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Kinesiology Taping does not Modify Electromyographic Activity or Muscle Flexibility of Quadriceps Femoris Muscle: A Randomized, Placebo-Controlled Pilot Study in Healthy Volleyball Players

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Data Interpretation D
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Background: Kinesiology taping (KT) is a popular method of supporting professional athletes during sports activities, traumatic injury prevention, and physiotherapeutic procedures after a wide range of musculoskeletal injuries. The effectiveness of KT in muscle strength and motor units recruitment is still uncertain. The objective of this study was to assess the effect of KT on surface electromyographic (sEMG) activity and muscle flexibility of the rectus femoris (RF), vastus lateralis (VL), and vastus medialis (VM) muscles in healthy volleyball players.

Material/Methods: Twenty-two healthy volleyball players (8 men and 14 women) were included in the study and randomly assigned to 2 comparative groups: "kinesiology taping" (KT; n=12; age: 22.30±1.88 years; BMI: 22.19±4.00 kg/m^2) in which KT application over the RF muscle was used, and "placebo taping" (PT; n=10; age: 21.50±2.07 years; BMI: 22.74±2.67 kg/m^2) in which adhesive nonelastic tape over the same muscle was used. All subjects were analyzed for resting sEMG activity of the VL and VM muscles, resting and functional sEMG activity of RF muscle, and muscle flexibility of RF muscle.

Results: No significant differences in muscle flexibility of the RF muscle and sEMG activity of the RF, VL, and VM muscles were registered before and after interventions in both groups, and between the KT and PT groups ($p>0.05$).

Conclusions: The results show that application of the KT to the RF muscle is not useful to improve sEMG activity.

MeSH Keywords: **Electromyography • Kinesiology, Applied • Quadriceps Muscle**

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Background

Kinesiology taping (KT) is a popular method of supporting professional athletes during sports activities. It is also part of both traumatic injury prevention and physiotherapeutic procedures after a wide range of musculoskeletal injuries [1–3].

KT is characterized by special parameters similar to the physical properties of human skin, particularly weight and thickness, with extensibility of 130–140% of its original length [4]. The supportive mechanisms of KT are explained by the effect of controlled skin elevation, which enhances trophic conditions of muscles by improving lymph and blood microcirculation [5].

General clinical applications of KT include treating a wide range of musculoskeletal pain syndromes of the spine [4,6–8], neurological diseases [9,10] and disorders of the extremities [11–13]. However, some recent studies suggest that the therapeutic effectiveness of KT is unclear and insufficient [14–17]. There are a few reliable, systematic reviews that show a small beneficial effect to support the use of KT in many musculoskeletal disorders [18–21]. An important issue that has been raised is the poor quality and misleading content of internet-based information discussing KT [22].

It is believed that muscle strength and flexibility, which provide joint stability, are two of the key indicators of physical performance in highly-trained adolescent athletes [23–25]. Witvrouw et al. [26] proved that preseason hamstring and quadriceps muscle flexibility testing can identify athletes who are at risk of muscle injuries. KT techniques in sports medicine aim to increase distensibility and flexibility conditions of tendons and muscles, which could be a positive factor in improving physical performance and reducing injuries. Also, KT could be a useful method to improve the dynamic balance of athletes with functional ankle instability [27].

The fact remains that KT applications are progressively being used among athletes, especially in the form of supportive techniques. Nevertheless, the effectiveness of KT, as determined in clinical and research areas, still leaves much to be desired. Moreover, there are some controversial findings that concern the use of KT to improve muscle performance [28–30], and which confirm that the effectiveness of KT in muscle strength and motor units recruitment is still uncertain [31–33].

The purpose of this study was to evaluate, by means of the Duncan-Ely test (DET) and sEMG examination, the effectiveness of KT application compared with the application of placebo taping (PT) on the performance of the quadriceps femoris (QF) muscle in healthy volleyball players. The primary study endpoints were the resting sEMG activity of the vastus lateralis (VL) and vastus medialis (VM) muscles and the resting and functional sEMG activity of the rectus femoris (RF) muscle before and after interventions in the KT and PT groups. The secondary study endpoint was the analysis of the changes in the RF muscle flexibility shown in the DET before and after appropriate tape application in the KT and PT groups. It was hypothesized that KT application would improve muscle flexibility in the DET and cause increased muscle activity in sEMG between the initial and final assessment and when compared to the PT group.

