***Journal of Sport Rehabilitation*, 2020, 29, 385-393**
https://doi.org/10.1123/jsr.2018-0389

Human Kinetics
ORIGINAL RESEARCH REPORT

The Effectiveness of Kinesio Taping in Recovering From Delayed Onset Muscle Soreness: A Crossover Study

Berkiye Kirmizigil, Jeffry Roy Chauchat, Omer Yalciner, Gozde Iyigun, Ender Angin, and Gul Baltaci

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 delayed onset muscle soreness enhances recovery of muscle soreness, edema, and physical performance. ***Participants:*** A total of 22 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 delayed onset muscle soreness. They accomplished 2 distinct trials, with or without KT. The washout period between trials was 6 weeks. 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 minutes, 24, 48, and 72 hours postexercise. Dynamic balance, sprint, and horizontal jump were evaluated at similar time frame except for 30-minute postexercise. ***Results:*** The findings showed that there were no significant differences between the KT group (KTG) and control group for all outcome variables ($P > .05$). Muscle soreness returned to baseline values 72 hours postexercise only within the KTG ($P > .05$). Although the horizontal jump performance decreased substantially from baseline to 24 and 48 hours postexercise only within the control group ($P < .05$), the performance increased significantly from 24 to 72 hours postexercise within the KTG ($P < .05$). Balance increased significantly from baseline to 48 hours postexercise ($P < .05$) in both groups. Balance also increased significantly from baseline to 72 hours postexercise only within the KTG ($P < .05$). The effect size of soreness which is our primary outcome was large in both groups ($r > .5$). ***Conclusions:*** KT is favorable in the recovery of muscle soreness after delayed onset muscle soreness. KT has beneficial effects on horizontal jump performance and dynamic balance.

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

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 hours postexercise,[3,4] peak 24 to 72 hours postexercise,[1,3,4] and disappear from 5 to 7 days postexercise.[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 (eg, tumor necrosis factor-alpha).[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 activity,[4] 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 underresearched.[2,4,6,10,11] According to the relevant published studies, to date, there was no consensus on how to apply KT. The KT cutting methods, amount of stretch in the tape, and application techniques may vary.[2,4,6,10,11] For example, Boobphachart et al[2] 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 that elastic tape application on quadriceps femoris recovered muscle strength and reduced muscle soreness after 72 hours postintensive exercise. They proposed that the reduction in muscle soreness might be due to blood and lymphatic flow enhancement, and these 2 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 al[11] 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 (KTG) had better scores in dynamic balance compared with the control group (CG). They postulated that KT

Kirmizigil, Iyigun, Angin, and Baltaci are with the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Eastern Mediterranean University, Famagusta, North Cyprus via Mersin 10, Turkey. Chauchat and Yalciner are with the Department of Sports Sciences, Faculty of Health Sciences, Eastern Mediterranean University, Famagusta, North Cyprus via Mersin 10, Turkey. Kirmizigil (berkiye.kirmizigil@emu.edu.tr, berkiyekirmizigil@yahoo.com) is corresponding author.

enhances fatigued muscles' proprioception, which may decrease the joint error, and thereby positively affects balance.[11] Lee et al[6] 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 hours 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 al[6] showed that KT decreases soreness significantly from 24 to 72 hours 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 Golgi tendon organ, which induces neurologic suppression resulting in pain reduction.[4] In contrast to the findings of studies reported previously, including Lee et al's[6] findings, 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 hours postexercise. 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 et al[10] stated that beneficial effects of KT, such as increase blood and lymphatic circulation, and stimulation of cutaneous mechanoreceptors might improve flexibility.

When we examined the relevant studies in the literature, we noticed that the KT inhibition technique was not used on rectus femoris muscle. This 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 Statistical Software, Kaysville, UT). 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, SD = 0.6, alpha = .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 2 groups by a simple randomization technique (14 in the KTG and 12 in the CG). Although 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; body mass index 25.03 [2.85] kg/m^2; and sport age 5.73 [3.27] y) completed the whole study as planned (see Figure 1). All the participants were recreational athletes (ie, they were participating in sports activities to be healthy and/or to have fun), and they were attending aerobic-based activities at least 2 sessions per week. They were informed to abstain from doing any lower body strength training or unaccustomed physical exercise at least 1 week before the beginning of this study. Participants who had any neuromuscular, cardiorespiratory, neurologic diseases, or underwent any musculoskeletal injuries over the last 6 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 5 days. To discard the potential effects of learning, the first day at least 48 hours 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 minutes, 24, 48, and 72 hours postexercise. 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-minute postexercise. Physical performance tests and DOMS induction were conducted at the same time of day (2:00 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 5 sets of 20 drop jumps from a 0.6 m high box with 10-second intervals between each jump. The rest between sets were 2 minutes.[12]

