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Title: Immediate effects of Kinesio Taping® on neuromuscular performance of quadriceps and balance in individuals submitted to Anterior Cruciate Ligament reconstruction: a randomized clinical trial.

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Abstract

Objective: Investigate the immediate effects of Kinesio Taping® (KT) on neuromuscular performance of femoral quadriceps and balance in individuals submitted to Anterior Cruciate Ligament (ACL) reconstruction. **Design**: This is a randomized clinical trial. **Methods:** Forty-seven male participants, between 12 and 17 weeks after ACL reconstruction, underwent initial assessment consisting of postural balance analysis using baropodometry, followed by eccentric and concentric isokinetic assessment at 60º/s of knee extensors, concomitant to electromyographic signals captured from the vastus lateralus muscle. They were then randomly allocated to one of the following groups: Control (CG), Placebo (PG) and Kinesio Taping® (KTG). KTG participants were submitted to KT on the femoral quadriceps of the affected limb, while PG subjects used the same procedure without the tension proposed by the method. The CG remained at rest for ten minutes. All participants were reassessed following the same procedure as the initial evaluation. The following variables were analyzed: peak torque/body weight and muscle potential using dynamometry; amplitude of antero-posterior and latero-lateral displacement from the center of pressure using baropodometry; and amplitude of muscle activation (*Root Mean Square* - RMS) applying surface electromyography. **Results:** None of the variables analyzed showed significant intergroup or intragroup differences. **Conclusion:** KT does not alter the neuromuscular performance of femoral quadriceps or balance of subjects submitted to ACL reconstruction, for any of the variables analyzed.

Keywords: electromyography; torque; dynamometry; muscle strength.

Introduction

The use of Kinesio Taping® (KT) has been increasing in recent years and is easily observed in both patients and competitive athletes. It involves an elastic bandage developed by the chiropractor Kenzo Kase, made from cotton fabric with viscosity that allows ventilation and water resistance. It can be stretched by up to 150% of its original size, and has been suggested as a therapeutic option since 1996. The technique consists of applying it over practically any skeletal muscle or joint on the body in order to provide functional support, relieve pain and improve muscle performance, as well as blood and lymphatic flow[1]. Such changes would occur due to the activation of skin receptors caused by tactile stimulation from bandage application and the increase in interstitial space[1].

Designed specifically for chronically week muscles, where increased strength is desired, the bandage should be applied in the origin-insertion direction of the muscle and stretched by more than 25%[1]. Neurofacilitation seems to be the possible mechanism that increases muscle activity during KT application[2,3]. According to Morini (2013)[4], the excitatory behavior of motor units may be influenced by skin mechanoreceptor stimuli, caused by the elastic and reactive strength of the bandages. After the somatosensory cortex receives sensitive afferents, the association cortex recognizes and interprets sensations. From the motor planning and primary motor cortex areas, stimuli can participate in the composition and sequencing of the movement[4]. Kaelin-lang *et al.*[5] observed that somatosensory stimulation increases cortical excitability in corticomotor representation areas of the stimulated segment in healthy participants, enhancing motor performance[5,6].

A number of studies have investigated the effect of KT on muscle activation[2,7], proprioception[3], muscle strength and function in healthy subjects, revealing discrepant results in the variables studied[8,9,10,]. Vithoulka *et al.*[11], for example, reported an increase in peak eccentric torque in healthy women when KT is applied to femoral quadriceps, which did not occur in other studies such as those by Fu *et al.*[12] and Lins *et al.*[13]. With respect to bandage application and its effects on individuals with musculoskeletal disorders, some studies have obtained increased muscle activity and pain relief [14,15,16]. Murray (2000) observed greater electromyographic activity in femoral quadriceps (FQ) during KT application in patients following anterior cruciate ligament (ACL) reconstruction[17]. However, according to Bassett *et al.*[18] in their systematic review of 321 studies assessed using the PEDro scale, only two exhibited high methodological quality, compromising result reliability.

There seems to be an inconsistency in the results obtained by studies involving healthy subjects and questions regarding the methodological quality of research conducted with individuals suffering from musculoskeletal disorders. Furthermore, the neuromuscular performance of quadriceps after ACL reconstruction reveals a little studied model in terms of the effects of KT. The postoperative phase is accompanied by alterations in the sensory and motor components of the knee joint. These alterations are reflected in disturbances in proprioceptive information, which compromise, among other things, kinesthetic perception and joint movements, as well as reduce quadriceps strength, likely due to arthrogenic muscle inhibition[19,20,21].

Analogical to the principle of trainability, which presumes that the better trained individuals are, the more difficult it is to improve their performance, the effect of KT may be enhanced under conditions of weakened muscles. For this investigation it is recommended that procedures using isokinetic tests be applied to assess the performance of muscles that act on the knees[22,23] and electromyographic signals be analyzed, since reduced neuromuscular performance is one of the main concerns in the rehabilitation phase.