Material and Methods

Subjects

Fifty volleyball players in the Academic Sport Association were enrolled in the research and submitted to the qualification procedures. Exclusion criteria were: any chronic disease (n=1), musculoskeletal disorders (n=4), lower limb injuries (n=4), pharmacological treatment (n=3), recent surgical interventions (n=1), lack of voluntary consent (n=3), and confirmed knowledge of the rules of KT application (n=12, excluded to avoid the possible situation of recognition of placebo intervention). Inclusion criteria were: lack of chronic diseases, lack of musculoskeletal disorders, unawareness of the rules of KT application, and agreement of the subject. Finally, 22 healthy volleyball players (8 men and 14 women), mean age of 22.0±2.00 years and body mass index (BMI) of 22.44±3.39 kg/m^2, took part in the study.

All subjects were randomly assigned to one of two comparative groups: "kinesiology taping" included 4 men and 8 women (age: 22.30±1.88 years; BMI: 22.19±4.00 kg/m^2) and "placebo taping" included 4 men and 6 women (age: 21.50±2.07 years; BMI: 22.74±2.67 kg/m^2). We performed a two-stage simple randomization using computer-generated random numbers hidden in sequentially numbered envelopes and then selected by subjects. The first stage of the randomization was performed by the researcher, who allocated the subjects into the study, marking one of two cards with "W" for the KT group or with "X" for the placebo control group (randomization 1). The second stage of the randomization was performed by the same researcher in the same way and designated the side of the RF muscle that would receive intervention ("Y" for the left and "Z" for the right RF muscle, randomization 2) (Figure 1). Both studied groups were homogenous with regard to all subject characteristics (p>0.05). Figure 2 illustrates a flow chart of study subjects through the experiment stages.

This study followed a prospective, single-blind, placebo controlled, randomized design. Before inclusion, informed consent in accordance with institutional ethics standards of the Ethics Committee on Human Experimentation was obtained from each subject (no. KB/01/08/2013). The trial was registered

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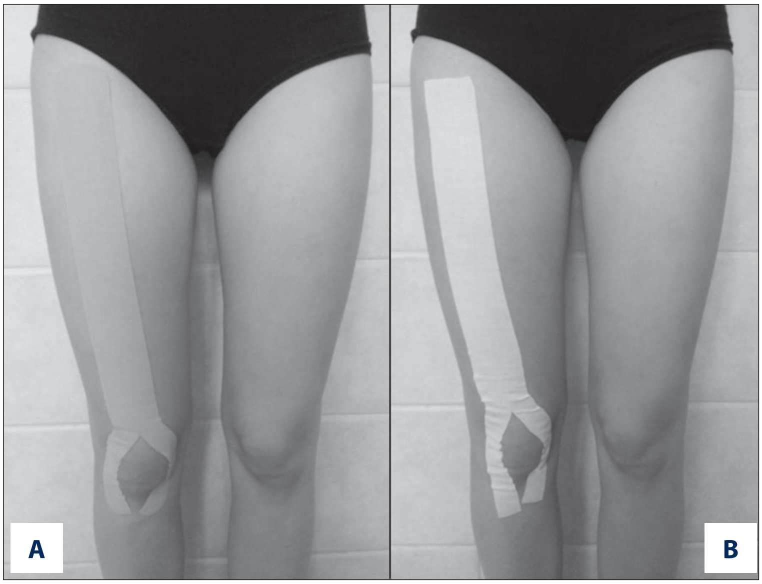

Figure 1. Kinesiology taping application in the KT group (**A**) and placebo adhesive tape application in the PT group (**B**) over the RF muscle.

