The Immediate Effect of Kinesio Taping On Pain, Swelling, Knee Range of Motion, And Muscle Activity of Quadriceps in the Acute Phase after Anterior Cruciate Ligament Reconstruction

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ABSTRACT

Background: *Kinesio Taping is recommended as an intervention for decreasing of complications and facilitation of function in the acute phase of rehabilitation after the ACL reconstruction. Therefore, the aim of this study was to investigate the immediate effects of Kinesio Taping on pain, swelling, knee range of motion, and muscle activity of the quadriceps muscle in individuals in the acute stage of the ACL reconstruction.*

Methods: *In this randomized clinical trial, 30 subjects with ACL reconstruction were included. The subjects were randomly divided into control group (routine intervention) and Kinesio Taping group (routine intervention combined with Kinesio Taping). Intervention was conducted 4 days. Pain, swelling, knee ROM and muscle activity of quadriceps were assessed before and after 4 days with VAS scale, tape, CPM, surface EMG, respectively. Data were analyzed with Paired sample t-test and Independent t-test.*

Results: *In Kinesio Taping group, pain intensity significantly changed from 4.9±2.0 to 0.9±1.3, knee flexion significantly changed from 74.9±13.1 to 102.8±8.3 and knee extension significantly changed from 7.6±5.4 to 2.4±3.6 ($p<0.05$), also, they have significant changes quadriceps muscle activity ($p<0.05$). However, there were not significant differences in quadriceps muscle activity in control group ($p>0.05$).*

Conclusion: *According to the results of the study, the positive effects of Kinesio Taping combined with routine intervention in muscle facilitation, reliving of pain and swelling and increasing of knee ROM were shown in acute stage of ACL reconstruction, so we suggest that in addition to routine intervention, kinsio Taping should also be considered in subjects with ACL reconstruction.*

Keywords: *ACL reconstruction, Muscle Activity, Surface EMG, CPM, Kinesio Taping*.

INTRODUCTION

The anterior cruciate ligament (ACL) performs important and extensive functions in daily activities and sports (1) and is the most important stabilizer of the knee, which result in increased chances of the knee injury (2). More than 200,000 cases of the ACL rupture occur annually in the United States (3,4), about 65% of which is cured by the reconstructive surgery (3). The ACL is usually reconstructed by autografts with two types of grafts, either bone-patellar tendon-bone (BPTB) or four strands hamstring tendon (4SHT) grafts (5,6,7,8). Generally, ligament reconstruction surgery leads to complications such as pain, swelling, decreased range of motion, declined muscle strength, and impaired sense of proprioception (1). In addition, the disadvantages of 4SHT are a prolonged recovery and rehabilitation period and long-term weakness of the knee flexors (9,10). Obviously, the rapid control of post-operative complications is an important goal of the rehabilitation program (1, 10). Due to the long time of the graft acceptance in the 4SHT reconstruction method and prolongation of the rehabilitation program, the transition from the acute phase of the lesion and reduction of the complications of this period are of dominant importance. Therefore, relieving of pain and swelling, increasing the ROM, and

