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RESEARCH REPORT

Efficacy of kinesio taping on isokinetic quadriceps torque in knee osteoarthritis: a double blinded randomized controlled study

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Abstract

Study design: Double blind pre-test post-test control group design. *Objectives*: To compare the isokinetic quadriceps torque, standardized stair-climbing task (SSCT) and pain during SSCT between subjects diagnosed with knee osteoarthritis pre and post kinesio tape (KT) application with and without tension. *Background*: Strength of the quadriceps and torque producing capability is frequently found to be compromised in knee osteoarthritis. The efficacy of KT in improving isokinetic quadriceps torque in knee osteoarthritis is unknown, forming the basis for this study. *Methods and measures*: Forty subjects were randomly allocated to either the experimental (therapeutic KT with tension) or control group (sham KT without tension) with the allocation being concealed. Pre and post test measurements of isokinetic quadriceps torque, SSCT and pain during SSCT were carried out by a blinded assessor. *Results*: A large effect size with significant improvements in the peak quadriceps torque (concentric and eccentric at angular velocities of 90° per second and 120° per second), SSCT and pain were obtained in the experimental group when compared to the control group. *Conclusion*: Application of therapeutic KT is effective in improving isokinetic quadriceps torque, SSCT and reducing pain in knee osteoarthritis.

Keywords

Kinesio taping, kinesio tape, knee, muscle strength, osteoarthritis, torque

History

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Introduction

With increasing age, osteoarthritis is known to be a common cause for disability and the annual expenditure is estimated to be around 89 billion dollars in the United States (Bitton, 2009). The prevalence of osteoarthritis varies from 22% to 39% (Mahajan, Verma, and Tandon, 2005) among which the knee joint is known to be the most commonly affected (Zhang et al, 2010).

During mechanical loading of the knee joint in activities such as gait, the ground reaction forces pass medial to the center of the knee joint, creating a knee adduction moment indicating loading in the medial knee joint compartment (Lim et al, 2009). This is found to be higher in subjects with knee osteoarthritis (Mündermann et al, 2004). Furthermore, increased knee adduction moment is an important predictor for the disease progression in osteoarthritis involving the medial knee joint compartment (Miyazaki et al, 2002). The quadriceps muscle group is the primary dynamic stabilizer for the knee joint in the saggital plane (Segal et al, 2010) and generates an abduction moment to resist the knee adduction moment (Shelburne, Torry, and Pandy, 2006), thereby reducing joint loading, absorbing shock and providing stability to the knee during gait (Serrão, Gramani-Say, Lessi, and Mattiello, 2012).

Strength of the quadriceps muscle and torque producing capability is commonly found to be compromised in knee osteoarthritis (Staehli, Glatthorn, Casartelli, and Maffiuletti, 2010). Different mechanisms may lead to the weakness of quadriceps namely arthrogenic muscle inhibition, swelling and atrophy due to prolonged disuse. Arthrogenic muscle inhibition is caused due to pain where there is a reflex neural inhibition preventing the full activation of the quadriceps leading to reduced force production (Baker et al, 2004; Rice and McNair, 2010). Other factors influencing arthrogenic muscle inhibition are joint laxity where increased translation of the joint surfaces causes shearing forces thereby activating the nociceptors (Rice and McNair, 2010). Damage to the joint articular receptors as a result of wear and tear causes loss of sensory afferent input from the knee joint which in turn leads to decreased efferent output from the quadriceps (Rice and McNair, 2010). Further, during inflammation, the inflammatory mediators sensitize the free nerve endings causing additional neural inhibition (Rice and McNair, 2010). Other than arthrogenic muscle inhibition, swelling of the knee joint leads to increased intra-articular pressure which in turn amplifies the discharge of group 2 afferents that are inhibitory in nature to the quadriceps (Rice and McNair, 2010). Also, the Hoffmans reflex response amplitude is found to be less in cases of knee effusion leading to inhibition of the alpha motor neuron from the spinal level reducing quadriceps strength (Rutherford, Hubley-Kozey, and Stanish, 2012). As a result of this inhibition, when quadriceps disuse is extended over a prolonged period of time, it leads to atrophy of the muscle (Hortobágyi, Garry, Holbert, and Devita, 2004) causing further weakness. Delayed motor unit recruitment and firing rates of the quadriceps have also been found in knee osteoarthritis (Berger, Chess, and Doherty, 2011) causing reduced force generating capacity.

In knee osteoarthritis, reduced quadriceps strength is one of the factors influencing development and advancement of the

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disease process (Segal and Glass, 2011), commonly affecting activities of daily functioning such as stair climbing (Schmitt, Fitzgerald, Reisman, and Rudolph, 2008). In addition, a deficit in the quadriceps strength increases the risk of re-injury to the knee joint and reduces the dynamic knee stability (Rice and McNair, 2010). Also, isokinetic quadriceps torque is found to be reduced in subjects with knee osteoarthritis (Serrão, Gramani-Say, Lessi, and Mattiello, 2012).

Recently, the use of kinesio tape (KT) as an intervention in musculoskeletal disorders has become popular among physiotherapists (Williams, Whatman, Hume, and Sheerin, 2012) and is primarily applied to decrease pain, reduce inflammation, provide mechanical support and either inhibit or facilitate a muscle (Kase, Wallis, and Kase, 2003). When applied to musculoskeletal knee pain such as patellofemoral pain syndrome, KT was found to be effective in reducing pain as well as improving range of motion, strength and functional performance (Aytar et al, 2011; Kuru, Yaliman, and Dereli, 2012). The afferent cutaneous stimulation provided by KT is believed to reduce pain as well as stimulate mechanoreceptors, which in turn is believed to enhance proprioception and improve muscle excitability through modulation of the central nervous system (Aytar et al, 2011; Kuru, Yaliman, and Dereli, 2012).