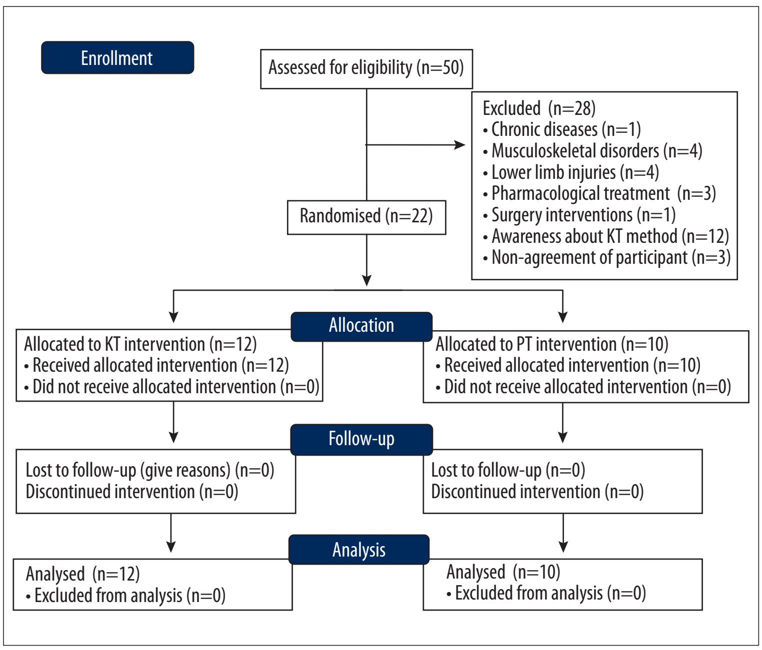

Figure 2. Flow chart of all study subjects through the study.

in the Australian and New Zealand Clinical Trials Registry (no. ACTRN12613001272785).

Procedures

Subjects were asked not to perform any physical activity involving their lower limbs during the 24 h preceding the study procedure. At the beginning, all subjects were placed for 10 min in a comfortable and safe supine position, aimed at postural adaptation and relaxation. Immediately after, subjects underwent the initial evaluation of resting sEMG activity of VL and VM muscles, resting and functional sEMG activity of RF muscle, and RF muscle flexibility level. Next, all subjects were taped according to their random allocation to either the KT or PT group. Before application, the skin was shaved, cleaned with alcohol, and dried. Both applications were performed by the same researcher, who was a certified KT physiotherapist.

For subjects in the KT group, the Kinesiologic Tape (Nitto Denko K-Active® Tape, Nitto Denko Tape Materials Corporation Ltd., Osaka, Japan) was placed over the RF muscle in a "Y" shape to increase muscle strength (facilitation technique). The subjects were in a supine position, with their knee joint passively flexed out of the bed over 90° until the end range of motion was reached to achieve maximal stretch of the RF muscle fibres. The KT was applied longitudinally in descending direction

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from the RF origin (anterior inferior iliac spine) to its insertion (tibial tuberosity). The base of the KT was applied from 2 to 3 cm below the RF origin without tension. The middle part of the KT was applied between the origin and the patella without tension but while the RF muscle was passively stretching at the flexed knee joint position. Finally, 2 tails were circled around the patella and placed on the skin without tension while the leg was in a 90° flexed knee joint position [5,34]. In the KT group, intervention involved the left RF (n=7) and the right RF (n=5), and application was continued for 24 h.

For subjects in the PT group, an adhesive, non-elastic tape with no therapeutic influence (adhesive tape Polovis Plus, 3M Poland Company Ltd., Warsaw, Poland) was used over the same muscle. Subjects were in a supine position with the knee joint position neutrally flexed at 30°. All parts of the PT were applied longitudinally in descending direction in an analogous "Y" shape. In the PT group, intervention involved the left RF (n=5) and the right RF (n=5), and application was continued for 24 h (Figure 1). In both groups, immediately after 24 h, KT or PT applications were removed and athletes underwent a final assessment, without tapes, identical to the initial assessment. All procedures were conducted in the same conditions (daytime, ambient temperature, research room).

Electromyographic resting activity of the VL and VM

The electromyographic signal was registered by a dual-channel sEMG NeuroTrac ETS® device integrated with computer software for digital analysis and report creation (Verity Medical Ltd., United Kingdom). This device has an amplitude range of 0.20–2000 µV root mean square (RMS) continuous in the frequency band of 2–100 Hz and a pulse width from 50 to 450 µS for recording signals generated by muscles. Device sensitivity is established at the level of 0.10 µV (4% accuracy; readings ±0.30 mV at 200 Hz), with a selectable bandpass filter (3 db bandwidth) and a 50 Hz notch filter (33 dbs; 0.10% accuracy). Mean values of bioelectrical activity of muscles were given according to the RMS algorithm [35].

