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Effects of Kinesio® Tape in low back muscle fatigue: Randomized, controlled, doubled-blinded clinical trial on healthy subjects

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Abstract.
BACKGROUND: Muscle fatigue of the trunk extensor musculature plays a considerable role in chronic low back pain (LBP). The underlying physiology of fatigue is complex and not fully understood. The Kinesio® Taping (KT) supports damaged structures while allowing mobility and at the same time may influence some of the mechanisms associated with muscle fatigue such as blood flow and proprioception.
OBJECTIVE: The aim of this study is to determine the influence of KT on the resistance to fatigue of the lumbar extensor musculature in a sample of young healthy subjects.
METHODS: A randomized, controlled, doubled-blinded clinical trial was conducted. Ninety nine healthy subjects were randomized in to the three arms of the study Kinesio® Tape (KT), placebo (P) and control (C). Directly after application of KT we measured lumbar extensor musculature endurance with the Biering-Sorensen test. Subjects and researchers were blinded to the intervention. Time achieved (seconds) was compared between groups with one-way ANOVA with confidence intervals of 95%.
RESULTS: There were significant differences between the time achieved in the KT group versus the control group ($p < 0.05$). The placebo group performed better than the control group but worse than the KT group, these were not significant in either case.
CONCLUSIONS: KT appears to improve the time to failure of the extensor muscle of the trunk obtained using the Biering-Sorensen test. These findings suggest that KT influences processes that lead to muscle fatigue and that KT could be effective in the management of LBP.

Keywords: Muscle fatigue, kinesio tape, isometric contraction, blood circulation, proprioception

1. Introduction

Low back pain (LBP) is the most common musculoskeletal reason for referral to a medical professional [1]. It has been estimated that between 60–80% of the population will suffer from at least one episode of LBP during their lifespan [2]. Management of and the resulting days of work lost make LBP the most costly musculoskeletal disease [1]. Approximately 5–10% of LBP progresses to chronic LBP, which generates between 60–90% of the costs related to this pathology [3,4].

It has been shown that delayed muscle activation, decreased ratio between lumbar flexors and extensors, suboptimal lumbopelvic control or resistance to fatigue

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of the lumbar extensor muscles are factors responsible for the development of chronic low back pain [5–7]. The relationship between paravertebral muscle fatigue and back pain has been widely studied. Several authors have shown specific patterns of muscle fatigue in the paravertebral muscles of subjects with LBP undergoing isokinetic fatigue test and evaluated with electromyography [8–10]. Candotti et al. [10] observed that a lower lumbar muscle strength in subjects with low back pain compared to controls. Moreover, in their study 89.5% of the subjects with pathology could be classified based on findings from a fatigue test. It is therefore logical that being able to measure the endurance or the resistance to fatigue of the trunk extensor musculature and create appropriate management strategies is of high clinical importance.

This Biering-Sorensen test, first described by Hansen in 1964 [11] and later popularized by Biering-Sorensen [12], is a validated [13–18] and reproducible [18,19] test designed to measure the resistance of the lumbar extensor musculature to fatigue. This test is sensitive enough to be able to differentiate healthy people from those people who have or have suffered from LBP and can also predict future episode of LBP [20]. Fatigue affects physical performance. It builds up progressively and gradually from the beginning of effort, with perceived difficulty in maintaining a constant effort increasing as duration of contraction progresses. All definitions of fatigue recognize two essential characteristics; the reduced ability to generate maximum muscular strength and decreased effort capacity or performance [21–24]. The degree of fatigue can be defined from the measurement of objective variables such as the strength and power [21]. Additionally, fatigue which can be perceived by the subject is a combination of many neurophysiological factors including performance expectation or prediction, mood and motivation and characteristics of the exercise. As well as neuropsychological factors including body temperature, buildup of metabolites, acid-base balance, oxygen delivery to muscle fibers or proprioceptive information [23].