The effect of KT on isokinetic knee performance has conflicting results in literature with few studies showing no effect of the tape on quadriceps torque (Fu et al, 2008; Lins et al, 2013; Vercelli et al, 2012; Wong, Cheung, and Li, 2012). Contrary to these findings, KT was shown to increase the isokinetic quadriceps torque production in healthy subjects (Aktas and Baltaci, 2011; Vithoulka et al, 2010) as well as subjects with patellofemoral pain (Aytar et al, 2011). When applied to facilitate the quadriceps, KT was found to improve the timing and ratio of vastus medialis to vastus lateralis activity in subjects with patellofemoral pain (Chen, Hong, Huang, and Hsu, 2007; Chen, Hong, Lin, and Chen, 2008; Lee, Lee, Jeong, and Lee, 2012) as well as improve bioelectric activity of the vastus medialis when applied to normal healthy subjects (Słupik, Dwornik, Białoszewski, and Zych, 2007). Hence, KT shows some merit in improving quadriceps activity, warranting further investigation with regards to the influence on peak torque producing capacity. The effect of KT on peak isokinetic quadriceps torque in knee osteoarthritis is unknown, forming the basis for this study.

Materials and methods

Study design

This randomized controlled study utilized a double blinded pre test post test control group study design, trial registration number CTRI*/2013/03/003486*. An ethical clearance was obtained from the ethical committee of M. S. Ramaiah Hospital and Medical College before the commencement of this study and was conducted according to the Declaration of Helsinki.

Sample size calculation

The sample size was calculated based on a previous pilot study ($n = 12$) conducted at the hospital. It was estimated that 36 subjects had to be included in this study for a power of 95% and α error of 1% with a calculated effect size of 1.38. Formula used for sample size calculation was $n_i = 2(\frac{Z_{1-\alpha/2}+Z_{1-\beta}}{ES})^2$ with $ES = \frac{|\mu_1-\mu_2|}{\sigma}$ where ES = effect size, $\mu_1 - \mu_2$ = difference in means between the two groups, σ = standard deviation, α is the selected level of significance and $1-\beta$ is the selected power. However, to account for the drop-outs, it was decided that forty subjects (experimental group = 20, control group = 20) would be recruited for this study.

Participants

Both males and females presenting with knee pain to the outpatient departments of Orthopaedics and Physiotherapy, M.S Ramaiah Hospitals from April 2013 to May 2013 were screened by the researcher for their eligibility in this study. The inclusion criteria for subjects in this study were: (1) Age group between 45 and 60 years; (2) Diagnosis of knee osteoarthritis according to the American College of Rheumatology criteria (Altman et al, 1986); and (3) Radiographic severity according to the Kellgren and Lawrence scale $\leq$grade 2 (Michael, Schlüter-Brust, and Eysel, 2010). The exclusion criteria for subjects were: (1) Clinical evidence of varus/valgus malalignment (Magee, 2006); (2) Neurological deficits; (3) Subjects who were undergoing any physiotherapy treatment for their current knee pain; (4) Infectious/systemic arthritis of the knee; (5) Any pathology preventing isokinetic testing (e.g. lumbar nerve root compression, myopathy); (6) Language/cognitive deficits that might limit the informed consent; (7) Current or past (within 4 weeks) use of oral corticosteroids; (8) Knee surgery or intra-articular corticosteroid injection within the past 6 months; (9) Knee instability or sensation of knee ''giving way''; (10) Unable to ambulate without gait aid; (11) Presence of other disorders affecting the lower limbs (e.g. plantar fascitis); (12) History of treatment with KT application; and (13) History of any skin allergy.

Study protocol and allocation

If the subject fulfilled the inclusion and exclusion criteria, a patient information sheet providing details about the study was given to them. For subjects willing to take part in this study, an informed consent was obtained. A brief assessment of the subject was taken prior to the commencement of the study. Subjects were randomly allocated using a random number generator with the allocation being concealed to either the experimental or control group. The random numbers were generated by the receptionist with every alternate number being marked either ''A'' or ''B''. However, the receptionist was blinded to the interventions assigned to group A (therapeutic KT) and group B (sham KT) respectively. During allocation, every subject was asked to pick up one enclosed envelope from a box containing numbers from 1 to 40. Depending on the number picked by the subject, they were allocated to either group A (experimental group) or group B (control group) by the receptionist. Therefore two groups of 20 participants each were created with an aim to minimize the risk of allocation bias.

Outcome measures

The primary outcome for this study was peak isokinetic quadriceps torque (concentric and eccentric at 90° per second and 120° per second). Standardized Stair Climbing Task (SSCT) and pain experienced during the SSCT (measured using the Visual Analogue Scale (VAS)) were used as secondary outcome measures.

Prior to the application of KT, subjects in both the groups were assessed for their baseline peak quadriceps torque (which was normalized to their body weight) using an isokinetic dynamometer (Cybex, Humac Norm, CSMi, Stoughton, MA). Peak isokinetic extensor torque measured by an isokinetic dynamometer in subjects with knee osteoarthritis has demonstrated excellent test–retest reliability (Kean et al, 2010). The subjects were tested in a seated position with the hip and knee flexed to 90°. The knee being tested was aligned with the axis of the attached lever arm. In the testing side of the knee, the pad of the lower leg attachment of the isokinetic dynamometer was placed 5 cm above the lateral malleolus. The thigh and the trunk were stabilized with velcro straps.