improving muscle function are ordered in the rehabilitation program of these people (4, 10,11).
In addition to routine rehabilitation treatments, Kinesio Taping is also recommended as a treatment in the acute phase of rehabilitation after the ACL reconstruction. A shortened period of immobility, early return of muscle function and the ROM of the knee, and finally the rapid transition from the acute phase are the advantages of Kinesio Taping (12). Kinesio Taping improves lymph movement, circulation, and muscle nutritional status by controlled lifting of the skin (13). Also, stretching the Kinesio tape on the skin raises the epidermis and reduces the pressure on the mechanoreceptors underlain the dermis, thereby decreasing pain stimuli and ultimately reducing the transmission of pain signals (14). Another mechanism of Kinesio Taping is the mechanical displacement of the skin during movement, which stimulates the skin mechanoreceptors, signals are transmitted to the posterior horn of the spinal cord, and blocks or inhibits the pain (15). Regarding the positive effects of Kinesio Taping on the reduction of edema and inflammation, it is noteworthy that it increases the space between the skin and subcutaneous tissue by lifting the skin, and thus reduces the lymph flow by decreasing the pressure on the lymphatic vessels. Furthermore, Kinesio Taping in the acute phase prevents the formation of fibrous tissue following edema by applying tension on the skin and its underlying tissue (15). In general, the use of skin and tactile stimuli, skin stretching, skin lifting, relieving pressure on lymphatic and superficial blood vessels, and thus increasing the circulation seem to be the mechanisms of Kinesio Taping (12). In a study conducted by Balki (2016), results showed that the Kinesio Taping play a major role in recovery of prepatellar inflammation, pain and hamstring muscle strengthening after acute phase of ACL reconstruction (1). In another study, Boguzewski et al. (2013) showed the beneficial effect of Kinesio Taping in decreasing of edema and increasing of knee range of motion (2). Donec and kriseiunas (2014) present the Kinesio Taping was more effective than routine intervention in decrease of pain and edema and knee extension range of motion in acute phase of knee arthroplasty (16). However, a systematic review study did not reveal that Kinesio Taping can be improve range of motion and decrease of pain (17).
It is well established that the quadriceps femoris muscle is inhibited after the ACL injury and reconstruction, particularly in the existence of joint effusion (18). Therefore, one of the primary goals of rehabilitation after the ACL reconstruction is to recover the activity of quadriceps muscle (4). One of the typical aims of Kinesio Taping is to improve muscle function. The elastic recoil property of the Kinesio tape corrects the length-tension relationship of muscles (19). It seems that Kinesio Taping can indirectly affect the level of muscle activity by the control of pain and swelling, as well as directly through the stimulation of skin mechanoreceptors (12-15). Halski et al. showed that Kinesiology Taping does not modify electromyographic activity or muscle flexibility of quadriceps femoris muscle in healthy volleyball players (13).
As a mentioned above, acute complications of the ACL reconstruction include pain, swelling, decreased ROM, and changes in the muscle activity (1,9,10), and the mechanism of action of Kinesio Taping reflects the positive effects of this treatment on pain, swelling, and consequently increased ROM and improved muscle activity (12-14). But there is no available research to refer the immediate effect of the Kinesio Taping in decrease of symptom and quadriceps muscle activity and knee range of motion in directly. Therefore, assuming that Kinesio Taping, along with other physiotherapy treatments, in the acute phase of the ACL reconstruction can facilitate the reduction of symptoms and facilitate the course of physiotherapy treatment in this period. Accordingly, the present study aims to investigate the immediate effects of Kinesio Taping on pain, swelling, knee ROM, and muscle activity of the quadriceps muscle in individuals in the acute stage of the ACL reconstruction.

Methods

This study was a randomized controlled trial. Thirty subjects with acute ACL reconstruction participated in this study and were divided into two groups by simple non-probability sampling method. The medical ethics committee at the Zahedan University of Medical Sciences approved the study ethics and issued the ethics certification number as IR.ZAUMS.REC.1398.175 and registered with the region's Clinical Trials Registry IRCT20180714040466N3. All participants signed written informed consents.

Inclusion criteria (1,12)
Men and women aged between 18 and 45 years, unilateral reconstruction of the ACL isolate with 4SHT graft, referral of the patient in the first 2 weeks post-surgery, no history of fracture, dislocations, and structural abnormalities in the lower limbs.
Exclusion criteria (1,12)
The patient's unwillingness to continue the treatment and inability to perform exercises to record data.

Sample Size

The sample size was determined based on a pilot study. Ten subjects were divided randomly into two equal groups, and the main part of study was conducted on them. The means and SDs for the parameters from this pilot study, with α= 0.05 and 90% power were used to calculate the sample size. According to the results of the pilot and the formula stated, the sample size in each group was considered 15 patients.

The sampling method was the simple, non-probabilistic and from the available population. Then, the participants were allocated randomly to two intervention groups, the control group and the Kinesio Taping group. Randomization was performed using random number sequence. The administrator and participants were informed about the grouping data. But the physiotherapist who assessed the subjects, measured the outcome, and analyzed the data was blinded about the grouping.

Procedure

The initial clinical examination study was performed by measuring demographic information. The recruited subjects were randomly divided into one of two groups. In the first group, in addition to the routine rehabilitation program of the ACL reconstruction in the acute stage, Kinesio Taping was performed by both the muscle and the lymphatic methods. The second (control) group received the routine rehabilitation program of the ACL reconstruction in acute stage. The first- and fourth-day measurements were done respectively before and immediately after the intervention.

