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SPORTS MEDICINE AND BIOMECHANICS

Acute and 24 h effect of kinesio taping on lower back muscle soreness during continued practice of cross-country skiing among collegiate students. A double-blind, randomized, placebo-controlled trial

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ABSTRACT
To examine the effects of kinesio taping on lower back muscle soreness immediately after its application and after 24 h during a cross-country skiing camp in collegiate students. The present study followed a double-blind, randomized, placebo-controlled trial design. Out of the 60 participants in a winter skiing camp, 54 volunteered to participate in the study (aged 21.3 years old, 20 females and 34 males). After 3 days of practical cross-country ski lessons (4 h per day), volunteers were, balanced by sex, randomly divided into three groups. One group had kinesio taping applied on the lower back, another had placebo tape applied and the third group nothing. The two-way ANOVA with the Bonferroni adjustment showed that the lower back muscle soreness levels in the kinesio taping group decreased statistically significantly from baseline to after 24 h of the kinesio taping application (p= 0.020). Kinesio taping reduced low back muscle soreness 24 h after its application produce by several days of cross-country skiing in physically active collegiate students. Kinesio taping method may be beneficial in reducing post-exercise delayed onset muscle soreness in healthy sport collegiate students.

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KEYWORDS
DOMS; muscle pain; elastic tape; young adults; skiers

Introduction

Cross-country (XC) skiing is a traditional winter sport, involving combined upper and lower-body exertion of varying intensity in competitions lasting from 3 min to more than 2 h in the longest distance races (FIS, 2019). It requires high force development and strength over a long period to provide propulsive forces (Nagle, 2015). XC skiing exercises employ most of the joints, muscles and tendons in the body, giving the skier an all-around workout. A few hours after intensive skiing, the symptoms of delayed onset muscle soreness (DOMS) may appear, which is mainly a result of the micro-damage within the myocytes (Klimek, 2010). According to Takashima et al. (2007), muscle soreness is developed in the thigh, leg, arm, shoulder and lower back muscles after a XC skiing race. Due to the repetitive forward flexion and lumbar loading on the back (Nagle, 2015), low back muscle soreness is a common complaint among XC skiers (Alricson et al., 2016).

Currently, one of the most popular treatments used by athletes to improve the quality of their motion and to aid in reducing muscle soreness (i.e., muscle pain) is kinesio taping (KT) (Boguszewski et al., 2017), despite the fact most studies on the effectiveness of KT on muscle pain are scarce and contradictory (Merino-Marban et al., 2021). KT leads to a decrease in muscle soreness in the bandaged area and, consequently, restores the movement pattern, making it more functional (Karatas et al., 2012). Some researchers highlight that applying KT reduces the levels of muscle soreness experienced by improving muscle function and strength, as it provides an environment conducive to recovery (Lee et al., 2015) and, reducing the mechanical load on free nerve endings within the fascia (O'Sullivan & Bird, 2011).

Research based on healthy samples in order to test the effect of KT on muscle soreness due to sport practice or competition (i.e., DOMS) is scarce and inconclusive. Merino-Marban et al. (2014, 2013) studied the subjective perception of local muscle soreness using KT during sport competition and applied KT to athlete's calves with hopeful results. Bae et al. (2014) and Lee et al. (2015) indicated KT can reduce overall soreness in the biceps brachii, 72 h after strenuous exercise. But testers were not blinded and the sample was composed of only males. Boguszewski et al. (2017) found that KT reduced muscle soreness of biceps brachii 48 h after exercise. But testers were not blinded and the sample was composed of only females. Kruszyniewicz et al. (2016) found that KT decreased muscle soreness in the leg and arm for up to 5 days' post-exercise compared with a non-taped muscle. Boobphachart et al. (2017) found less muscle soreness in the KT group at 72 h post-exercise in the quadriceps after intensive eccentric exercise. To our knowledge, no double-blind randomized placebo-controlled research examining the effects of KT on lower back muscle soreness during sport practice in healthy participants has been carried out. Consequently, the purpose of the present

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study was to examine the effects of KT on lower back muscle soreness immediately after its application and after 24 h during a XC skiing camp in collegiate students.