Before electrodes application, the skin was prepared with 70% alcohol to reduce skin impedance. Bipolar, self-adhesive, round 30-mm electrodes with hypoallergenic gel were used. All electrodes on the VL, VM, and RF muscles were placed over the center part of the muscle bellies according to the SENIAM (Surface Electromyography for the Non-Invasive Assessment of Muscles) and ISEK (International Society of Electrophysiology and Kinesiology) recommendations [36,37]. The monopolar, self-adhesive reference electrode was placed above the active electrodes on the anterior superior iliac spine on the same side. It is important to emphasize that the sEMG electrodes were not removed before and after application of the KT or PT and were placed at stable locations during the initial and final sEMG measurements, in accordance with the sEMG recommended practices. The placement of sEMG electrodes on the VL, VM, and RF muscles is shown in Figure 3.

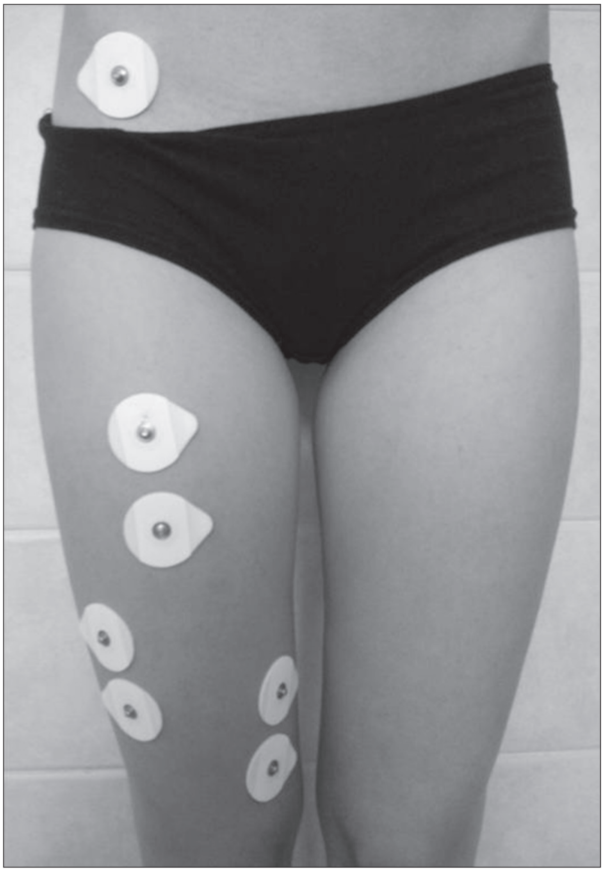

Figure 3. The surface electromyography electrodes placement over the VL, VM, and RF muscles' bellies, and reference electrode on the anterior superior iliac spine.

Resting sEMG activities of the VL and VM muscles were registered in static conditions and lasted 50 s. Subjects were placed in a comfortable and safe supine position with 30° hip joint flexion and 50° knee joint flexion to exclude external artifacts and stress muscle tension and to ensure optimal relaxation of the musculoskeletal system.

Electromyographic resting and functional activity of the RF

The same protocol for recording resting sEMG activity of the RF muscle was repeated. The sequence of the sEMG recording protocol was not done, for convenience. First, resting measures of the VL, VM, and RF muscles were assessed, and second, functional registration of the RF muscle was recorded. The aim of this order was to ensure optimal preparation before resistance trials of the RF muscle and to avoid fatigue of muscles, which could influence results during passive sEMG registrations.

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Figure 4. Participants' position during a functional test using the system of columns destined to resistance exercises.

Subsequently, functional sEMG activity of the RF muscle was measured during an exercise test by using a system of columns destined for resistance exercises. The surface electrode topography was analogous to the resting sEMG measures. During this test, all subjects were placed in a sitting position with the trunk, pelvis, and opposite thigh stabilized. Both knee joints were initially flexed at 90°. The test was performed over the whole range of motion in a synchronized rhythm of 5 s total knee joint extension, with a 5 s rest between each trial. The resistance that was applied during the test was set individually at a level of 10% of body weight of each subject. Following the dynamic test, the subject completed 5 trials of each movement with resistance.

Assessment of the level of RF flexibility

Flexibility of the RF muscle was evaluated using the DET, which has been commonly accepted as a clinical tool [38,39]. Subjects were placed in relaxed prone position, and they were asked not to actively participate. Passive flexion of the knee joint was performed until the first elastic resistance was noticed. The distance between the calcaneal tuberosity and the buttocks was than measured with a measuring tape marked in centimeters. For more accurate and repeatable conditions based on constant anatomical landmarks, the special point was located in the buttocks region. It was assigned every time in the same way by the crosscut of 2 lines, where the first line (the horizontal line) connected the left and right greater trochanters of a femur and the second line (the vertical line) was perpendicular to the first one, downwards from the posterior superior iliac spine on the tested side (Figure 4).