Taping Application

The 5-cm width Kinesio tape (Kinesio® Tex Gold™, Albuquerque, NM) 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 to 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.

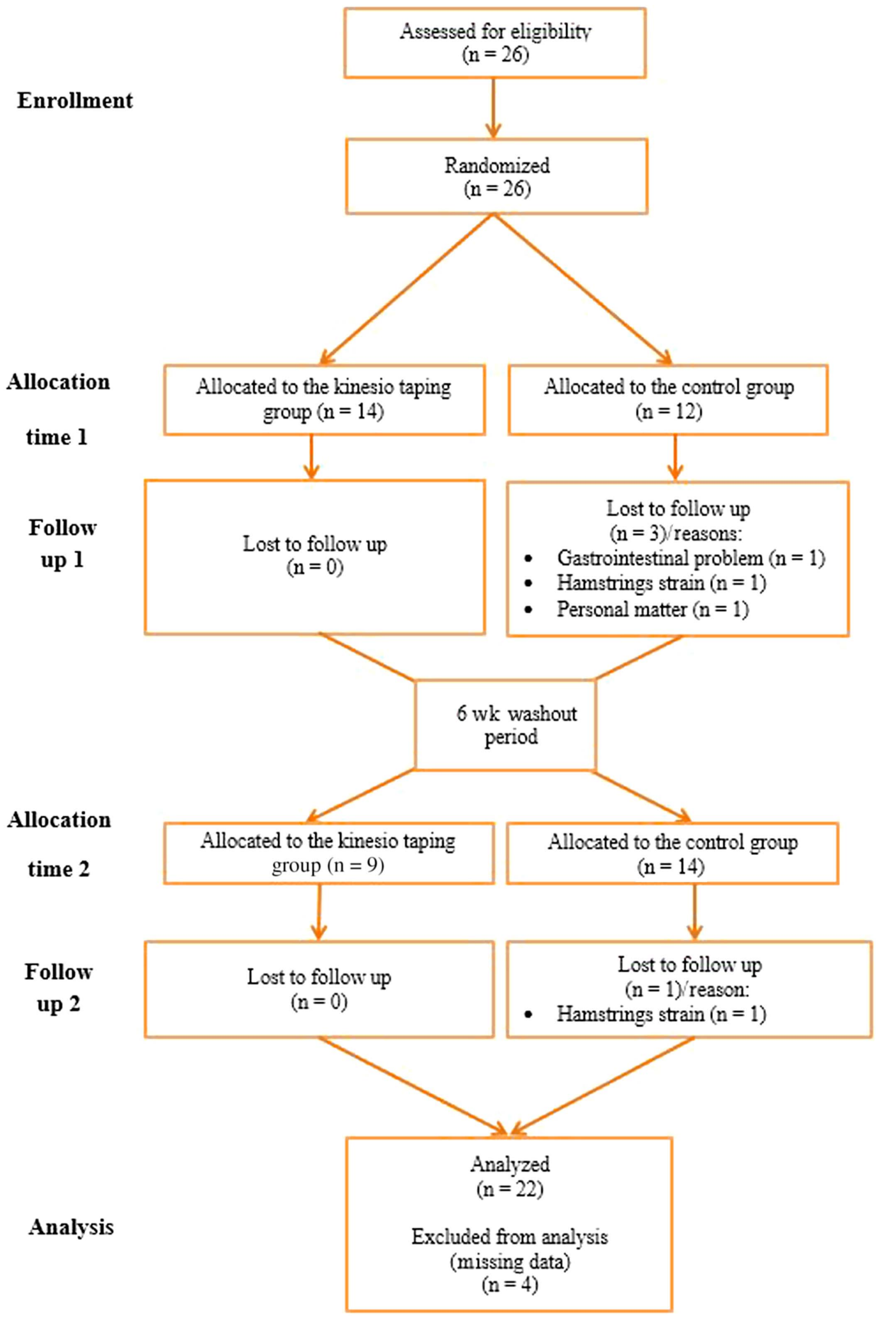

Figure 1 — Consort flow diagram showing the flow of participants through each stage of the randomized crossover trial. CG indicates control group; KTG, Kinesio taping group.