Material and method

Participants

The present study is reported according to the CONSORT 2010 Statement guidelines (Moher et al., 2010). The protocol conforms to the Declaration of Helsinki statements (64th WMA, Brazil, October 2013) and was approved by the Ethical Committee of the Latvian Academy of Sport Education. All the 60 collegiate students enrolled in a winter XC skiing camp (6 days and 4 h each day of XC ski training) organized by the Latvian Academy of Sport Education at Ergli technical professional school (Latvia) were invited to participate in the present study. All the collegiate students were fully informed about the features of the project. Participants' signed written informed consent was obtained before taking part in the study. Recruitment was carried out on 28 January 2019, and data collection from 28th January to 2 February 2019.

Of the 60 collegiate students (23 females and 37 males) enrolled in the camp, 54 voluntarily agreed to participate in the present study (mean age 21.3 years old). The inclusion criteria were: (a) not being diagnosed with any neuromuscular diseases; and (b) not having received medications in the last 6 months. The exclusion criteria were: (a) not performing all the ski practical lessons; and (b) not having registered low back muscle soreness during all the measurements. From the initial sample of 54 collegiate students (20 females and 34 males) who agreed to participate, all met the inclusion criteria. Finally, a sample of 51 students (20 females and 31 males) satisfactorily passed the exclusion criteria. Three males from the CG did not attend the last measurement of muscle soreness and were eliminated (Figure 1). For general characteristics of the participants, see the results section. A priori sample size calculation was estimated with the G*Power Version 3.1.9.4 for Windows. Based on previous related studies (e.g., Merino-Marban et al., 2014), parameters were established in a conservative manner as follows: effect size f = 0.25, significance level α = 0.05, statistical power $(1 - \beta)$ = 0.80, and correlation among

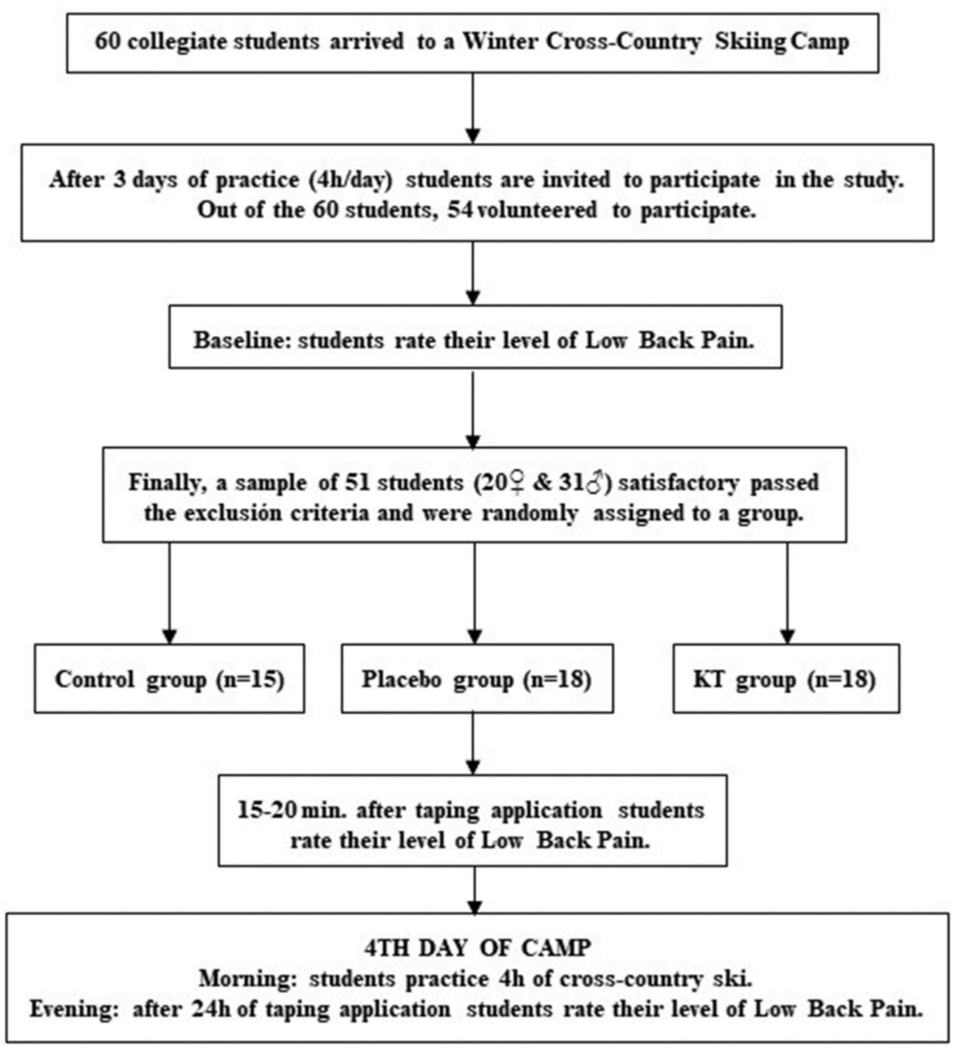

Figure 1. Flowchart of the study process.

repetitive measures $r = 0.5$. A final total sample size of about 36 participants (12 for each group) was estimated.