After familiarizing the subjects with the working of the machine with sub maximal trial repetitions, they rested for 30 min to account for factors of pain or fatigue of the muscle. Following this, the peak isokinetic quadriceps torque (concentric and eccentric) was tested at angular velocities of 90° per second and 120° per second with five repetitions at each velocity. A 30 s rest period was allowed between the sets. During testing, visual and verbal encouragement was given for achieving the maximum capable peak torque. After recording the quadriceps peak torque, the subjects rested for 15 min. Following this, they performed the SSCT where the time taken to ascend and descend five stairs ''as quickly and as safely'' as possible was noted. This is a performance task affected in subjects with knee osteoarthritis and has a test–retest reliability of 0.88 (Rejeski, Ettinger, Martin, and Morgan, 1998). Railings were provided on both sides of the stairs and the subjects were instructed to make use of them only if they found the task to be extremely difficult. Also, the pain experienced in the knee during the SSCT was noted using a VAS.

After application of the tape, subjects in both the groups were rested for 30 min. Following this, the post test measurements of the peak quadriceps torque, stair climbing task and pain (using VAS) was carried out. Both the pre test and post test measurements was done by an assessor blinded to the study.

Taping technique

The experimental group received therapeutic KT (according to principles of application) (Kase, Wallis, and Kase, 2003) and the control group received a sham tape application. For therapeutic KT application (Kinesio Tape, Nitto Denko, Japan), three ''I'' strips were taken and applied as shown in Figure 1. The base of the first strip was applied 10 cm below the anterior superior iliac spine. Following this, the tape was pulled with a 50% – 75% tension along the course of the rectus femoris until the superior border of the patella. The knee was then flexed to 45° with the remaining strip applied in a paper-off tension (without tension) extending over the superior border of the patella. The base of the second ''I'' strip was applied below the greater trochanter and the tape was pulled with a 50% – 75% tension along the course of the vastus lateralis until the lateral border of the patella. Next, the knee was flexed to 45° and the remaining strip was applied with a paper-off tension (without tension) around the lateral border of patella towards the tibial tuberosity. The base of the third strip was applied from the middle 1/3rd of the medial aspect of the thigh. The tape was pulled with a 50% to 75% tension along the course of vastus medialis towards the medial border of the patella. Next, the knee was flexed to 45° and the remaining strip was applied with a paper off tension (without tension) around the medial border of patella ending towards the tibial tuberosity. After application of the tape, they were rubbed upon with paper to activate the glue.

For the control group receiving sham taping, the directions of the tape application with the three ''I'' strips were the same as the experimental group (Figure 2). However, no stretch was applied in the tape and the knee was not flexed for the paper off application. That is, the tape was stuck as such on the knee with no activation of the glue.

Statistical analysis

Statistical analysis was performed using the Statistical Package for Social Science (SPSS version 10.5, SPSS Inc., Chicago, IL) software on an intention to treat basis. Descriptive statistics comparing the baseline characteristics of the experimental and the control group (age, gender, side tested, weight, Kellgren and Lawrence scale and mean onset of time since knee pain) were analyzed using the Chi-square test and independent *t* test.

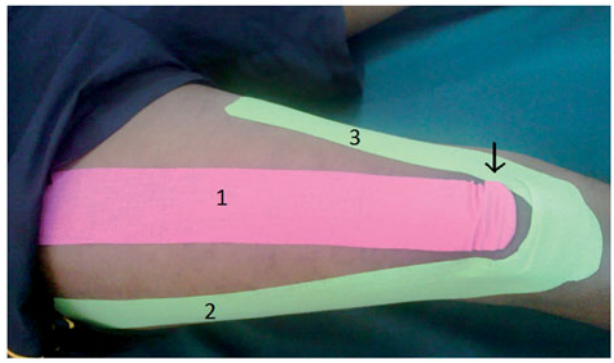

Figure 1. The above figure shows the application of therapeutic KT. The three tapes applied in sequence are numbered from 1, 2 and 3 respectively. The black arrow indicates the ''convolutions'' created as a result of the tape application.

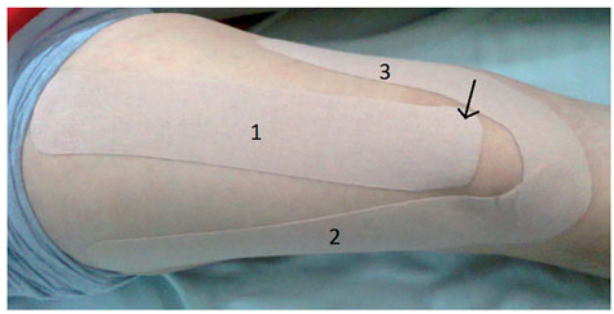

Figure 2. The above figure shows the application of sham KT. The three tapes applied in sequence are numbered from 1, 2 and 3 respectively. The black arrow indicates the absence of ''convolutions'' in the sham tape in contrast to therapeutic KT application.

Normality of distribution for both the groups were analysed using the Kolmogorov–Smirnov test. Normality testing was followed by a 2×2 Multivariate Analysis of Variance (MANOVA) comparing group (experimental versus control) and time (pre taping versus post taping values of all the dependent variables) with an α of 0.05.