Outcome Measures

Demographic and Anthropometric Evaluation. On day 1, 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 analog scale 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 and the superior margin of the patella, and then marked with a pen to record the length of the femur by using a tape measure. Next, we found the midpoint between the anterior superior iliac spine and superior margin of the patella 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, 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 3 runs. They rested 1 minute 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 to land on 2 feet. The jump-length measurement was determined using a metric tape measure, from the takeoff line to the nearest point of landing contact (ie, the back of the heels).[17] Each subject completed 3 attempts. The rest between attempts was 1 minute. The mean of the 3 jump distances was taken.

Dynamic Balance. We used a computer-based balance device (PK200WL; Prokin TecnoBody, Bergamo, Italy) such as the one used by Birinci and Demirbas.[18] However, the disequilibrium assessment was chosen to test dynamic balance on bipedal stance for 30 seconds (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 3 attempts, interspersed by 1-minute intervals. The mean of the 3 attempts was recorded.

Statistical Analysis. All statistical analysis was performed by using IBM SPSS 22 package (SPSS Inc, Chicago, IL). 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 nonparametric 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 $P < .05$.

The "$r = z/\sqrt{(n \times 2)}$" formula is used to determine the effect size of the changes over time in the KTG and CG. Effect sizes were interpreted as small ($r \le .1$), moderate ($r = .30$), and large ($r \ge .5$).[20]

Results

The characteristics of the participants were displayed in Table 1.