Measures

Participants' low back muscle soreness was measured by a Numerical Pain Rating Scale (NPRS) (0 = no pain; 10 = maximum pain) (Haksever et al., 2016). Each participant was asked to rate their current level of low back muscle soreness. The participant was shown a line drawn on a sheet with "no pain" marked at one end of the scale and "maximum pain" marked at the other. The NPRS is a valid, reliable and sensitive instrument to assess muscle soreness among adults (Merino-Marban et al., 2014, 2013; Williamson & Hoggart, 2005)

Procedure

The present study followed a double-blind, randomized, placebo-controlled trial design. All measures were obtained prior to tape application (preKT), immediately after taping (postKT), and 24 h after KT application (24 hpostKT). The KT was applied on the lower back of students between 5 and 6 h after the ski practice of the third day of the winter ski camp (according to Kanda et al., 2013 DOMS increases significantly at 48 h and peaks around 72 h after exercise). The students from the placebo taping group were unaware of what kind of tape was applied to them (i.e., they were told to be in the KT group and, thus, being applied KT). After the tape application, in an adjacent room, the students put on a shirt before rating the level of low back muscle soreness (as well as they were instructed not to reveal their taping condition to the evaluator). Thus, the NPRS evaluator did not know which assignment group the students were from either. The NPRS evaluator and the KT practitioner were not the same person. Moreover, although because of feasible reasons the taping condition could not be blinded to the KT practitioner, the KT practitioner did not reveal the type of taping to the participants.

After 3 days of XC ski lessons during the winter camp (4 h per day of XC skiing practice in the morning, and 4 h of theory in the afternoon), participants were, balanced by sex, randomly divided into 3 groups (allocation ratio 1:1:1). One group had KT applied to the lower back (KT group, *n*= 18, 6 females and 12 males), another had placebo tape applied (Tensoplast®) (Placebo taping group, *n* = 18, 8 females and 10 males), and the third group had nothing (Control group, *n* = 18, 6 females and 12 males). To generate the random assignment sequence, the data collection sheets were randomly marked with a small letter a, b or c. Only the KT practitioner knew that these letters corresponded to one of the three groups. All participants received the KT or placebo tape from the first author, a certified KT practitioner with more than 10 years of experience.

Taping Application. A 5 cm wide KT (Kinesiology tape, Korea) was applied to the lower back using the Y-shaped taping technique (Yoshida & Kahanov, 2007). The base of the tape was placed without stretching, with the participant in a neutral body position, just distal to the insertion of the muscle. Then the two functional strips were applied on the stretched muscle belly, maintaining the original 10% tape pre-stretching. Next, the two anchorages were applied without stretching, just proximal to the insertion of the muscle in a neutral body position (Kase et al., 2003) (Figure 2A). The placebo group went through the same procedure but placebo tape (Tensoplast®) was applied (Figure 2B). The CG went through the same procedure, including the stretching, but the KT was not applied. The participants did not need a skin preparation before tape application because they had