Effect size (Cohens d) calculation and 95% Confidence Intervals (CI) along with the Minimal Detectable Change (MDC) were also calculated for the mean differences between both the groups. Effect sizes of 0.2, 0.5 and 0.8 were considered to correspond to small, medium and large differences respectively (Cohen, 1988). The MDC was calculated using the formula: $MDC_{95\%} = z \times SEM \times \sqrt{2}$ where SEM was the standard error measurement of values and z being considered 1.96 for a 95% CI (Lehman and Velozo, 2010). The SEM was calculated by the formula: $SEM = SD \times \sqrt{(1 - ICC}$ where SD is the baseline standard deviation of scores for all the subjects and ICC is the Intraclass Correlation Coefficient for test–retest reliability.

Results

Forty subjects were recruited for the study (20 in experimental group, 20 in control group) with no drop outs. The flow diagram of subjects throughout the study course is given in Figure 3.

Baseline characteristic differences between subjects in the experimental and control group are given in Table 1.

Normality of distribution using the Kolmogorov–Smirnov test (α level $= 0.05$) revealed that the pre test peak quadriceps concentric torque at 90° per second rejected the null hypothesis of normal data distribution ($p \leq 0.05$).

A MANOVA 2×2 analysis relating to the main effect of the group (experimental versus control) (regardless of the time), time

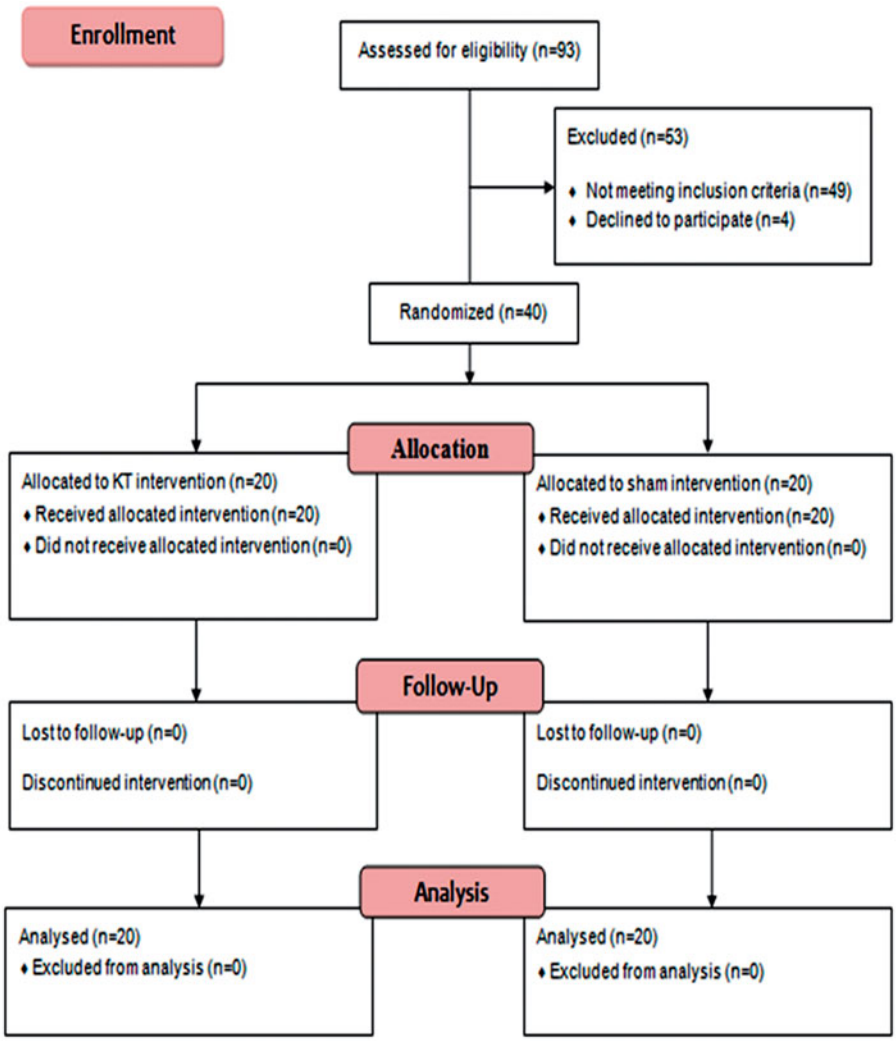

Figure 3. Flow diagram of the progress between the therapeutic KT (experimental) and sham KT (control) group subjects in the study.

Table 1. Baseline demographics for both the groups*.

	Sham KT ($n = 20$)	Therapeutic KT ($n = 20$)	p Value
Age (years)	55.9 ± 5.0	55.7 ± 5.8	0.907
Sex (Male/Female)	8/12	9/11	0.749
Weight (Kilograms)	79.3 ± 8.5	79.9 ± 6.8	0.794
Side tested (Left/Right)	9/11	11/9	0.527
Mean onset of pain (months)	8.4 ± 1.1	8.4 ± 1.5	1.000
K–L severity scale (Grade 1/Grade 2)	10/10	10/10	1.000
Concentric peak torque at 90°/sec (nm/kg)	0.11 ± .04	0.12 ± .06	0.541
Concentric peak torque at 120°/sec (nm/kg)	0.11 ± .05	0.10 ± .04	0.854
Eccentric peak torque at 90°/sec (nm/kg)	0.34 ± 0.14	0.34 ± 0.12	0.992
Eccentric peak torque at 120°/sec (nm/kg)	0.35 ± 0.15	0.34 ± 0.12	0.813
SSCT (seconds)	21.0 ± 4.8	19.6 ± 4.7	0.338
VAS (cm)	7.3 ± 1.3	7.4 ± 1.1	0.829

*Data are Mean ± SD except for sex, side tested and K–L severity scale; K–L = Kellgren and Lawrence; nm/kg = Newton meter per kilogram.

