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ARTICLE

The prolonged effect of Kinesio Taping on joint torque and muscle activity

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ABSTRACT

Purpose: Although Kinesio Taping has been extensively used, evidence about the effect of Kinesio Taping is still insufficient. The aim is to determine the effect of Kinesio Taping on elbow joint torque and muscle activity in time and frequency domains.
Materials and Methods: Thirty-eight healthy subjects were (27 females and 11 males) randomly divided into control and Kinesio Taping groups. Kinesio Taping was applied over biceps brachii muscle in Kinesio Taping group, whereas no taping was applied to control group. Maximum elbow joint torque and electromyography activity in time and frequency domains were assessed during maximum isometric contraction of biceps brachii muscle at baseline, after 10 min, 30 min, and 24 h. Repeated measure ANOVA and mixed ANOVA tests were used for in-group and between-group comparisons, respectively.
Results: Elbow joint torques among four assessment sessions were statistically altered in Kinesio Taping group and greater in Kinesio Taping group than in control group ($F(3,57)= 3.317$, $p = 0.026$, $\eta p2 = 0.149$; $F(3,108)=3.325$, $p = 0.022$, $\eta p2 = 0.085$; respectively). No difference was found in time domain muscle activity among assessment sessions in each group and comparison of groups ($p > 0.05$). Low-gamma band activity was changed among assessment sessions in Kinesio Taping group ($F(3,57)= 6.946$, $p < 0.001$, $\eta p2 = 0.268$) while group × time interaction was not determined.
Conclusions: Kinesio Taping may influence joint torque of elbow more than without Kinesio Taping condition in 24th hour but the interpretation of this effect as a muscle strength enhancement compared with baseline can be arguable. Even if Kinesio Taping could not affect muscle activity in time domain, low-gamma band activity which is closely related to somatosensorial input may reach highest magnitude 24 h after Kinesio Taping.

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1. Introduction

Kinesio Taping (KT) is a taping technique based on the hypothesis that both the skin and subcutaneous tissues can be mechanically stimulated via an elastic tape applied with a specific tension level and direction (Kase et al. 2003). This technique is commonly used to improve muscle performance and facilitate or inhibit muscle activity, muscle strength, and neuromuscular performance in rehabilitation (Lins et al. 2016; de Freitas et al. 2018; Denizoglu Kulli et al. 2019; Camacho et al. 2020). However, recent systematic reviews demonstrated that the evidence about the effect of KT is still insufficient (Csapo and Alegre 2015; Lau and Cheng 2019; Ramirez-Velez et al. 2019). Nevertheless, KT is extensively used in clinics and research (Camacho et al. 2020; Donec and Kubilius 2020; Yildiz et al. 2021).

The evidence about the effect of KT on joint torque remains controversial. Although some studies reported its effectiveness (Lumbroso et al. 2014; Yeung et al. 2015), several studies have refused the beneficial effects of KT on muscle strength parameters in different duration of KT application (Gomez-Soriano et al. 2014; Lins et al. 2016; Limmer et al. 2020). Contrary, recent studies present strong evidence about preventing the effect of fatigue on muscle strength (Kirmizigil et al. 2020; Merino-Marban et al. 2021). Furthermore, the studies focussed on muscle activity after KT is more or less in consensus that KT did not alter electromyographic (EMG) activity immediately after KT (de Almeida Lins et al. 2013; Chen YS et al. 2020). However, some studies showed that KT can change muscle activity in time, especially 24th hours after KT has been pointed out in the literature (Słupik et al. 2007; Watcharakhueankhan et al. 2022). It is claimed that KT can alter muscle functions through mechanoreceptors via applying pressure and stretching on the skin surface (Kase et al. 2003). Studies revealed that when the modulatory mechanisms within the central nervous system are activated through proprioception feedback, muscle excitability may increase (Vithoulka et al. 2010; Lin et al. 2011; Fratocchi et al. 2013). Some indirect results support that KT creates changes in parameters related to the pattern of recruitment of motor units by stimulation of cutaneous mechanoreceptors (Gomez-Soriano et al. 2014; Yeung et al. 2015; Magalhaes et al. 2016). Two of these parameters are

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stretch and Hoffmann-reflex (H-reflex) which reflect changes in the level of facilitation or inhibition acting on the motoneuron pool (Pierrot-Deseilligny and Burke 2005; Yeung and Yeung 2016). On the other hand, some studies revealed controversial findings regarding the influence of KT application on these parameters (Alexander et al. 2003; Lin et al. 2011; Bagheri et al. 2018; Magalhaes et al. 2020).