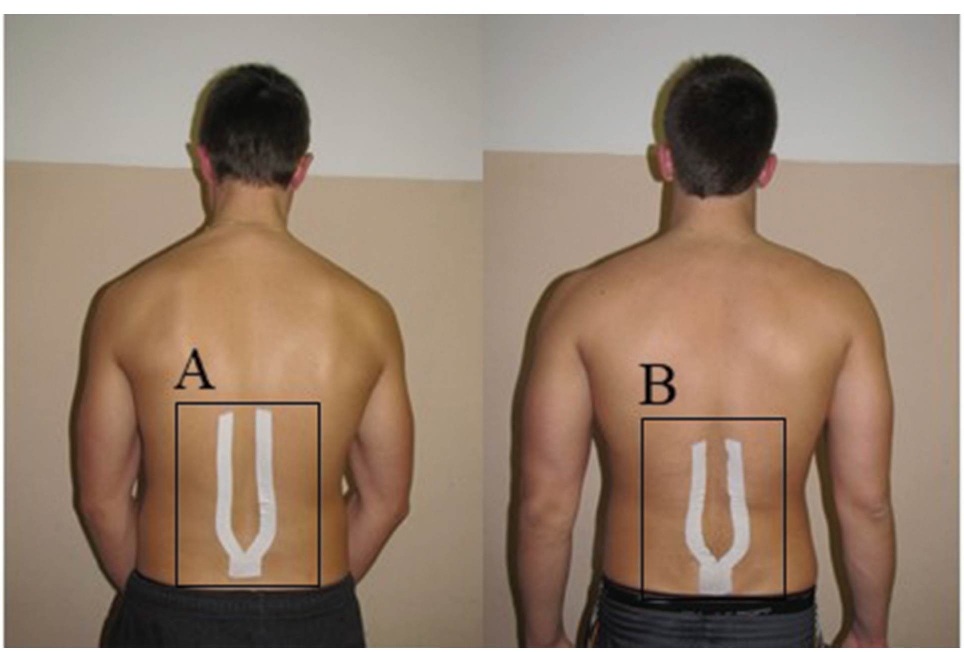

Figure 2. A) Kinesio taping and B) Placebo taping.

Table 1. General characteristics of the included participants and differences between the three groups.

	Total (*n*= 51)	Control (*n*= 15)	Placebo taping (*n* = 18)	Kinesio taping (*n* = 18)	p^a
Age (years)	21.3 (0.1)	21.3 (0.2)	21.3 (0.1)	21.3 (0.1)	-
Sex (males/ females)	61/ 39	60/ 40	56/ 44	67/ 33	0.790
Body mass (kg)	74.5 (1.8)	71.0 (3.1)	75.6 (2.8)	76.2 (3.5)	0.466
Body height (cm)	178.0 (1.3)	174.4 (2.0)	178.1 (2.0)	180.9 (2.4)	0.123
Body mass index (kg/ m^2)	23.4 (0.4)	23.3 (0.9)	23.7 (0.5)	23.1 (0.7)	0.844
PreKT scores[b]	2.1 (1.9)	2.6 (2.2)	1.6 (1.4)	2.3 (2.0)	0.265

Note. Data are reported as mean (standard error) for continuous variables and frequency for categorical variables. [b] Participants' baseline Numerical Pain Rating Scale scores at the baseline.

[a]Significance level from the one-way analysis of variance for body mass, body height and body mass index, and from the chi squared test for the sex ratios.

a shower after the practical ski lesson of that morning (skin was free of oils, lotions and clean). The KT practitioner was in a room applying the KT to students and was unaware of participants' low back muscle soreness scoring. The NPRS took place in a different room to the taping application.

Statistical analysis

Descriptive statistics (mean ± standard error or frequency) for general characteristics of the included sample and lower back muscle soreness levels were calculated. Outliers were not identified and statistical test assumptions were met (e.g., histograms and Q–Q plots for normality). Chi-squared analyses were carried out to test the ratio differences of males-females between the three groups. A one-way analysis of variance (ANOVA) was conducted to examine potential differences between the three groups in terms of body mass, body height and body mass index. Then, the effect of KT on lower back muscle soreness immediately after its application and after 24 h during a XC skiing camp was examined using a two-way ANOVA applied over the dependent variable (NPRS score), including group as an independent variable (CG, PT and KT) and time as a dependent variable (preKT, postKT and 24 hpostKT). Subsequently, the post-hoc with the Bonferroni adjustment was used for between-group pairwise comparisons. Previously, after exploring all the potential confounding variables (i.e. age, sex, body mass, body height, body mass index, and preKT scores), any covariable was discarded. Effect sizes were estimated using the partial eta squared (η^2_p) and Cohen's d for the overall and pairwise comparisons, respectively. All the participants were included in the statistical analyses regardless of adherence to the taping protocol (i.e., intention-to-treat approach). However, since implementation of the missing data requires strong assumptions that are hard to justify, "complete case" analyses including only those whose outcomes were known were used (Moher et al., 2010). All statistical analyses were performed using the SPSS Version 21.0 for Windows (IBM® SPSS® Statistics). The statistical significance level was set at $p< 0.05$.