(pre test versus post values of dependent variables) (regardless of the group) and group × time interactions are given in Tables 2–4 respectively.

Statistically significant main effects were observed for the group in all variables ($p \leq 0.001$) except peak eccentric quadriceps torque (Nm/kg) at 90° per second and 120° per second respectively (Table 2). Also, MANOVA did not indicate a statistically significant effect for group × time interaction of peak eccentric torque (Nm/kg) at 90° per second (Table 4).

Regarding SSCT, though no statistically significant effect was obtained for time ($F = 3.822$, $p \geq 0.05$) (Table 3), subjects in the control group performed the SSCT slower (−2.9; 95% CI: −4.29, −1.50) and experienced more pain (−0.26; 95% CI: −0.442, −0.077) in contrast to the experimental group subjects who had an improved performance (7.1; 95% CI: 5.55, 8.64) experiencing lesser pain (2.39; 95% CI: 1.923, 2.856) (Table 5). Table 5 summarizes the 95% CI for the mean differences between the experimental and control groups.

The $MDC_{95\%}$ (i.e. the minimum amount of change beyond threshold of error that reflects true change in subjects) calculated for the primary and secondary outcomes are given in Table 6. A large effect size was obtained for the mean differences in primary and secondary outcomes between the control and experimental group (Table 7).

Discussion

The current study primarily investigated the immediate effects of KT on isokinetic quadriceps torque in knee osteoarthritis. The results indicate that KT significantly improves the concentric and eccentric quadriceps torque production in knee osteoarthritis at angular velocities of 90° per second and 120° per second respectively. This finding deviates from the findings

Table 2. MANOVA analysis to determine the main effect of the group (regardless of the time)*.

Outcomes	Group (Experimental versus Control)	Pre taping value	Post taping value	Mean value	$F_{(1, 76)}$	*p* Value
Peak concentric torque (nm/kg) at 90°/second	Experimental	0.12 ± 0.06	0.28 ± 0.09	0.20 ± 0.11	43.55	0.000
	Control	0.11 ± 0.04	0.10 ± 0.04	0.10 ± 0.04		
Peak concentric torque (nm/kg) at 120°/second	Experimental	0.10 ± 0.04	0.28 ± 0.13	0.19 ± 0.13	23.62	0.000
	Control	0.11 ± 0.05	0.11 ± 0.04	0.11 ± 0.05		
Peak eccentric torque (nm/kg) at 90°/second	Experimental	0.34 ± 0.12	0.44 ± 0.08	0.39 ± 0.11	1.98	0.163
	Control	0.34 ± 0.14	0.37 ± 0.14	0.35 ± 0.14		
Peak eccentric torque (nm/kg) at 120°/second	Experimental	0.34 ± 0.11	0.47 ± 0.12	0.41 ± 0.13	2.85	0.096
	Control	0.35 ± 0.15	0.37 ± 0.13	0.36 ± 0.14		
SSCT (seconds)	Experimental	19.6 ± 4.7	12.5 ± 4.7	16.0 ± 5.8	36.06	0.000
	Control	21.0 ± 4.8	23.9 ± 5.1	22.5 ± 5.1		
VAS (cm)	Experimental	7.4 ± 1.1	5.0 ± 1.3	6.2 ± 1.7	21.05	0.000
	Control	7.3 ± 1.3	7.5 ± 1.2	7.4 ± 1.2		

*nm/kg = Newton meter per kilogram; Experimental = therapeutic KT; Control = sham KT.

Table 3. MANOVA analysis to determine the main effect of the time (regardless of the group)*.

Outcome	Time (Pre taping versus Post taping)	Experimental group	Control group	Mean value	$F_{(1,76)}$	*p* Value
Peak concentric torque (nm/kg) at 90°/second	Pre taping	0.12 ± .06	0.11 ± .04	0.11 ± 0.05	31.48	0.000
	Post taping	0.28 ± 0.09	0.10 ± 0.04	0.19 ± 0.11		
Peak concentric torque (nm/kg) at 120°/second	Pre taping	0.10 ± .04	0.111 ± .05	0.10 ± 0.04	29.70	0.000
	Post taping	0.28 ± 0.13	0.11 ± 0.04	0.20 ± 0.13		
Peak eccentric torque (nm/kg) at 90°/second	Pre taping	0.34 ± 0.12	0.34 ± 0.14	0.34 ± 0.13	4.93	0.029
	Post taping	0.44 ± 0.08	0.37 ± 0.14	0.41 ± 0.12		
Peak eccentric torque (nm/kg) at 120°/second	Pre taping	0.34 ± 0.12	0.35 ± 0.15	0.35 ± 0.13	6.03	0.016
	Post taping	0.47 ± 0.12	0.37 ± 0.135	0.42 ± 0.13		
SSCT (seconds)	Pre taping	19.6 ± 4.7	21.0 ± 4.8	20.3 ± 4.7	3.82	0.054
	Post taping	12.5 ± 4.7	23.9 ± 5.1	18.2 ± 7.5		
VAS (cm)	Pre taping	7.4 ± 1.1	7.3 ± 1.3	7.3 ± 1.1	15.41	0.000
	Post taping	5.0 ± 1.3	7.5 ± 1.2	6.2 ± 1.8		

*nm/kg = Newton meter per kilogram; Experimental group = therapeutic KT; Control group = sham KT.