The Kinesio® Taping (KT) method was developed by Dr. Kenzo Kase and its use has recently grown in popularity. KT is an adhesive tape, applied in varying states of stretch to the skin, specially designed to replicate the physical properties and characteristics of human skin. It has approximately the same elasticity as skin (it can be stretched between 40–60% of its original length), weight and thickness and is breathable [25–27] and contains neither medical substances nor latex [25,26,28]. One of its main differences compared to traditional tapes is that it activates the region over which it is applied instead of restricting movement resulting in proprioceptive and nociceptive stimulation [29–33]. Its effect is based on four main pillars [34]: it provides support for muscles [27,33,35–42], it corrects joint malalignment [29–33,36,39,43–46], activates the endogenous analgesic system [31–33, 37] and eliminates congestion fluids [27,37,45,47–50]. Several studies have demonstrated a significant beneficial effect of KT when compared to various placebo applications [36,51–53] with only one study reporting an adverse effect from its application [46].

The contraction during the Biering-Sorensen test has been measured to be equivalent to approximately 45–55% of maximal voluntary contraction (MVC) [9,54–56]. It has been demonstrated that during an isometric contraction, of 50% tension or more, intramuscular pressure increases [24,57,58] causing constriction of blood capillaries resulting in accelerated muscle fatigue. This also decreases the removal of and causes accumulation of metabolites, which acidifies the interstitial fluid and stimulates the release of chemical agents such as bradykinin, which in turn stimulates nociceptors [23,24]. KT has been proposed to positively affect all these factors and it is therefore plausible to hypothesize that KT could improve the resistance to fatigue of the trunk extensor musculature.

The aim of this study was to determine the influence of the KT application on the resistance to fatigue of the paravertebral muscles in a sample of healthy young subjects measured by Biering-Sorensen test.

2. Methods

2.1. Study design

The design for this study is a randomized, controlled, doubled-blinded clinical trial.

2.2. Subjects

Subjects for this study were students recruited using a non-probability consecutive sampling method from the Faculty of Medicine, University San Pablo CEU. Subjects were included in the clinical trial if they were aged 18 years or older and they were willing to voluntarily participate in the study [59]. Subjects were excluded if they had history of LBP in the last 6 months of duration 1 week or more and/or had required medi-

Fig. 1. Kinesio Taping Modalities. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/BMR-130437)

cal attention for and/or had been off sick due to LBP [8, 13,18,59,60], undergone back surgery [8,15,18,60,61], suffered from intervertebral disc herniation or protrusions [8,13,15,16,18,61], or severe spinal scoliosis [8, 61]. Additionally subject were excluded if they had been diagnosed with cardiovascular or neurological disease or, had pain from a disease presenting infection, tumor or injury to an anatomical structure stressed during the test process [16,18,61]. Following signing of the informed consent form background information and anthropometric measurements were taken [62]. Subjects were then randomly allocated into one of the three treatment arms, Kinesio® Tape (KT), placebo (P) or control (C) group using a computerized system (Research Randomizer) [63]. This was performed in a closed room and only the physiotherapist applying the KT, who was not involved in the data collection, was aware of treatment allocation.

2.3. Taping techniques

In the closed room where randomization was completed, an expert in the application of Kinesio® Taping applied the appropriate taping technique to the subject. After application the subject covered the taping with a loose shirt in order to blind the other researchers to the intervention. Further, subjects were blinded from the treatment as they were unable to see the application or had prior knowledge of the technique on which to base an assumption of treatment allocation. When necessary, prior to application of the tape, the participants' skin was prepared (shaving, degreasing or washing in each case).

The treatment taping (KT) consisted of two 5 cm strips of beige Kinesio® Tex Gold™ (Albuquerque, NM, USA) in the form of an "I" on either side of the lumbar spine, from the sacroiliac joint to the ipsilateral transverse process of T12. Length of the tape was measured first in comfortable standing. The first and last 2.5 to 5 cm of tape were applied with 0% stretch in standing while the rest of the tape was applied in a position of unforced maximum trunk flexion with a tension of between 10% and 15% corresponding to the tension of the material on its protective paper. Throughout application knees were maintained in full extension with feet together. Both strips were applied at the same time in order to minimize duration of stretch in the lower back musculature. The placebo (P) taping consisted of two 10 cm length strips of the same material, adhered transversely to the skin of the paravertebral muscles fibers and applied with the subject in the same position of maximum trunk flexion. Both strips were applied with a tension of 0%. One strip was placed at the level of the sacral promontories and the other at the level of the spinous process of T12. Participants in the control (C) group completed the test without any tape (Fig. 1).