Results

General characteristics

Table 1 shows the general characteristics of the included participants and differences between the three groups. The chi-square analyses showed that the three groups had a balanced representation of males and females ($p > 0.05$). Additionally, the one-way ANOVA results did not show statistically significant differences in terms of body mass, body height and body mass index between the three groups ($p > 0.05$).

Lower back muscle soreness

Table 2 shows the effect of KT on lower back muscle soreness immediately after its application and after 24 h during a XC skiing camp in collegiate students. The results of the two-way ANOVA, on average, obtained in the lower back muscle soreness levels showed a significant interaction effect between the group and time variables ($F = 3.368$, $p = 0.013$; $\eta^2_p = 0.123$). Subsequently, for post hoc analyses, the ANOVA with the Bonferroni adjustment showed that the lower back muscle soreness levels in the KT group decreased statistically significantly from preKT to 24hpostKT ($p = 0.020$). However, for the KT group statistically significant changes were not found from preKT to postKT ($p = 0.075$), and postKT to 24hpostKT ($p = 0.790$). Moreover, for both the control and placebo groups no statistically significant differences were found (preKT vs. postKT, $p = 1.000$ and 1.000; preKT vs. 24hpostKT, $p = 0.588$ and 0.264; postKT vs. 24hpostKT, $p = 0.239$ and 0.196). On the other hand, at the preKT statistically significant differences between the three groups were not found either (control vs. placebo, $p = 0.345$; control vs. KT, $p = 1.000$; placebo vs. KT, $p = 0.813$).

Table 2. Effect of kinesio taping on lower back muscle soreness immediately after its application and after 24 h during a cross-country skiing camp in collegiate students.

	PreKT (1)	PostKT (2)	24hpostKT (3)	Two-way ANOVA[a]				Effects size (*d*)		
Groups	Mean (SE)	Mean (SE)	Mean (SE)	*F*	*p*	η^2_p	Comp.	1–2	2–3	1–3
Control (*n* = 15)	2.6 (0.6)	2.6 (0.6)	3.0 (0.7)	3.368	0.013	0.123	PT-CG	0.02	−0.45	−0.43
Placebo taping (*n* = 18)	1.6 (0.3)	1.6 (0.4)	1.1 (0.4)				KT-CG	−0.22	−0.36	−0.58
Kinesio taping (*n* = 18)	2.3 (0.5)	1.8 (0.3)	1.6 (0.4)*				KT-PT	−0.24	0.09	−0.15

Note. SE = standard error; CG = Control group; PT = Placebo taping group; KT = Kinesio taping group.

[a]Two-way analysis of variance with the *post hoc* analysis with Bonferroni adjustment: Change statistically significant from preKT to after 24 h the application of the kinesio taping (*$p < 0.05$).

Discussion

The purpose of the present study was to examine the effects of KT on lower back muscle soreness in collegiate students immediately after its application and after 24 h, during a XC skiing camp. According to the results of the present study, the KT reduced low back muscle soreness caused by several days of XC skiing in collegiate students, 24 h after its application. Additionally, although there was not a statistically significant change, in the KT group the low back muscle soreness levels tended to decrease from preKT to postKT application (i.e., $p < 0.10$).

In general, research based on healthy samples in order to test the effect of KT on muscle soreness due to sport practice or competition (i.e., DOMS) are in line with the results of the present study. Most of the studies observed positive results of the KT in the reduction of DOMS, although almost all did so at 48 and/or 72 h (Table 3). However, it is very important to note that in most studies the induction of DOMS was carried out through a punctual and intense eccentric exercise, unlike the present study in which the participants had been practicing XC skiing for 3 days before applying the KT. In addition, DOMS, as its name indicates, usually appear 24 or 48 after exercising.

In the present study, after 3 days practicing XC skiing, in the KT group the low back muscle soreness levels tended to decrease from preKT to immediately postKT application. In the 4 studies that make a measurement of muscle soreness, NPRS, immediately after the application of KT there was also no decrease in muscle soreness. Because the participants had not competed in the duathlon, which was a strenuous physical activity (Merino-Marban et al., 2014, 2013), and for the reason that there had been no time for the intense and punctual eccentric exercise to cause DOMS (Haksever et al., 2016; Kim et al., 2016).