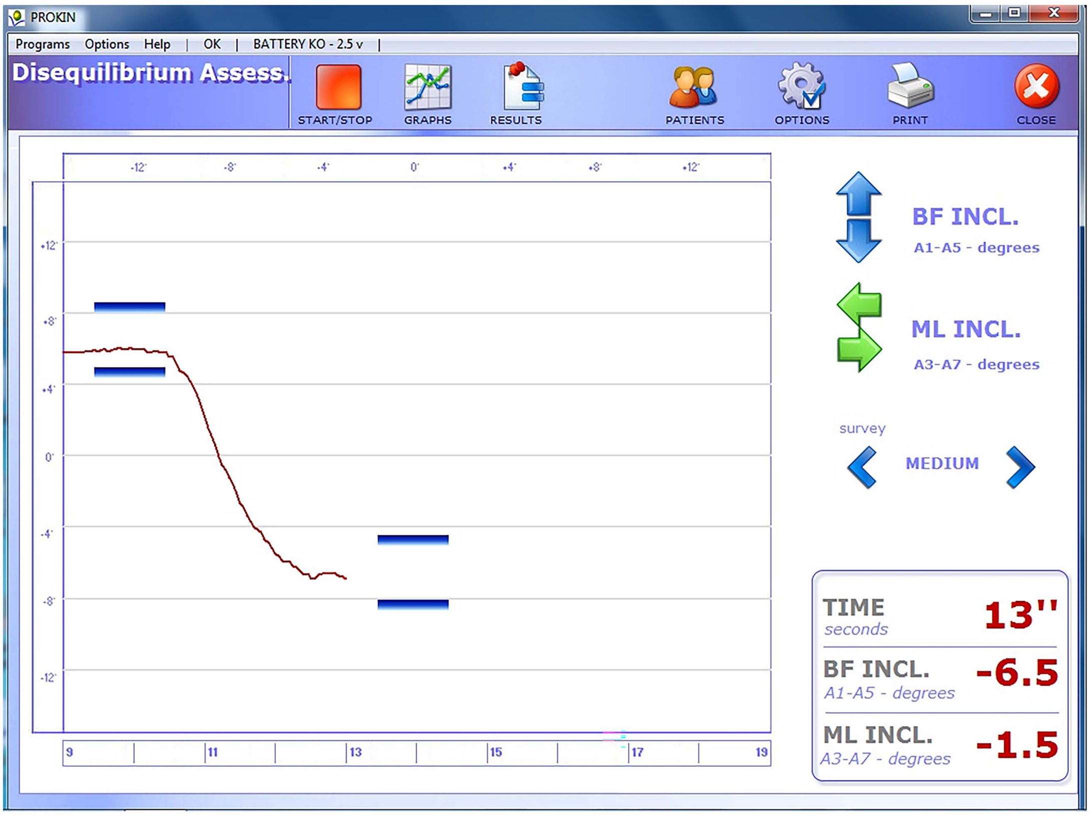

Figure 2 — Dynamic balance test (disequilibrium assessment).

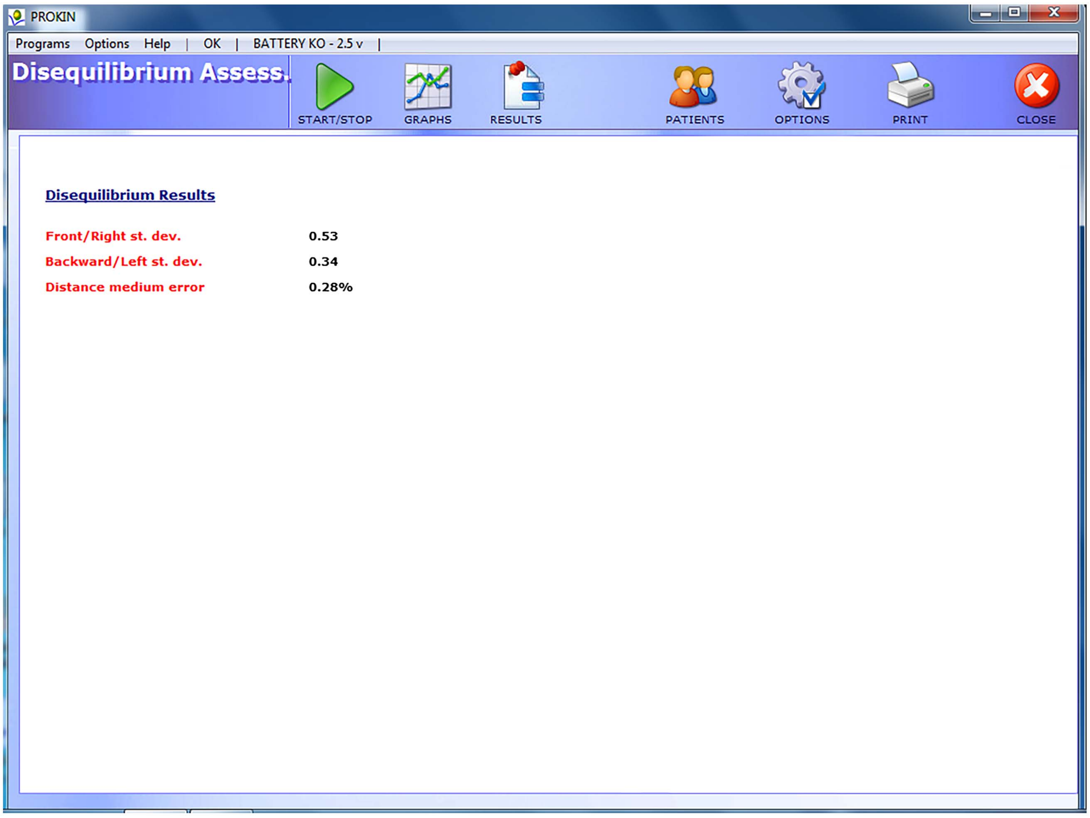

Figure 3 — Dynamic balance test (disequilibrium assessment) results.

Table 1 Participants' Characteristics

	N	Mean (SD)
Age, y	22	21.36 (1.68)
Height, cm	22	178.14 (6.57)
Weight, kg	22	79.43 (10.07)
BMI, kg/m^2	22	25.03 (2.85)
Sport age, y	22	5.73 (3.27)
Training sessions per week (number)	22	3.77 (1.48)

Abbreviation: BMI, body mass index.

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.