The motor unit recruitment capacity and firing frequency of the motor units are directly affected by descending cortical command. Descending drives from the motor cortex may be determined using frequency-based assessments of electromyography (EMG) because action potentials of muscle fibres are produced via neuromuscular transmission (Brown 2000; Neto et al. 2010; Neto and Christou 2010; Pereira et al. 2010; Pereira et al. 2012). Low-gamma band activity (30–60 Hz) of EMG signals has been attributed to close interaction with the cortical descending command to muscles influenced by somatosensory input (Brown 2000; Pereira et al. 2012). It is assumed that KT affects the musculature via facilitating sensorial receptors, therefore investigating low-gamma band activity of muscle activity under taping conditions may provide insight into sensorial input effect of KT.

The importance of exploring the underlying factors of KT effectiveness may provide insight for the prevention and treatment of sensorimotor deficits caused by central or peripheral injuries in the clinical application of KT. Additionally, to reveal probable time-depending effects of KT may be beneficial for the usage of KT during sports activities and rehabilitation. Accordingly, we aimed to determine the effect of KT on joint torque and muscle activity in time and frequency domains in this study.

2. Materials and methods

2.1. Participants

Thirty-eight healthy and right-hand dominant subjects (27 females and 11 males) without a history of acute musculoskeletal injury or neurological diseases participated in the study. The subjects with a routine physical training program or moderate to vigorous physical activity were excluded from the study. The subjects were randomly allocated into two groups as KT (14 females and 6 males) and control (13 females and 5 males) groups by an electronic random sequence generator (www.random.org). The subjects were informed about not ingesting caffeine, alcohol, or any form of central nervous system stimulant or depressant and performing a high-intensity exercise program for at least 6 h prior to testing. Written informed consent was obtained from all subjects. The experimental procedure was approved by the Bezmıalem Vakıf University Human Research Ethics Committee and the experiments were performed in accordance with the Declaration of Helsinki (the approval number: 12/234).

We estimated that a sample size of at least 18 participants for each group would have a power of 80% with an alpha value of 0.05 according to the results of Yeung et al. using the GPower program (Faul et al. 2007; Yeung et al. 2015).

2.2. The study design

We have conducted a randomized controlled study. The assessments of all the participants were performed using simultaneous EMG measurement and isokinetic testing for consecutive two days (a total of four times). The KT group performed maximum isometric voluntary elbow flexion without KT, immediately after KT, and 30 min and 24 h after KT application. Likewise, the control group was evaluated at the same time-point intervals as the KT group. These were named baseline and 10th min, 30th min, and 24th hours assessment sessions.

The study was registered to ClinicalTrial.Gov website with the registration number NCT04352192.

2.3. KT application

Kinesio tape (Kinesio Tex Gold, Kinesio USA, Albuquerque, NM) was applied to shaved and clean skin from origin to insertion of the biceps brachii muscle of the KT group with paper-off tension (without stretch) according to the prescription of Kenzo Kase for the biceps brachii facilitation after the baseline assessment (Kase et al. 2003). 'X' taping technique was applied since the origin and insertion of the biceps brachii alter depending on the movement (Kase et al. 2006). The length between the supraglenoid tubercle and coracoid process to the proximal third of the supinated forearm in the 30–45° flexion of the elbow was accepted as the applied kinesio tape length. The medial and lateral tails of the proximal ends of the kinesio tape were applied from the coracoid process to the antecubital crease and from the supraglenoid tubercle to the antecubital crease, respectively. The middle portion of the kinesio tape was applied onto the antecubital area with the elbow in 30–45° flexion. The lateral and medial tails of the distal ends of the kinesio tape were applied on the proximal third of the forearm (Kase et al. 2003) (Figure 1).

2.4. Measurement of maximum elbow joint torque

Subjects were placed on an isokinetic dynamometer (Humac Norm, Cybex CSMI, Stoughton, MA, USA) to record the peak torque during maximum voluntary isometric contraction (MVIC) of the elbow flexion. The subjects performed isometric contraction for 5 s at an angle of 90° of elbow flexion with a maximal effort. The MVIC was performed three times with 1-min intervals.