Table 4. MANOVA analysis to determine the interaction of group (experimental versus control) and time (pre tape versus post tape values)*.

			Group × time	
Variable	Group	Mean difference ± SD	$F_{(1,76)}$	*p* Value
Peak concentric torque (nm/kg) at 90°/second	Experimental	0.16 ± 0.08	34.41	0.000
	Control	0.00 ± 0.02		
Peak concentric torque (nm/kg) at 120°/second	Experimental	0.18 ± 0.13	25.08	0.000
	Control	0.01 ± 0.04		
Peak eccentric torque (nm/kg) at 90°/second	Experimental	0.10 ± 0.11	1.94	0.168
	Control	0.02 ± 0.09		
Peak eccentric torque (nm/kg) at 120°/second	Experimental	0.13 ± 0.14	4.13	0.046
	Control	0.01 ± 0.14		
SSCT (seconds)	Experimental	7.1 ± 3.3	21.67	0.000
	Control	−2.9 ± 3.0		
VAS (cm)	Experimental	2.4 ± 1.0	23.85	0.000
	Control	−0.3 ± 0.4		

*nm/kg = Newton meter per kilogram; Experimental = therapeutic KT; Control = sham KT; SD = standard deviation.

of the previous studies (Fu et al, 2008; Lins et al, 2013; Vercelli et al, 2012; Wong, Cheung, and Li, 2012) where no effect of KT on isokinetic quadriceps torque was found. One possible reason could be that in these previous studies isokinetic quadriceps torque was assessed on normal healthy subjects whereas in the current study the subjects all had musculoskeletal knee pain. Furthermore, the carryover effects were ruled out in the current study by using a pre-test and post-test control group study design unlike some of the previous studies which used a cross over design (Vercelli et al, 2012; Wong, Cheung, and Li, 2012). Also, according to principles of KT (Kase, Wallis, and Kase, 2003), a gap of at least 30 min should be given after the tape application for achieving complete activation of the glue, which in turn is believed to improve the performance of the tape on the muscle. It must be noted that in most studies (Fu et al, 2008; Lins et al, 2013; Vercelli et al, 2012), a gap of $\leq$10 min was given after KT

Table 5. Confidence interval (CI) values for the within group and between group differences*.

Outcomes	Mean difference within the groups (95% CI) Experimental group Pre test – post test values	Control group Pre test – post test values	Mean difference between the groups (95% CI)
Concentric 90°/sec (nm/kg)	0.16 (0.12 to 0.20)	0.00 (−0.01 to 0.00)	0.16 (0.13 to 0.20)
Concentric 120°/sec (nm/kg)	0.18 (0.12 to 0.24)	0.01 (0.00 to 0.02)	0.17 (0.11 to 0.23)
Eccentric 90°/sec (nm/kg)	0.10 (0.05 to 0.15)	0.02 (−0.02 to 0.06)	0.08 (0.02 to 0.14)
Eccentric 120°/sec (nm/kg)	0.13 (0.06 to 0.19)	0.01 (−0.05 to 0.08)	0.12 (0.03 to 0.20)
SSCT (seconds)	7.1 (5.6 to 8.6)	−2.9 (−4.3 to −1.5)	10.0 (7.9 to 12.0)
VAS (cm)	2.4 (1.9 to 2.9)	−0.3 (−0.4 to −0.1)	2.7 (2.2 to 3.1)

*nm/kg = Newton meter per kilogram; Experimental = therapeutic KT; Control = sham KT.

Table 6. ICC, SEM and $MDC_{95\%}$ values for all the outcome measures.

Outcome measures	$ICC_{3,1}$ (95% CI)	SEM	$MDC_{95\%}$
Concentric 90°/sec (nm/kg)	0.87 (0.71 – 0.95)	0.02	0.05
Concentric 120°/sec (nm/kg)	0.92 (0.82 – 0.97)	0.01	0.03
Eccentric 90°/sec (nm/kg)	0.72 (0.65 – 0.81)	0.07	0.19
Eccentric 120°/sec (nm/kg)	0.86 (0.75 – 0.94)	0.05	0.14
SSCT (sec)	0.94 (0.91 – 0.98)	1.2	3.2
VAS (cm)	0.95 (0.92 – 0.97)	0.3	0.7

application prior to checking the quadriceps torque. In this study, the subjects were rested for 30 minafter KT application. It is possible that the time given for activation of the glue could have improved the effect of the tape on the knee, which in turn could have improved the peak concentric and eccentric torque production values.

Baseline discrepancies between the peak concentric and eccentric torque production values are given in Table 1 with concentric torque values being lower than the eccentric torque values in both the experimental and control group. This discrepancy can be explained by the force velocity relationship for a muscle where force declines in a hyperbolic fashion relative to the isometric force as the shortening velocity increases with the reverse holding true when the muscle is stretched during eccentric contraction (Oatis, 2009). After therapeutic taping, even though a large effect size was obtained in the peak concentric quadriceps torque (90° per second and 120° per second) for the experimental group when compared to the control group (Table 7), the baseline value of peak concentric torque (Nm/kg) at 90° per second is slightly higher in the experimental group (0.115 ± 0.06) than the control group (0.105 ± 0.043). Further, the normal distribution of values for the pre test peak concentric torque at 90° per second was rejected ($p \leq 0.05$). Hence, caution needs to be exerted while generalizing the findings of this therapeutic improvement seen in the experimental group.