Statistical analysis

STATISTICA 10 software by StatSoft Company was used for statistical data analysis. Arithmetic means, standard deviations, and ranges of variation were calculated for measurable variables. A non-parametric Wilcoxon sequence pair test for dependent variables was used for comparison of results before and after the intervention. Statistical significance was set at $p<0.05$. A non-parametric Mann-Whitney U test for independent variables ($p=0.05$) or a chi^2 test ($p=0.05$) was used for comparison between groups.

Results

Electromyographic resting activity of the VL and VM

There were no significant differences in resting sEMG activity between initial and final evaluations for the VL and VM muscles in the KT group or in the PT group ($p>0.05$). Mean values of resting sEMG activity for the VL muscle in the KT group increased by 13.00%, while in the PT group they decreased by 7.10%. Mean values of resting sEMG activity for the VM muscle increased in the KT and PT groups by 6.10% and 7.10%, respectively. Additionally, no significant differences between the groups were present ($p>0.05$) (Table 1).

Electromyographic resting and functional activity of the RF

There were no significant differences in resting and functional sEMG activity between initial and final observations for the RF muscle in either of the study groups ($p>0.05$). Mean values of resting sEMG activity for the RF muscle decreased in both studied groups, by 7.10% in the KT group and 21.10% in the PT group. Mean values of functional sEMG activity for the RF muscle decreased in the KT and PT groups, by 6.00% and 1.20%, respectively. Furthermore, no significant differences between the groups were registered ($p>0.05$) (Table 1).

Flexibility level of RF

Flexibility level of the RF muscle in the DET showed non-significant differences between initial and final assessments in either of the study groups ($p>0.05$). Mean values of the distance decreased by 1.00% in the KT group and by 2.50% in the PT group. Moreover, no significant differences between the groups were registered ($p>0.05$) (Table 1).

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Table 1. Means and standard deviations of the variables in both groups.

Variables (n=22)	PT (n=10) Mean ±SD		KT (n=12) Mean ±SD		p*	p**	p***
	Pre	Post	Pre	Post			
VL RMS rest. (µV)	1.22±0.78	1.14±0.59	0.99±0.41	1.17±0.60	0.72	0.33	0.45
VM RMS rest. (µV)	0.94±0.26	1.38±0.57	0.98±0.56	1.03±0.40	0.18	0.72	0.18
RF RMS rest. (µV)	1.39±0.47	1.14±0.50	1.38±0.83	1.25±0.56	0.31	0.81	0.79
RF RMS funct. (µV)	90.97±44.10	89.94±34.15	102.41±24.05	96.31±31.05	0.39	0.28	0.87
RF flex. (cm)	16.00±3.06	15.55±3.05	14.04±2.55	13.92±2.53	0.61	0.72	0.81

Resting sEMG activity of the VL (VL sEMG rest.), resting sEMG activity of the VM (VM sEMG rest.), resting sEMG activity of the RF (RF sEMG rest.), functional sEMG activity of the RF (RF sEMG funct.), RF flexibility in DET test (RF DET flex.); pre and post interventions in kinesiology taping (KT) and placebo taping (PT) group. Comparing pre and post in PT (*p**), comparing pre and post in KT (*p***), difference between PT and KT (*p****).

Discussion

In light of the scarcity of research on the effects of facilitative techniques of KT on muscular performance in athletes, especially motor units recruitment and flexibility of QF muscle, the present pilot study provides important initial evidence. The biomechanical parameters could be determined by using objective measurement tools and functional tests (e.g., sEMG and the DET), whose clinical and research utility have been widely confirmed [38–42].

The results of this study suggest that when KT is applied over the RF muscle in healthy volleyball players, it does not improve muscle bioelectrical activity in sEMG examination or muscle flexibility in the DET. In our case, KT was somewhat insufficient to modify the recruitment of the motor units of the QF muscle or to create any significant changes in the length of its fibers.