2.5. Measurement of muscle activity

Electromyographic activity of the biceps brachii muscle was recorded during MVIC by a surface EMG device (Nihon Kohden EMG device, model 9400, Japan) for 5 s simultaneously with the elbow joint torque (with a sample rate of 2000 Hz). Before placing the electrodes, the skin surface was shaved and lightly abraded with 70% alcohol. Ag/AgCl disc electrodes with 10 mm diameter were placed on the middle of the biceps brachii muscle belly, parallel to the direction of

Figure 1. KT application and SEMG electrode placement.

muscle fibres. A bipolar configuration with 20 mm of inter-electrode distances was adopted. The reference electrode was placed on the wrist (Figure 1). Locations of the electrodes on the skin were marked on the first assessment using an indelible pen to ensure the same position was used on subsequent tests. The surface EMG recording procedure was carried out according to the recommendations of the SENIAM Project (Hermens et al. 1999). All the procedures were performed by the same investigator.

2.6. EMG signal processing

Time intervals between 0.5 and 4 s of EMG signals were extracted, and then raw EMG signals were filtered with a 6th order Butterworth bandpass filter (20–450 Hz pass-band) and full-wave rectified. The signals were segmented via sliding windows of 200 ms duration (Arslan et al. 2010). The time interval between the successive windows was chosen as 25 ms (Chen et al. 2013). The root mean square (RMS) value was calculated for each segmented window and the average of RMS values was calculated for the entire signal. Average RMS values obtained from each subject were normalized to the corresponding EMG value recorded at the baseline assessment.

EMG data recorded at the peak maximum voluntary contraction were also used for the frequency-domain signal analyses. Frequency-domain analyses of EMG signals were carried out using Fast-Fourier transformation and the power spectrum density (PSD) (Anaclet et al. 2015; Casabona et al. 2021; Chow and Stokic 2021). Since we quantified the frequency band between 30 and 60 Hz, EMG signals were filtered using

Table 1. Physical characteristics of the groups.

	Control group	KT group	p
Age (years)	22.3 ± 1.7	21.9 ± 1.7	0.494
Sex (female/male)	13/5	14/6	0.880
Height (m)	1.68 ± 0.1	1.69 ± 0.1	0.737
Mass (kg)	62.6 ± 10.4	63.3 ± 9.0	0.819
Body mass index (kg/m^2)	21.7 ± 2.3	22.3 ± 2.2	0.434

6th order Butterworth bandpass filter with a 30–60 Hz pass-band. It has been claimed that the low gamma band activity of EMG is closely related to the cortical descending command to muscles influenced by somatosensory input (Brown 2000; Pereira et al. 2012). RMS values of PSD data of the EMG signal that is corresponding to the relevant torque measurement trial were calculated. To do so, 200 ms duration for sliding windows and 25 ms for the time interval were selected similar to the time-domain analyses of the EMG signals. Afterward, average RMS values of the corresponding PSD data for each subject were computed.

2.7. Statistical analysis

Statistical analysis was performed with SPSS software, version 22.0 (IBM Corporation, New York, USA). Normality assumptions were confirmed by the Shapiro–Wilk test. Time-domain muscle activity and low gamma band activity were normalized using baseline values of each parameter for the statistical analysis. Repeated measures ANOVA and Bonferroni *post hoc* tests were used to determine differences in the maximum elbow joint torque, time, and frequency domain muscle activities among four assessment sessions for each group. A mixed repeated measures analysis of variances was performed to examine the differences between groups with respect to time for the maximum elbow joint torque, time, and frequency domain muscle activities. The statistical significance was accepted at 5% ($p < 0.05$).

3. Results

The physical characteristics of the groups are given in Table 1. There was no significant difference in age, number of female and male participants, height, mass, and body mass index between the control and KT groups.