In all the studies examined, an eccentric and punctual exercise was carried out in the laboratory to induce DOMS. Except for Merino-Marban et al. (2014, 2013), which studied the effect of KT on DOMS 10–15 min after a duathlon competition (5 km running + 20 km cycling + 2.5 km running). However, only one out of these two previous studies found a statistically significant result from preKT to immediately after competition. These should have measured muscle soreness of the participants at 24 and 48 h after the competition. Because, when inducing DOMS, participants show increased muscle soreness levels 24 h after the intervention, reaching a maximum 48 h post-intervention and decreasing at the 72 h mark (Lee et al., 2015) Unaccustomed exercise with eccentric muscle contraction and exhaustive exercise cause muscle damage, inflammation and soreness on and several days after the exercise (Kanda et al., 2013). Perhaps if DOMS had been measured 24 hours after the competition, the KT would have had time to act and be effective in both studies. KT should be used during exercise and after exercise in order to promote faster recovery following eccentric exercise (Kim et al., 2016). Therefore, athletic trainers and physical therapists may apply the KT to athletes before competition in order to control soreness or cramping in the muscles (Merino-Marban et al., 2013).

In most studies with statistically significant decreased muscle soreness, this occurred at 48 and/or 72 h post-DOMS induction (Table 3). Only Bae et al.(2014) and Kruszyniewicz et al., (2016) found a DOMS reduction at 24 h post-exercise. It should be kept in mind, that in most of the studies the KT was applied previously or immediately after an eccentric, intense and punctual exercise. In the present study, the participants had 3 days of intensive XC skiing practice and continued training the day after the KT application, with the KT stuck to the lower back muscles (4 h XC ski/day). Maybe these circumstances allowed the DOMS reduction at 24 hours. In line with this comment, Kim et al. (2016) found in their study that the KT-24h group (KT remained on the muscle 24 h post-exercise) showed a creatine kinase (CK) activity significantly lower and a faster recovery time than the CG and KT-post groups (KT removed immediately after exercise and 30 min later). KT-24h showed lower DOMS at 48, 72, and 96 h after exercise compared to CG. These findings suggest that prolonged application of KT had a positive effect on markers of muscle damage and DOMS. The authors attributed this to increased CK clearance due to improved blood and lymphatic flow after KT application. In contrast, Aminaka et al. (2017) investigated the effects of KT on serum CK level during the 72-h recovery period from DOMS, and they found no differences among the KT group, placebo group and the CG.

Kase et al. (2003) set down a series of guidelines that, if not followed, he proposed would limit the effectiveness of the KT and even negate its effect. Some authors applied KT before the exercise protocol, but except for a few, Merino-Marban et al. (2014, 2013) most did not mention the time that passed between the application of KT and exercise (Boobphachart et al., 2017; Kim et al., 2016). Even, Ozmen et al. (2017) study with negative result, remarked that KT was applied immediately before the exercise protocol. According to Kase et al. (2003)

Table 3. General characteristics of post-exercise delayed onset muscle soreness-based research studies using Kinesio taping.

Reference	Design	DOMS Induction	DOMS Measurements	Positive results
Bae et al., 2014	RP-CT	REE	24, 48, 72 h	*24, 48, 72 h
Boguszewski et al.,2016	RCT	RIE	24, 48, 72, 96 h	*48 h
Boobphachart et al., 2017	RP-CT	REE	24, 48, 72 h	*72 h
Haksever et al., 2016	RCT	REE	I, 1, 48 h, 7th day	*48 h & 7th day
Hazar et al., 2014	RP-CT Pilot	REE (drop jumps)	48, 72 h	*48 h
Hazar et al., 2019	RP-CT	REE (drop jumps)	48, 72 h	*72 h
Kim et al., 2016	RCT	REE	I, 24, 48, 72, 96 h	*48, 72 & 96 h
Kirmizigil et al., 2020	RC-O	REE (drop jumps)	24, 48, 72 h	*72 h
Kruszyniewicz et al., 2016	C	REE	24, 48, 72, 96, 120 h	*24, 48, 72, 96 & 120 h
Lee et al., 2015	RCT	REE	24, 48, 72 h	*72 h
Merino-Marban et al., 2013	RCT	Duathlon competition	I, after competition	-
Merino-Marban et al., 2013	RCT	Duathlon competition	I, after competition	After competition
Merino-Marban et al., 2021	RCT	Half marathon	I, after competition	-
Ozmen et al., 2017	RCT	REE	24, 48 h	-

I: Immediately, RC-O: Randomized Cross Over, RP-CT: Randomized Placebo Controlled Trail, RCT: Randomized Controlled Trail, REE: Repetitive Eccentric Exercise, RIE: Repetitive Isometric Exercise.

approximately 20–30 minutes is required for the glue to become fully activated before the participant can become physically active. If activity occurs prior to this time, the tape may come off.