Control group muscle soreness remained substantially elevated 30 minutes, 24, and 48 hours postexercise compared with baseline ($P < .001$, confidence interval [CI] = 1.7 [0.10 to 6.6]; $P = <.001$, CI = 1.9 [0.10 to 5.4]; $P = <.001$, CI = 2.7 [–0.3 to 9.2], respectively). In the meantime, muscle soreness remained also significantly elevated 24 and 48 hours postexercise compared with baseline within the KTG ($P = <.001$, CI = 2.8 [0.2 to 6.2]; $P = <.001$, CI = 2.8 [0.1 to 6.4], respectively). Even if muscle soreness remained significantly elevated 30-minute postexercise

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

Variables	Groups	Baseline	Post 30 min	Post 24 h	Post 48 h	Post 72 h
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, deg	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)

Abbreviations: CG, control group; KTG, Kinesio taping group; VAS, visual analog scale. Note: Data are represented by mean (SD).
[a]Significant difference from baseline. [b]Significant difference from 48 to 72 hours postexercise. [c]Significant difference from 24 to 72 hours postexercise. [d]Significant difference from 30 minutes to 24 hours postexercise. [e]Significant difference from 30 minutes to 48 hours postexercise. [f]Significant difference from 30 minutes to 72 hours postexercise ($P < .05$).

Table 3 Biomotor Abilities Performance Tests

Variables	Groups	Baseline	Post 24 h	Post 48 h	Post 72 h
20-m sprint time, s	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)
	KTG	1.20 (0.83)	0.92 (0.68)	0.59 (0.55)[a]	0.50 (0.44)[a]

Abbreviations: CG, control group; KTG, Kinesio taping group. Note: Data are mean (SD).
[a]Significant difference from baseline. [b]Significant difference from 24 to 72 hours postexercise ($P < .05$).

compared with baseline ($P = .01$) within KTG, CI was 1.7 (–0.3 to 4.3). Muscle soreness remained substantially elevated 72 hours postexercise compared with baseline ($P = <.001$) within the CG but CI was 1.5 (–0.8 to 6.7). On the other side, it returned to baseline values 72 hours postexercise within the KTG. Although there was a significant drop in muscle soreness from 24 to 72 hours postexercise ($P = .01$) within the KTG, CI was −1.8 (−5.6 to 1.9). Otherwise, there was a significant increase in muscle soreness from 30 minutes to 24 hours postexercise in the KTG ($P = .03$) but CI was found 1.7 (−1.5 to 6.5).

Meanwhile, as shown in Table 2, there was a significant increase in the level of edema from baseline to 48 hours postexercise in both groups ($P < .001$ in CG and $P = .01$ in KTG). However, from baseline to 48 hours postexercise, CI was 0.8 (–0.4 to 2.4) in KTG and 0.53 (–4.3 to 2.6) in CG.

No significant time effect was found in the knee-flexion ROM among the KTG ($P > .05$).

In both groups, speed decreased significantly only from baseline to 24 hours postexercise ($P = .02$ in CG and $P = .04$ in KTG), but CI was 0.01 (–0.3 to 5) in KTG and 0.1 (–0.1 to 0.7) in CG.

There were substantial decreases in the horizontal jump performance from baseline to 24 and 48 hours postexercise ($P = .04$ and $P = <.001$, respectively) within the CG. However, CI values were −7 (–46 to 10) and −7.7 (–26 to 2), respectively. In addition, there was a significant increase in the horizontal jump performance from 24 to 72 hours postexercise within the KTG ($P < .001$); however, CI was 1.5 (−2.2 to 6.1).

The DME in the disequilibrium assessment decreased significantly from baseline to 48 hours postexercise in both groups ($P = .03$ in CG and $P = .02$ in KTG), but CI was –0.9 (–4.1 to 0.5) in CG and –0.6 (–1.8 to 0.8) in KTG.

There were no differences between the groups at all times, at any parameters ($P > .05$). In addition, the effect size of our primary outcome (ie, soreness) was found large in both groups ($r = .72$ in both groups). Apart from the effect size of KT balance value which is large ($r = .53$), all other parameters' effect size were moderate in both groups ($0.1 < r < .5$).