Thus, the present study aimed at investigating the immediate effects of KT on quadriceps muscle performance in individuals following to ACL reconstruction using isokinetic dynamometry and electromyography, as well as its interference in postural balance, as analyzed by baropodometry. We postulate that KT improves the neuromuscular performance of quadriceps as well as unipodal postural balance, in subjects submitted to ACL reconstruction.

Methods

The study sample consisted of 47 men (mean age of 28.6 ± 3.8 years) submitted to ACL reconstruction using a gracilis-semitendinous graft. The following inclusion criteria were adopted:

subjects between the 12th and 17th postoperatory week; without pain or inflammatory signs in the joint assessed; absence of labyrinthine and neurological disorders; range of motion greater than 90º flexion and complete extension; recreationally active participants (engaging in recreational physical activity 2 or 3 times a week, without competitive training before the injury); no previous history of lower limb surgery before the lesion. Exclusion criteria were: inability to understand and/or perform the required maneuvers, presence of pain at the time of the tests or any complication preventing collection.

Subjects were randomly distributed into three groups of 15 individuals each: Control Group (CG), Placebo Group (PG) and KT Group (KTG). This study was approved by the Research Ethics Committee of Universidade Federal do Rio Grande do Norte (UFRN) via the Plataforma Brasil national interface, under protocol number 392.477. The present study complied with ethical aspects based on Resolution 466/12 of the National Health Council and Declaration of Helsinki. All the participants volunteered to take part in the study and gave their consent after being informed of the objectives, risks and benefits of the research.

Initially all participants warmed up for ten minutes on a stationary bicycle *(Ergo 167 Cycle - ERGO FIT®)* with a load of 20W and the seat adjusted to the height of the greater trochanter of the femur. Immediately afterwards they were assessed for balance on a computerized baropodometer (Eclipse 3000 - Guy-Capron® SA, France) with a 40x40cm surface and acquisition frequency of 20Hz. Individuals supported the affected limb, with knees flexed at 20º, measured using a universal goniometer. Participants were instructed to maintain their head in a neutral position, while staring at a fixed point, their torso erect and comfortable and arms at their sides. The non-affected lower limb remained with the hip at 0º and the knee at 90º flexion. Data acquisition lasted 10 seconds with a one-minute rest period between each test. Each condition was repeated twice and the best measure of amplitude of displacement from the center of pressure was analyzed[24].

To record electromyographic activity, the skin was prepared by trichotomy and the area was cleaned with 70% alcohol prior to electrode placement. We used an MCS 1000 4-channel conditioning module (EMG System®, Brazil) equipped with a 12/36-60k analogue/digital converter, 12-bit resolution, common mode rejection ratio > 100dB and sampling frequency configured at

2000 Hz. The signal was filtered between 20 and 500 Hz and amplified 1000 times. EMGLab® software was used for signal analysis. Electromyographic activity of the Vastus Lateralis (VL) muscle was captured in accordance with Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles (SENIAM), with the capture electrode on the VL muscle positioned 2/3 of the distance from the imaginary line that runs from the anterosuperior iliac spine to the lateral edge of the patella on the limb assessed.

The root mean square (RMS) amplitude values of activated muscles were recorded during concentric and eccentric contractions. To normalize RMS values of the VL muscle, two maximum voluntary isometric contractions were used with knee at 60º flexion for 5 seconds, and a 60-second rest between contractions[25]. Of the two contractions, the one with the highest isometric torque was recorded by the isokinetic dynamometer and used to normalize the electromyographic signal, in accordance with recommendations proposed by DeLuca[26]. For analysis of RMS in concentric and eccentric assessment, the electromyographic signal with the highest torque among the 5 contractions recorded by the isokinetic dynamometer was considered.

Simultaneously to electromyographic signal recording, participants were assessed for peak torque normalized for body weight (PT/BW) and average power as measured on a Multi-Joint System 4 computerized isokinetic dynamometer (Biodex®, USA). Subjects were placed in the dynamometer chair and stabilized with straps across the thorax, pelvis and thigh of the non-assessed limb. All adjustments followed Dvir's recommendations[27], such that the axis of rotation of the dynamometer was aligned with the lever adjusted and fixed to the distal region of the leg (5cm above the medial malleolus of the ankle). The gravity correction factor was performed on the dynamometer itself, using the weight of the lower limb relaxed at 60° of knee flexion. For isokinetic assessment, 5 maximum concentric contractions of the affected knee were performed 60º/s, from 90º of flexion to complete extension. Next, 5 maximum eccentric contractions of the knee extensors were carried out at the same velocity, from 20º to 90º of flexion. Both assessments were preceded by familiarization tests using two submaximal contractions, followed by a 120-second rest period before the start of testing. In order to minimize the effects of muscle fatigue, individuals remained at rest for two minutes between series. Verbal encouragement and visual feedback through the dynamometer monitor were provided during the entire assessment. The instruments applied in our study are often used in research due to their high reliability, validity and sensitivity.