It is interesting to note that in this study, though KT was applied from the origin of the quadriceps muscle to the insertion with an aim to facilitate the concentric torque, even the eccentric quadriceps torque (nm/kg) was found to be increased immediately post taping at angular velocities of 90° per second (0.100; 95% CI: 0.050, 0.149) and 120° per second (0.129; 95% CI: 0.064, 0.193) respectively with a large effect size (Table 7). One neurophysiological hypothesis for this is that the cutaneous stimulation provided by the tape may have attenuated the 1a inhibitory afferent activity of the muscle by modulating the gamma motor neuron, thus, regulating the tone of the quadriceps muscle (Konishi, 2013). By this mechanism, it is possible that the tape acted as a tone regulator rather than a tone facilitator. In addition, it has been recently found that the fascia also has contractile properties in addition to transmitting forces, influencing the mechanics of the musculoskeletal system (Benjamin, 2009). Hence, it may be possible that by lifting the skin due to the ''convolutions'' created by KT (Figure 1), unloading of the fascia could have occurred by reducing the mechanical load (Kase, Wallis, and Kase, 2003), thereby improving control of the force production and force transmission across the quadriceps muscle. Thus, the tape may have acted as a controller of tone leading to improvements seen in the eccentric torque production among the experimental group subjects. Though a large effect size was obtained for the mean difference in peak eccentric torque production, MANOVA analysis did not show a statistically significant effect for group × time interaction of peak eccentric torque (Nm/kg) at 90° per second (Table 4), indicating that the changes in scores over time did not depend on the group assignment (therapeutic KT or sham KT).

In this study, KT caused an immediate reduction in pain and improved the performance of the stair climbing task in the experimental group when compared to the control group. In a recent meta-analysis investigating the effect of KT in sports injuries (Williams, Whatman, Hume, and Sheerin, 2012), most of the objective variables showed conflicting results as a consequence of the placebo effect. Further, the placebo effect was demonstrated in a study done by Vercelli, Ferriero, Bravini, and Sartorio (2012) where in the post experiment interview, 30% of the subjects in the control group felt stronger after a placebo tape application. In the current study, deteriorated performance during the stair climbing task (-2.9 ± 2.97 s with nine subjects negatively exceeding the $MDC_{95\%}$) and increased pain levels (-0.26 ± 0.38 cm with $MDC_{95\%}$ being 0.71 cm) post taping among the control group subjects suggests that the placebo effect can be ruled out. However, this can also be explained by the fact that after measuring the isokinetic quadriceps torque, the subjects were rested for a period of 15 min. It is possible that this time period was perhaps insufficient to completely wash away the pain or fatigue after the peak isokinetic quadriceps torque measurement in the control group, thus, accounting for the deteriorated performance during the SSCT and increased pain levels. Hence, this may be one variable which could have negatively influenced the results in the control group. On the other hand, the improved performance of the experimental group subjects in all the dependent variables (isokinetic quadriceps torque, SSCT, VAS (pain)) is suggestive of the fact that KT indeed had a therapeutic benefit.

The postulated mechanism by which KT could have increased the quadriceps torque, improved the performances in the SSCT and reduced pain experienced during SSCT could be due to a central nervous system neuromodulation. Tension exhibited by KT onto the skin provides an afferent cutaneous stimulation and is believed to stimulate the mechanoreceptors (Thelen, Dauber, and Stoneman, 2008). This in turn is believed to modulate pain as proposed by the gate control theory where nociception carried by the small diameter nerve fibers is alleviated by the afferent

Table 7. Effect size calculation and the number of subjects exceeding the $MDC_{95\%}$ score in the experimental and control groups.

Outcomes	Groups	Effect size*	$++MDC_{95\%}$**	$--MDC_{95\%}$***
Concentric 90°/sec (nm/kg)	Experimental	2.65	18	0
	Control	−0.07	0	0
Concentric 120°/sec (nm/kg)	Experimental	4.41	20	0
	Control	0.16	3	0
Eccentric 90°/sec (nm/kg)	Experimental	0.82	5	0
	Control	0.16	0	0
Eccentric 120°/sec (nm/kg)	Experimental	1.11	12	1
	Control	0.08	4	4
SSCT (seconds)	Experimental	1.52	17	0
	Control	−0.60	0	9
VAS (cm)	Experimental	2.26	19	0
	Control	−0.20	0	1

*Effect sizes of 0.2, 0.5 and 0.8 correspond to small, medium and large differences respectively (Cohen, 1988); **$++MDC_{95\%}$ indicates the number of subjects in whom the change of score positively exceeded the $MDC_{95\%}$; ***$--MDC_{95\%}$ indicates the number of subjects in whom the change of score negatively exceeded the $MDC_{95\%}$.

feedback carried by the large diameter nerve fibers (González-Iglesias et al, 2009), thereby improving the performance in quadriceps torque and SSCT. Also, according to the cutaneous fusimotor reflex theory, when the skin is stimulated by various stimuli (e.g. vibration), the muscles below the area of stimuli contract through gamma motor reflexes (Ridding et al, 2000). Cutaneous stimulation provided by KT could have reduced the threshold levels of the motor neuron (Garnett and Stephens, 1981), thus, resulting in easier recruitment of the quadriceps motor units and increased quadriceps torque production. Direct facilitation of the quadriceps muscle by KT has shown to improve the bioelectric activity of vastus medialis in healthy subjects (Słupik, Dwornik, Białoszewski, and Zych, 2007). Furthermore, application of KT to facilitate the quadriceps has also shown improved timing and ratio of vastus medialis to vastus lateralis activity in subjects with patellofemoral pain (Chen, Hong, Huang, and Hsu, 2007; Chen, Hong, Lin, and Chen, 2008; Lee, Lee, Jeong, and Lee, 2012). This is believed to occur as a result of the concentric pull on the fascia exerted by the tape application from the origin of the quadriceps muscle to the insertion, stimulating an increased concentric quadriceps torque production (Mostafavifar, Wertz, and Borchers, 2012).