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 this study showed that significant changes occurred in variables, such as muscle soreness; explosive power (ie, horizontal jump); and balance, in both groups. However, unlike the CG, recovery of muscle soreness occurred 72 hours postexercise compared with baseline in the KTG. Although significant drops in the horizontal jump performance occurred from baseline to 24 and 48 hours postexercise 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 hours postexercise in the KTG. While balance performance increased significantly in both groups from baseline to 48 hours postexercise, balance performance increased significantly from baseline to 72 hours postexercise only within the KTG.

There are different methods inducing DOMS (eg, 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 this study. Many studies related to DOMS showed that muscle soreness tended to increase within 24 hours postexercise, peaked at 48 hours postexercise, and started to decrease 72 hours postexercise.[1,3,4,6,10,15] The results of this study are in line with the literature.[1,4,6,10,15] Muscle soreness began 30 minutes postexercise, gradually increased over time, and peaked at 48 hours postexercise in both groups. While muscle soreness returned to its baseline value 72 hours postexercise in the KTG, it remained significantly elevated 72 hours postexercise compared with 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, such as this study, were about the lower-extremity. Ozmen et al,[10] who applied *Y*-shaped KT on quadriceps femoris muscle from origin to insertion, demonstrated that muscle soreness increased 48 hours postexercise compared with baseline in the KTG. No changes were found in the intergroups. Therefore, they concluded that KT was not an efficient method to reduce muscle pain.[10] Likewise, Boobphachart et al,[2] who used KT facilitation technique on superficial muscles of the quadriceps femoris, found out that muscle soreness remained elevated 72 hours postexercise compared with baseline in the elastic taping group. However, muscle soreness was lower at 72 hours postexercise in the KTG compared with 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 hours postexercise compared with baseline; however, soreness decreased 72 hours postexercise compared with 24 hours in KTG.[4,6] Unlike this 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 hours postexercise. Several explanations are put forward to explain the favorable effects of KT on muscle soreness. First , 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, 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] Third, KT triggers the Golgi tendon organ by pulling the muscles, which causes inhibition of the contraction which is called autogenic inhibition.[4] Fourth, 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 this study, the recovery of muscle soreness occurred 72 hours postexercise 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 biomotor 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 al,[9] 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 al[9] showed that direction of the tapes' application (ie, 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 al[6] 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 this 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 this 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 athletes[22] 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 Merino-Marban et al[24] showed that *I*-shaped KT application with %10 tension did not affect ankle ROM in duathletes after an exercise, Eom et al,[25] who used the same KT application technique that we also used, indicated that KT had beneficial effects in university students. Moreover, Boobphachart et al[2] concluded that KT application was not effective in the recovery of ROM immediately and 24 hours postexercise inducing DOMS. However, ROM returned to baseline values 48 hours postexercise. 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 ROM.[2] In this 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 Golgi tendon organ. 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 al,[8] the development of proprioceptive skills might also be due to this fact. Nonelite 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 al[11] 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 this study, we noticed that a substantial decrease of DME still occurred from baseline to 72 hours postexercise only in the KTG. The same physiologic mechanism underlined by Tajik et al[11] may explain why KT had beneficial effects on balance in this study.

Delayed onset muscle soreness induced by unaccustomed physical activities reduced explosive power.[15] In a study conducted by Aktas and Baltaci,[7] 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 with the brace group and the brace plus KTG. They postulated that the favorable 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 and Baltaci,[7] we found out that performance did not decrease in any time frame compared with baseline and increased significantly from 24 to 72 hours postexercise only in the KTG. Applying KT on rectus femoris which are known to generate power to thrust the body forward[27] may increase the skin mechanoreceptors stimulation. The improvement of explosive power may be explained by 2 following different reasons: the mechanoreceptors stimulation first provides information about joint position and movement to decrease joint error, and second increases motor unit firing which is a physiologic mechanism argued previously by Aktas and Baltaci.[7]

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 with 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 this 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 this 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. Second, the findings of this study should only be applied to young recreational athletes.

Implications for Practice, Education, and Future Research

The findings obtained in this 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.

Conclusions

Muscle soreness returned to baseline values 72 hours postexercise only within the KTG. Balance improved from baseline to 72 hours postexercise only in the KTG. KT had a favorable effect on horizontal jump performance from 24 to 72 hours postexercise only in the KTG. The KTG and CG had similar results related to the midbelly circumference of quadriceps, sprint performance, and ROM.