The maximum elbow joint torques were altered in the KT group (Figure 2) ($F(3,57) = 3.317$, $p = 0.026$, $\eta p2 = 0.149$). The *post hoc* analysis showed that there was a statistically significant difference in the maximum elbow joint torque between the 24th hour and 30th min ($p = 0.002$). The control group did not demonstrate any significant changes in the torques among the assessment sessions ($F(3,51) = 1.178$, $p = 0.327$, $\eta p2 = 0.065$) (Figure 2). No statistically significant difference was found on muscle activity among four assessment sessions for both the control and KT groups ($F(3,51) = 2.335$, $p = 0.126$, $\eta p2 = 0.121$; $F(3,57) = 1.528$, $p = 0.217$, $\eta p2 = 0.074$, respectively) (Figure 3). The magnitude of low-gamma band activity among four assessment sessions was changed in only the KT group, but not in the control group ($F(3,57) = 6.946$, $p < 0.001$, $\eta p2 = 0.268$; $F(3,51) = 1.072$, $p = 0.369$, $\eta p2 = 0.059$, respectively). According to Bonferroni *post hoc*

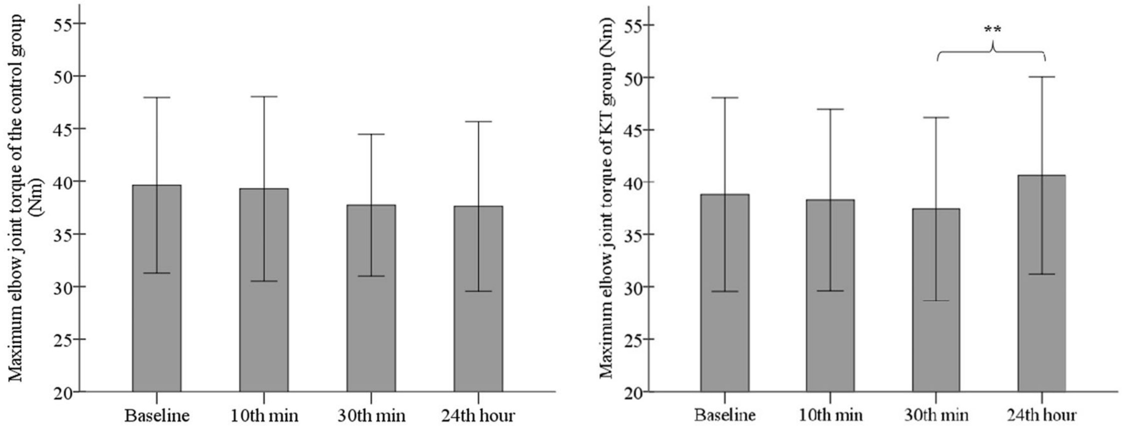

Figure 2. In group comparison of maximum elbow joint torque among four assessment sessions. The maximum elbow joint torques found statistically different in KT group and *post hoc* analysis showed that the difference was between the 24th hour and 30th minute session (**$p < 0.01$).

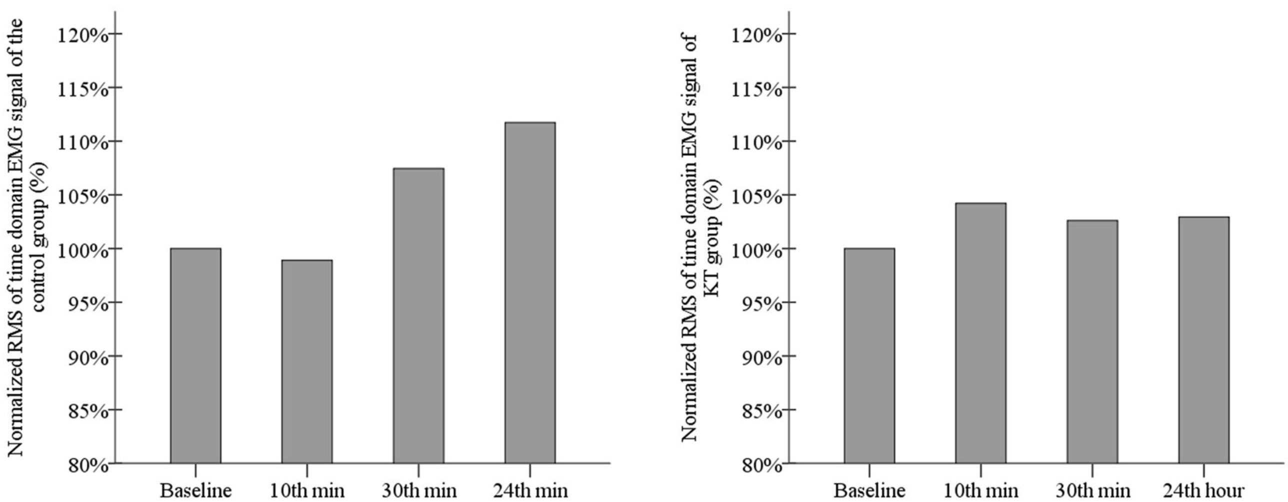

Figure 3. In group comparison of normalized RMS of time-domain EMG signals among four assessment sessions.