Measurement

1. *Intensity of Pain: The VAS (Visual Analogue Scale) of McGill Short Questionnaire was used to measure the intensity of pain (20).*
2. *Edema: The limb circumference was measured in supine position in two areas, once at the joint surface and the other at 10 cm above the patella bone using a meter (2).*
3. *Passive ROM: The painless passive range of motion was measured using the Continuous Passive Motion (CPM) device (Spectra model, Kinetic Co., France). Patient lied in a supine position, the arms of the device were adjusted according to the limb length, and fixed with a strap in the ankle area above the knee. The device was set on the Modulation Mode. The movement in the knee joint was performed by the device and with manual control and the device was stopped until the patient reported feeling pain or discomfort. The onset of pain indicated the end of the passive ROM. The number of the intended ROM was displayed on the device monitor. The movement was performed and recorded in the two directions of flexion and extension of the knee (21,22).*
4. *Muscle Activity: In the present study, a surface electromyography device (Bio Graph Infiniti, 2180 Belgrave Avenue, Montreal, QC H4A 2L8 Canada) was used to record the electrical activity of the quadriceps (Vastus medialis, vastus lateralis and rectus femoris). The patient was lying supine. The thigh area of the foot was completely exposed and completely shaved and then cleaned of fat with alcohol. Electrodes were placed 5 cm above the patella on the muscle for vastus medialis, slightly below the middle of the thigh on the muscle for vastus lateralis, and exactly above the midline of the limb immediately above the middle of the thigh for rectus femoris (23). After selecting the EMG 10 channel, the required chart type was selected from the RMS option. Ambient noise was reduced using a band pass-filter that filters frequencies below 10 Hz and above 500 Hz. A conductive gel was used before attaching the electrodes (24,25).*

To record maximum electrical activity of the quadriceps, patient was placed on a quadriceps chair and the arm of the device was adjusted in such a way to place the knee at the 60° angle of flexion. In this position, the patient was asked to contract the quadriceps by maximum power. This level of contraction was maintained and recorded for 5 seconds (26,27). This task was repeated 3 times and the patient was allowed to have a 2-min break between the two tasks to avoid fatigue.

To record the functional activity of the muscle, patient performed the squat up to an angle of 30° of flexion for 3 seconds, maintained this angle for 3 seconds, and then returned to the starting position in 3 seconds. After resting for 1 minute, the measurement was repeat, which was repeated 3 times (28).

Muscle activity was normalized using the following formula:

Muscle activity level = RMS/MVC × 100

Intervention

the patient was randomly assigned to one of the two groups of control group and Kinesio Taping group.

Individuals in the control group received the following treatments (1,3,4,10,11,21): adjustable knee braces, electrical stimulation (FES), CPM, ice, passive patella mobilization, isometric quadriceps contractions and ankle pumping exercise, SLR, semi-squat and wall slide. The patient performs exercises 10 times and repeats it 3 times a day (21).

For subjects in the Kinesio Taping group, the Kinesio tape (3NS K-tape, Korea) was used in addition to the

abovementioned routine treatments. The Kinesio tape was applied both by facilitating muscle activity method (Fig.1) and by the lymphatic method (Fig.2). The tape remained on the patients' bodies for up to 3 days and was removed in the fourth session.

Fig1.

Fig.2

The facilitation technique was used for rectus femoris muscle. To do this, the patient laid down supine and the anchor was attached to the muscle origin in the AIIS area without tension. The knee was then placed out of the bed and lied passively at a 90° angle of flexion (or as far as allowed by the patient's knee ROM). The base type was then attached downward longitudinally with 35% tension. To prevent tension or force on the patella, the end of Kinesio Taping above the patella was made into Y-shaped biceps and passed through both sides of the patella. Both branches attach to the tibial tuberosity down the patella (13, 17). The lymphatic drainage method was also used for this group. To that end, the anchor of two fan shape tapes was attached in the place of lymph nodes inside and outside the popliteal cavity. The knee was then flexed slightly and the fan shape tapes were attached as one from the inside of the patella to the outside on the patella and the other vice versa, both with 20% tension (1,13,17).

Statistical Analysis

Results were presented as mean values and standard deviation (SD). Criterion of significancy was set as $p<0.05$. Data analysis was performed with SPSS version 27. The assumption of a normal distribution was assessed using the Kolmogorov-Smirnov test. The assumption of equality of variances was tested using Levene's test. The paired t-test and independent samples t-test were used for within- and between-group comparisons, respectively.

Results

Using a pilot study, a sample size of 30 individuals was estimated for the two groups (n=15) and 30 eligible subjects completed the study. Demographic information of patients, including age, height, weight, and body mass index (BMI) are shown in Table 1. There were no differences between the two groups in terms of these variables ($p>0.05$).

Table 1. Demographic and baseline characteristics of subjects

	Kinesio Taping Group (n=15)	Control Group (n=15)	p-value
Age (year)	29.3±8.4	31.4±11.4	0.5*
Weight (kg)	69.6±15.4	74.2±13.5	0.3
Hight (m)	1.74±7.6	1.77±4.7	0.3
BMI (Kg/m^2)	22.6±3.6	23.6±4.3	0.4

**Significant $P<0.05$.*

The normality of data was determined by Kolmogorov-Smirnov test and the results showed the normal distribution of the studied variables ($p > 0.05$).