After initial evaluation, participants were submitted to the protocol. The CG remained at rest for 10 minutes while the KTG underwent KT, applied by a second evaluator, to the femoral quadriceps of the affected limb, in accordance with Kase *et al*[1].

The skin was shaved, followed by application on Rectus Femoris (RF), VL and Vastus Medialis (VM) muscle in the longitudinal direction, from proximal to distal. The anchor proximal was applied to the RF 5cm below the anterosuperior iliac spine and the anchor distal to the upper edge of the patella. The anchor proximal and distal were fixed to the greater trochanter of the femur and lateral edge of the patella, respectively. On the VM muscle the anchor proximal was applied to the middle third of the medial region of the thigh and the anchor distal to the medial edge of the patella. For the three muscles in question the anchors were applied with 0% tension and the therapeutic zone (region between the anchors) followed over the belly of the muscles with a tension of 50%. The anchors were applied by an evaluator with proven experience in the technique and participants standing in unipodal support with hip at 0° and knee at maximum flexion – stretching position. In the PG, KT was applied in the same manner as in the KTG, but with no tension, in contrast to technique recommendations.

INSERT FIGURE 1

At the end of the protocol participants were immediately submitted to final assessment, identical to initial evaluation, except for familiarization tests that preceded isokinetic assessment.

Statistical analysis was conducted using the Statistical Package for the Social Sciences (SPSS) 20.0, with a significance level of 5%. Inferential statistical analysis used the Kolmogorov-Smirnov test to check for data normality and mixed Analysis of Variance (ANOVA) was applied to determine if there was an intergroup difference and between the first and second assessment for intragroup analysis.

Results

Two participants were excluded from the study for presenting with pain during initial assessment, while 45 concluded the procedures.

Electromyographic activity showed no significant alteration between initial and final assessments for concentric and eccentric RMS of the VL, in any of the study groups. Similarly, no differences were recorded between initial and final evaluations in the three groups for the variables concentric and eccentric PT/BW and average power. In relation to one-footed static balance, no significant differences were found between initial and final assessments for the variables antero-posterior amplitude, latero-lateral amplitude in the three group. Nor was any significant difference detected between the three groups (Table 1).

INSERT TABLE 1

Discussion

With respect to electromyographic activity, our study revealed no significant inter or intragroup differences. Some of the theories that could explain how KT would increase neuromuscular recruitment include activation of skin receptors caused by tactile stimulation from bandage application and the increase in interstitial space, with possible improvement in blood flow[1]

. However, studies do not confirm that KT application actually increases local blood flow, perhaps because a reliable validated instrument was not used. Furthermore, even if increased flow does occur, studies have not shown significantly higher muscle activation after KT application[7,9,11].

Results of the present study differ from those of other investigations conducted in a population with neuromuscular impairment that reported an increase in electromyographic activity[14,16,17]. Possible explanations for these discrepancies may lie in the rigor of the methods used. Murray *et al.*[17] conducted a preliminary study with only two subjects and the collection methods adopted were not clearly explained. Hsu *et al.*[14] observed an increase in muscle activation when KT was applied to the inferior trapezius muscle in athletes with shoulder impingement syndrome. These authors attribute the results to the fact that KT provided functional support to the scapulohumeral joint and consequent improvement in joint kinematics, indirectly favoring muscle activation.

With respect to concentric PT/BW, a number of studies show that KT application demonstrated no significant differences in healthy subjects, since in this population the technique did not immediately enhance muscle performance because individuals exhibited no obvious impairments[8,10,11]. Although the present study involved a muscle group with musculoskeletal disorders, significant differences were also not detected. Schleip *et al*[28]. reports that skin mechanoreceptors can be activated by rapid stimulation and induce greater muscle recruitment. Based on this premise, it was expected that tactile stimulation provided by KT would be enough to provoke these alterations. In contrast to the allegation that a bandage applied under tension in the direction of muscle fibers would increase muscle strength[1], our study found no such evidence.

In relation to eccentric PT/BW, Vitoulka *et al*.[10] observed a significant difference in healthy women. These authors suggest that KT is a proprioceptive facilitator that, along with fascia, plays an important role in the mechanical transmission generated by muscle contraction, and can thus influence the elastic and dynamic components of muscles. However, our study does not support these theories, suggesting that the tension generated by KT is not enough to produce this effect.

In regard to the variable power, earlier studies did not investigate the relationship between the effects of KT and this variable. However, Wong *et al*.[13] analyzed normalized total work in relation to the effects of KT application in healthy participants. Although changes in this variable could modify power, the authors observed no significant differences.