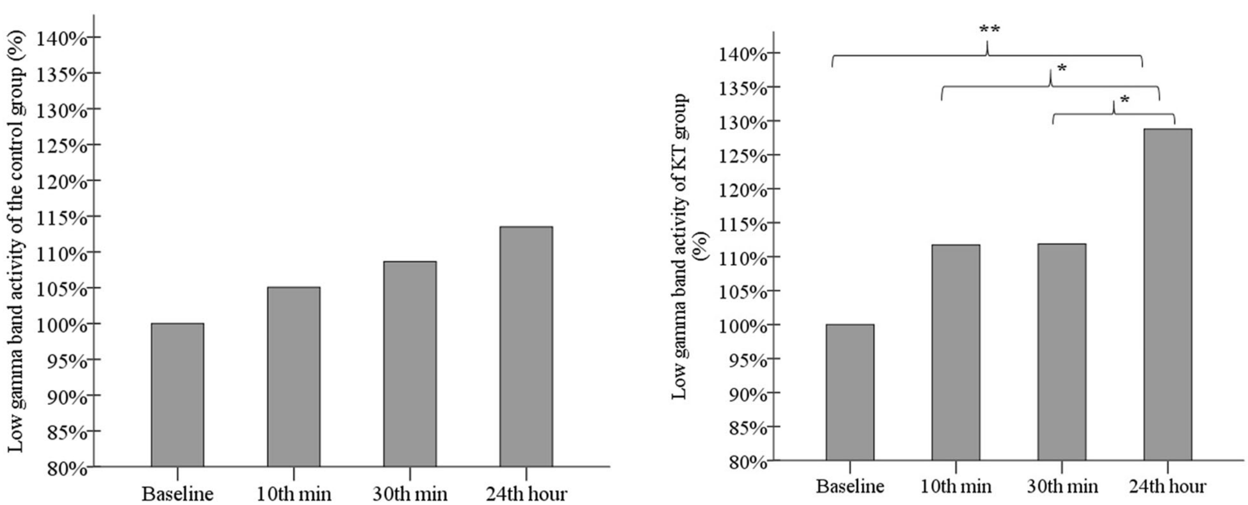

Figure 4. In group comparison of low-gamma band activity among four assessment sessions. The low gamma band activity was showed statistically significant differences among four assessment sessions in KT group and the higher low gamma band activity were determined in the 24th-hour assessment session than in the baseline, 10th minute, and 30th minute assessment sessions according to *post hoc* analysis (*$p < 0.05$ and **$p < 0.01$).

test, the greater low-gamma band was determined in the 24th-hour assessment session than in the baseline, 10th min, and 30th min assessment sessions ($p = 0.003$, $p = 0.018$, and $p = 0.021$, respectively) (Figure 4).

When the maximum elbow joint torque values of four assessments compared between the control and KT groups, a significant interaction was found ($F(3,108)=3.325$, $p = 0.022$, $\eta p2 = 0.085$) (Figure 5). In terms of muscle activity, a

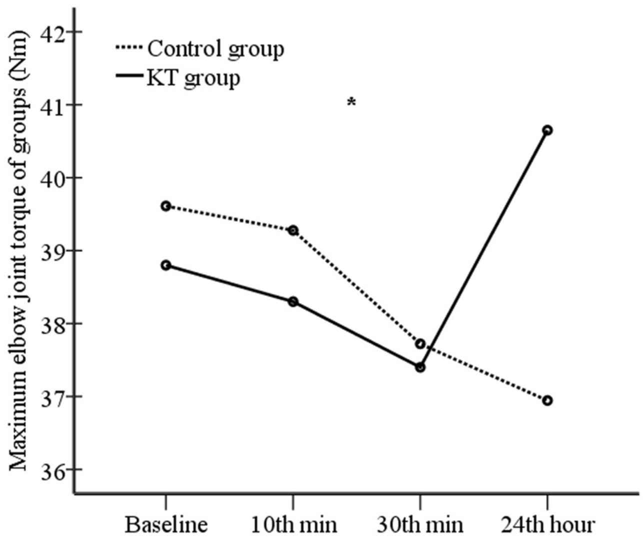

Figure 5. Group × time interactions of maximum elbow joint torque. *differences between groups (KT vs. control) with $p < 0.05$.