The within group and between group results were compared using the paired t-test and independent t-test, respectively.

The results of paired t-test show that the pain intensity and swelling significantly decreased in both group ($p < 0.05$). Also, range of motion of the knee showed significant changes in both groups ($p<0.05$). The changes in

the muscle activity of quadriceps were not significant in control group (p>0.05), while significant changes of quadriceps muscle activity were observed in the Kinesio Taping group (p < 0.05) (Table-2).

To ensure the accuracy of the randomization process, we compared the pre-study data of the groups. The results showed that there was no difference between the two groups in variables before intervention (p> 0.05). The results of Independent t-test show that there are no statistically significant differences between the two groups in the variables of swelling, ROM, and the muscle activity (p > 0.05). The only variable with a significant difference is the pain intensity, which is 2.3 ± 1.7 and 0.9 ± 1.3 in control and Kinesio Taping groups, respectively (p = 0.02).

Table-2. Means and standard deviations of variables and p-values for within and between group comparisons

	Kinesio Taping Group (n=15)			Control Group (n=15)			p-value between group **
	Before *	After	P-value	Before	After	P-value **	
Pain	4.9±2.0	0.9±1.3	0.000	5.5±1.8	2.3±1.7	0.000	0.02
Swelling around the knee	39.3±4.7	37.8±4.4	0.000	41.3±4.4	39.4±3.4	0.008	0.28
Swelling 10 cm above knee	43.2±7.5	41.4±6.5	0.003	43.3±6.8	41.2±5.9	0.000	0.91
Extension ROM	7.6±5.4	2.4±3.6	0.003	3.2±2.8	0.8±1.7	0.006	0.13
Flexion ROM	74.9±13.1	102.8±8.3	0.000	79.0±13.4	96.6±12.8	0.000	0.13
Rectus femoris muscle activity	35.7±15	55.2±18.7	0.000	59.3±26.3	63.6±15.5	0.61	0.19
Vastus medialis muscle activity	46.4±20.7	52.3±23	0.24	57.5±21.6	57.2±19.5	0.97	0.34
Vastus lateralis muscle activity	46.2±19.8	58.7±22.8	0.03	68.7±23	66.7±22.9	0.82	0.52

** Values are means ± SD*

*** Significant P<0.05.*

Discussion

The results of this study demonstrate that both the control and Kinesio Taping intervention are effective in the control of pain and swelling and recovery of knee ROM. It seems that Kinesio Taping is more effective than the routine treatment in modifying the muscle activity of the quadriceps muscle. In other words, the routine treatment supplementation with Kinesio Taping facilitates the muscle activity of the quadriceps.

The Kinesio tape can reduce pain through two mechanisms, the first of which is by lifting the skin and relieving pressure on the nociceptors (1,14,15). Another mechanism is the stimulation of skin mechanoreceptors by the

Kinesio tape and thereby the block or inhibition of pain signals due to the gate control theory (14,15,29). The Kinesio tape reduces pain by stimulating skin mechanoreceptors and increasing the afferent feedback to the central nervous system (30), thereby stimulating the low-threshold mechanoreceptors by mechanical movement of the skin reduce the transmission of pain signals in small nociceptive fibers (31). Castro-Sandez et al. (2012) examined the effect of Kinesio Taping on pain and disability in patients with nonspecific chronic low back pain and proposed the gate control mechanism as one of the hypotheses in the pain relief mechanism (32). Donec and Kriseiunas (2014) reported beneficial effects of Kinesio Taping on pain and swelling reduction in the acute phase after complete knee joint replacement. Although they did not propose a mechanism for this conclusion, they stated that Kinesio Taping could be used as a tool alongside patients' rehabilitation program after complete knee joint replacement (16). A study by Bulki et al. (2016) revealed that adding Kinesio Taping to the acute phase physiotherapy program of the ACL reconstruction had beneficial effects on pain reduction in these patients (1). As mentioned above, our results do not clinically support our hypothesis concerning the effect of Kinesio Taping on swelling reduction in the acute period of the ACL reconstruction. This can be due to the short period of using the tape, additionally, our patients were visited in acute period, one of the characteristics of which is increased inflammation and swelling as part of the injury process. Therefore, if the kinsio Taping is used in another period of injury or it is also continued after the acute period, better results may be reported in the reduction of swelling.