If the primary therapeutic goal is muscle soreness reduction, the practitioner may use a basic muscle technique from insertion to origin (I-O, inhibition technique) (Kase et al., 2003). Only a few studies used the I-O technique (Hazar et al., 2019; Kim et al., 2016; Kirmizigil et al., 2020; Merino-Marban et al., 2014, 2013). All of them observed a soreness reduction in muscles with KT applied, except for Merino-Marban et al. (2013). Even though KT led to the control of calf muscle soreness produced by the competition, a limitation of these last studies is that they did not measure the muscle soreness at 24 and 48 h.

The tension of KT in the studies, when it is informed, is correct except for in Aminaka et al. (2017). They used an O-I technique with the tape off tension on the vastus medialis, when it should have been 25–50% of available tension (Kase et al., 2003). Maybe their non-positive results regarding CK level, EMG and muscle performance was due to not fulfiling Kase's et al. (2003) guidelines.

In the present study, the collegiate students presented a light level of initial muscle soreness after 3 days of XC skiing (on average, between 1.6 and 2.6 values over 10 points), which is considered to be a mild soreness (Kelly, 2001). Moreover, although the lower back muscle soreness levels in the KT group decreased significantly statistically from preKT (2.3) to 24hpostKT (1.6) ($p = 0.020$), taking into account that the most commonly used minimum value in musculoskeletal soreness medicine as minimum clinically important difference (MCID) is 1.4 (Tashjian et al., 2009), the average decrease in muscle soreness was low (0.7; below 10%). Therefore, it could be thought that although the difference is significant, its clinical importance is trivial. On the other hand, clinical significance and statistical significance are not necessarily the same and it is the clinical impact on patients which is of the greatest importance (Kelly, 2001). In addition, we must bear in mind that the MCID is context-specific and potentially misguiding if determined, applied or interpreted inappropriately. Explicit and conscientious reflections on the choice of a reference value are required when using MCID to classify research results as clinically important or trivial (Olsen et al., 2017).

In the present study, the participants were recreational, physically active collegiate students (3 –5 h physical activity per week) involved in a XC ski camp for 1 week (4 h XC ski per day). In the researches about the effect of KT on DOMS, samples were composed of untrained participants (Bae et al., 2014; Boguszewski et al., 2017; Boobphachart et al., 2017; Haksever et al., 2016; Hazar et al., 2019, 2014; Kim et al., 2016; Ozmen et al., 2017), recreational competitors (Merino-Marban et al., 2014, 2013) and amateurs to highly physically active participants (Kirmizigil et al., 2020; Kruszyniewicz et al., 2016). Therefore, the results may not be directly applied to athletes for sport performance improvement (Boobphachart et al., 2017).

Strength and limitations

In the present study, a subjective perception of muscle soreness in the form of the NPRS was used throughout. Evidence for the impact of KT on the symptoms of DOMS should be achieved by means of more objective methods of evaluating and interpreting the sensation of soreness and muscle functions.

The effect sizes were very low. Like those found in Merino-Marban et al. (2014), the only article in Table 3 that provided them. This is reasonable because the initial muscle soreness values were already low. Perhaps it would be interesting to start from really higher muscle soreness values to check the effect of KT on DOMS. Although this would require a very tough protocol for the research participants to cause severe muscle soreness.

DOMS were rated just 24 h after KT had been applied to the lower back muscles. Low back muscle soreness measurements should have continued for the rest of the camp and some days after completion. Therefore, there is a need to expand this study in terms of length of time, as well as using different types of KT applications, in accordance with the principles of evidence-based medicine.

Conclusions

Light low back muscle soreness caused by several days of XC skiing in physically active collegiate students was reduced 24 h after the application of KT (below 1 point, i.e., <10%). The KT method may be beneficial in reducing post-exercise 24 h DOMS and in enabling a faster return to physical activity in healthy sport collegiate students. Therefore, athletic trainers and physical therapists may apply KT to athletes before competition in order to control soreness or cramping in the muscles.

Disclosure of potential conflicts of interest

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