Acknowledgments

The authors would like to thank Assist. Professor Levent Eker, MD for the valuable guidance in statistics of this study. This project was supported by Kinesio Taping Association International (KTAI) Research Committee. The authors confirm that there is no conflict of interest, financial, and personal relationship with other people or organizations that could inappropriately influence (bias) this study.

References

1. Bleakley C, McDonough S, Gardner E, Baxter DG, Hopkins TJ, Davison GW. Cold-water immersion (cryotherapy) for preventing and treating muscle soreness after exercise. *Sao Paulo Med J*. 2012;130:348. doi:10.1590/S1516-31802012000500015
2. Boobphachart D, Manimmanakorn N, Manimmanakorn A, Thuwakum W, Hamlin MJ. Effects of elastic taping, non-elastic taping and static stretching on recovery after intensive eccentric exercise. *Res Sport Med*. 2017;25:181–190. doi:10.1080/15438627.2017.1282360
3. Cheung K, Hume P, Maxwell L. Delayed onset muscle soreness: treatment strategies and performance factors. *Sport Med*. 2003;33:145–164. doi:10.2165/00007256-200333020-00005
4. Bae SH, Lee YS, Kim GD, Kim KY. The effects of kinesio-taping applied to delayed onset muscle soreness on changes in pain. *Int J Bio-Science Bio-Technology*. 2014;6:133–142. doi:10.14257/ijbsbt.2014.6.3.16
5. Kim J, Kim J, Lee J. Effect of compression garments on delayed-onset muscle soreness and blood inflammatory markers after eccentric exercise: a randomized controlled trial. *J Exerc Rehabil*. 2017;13:541–545. PubMed ID: 29114528 doi:10.12965/jer.1735088.554
6. Lee YS, Bae SH, Hwang JA, Kim KY. The effects of Kinesio taping on architecture, strength and pain of muscles in delayed onset muscle soreness of biceps brachii. *J Phys Ther Sci*. 2015;27:457–459. PubMed ID: 25729190 doi:10.1589/jpts.27.457
7. Aktas G, Baltaci G. Does kinesiotaping increase knee muscles strength and functional performance? *Isokinet Exerc Sci*. 2011;19:149–155. doi:10.3233/IES-2011-0408
8. Bischoff L, Babisch C, Babisch J, et al. Effects on proprioception by Kinesio taping of the knee after anterior cruciate ligament rupture. *Eur J Orthop Surg Traumatol*. 2018;28(6):1157–1164. PubMed ID: 29525979 doi:10.1007/s00590-018-2167-1
9. Pop TB, Karczmarek-Borowska B, Tymczak M, Hałas I, Banaś J. The influence of Kinesiology taping on the reduction of lymphoedema among women after mastectomy—preliminary study. *Contemp Oncol*. 2014;18(2):124–129. doi:10.5114/wo.2014.40644
10. Ozmen T, Aydogmus M, Dogan H, Acar D, Zoroglu T, Willems M. The effect of Kinesio taping on muscle pain, sprint performance, and flexibility in recovery from squat exercise in young adult women. *J Sport Rehabil*. 2016;25:7–12. PubMed ID: 25559694 doi:10.1123/jsr.2014-0243
11. Tajik A, Shokri E, Ghanbari A. The effect of Kinesio taping of quadriceps muscle on the balance of non-elite football players after a local fatigue induced protocol. *J Rehabil Sci Res*. 2016;1:5–10.
12. Goodall S, Howatson G. The effects of multiple cold water immersion on indices of muscle damages. *J Sports Sci Med*. 2008;7(2):235–241. PubMed ID: 24149455
13. Vercelli S, Sartorio F, Foti C, et al. Immediate effects of Kinesio taping on quadriceps muscle strength: a single-blind, placebo-controlled crossover trial. *Clin J Sport Med*. 2012;22:319–326. PubMed ID: 22450591 doi:10.1097/JSM.0b013e31824c835d
14. Sellwood KL, Brukner P, Williams D, Nicol A, Hinman R. Ice-water immersion and delayed-onset muscle soreness: a randomised controlled trial. *Br J Sports Med*. 2007;41:392–397. PubMed ID: 17261562 doi:10.1136/bjsm.2006.033985
15. Vaile JM, Gill ND, Blazevich AJ. The effect of contrast water therapy on symptoms of delayed onset muscle soreness. *J Strength Cond Res*. 2007;21:697–702. PubMed ID: 17685683
16. Milanese S, Gordon S, Buettner P, et al. Reliability and concurrent validity of knee angle measurement: smart phone app versus universal goniometer used by experienced and novice clinicians. *Man Ther*. 2014;19:569–574. PubMed ID: 24942491 doi:10.1016/j.math.2014.05.009
17. Loturco I, Kobal R, Kitamura K, et al. Mixed training methods: Effects of combining resisted sprints or plyometrics with optimum power loads on sprint and agility performance in professional soccer players. *Front Physiol*. 2017;8:1–9. doi:10.3389/fphys.2017.01034
18. Birinci T, Demirbas SB. Relationship between the mobility of medial longitudinal arch and postural control. *Acta Orthop Traumatol Turc*. 2017;51:233–237. PubMed ID: 28462802 doi:10.1016/j.aott.2016.11.004
19. PK200WL, Prokin TecnoBody. http://www.tecnobody.it. Accessed February 02, 2018.
20. Rosenthal R. Parametric measures of effect size. In: Cooper H, Hedges LV, Valentine JC, eds. *The Handbook of Research Synthesis*. New York, NY: Russell Sage Foundation;1994:231–244.