The results showed that the ROM of the knee joint increased in both groups. It can generally be concluded that Kinesio typing alongside the routine treatment helps to faster restore the ROM of the knee after the ACL reconstruction. Fear of movement (Kinesiophobia) in the acute phase after the ACL reconstruction has negative effects on active and passive ROM of the knee (33). Pain reduction allows the patient to begin basic functional exercises of the knee, resulting in an improvement in the ROM (34). It can be assumed that Kinesiophobia diminished in the Kinesio Taping group, with further pain reduction of the patient, who can faster regain the ROM of the knee. Balki et al. (2016) observed reduced pain and improved ROM of the knee flexion by adding Kinesio Taping to the treatment program of patients in the acute phase of the ACL reconstruction, similar to that of our study. They attributed the increased ROM to an increase in hamstring muscle strength as a result of muscle Taping. However, the results of our study suggest that the mechanism of Kinesio Taping effect on the improved ROM of the knee flexion is not limited to its facilitating effects on the hamstring muscles, pain reduction can be considered as a cause of the improved ROM of flexion following Kinesio Taping (1). Abolhasani et al. (2019) also pointed out the positive effects of Kinesio Taping on pain reduction and a significant improvement in the ROM of the knee in patients with osteoarthritis. They considered pain reduction and elimination of kinesophobia to be a possible mechanism for the increased ROM, which is in line with the results of our study (35).

The results were indicative of more changes in the muscle activity of quadriceps muscles after the using of Kinesio Taping. Clinically, it can be claimed that adding the tape to the routine treatment can facilitate muscle activity in a functional state, such as the squat. Clearly, the quadriceps suffers from arthrogenic muscle inhibition (AMI) following traumatic injuries and knee surgeries (36). It has been suggested Kinesio Taping indirectly improve muscle activity by the control of pain and swelling (12,15). Meanwhile a more significant reduction in pain intensity was observed in the Kinesio Taping group of this study, it can be claimed that pain reduction led to improve the muscle functional performance. In addition, Kinesio Taping has been reported to directly affect the level of muscle activity by stimulating skin mechanoreceptors (13-15). According to Bagheri et al., the main mechanism of the Kinesio Taping effect on the motor neuron pool is through skin receptors (37). Skin afferent signals modulate the excitability of motor units. Kinesio Taping affects the input of these skin afferents and can be change the excitability of motor neurons (19). It has been suggested that the elastic recoil property of Kinesio Taping corrects the length-tension relationship of muscles. As such, when the tip is attached from the muscle origin to its insertion, the tape recoil facilitates muscle contraction toward the origin (the tape tendency to return to its origin) by increasing the reflective contraction of muscle spindles (and lowering the stimulation threshold of motor neurons) (19). In this study, the facilitation method from the origin to insertion was used for quadriceps muscle. Therefore, it can be lower the stimulation threshold of motor neurons, leading to better function of the muscle during functional skills. Balki and Göktas (2017) investigated the positive effect of Kinesio Taping on hip muscle weakness. They suggested swelling reduction and facilitation of hip muscle activity following Kinesio Taping as the mechanism of its positive effect on the hip muscle activity (38). In a clinical trial, Choi and Lee (2018) reported an increase in quadriceps torque after Kinesio Taping (39). Ahn et al. (2015) also investigated the effect of Kinesio Taping on quadriceps function after muscle fatigue and found that Kinesio Taping was effective in restoring reduced quadriceps strength after the induction of muscle fatigue (40). According to the presented studies, it can be expected that Kinesio typing

can effectively increase muscle activity in quadriceps muscle due to the decreasing of pain and swelling, the increasing in the excitability of motor neurons caused by the stimulation of skin mechanoreceptors following Kinesio Taping. In other words, both direct and indirect mechanisms were involved in the increase of quadriceps muscle activity. Given that this muscle is strongly affected after the ACL reconstruction, the rehabilitation of this muscle will have a remarkable impact on the reduction of patient's disability and restore of the function of lower limbs. In addition, postoperative complications are reduced with rapid rehabilitation of this muscle and the patient will return faster to work and activity.

Conclusion

The results of the study clearly demonstrate the beneficial effects of Kinesio Taping along with routine treatments after the ACL reconstruction. Addition of Kinesio Taping to these people in the acute postoperative period reduces pain, improves the knee ROM, and facilitates quadriceps muscle activity. Therefore, administration of Kinesio Taping is recommended in the acute period of the ACL injuries.

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Authors' contributions:

All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

Conflict of interest

The authors declared no conflict of interest.

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