This study obtained a result similar to those obtained by Lins et al. [43], who showed that the application of KT to the RF, VL, and VM muscles does not lead to significant changes during dynamic tasks in lower limb function, postural balance, knee extensor peak torque, or sEMG neuromuscular activity. In our study, the VM and VL were used as experimental muscles and were not covered with tape, but we expected that KT applied directly over the RF muscle would change the resting sEMG activity of adjacent muscles that compose the coherent functional group of knee extensors. It showed some weakness of KT application only for the RF muscle to receive positive effect, as well as in the VM and VL, especially that the most practical KT applications for the QF muscle consist of covering the RF muscle alone.

However, no significant differences were demonstrated in the resting and functional sEMG activity of the RF muscle or in the resting sEMG activity of the VL and VM muscles. The most distinct change, in the direction of increasing sEMG activity in the KT group, was determined for the VL at 0.18 µV (15.38%). Notwithstanding, in the PT group, there was noticeably higher activity for the VM at 0.44 µV (31.88%). The other results of muscle activity showed some inverse tendencies: decreased sEMG changes in both the KT and PT groups. This situation could show some weakness of KT application for the RF muscle.

In our study, there were no significant changes in assessed parameters after KT was applied for 24 h. It is probable that longer periods of tape application would be more likely to register demonstrable changes in muscle sEMG activity and flexibility. Nevertheless, Slupik et al. [44] observed an increase of sEMG activity of the VM muscle within 24 h of KT application, and the effect continued for the following 48 h, which suggests a short-term supportive effect of KT.

There is no reliable study that explains the influence of KT application on muscle flexibility level. In the present study, it was observed that KT applied over the RF muscle did not significantly modify muscle flexibility in DET. It is remarkable that we registered some tendency towards a limited increase of the RF flexibility. The mean pre- and post-intervention difference in the KT group was determined at 1.2 cm (8.60%), compared to 0.5 cm (3.10%) in the PT group. This could be explained by the hypothesis of controlled skin elevation, which could lead to a reduction of interstitial resistance and increased mobility of muscle fibers. Nevertheless, these positive results were also observed in the PT group and would appear to be due to measurement error. A similar result was demonstrated by Gómez-Soriano et al. [45], who showed no significant effect of KT on healthy muscle tone, extensibility, or strength of the gastrocnemius muscle. Ozmen et al. reported that KT application of the QF muscle performed immediately before squat exercise has no

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effect on muscle pain and short sprint performance but maintained flexibility at 2 days of recovery compared to baseline [46].

Finally, this study does not confirm our hypothesis that KT application would improve muscle sEMG activity and flexibility as part of a support procedure in healthy volleyball players. This could be because the facilitative effects of KT applied over healthy muscles may not be effective at a demonstrable level. It would be justified to prepare a similar study in clinical conditions with patients suffering from deficient neuromuscular problems or muscle atrophy as a consequence of immobilization. In these subjects, muscle improvement after KT application might be more noticeable.

Study limitations

Our prospective, single-blind, placebo controlled, randomized pilot trial seems to be a strong research design. However, there are limitations to this study, such as the small number of subjects and lack of the follow-up results. Another potential limitation of our study is the lack of a parameterized control of the movement speed and subject effort during the dynamic sEMG test. Also, we did not use a more sensitive multichannel sEMG and we applied the KT or PT for only 24 h. Longer periods of tape application seem to be more appropriate for registering stronger changes in muscle sEMG activity and flexibility. The next limitation includes the fact that a little more tension (25–50%) during KT tapes application should be considered to activate facilitation of elastic fibres. We acknowledge the need to continue this research in larger numbers of subjects; therefore, according to statistical estimation, we would like to clarify that the population over 35–40 in each group is needed for further analysis of normal distribution and to use the parametric tests. At this moment (12 individuals in KT group and 10 in PT group) was estimated that a power of test is 0.84 compared to parametric statistics conducted on a large population with Gauss decay (30 subjects in 1 group). At the same time, we emphasize the pilot character of this study, which describes the insufficient utility of KT for improving muscles performance in adolescent athletes.

Conclusions

There is a lack of reliable studies discussing the positive results of KT applications on improving muscle activity parameters. Our findings in young healthy volleyball players indicate no significant differences in sEMG activity of the RF, VL, or VM muscles and no positive changes in RF muscle flexibility compared to PT intervention. In future research, a little more tension (25–50%) during KT tapes application, as well as longer periods of KT tape application seem to be more appropriate for showing stronger changes in muscle sEMG activity and flexibility.

Conflict of interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

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