21. Thelen MD, Dauber JA, Stoneman PD. The clinical efficacy of Kinesio tape for shoulder pain: a randomized, double-blinded, clinical trial. *J Orthop Sports Phys Ther*. 2008;38:389–395. PubMed ID: 18591761 doi:10.2519/jospt.2008.2791
22. Harput G, Guney H, Toprak U, Colakoglu F, Baltaci G. Acute effects of scapular Kinesio Taping® on shoulder rotator strength, ROM and acromiohumeral distance in asymptomatic overhead athletes. *J Sports Med Phys Fitness*. 2017;57:1479–1485. PubMed ID: 27391411
23. Ujino A, Eberman LE, Kahanov L, Renner C, Demchak T. The effects of Kinesio tape and stretching on shoulder ROM. *Int J Athl Ther Train*. 2013;18:24–28. doi:10.1123/ijatt.18.2.24
24. Merino-Marban R, Mayorga-Vega D, Fernandez-Rodriguez E. Effect of Kinesio tape application on calf pain and ankle range of motion in duathletes. *J Hum Kinet*. 2013;37:129–135. PubMed ID: 24146713 doi:10.2478/hukin-2013-0033
25. Eom SY, Lee WJ, Lee J II, Lee EH, Lee HY, Chung EJ. The effect of ankle Kinesio taping on range of motion and agility during exercise in university students. *Phys Ther Rehabil Sci*. 2014;3:63–68. doi:10.14474/ptrs.2014.3.1.63
26. Cimino SR, Beaudette SM, Brown SHM. Kinesio taping influences the mechanical behaviour of the skin of the low back: a possible pathway for functionally relevant effects. *J. Biomech*. 2018;67:150–156. doi:10.1016/j.jbiomech.2017.12.005
27. Johnson MD, Buckley JG. Muscle power patterns in the mid-acceleration phase of sprinting. *J Sports Sci*. 2001;19(4):263–272. PubMed ID: 11311024 doi:10.1080/026404101750158330
28. Strutzenberger G, Moore J, Griffiths H, Schwameder H, Irwin G. Effects of gluteal Kinesio-taping on performance with respect to fatigue in rugby players. *Eur J Sport Sci*. 2016;16:165–171. PubMed ID: 25647686 doi:10.1080/17461391.2015.1004372
29. Mostaghim N, Jahromi MK, Shirazzi ZR, Salesi M. The effect of quadriceps femoris muscle Kinesio taping on physical fitness indices in non-injured athletes. *J Sports Med Phys Fitness*. 2016;56:1526–1533. PubMed ID: 27029956
30. de Hoyo M, Álvarez-Mesa A, Sañudo B, Carrasco L, Domínguez S. Immediate effect of Kinesio taping on muscle response in young elite soccer players. *J Sport Rehabil*. 2013;22:53–58. PubMed ID: 23006787 doi:10.1123/jsr.22.1.53