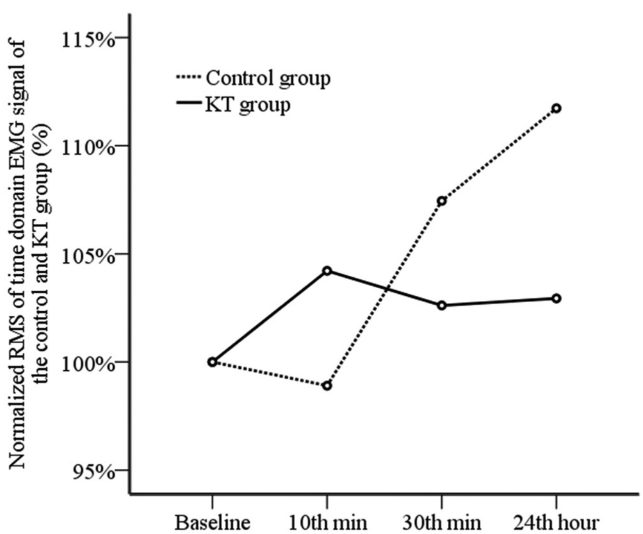

Figure 6. Group × time interactions of normalized RMS of time-domain EMG signals.

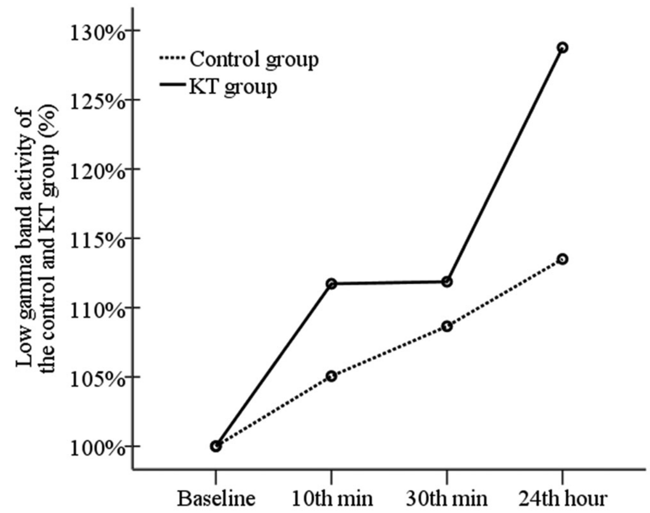

Figure 7. Group × time interactions low-gamma band activity.

significant group × time interaction effect was not found between the groups for four assessment sessions ($F(3,108) = 2.642$, $p = 0.089$, $\eta p2 = 0.058$) (Figure 6). Additionally, there was no statistically significant group × time interaction effect on low-gamma band activity ($F(3,108) = 0.869$, $p = 0.459$, $\eta p2 = 0.024$) (Figure 7).

4. Discussion

We aimed to determine the effect of KT on joint torque and muscle activity. To achieve this goal, elbow joint torque and biceps brachii EMG activity were measured during MVIC in four consecutive assessments at baseline, after 10 min, 30 min, and 24 h. EMG signals were analysed in time (RMS) and frequency (low-gamma band activity) domains. The assessment of low-gamma band activity is a crucial aspect of this study because differences in these parameters among four assessment sessions or between the KT and control groups can be attributed to proof of the somatosensorial effect of KT via mechanoreceptors (Brown 2000; Pereira et al. 2012). While all the parameters were found altered among four assessment sessions, except EMG activity in the KT group, no differences were found for the control group. The elbow joint torque was found different, but time-domain EMG activity and normalized low gamma band activity were not statistically significant between the groups.