In relation to the baropodometry values, our findings contradict the results obtained by Bonfim *et al*.[29], who observed significant differences in antero-posterior and latero-lateral amplitudes, when the infrapatellar bandage is applied in patients submitted to ACL reconstruction. The discrepant results may be due to methodological differences. The bandage was applied to different sites in the two studies. In the earlier study, because the bandage was applied to a joint, it may have provided greater mechanical stabilization, thereby favoring enhanced balance.

Naranjo and Rodrígues-Fernandéz[30] also observed a significant improvement in antero-posterior displacement away from the center of pressure immediately after KT application. In this study, KT was applied to the belly of the medius gluteus, rectus femoris, ischiotibial and gastrocnemius muscles. One of the hypotheses raised by the authors is the influence of KT on muscle strength and its relationship with greater postural control. In the present study, no significant differences were observed in any strength-related variable, in contrast to the hypothesis of the earlier study.

Using a similar protocol, Lins et al observed no significant differences when KT and rigid bandages are applied to the femoral quadriceps of young healthy women[11]. We believe that these results occurred because the study was conducted in a healthy population, with no articular or muscular disorders that could compromise postural balance. Although the present study involved a population with neuromuscular disorders and probable compromised postural balance, no significant differences in results were observed.

Thus, we suggest that the tactile stimulus generated by KT is not enough to increase muscle activation, alter PT/WB, muscle strength or improve postural balance in subjects with musculoskeletal alterations.

Conclusion

The results of the present study suggest that the use of KT on the femoral quadriceps of subjects submitted to ACL reconstruction is incapable of immediately improving performance of the muscle, rejecting our hypothesis that its application would promote enhanced muscle performance or balance. We conclude, therefore, that the effect of KT application, under the conditions presented here, is insufficient in promoting alterations in muscle performance, contradicting the theories that would justify the use of this technique.

We underscore that the present study was an investigation of the immediate effect of KT and we suggest that future studies assess the chronic effect associated or not with training protocols, since the mechanisms by which its application could alter muscle performance remain unknown.

Practical Implications

- Tactile stimulation resulting from applying the bandage under tension does not improve neuromuscular activation, as claimed by advocates of the technique;

- The use of Kinesio Taping when applied on the quadriceps does not immediately promote enhanced balance in individuals submitted to Anterior Cruciate Ligament reconstruction.
- When applied under tension and on the quadriceps, the elastic bandage does not immediately promote enhanced strength or power, in individuals submitted to Anterior Cruciate Ligament reconstruction, which would not justify the use of the technique in these subjects.

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Figure Legend

Figure 1. Kinesio Tapping applied on quadriceps muscle.

Figure 1.

Table 1. Mean ± Standard Deviations of the variables analised before and after applying the protocol in three groups.

Variables n=45	CG N = 15		PG N = 15		KTG N =15		p
	Pre	Post	Pre	Post	Pre	Post	
PT/BW (%) Conc	193,2 ± 53,0	197,3 ± 52,2	190,3 ± 61,7	195,0 ± 85,2	153,9 ± 59,2	160,6 ± 61,3	0,21
PT/BW (%) Exc	262,4 ± 58,6	267,3 ± 59,8	274,4 ± 88,9	263,3 ± 79,1	216,7 ± 96,5	208,3 ± 92,1	0,26
Power (W) Conc	101,3 ± 38,7	105,7 ± 35,5	95,1 ± 32,7	97,5 ± 26,8	83,6 ± 27,1	80,8 ± 27,8	0,50
Power (W) Exc	72,8 ± 26,2	76,4 ± 29,7	75,2 ± 27,8	72,6 ± 32,9	53,9 ± 24,9	56,6 ± 24,0	0,67
RMS (%) Conc	119,4 ± 39,3	97,5 ± 51,4	107,1 ± 20,6	119,4 ± 25,5	111,5 ± 28,6	116,8 ± 24,7	0,42
RMS (%) Exc	105,9 ± 21,7	103,9 ± 16,2	105,2 ± 15,0	103,0 ± 20,8	108,3 ± 27,2	104,1 ± 24,1	0,25
Ampl A/P (mm)	17,5 ± 5,4	16,0 ± 3,5	17,5 ± 6,9	14,9 ± 5,5	15,7 ± 4,3	13,6 ± 6,4	0,40
Ampl L/L (mm)	10,2 ± 2,4	8,2 ± 2,9	8,4 ± 3,0	9,0 ± 3,3	8,3 ± 3,5	7,2 ± 3,0	0,08

CG = Control Group; PG = Placebo Group; KTG = KT Group; Conc = Concentric; Exc = Exccentric; PT/BW= peak torque normalised by body weight; RMS= root mean square; Ampl A/P= displacement amplitude antero-posterior; Ampl L/L = displacement amplitude latero-lateral; Pre = before the protocol; Post = after the protocol.