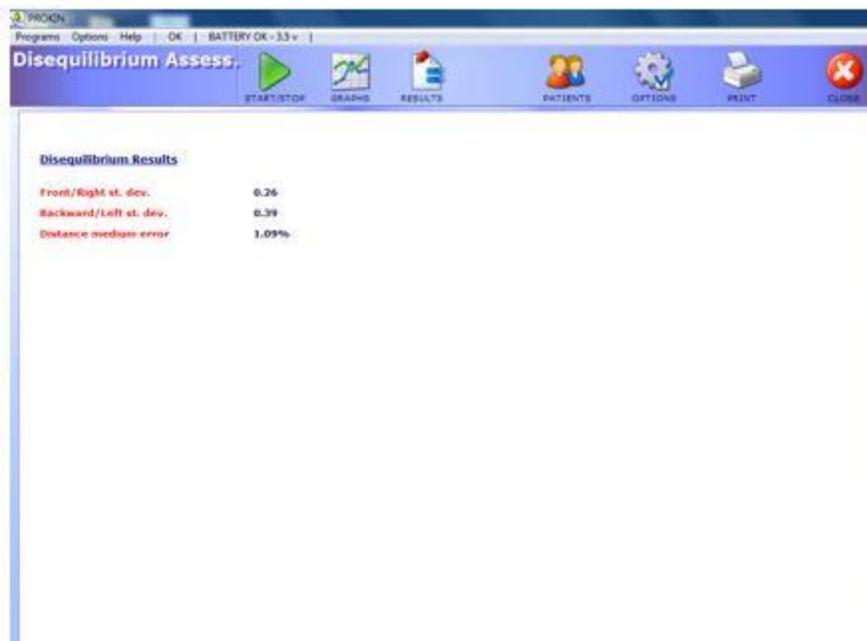


Figure 3. Dynamic balance test (disequilibrium assessment) result

Table 1: Participants’ characteristics.

	N	Mean±SD
Age (years)	22	21.36±1.68
Height (cm)	22	178.14±6.57
Weight (kg)	22	79.43±10.07
BMI (kg/m²)	22	25.03±2.85
Sport Age (years)	22	5.73±3.27
Training session per week (number)	22	3.77±1.48

Data are means ± Standart Deviation (SD).

Body mass Index: BMI.

Table 2: Evaluation of Pain, Edema and Range of Motion.

Variables	Groups	Baseline X±SD	Post-30 min X±SD	Post-24 h X±SD	Post-48 h X±SD	Post-72 h X±SD
VAS (out of 10)	CG	0.51±0.34	2.17±1.50 ^a	2.45±1.84 ^a	3.16±2.36 ^a	1.98±2.00 ^a
	KTG	0.68±0.67	2.35±1.82 ^a	3.52±2.02 ^{a,d}	3.46±1.84 ^a	1.76±1.52 ^{b,c}
Mid-Thigh Circumference (cm)	CG	60.05±4.27	60.57±4.51	60.65±4.20	60.58±4.53 ^a	60.58±4.25
	KTG	59.80±4.16	60.16±4.25	60.27±4.28	60.56±4.08 ^{a,e}	60.11±4.22
Knee Flexion (°)	CG	122.68±6.12	124.32±6.23	121.45±7.24	118.64±8.59	118.45±9.47 ^f
	KTG	123.23±7.86	122.82±7.29	123.09±8.28	122.50±8.08	117.77±24.87

Data are means ± SD.

^a Significant difference from baseline,

^b Significant difference from 48 h to 72 h post exercise,

^c Significant difference from 24 h to 72 h post exercise,

^d Significant difference from 30 min to 24 h post exercise,

^e Significant difference from 30 min to 48 h post exercise,

^f Significant difference from 30 min to 72 h post exercise (p<0.05).

KTG: Kinesio Taping Group.

CG: Control Group.

VAS: Visual Analogue Scale.

Table 3: Biomotor Abilities Performance Tests.

Variables	Groups	Baseline X±SD	Post-24 h X±SD	Post-48 h X±SD	Post-72 h X±SD
20 m sprint time (sec)	CG	3.34±0.15	3.45±0.20 ^a	3.44±0.21	3.39±0.18
	KTG	3.39±0.16	3.48±0.25 ^a	3.45±0.20	3.46±0.20
Horizontal jump (cm)	CG	211.00±16.47	204.05±21.72 ^a	203.32±18.75 ^a	205.23±18.78
	KTG	206.41±18.87	202.41±19.58	205.91±17.98	209.59±18.38 ^b
Disequilibrium Assessment/ Distance Medium Error (%)	CG	1.62±1.84	0.85±0.73	0.69±0.71 ^a	0.76±0.82
	KT	1.20±0.83	0.92±0.68	0.59±0.55 ^a	0.50±0.44 ^a

Data are means ± SD.

^a Significant difference from baseline,

^b Significant difference from 24 h to 72 h post exercise (p<0.05).

KTG: Kinesio Taping Group.

CG: Control Group.