The question of whether KT application can improve muscle strength has been a topic of interest and debate in the literature (Csapo and Alegre 2015). Although our findings comply with previous studies in which the effectiveness of KT was shown on joint torque, these studies have only focussed on the acute effect of KT (Fratocchi et al. 2013; Yeung and Yeung 2016; Doğan et al. 2019). In our study, the joint torque declined from baseline to 10th- and 30th-min assessment sessions however, the KT group showed an increment and reached nearly baseline value after the 24th hour while the control group persisted to reduction. We found a group × time interaction for joint torque values however, any difference between baseline and other joint torque values was not determined in *post hoc* analysis in both groups as in previous studies (Gomez-Soriano et al. 2014; Lins et al. 2016; Magalhaes et al. 2016; Dos Santos Gloria et al. 2017; Limmer et al. 2020). Only joint torque in the 24th hour was found significantly greater than in the 30th min in the KT group. In our study, despite the subjects did not perform a fatigue protocol, the incrementally decreased joint torque values and alteration in the 24th hour in only the KT group may be interpreted as a recovery effect of KT on muscles after 24 h (Kirmizigil et al. 2020; Merino-Marban et al. 2021).

In the studies that used EMG to determine the effect of KT, EMG signals were recorded during either an active muscle contraction or reflexive muscle action (Słupik et al. 2007; Dos Santos Gloria et al. 2017; Chen YS et al. 2020). Studies are almost in agreement that KT does not affect EMG activity immediately after KT application (de Almeida Lins et al. 2013; Yeung and Yeung 2016; de Freitas et al. 2018; Chen et al. 2020). Nevertheless, a recent study by Watcharakhueankhan et al. (2022) reported an alteration in

EMG activity of hip muscles during running. The delayed effect of KT on muscle activity among healthy adults was controversial. Słupik et al. (2007) found that KT increased the quadriceps muscle activity 24 h after the taping and that effect could be maintained 48 h after the tape was removed. Contrary, Dos Santos Gloria et al. (2017) did not present any difference in rectus femoris muscle EMG activity among baseline, 30th minutes, and 24th-hour evaluation sessions. Similarly, we also examined the EMG activity at baseline, 10th minutes, 30th minutes, and 24th hour but, no significant alteration was found for intra- or inter-group analysis. Studies assessed H-reflex or stretch reflex under taping conditions using EMG to explain the motor influence of KT via skin (Yeung and Yeung 2016; Chen et al. 2020; Chen et al. 2021). Yeung and Yeung (2016) did not determine differences in patellar tendon stretch reflex response among facilitative, inhibitory KT, and placebo taping conditions. Some studies examined H-reflex to determine the proprioceptive effect of KT. Magalhaes et al. (2020) showed no differences in H-reflex between non-tape, facilitation, and inhibition taping conditions after 48 h of taping. Controversially, Bagheri et al. (2018) control group, with only anaesthetic application, only KT application, and only sham taping, and application with KT and anaesthetic applications. H-reflex parameters were measured higher under KT than in the other conditions. However, the tension of KT was not found as a clear factor in H-reflex (Chen et al. 2020). It was speculated that the cutaneous mechanoreceptors may not be a primary factor to regulate H-reflex modulation (Chen et al. 2021). We assessed low-gamma band activity through EMG signals that exhibits a close relationship with the cortical descending command to muscles originated by somatosensory input (Neto et al. 2012; Pereira et al. 2012). Low-gamma band activity exhibited a significant enhancement in the KT group; the *post hoc* analysis revealed that low gamma band activity at the 24th hour was greater than the others. However, any difference was not determined between the KT and control groups.

There were some limitations in our study. First, we did not measure the EMG signals from other elbow flexor muscles which may probably affect elbow joint torque. Future research could evaluate synergistic muscles responsible for elbow flexion movement. Second, our results from healthy adults may not be generalized to people with musculoskeletal problems. According to the results of our study, KT may use to prevent muscle weakness or support muscle strength both during sports activities and during exercises for rehabilitation in musculoskeletal and/or neuromuscular dysfunctions. A slight increase in strength following 24 h of application of KT could be helpful. Additionally, it was considered that sensory input of KT altered efferent pathways and gradually increased 24 h after KT. Further studies may investigate the effect of KT techniques on low-gamma band activity in people with neurological and musculoskeletal diseases.

5. Conclusion

We concluded that KT may influence elbow joint torque in 24 h. Especially, the joint torque could be increased at the 24th hour, but it cannot be interpreted as a muscle strength enhancement compared with the baseline. Even if KT could not affect muscle activity in the time- domain, low-gamma band activity which is closely related to somatosensorial input, may reach the highest magnitude 24 h after KT. Consequently, KT may be applied at least 24 h before for supporting muscle and benefit from sensorial effects in clinics

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