Recently, Kean et al. (2010) examined the test–rest reliability and quantified the MDC of quadriceps strength in patients with knee osteoarthritis having a Kellgren and Lawrence grade of OA severity $\geq$2. At an angular velocity of 60° per second, baseline quadriceps torque of 1.43 ± 0.53 nm/kg and a $MDC_{90\%}$ of 0.27 nm/kg were obtained. However, in this study where subjects were recruited with a Kellgren and Lawrence grade of OA severity <2, the baseline concentric quadriceps torque values at angular velocities of 90° per second and 120° per second (Table 1) are lower than the reported $MDC_{90\%}$ of 0.27 nm/kg (Kean et al, 2010). Also, the magnitude of increased peak quadriceps torque observed post therapeutic KT deviates from some previous studies (Aktas and Baltaci, 2011; Vithoulka et al, 2010). For example, the increase in peak concentric quadriceps torque at 90° per second after therapeutic KT is 0.161 (95% CI: 0.123, 0.198) in contrast to −0.004 (95% CI: −0.012, 0.004) after same KT. The ICC's for all the measures are given in Table 6 and show a wide CI range for quadriceps torque. These findings suggest that the positive changes observed in the quadriceps torque post therapeutic KT seems to be partially as a result of a testing bias rather than a real treatment effect and caution needs to be exerted while interpreting the magnitude of the therapeutic improvement obtained in the experimental group.

Strength of the quadriceps is important in knee osteoarthritis as it has the ability to predict the level of functional disability (McAlindon, Cooper, Kirwan, and Dieppe, 1993) and activities of daily functioning (Mizner, Petterson, and Snyder-Mackler, 2005). For subjects with knee osteoarthritis who are rehabilitated using an isokinetic exercise training program, KT can be utilized as an adjunct tool to improve the efficiency of quadriceps torque production. Quadriceps function is important for stair climbing activities (Asay, Mündermann, and Andriacchi, 2009) and the increased quadriceps torque production seen in the experimental group could have caused an immediate reduction in the time taken to climb up and down the stairs during the SSCT. Although the positive changes observed in the quadriceps torque post therapeutic KT seem to be partially as a result of a testing bias, KT can be applied to cause immediate meaningful improvements in the performance of stair climbing activities in subjects with knee osteoarthritis, forming an implication for clinical practice. Future studies need to substantiate this finding linked to the correlation between increased peak quadriceps torque and the ability to predict an improvement in the stair climbing activity among subjects with knee osteoarthritis.

Even though improvements were noted in the quadriceps torque production, performance of SSCT and reduction of pain during SSCT in the experimental group, caution needs to be exerted while interpreting the findings of this study. It must be noted that subjects with a Kellgren and Lawrence radiographic severity scale of <grade 2 and a mean onset of knee pain 8.40 months were recruited in this study. Thus, the effect of KT in subjects with a Kellgren and Lawrence radiographic severity >grade 2 having knee pain for a more chronic duration is unknown. Also, generalization of the findings of this study across various age groups is limited as the subjects recruited for this study fell under a narrow age group of approximately 50 to 65 years. Further, it is unknown if the short rest period of 15 min prior to assessing the SSCT had any negative carry over influencing the subjects performance of the SSCT and VAS (pain) in this study.

It must be noted that the beneficial effects of KT have been shown to be observed 24 to 48 h after the tape application (Słupik, Dwornik, Białoszewski, and Zych, 2007; Thelen, Dauber, and Stoneman, 2008). In this study, the immediate effects of KT on isokinetic quadriceps torque were investigated. Hence, the ability of KT to sustain the improvements seen in the quadriceps torque production or SSCT in subjects with knee osteoarthritis is unknown, forming an area for future clinical research.

Furthermore, only the total quadriceps torque production was measured in this study. In healthy subjects, even though no improvement in the total quadriceps torque was found, the time taken to generate the peak torque was found to be considerably reduced (Wong, Cheung, and Li, 2012). Hence, in this study, though improvements in the quadriceps peak torque production was found in the experimental group when compared to the control group, parameters like the time taken for generation of the peak torque, the duration for which the peak torque is sustained, the joint angle at which the peak torque occurs and the total work done during five repetitions at angular velocities of 90° per second and 120° per second is unknown, forming implications for future clinical research. Future studies can also focus on standardizing the tension exhibited by the tape onto the skin during application of the tape by using a strain gauge. This may improve the internal consistency of future studies when the tape is applied to a variety of musculoskeletal conditions.

Conclusion

Subjects in the experimental group who received therapeutic KT application showed significant improvements in the peak quadriceps torque production (concentric and eccentric at 90° per second and 120° per second), SSCT and VAS (pain) when compared to subjects in the control group who received sham taping. Hence, from this study it can be concluded that when KT is applied to facilitate the quadriceps muscle, it has an immediate effect on improving the peak concentric and eccentric quadriceps torque production in subjects with knee osteoarthritis. However, the long term effects of KT on peak quadriceps torque and the correlation between improvements in the peak quadriceps torque and stair climbing ability is unknown, forming implications for future clinical research.

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Declaration of interest

The authors report no declarations of interest.

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