2.4. Biering-Sorensen test

The Biering-Sorensen test is designed to measure the resistance of the lumbar extensor musculature to fatigue [11,12]. The test requires the participant to maintain a horizontal position while trunk and upper body are unsupported. As the muscles gradually fatigue and strength of the muscle contraction is no longer sufficient the trunk drops below the horizontal, stopping the test. This is a validated test, with intrarater and interrater coefficients ranging between 0.73 and 0.83 [13–18] and good reproducibility coefficients of 0.82 and 0.68 [18,19] respectively. Correct technique is essential to ensure the test is valid and measures appropriately and reliably the extensor musculatures' resistance to fatigue [59].

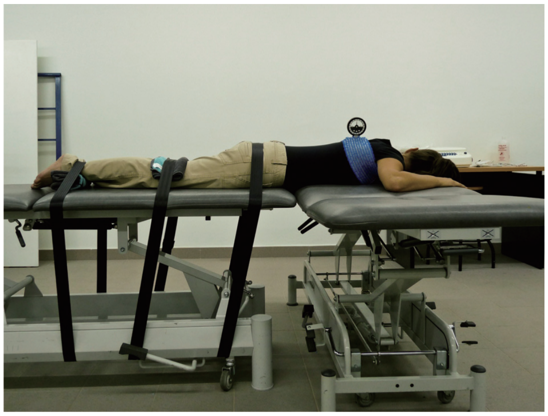

Fig. 2. Pre-test situation of the subject. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/BMR-130437)

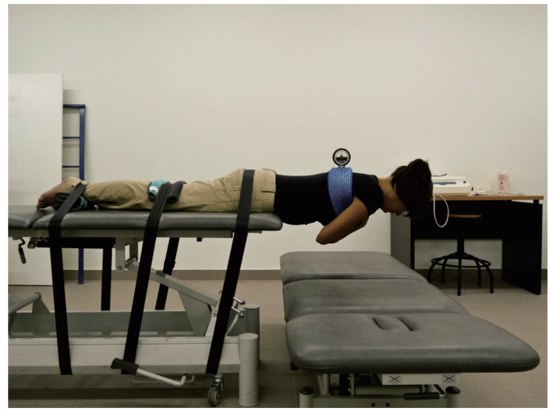

Fig. 3. Subject during the performing of the test. (Colours are visible in the online version of the article; http://dx.doi.org/10.3233/BMR-130437)

2.5. Data collection procedure

The test protocol was fully explained to the participant before initiation of the test. In particular it was emphasized that it is a maximal test during which maintaining the required position as long as possible is essential [14]. The test was performed immediately after the application of the KT. The participant was placed in the starting position for the test, prone on a plinth with the upper edge of the iliac crests aligned with the edge of the table. A second hydraulic table was transversely placed at the same height to the first one under the trunk and upper body, in order that the participants may be supported completely in prone position before initiation of the test. The lower limbs were fixed to the table in full extension, together, and with ankles in plantar flexion using three straps perpendicular to the midline. The first strap was located at the level of the greater trochanter, the second one at the level of the popliteal fossa and the last one at the level of the Achilles tendon insertion as close as possible to the malleoli [12,16,19,60] (Fig. 2). Each strap was independently tightened as hard as possible so that the subject obtained a feeling of total immobilization of the legs without undue discomfort [16]. A towel was placed between the strap and the popliteal fossa and between the table and feet, to ensure the comfort of the participant. An inclinometer (Isomed brand, model Bi-Level inclinometer. Portland, USA), fixed to the participant's inter-scapular region [16] by an elastic strap around the chest, was used to measure changes in flexion or extension of the subjects during the test [16,17, 64]. The Inclinometer was reset to 0 while the participant laid prone fully supported in the starting position with arms relaxed in external rotation, 90° shoulder abduction, forearms in pronation and 90° elbow flexion. Cervical spine was rotated laterally for comfort. It was presumed that in this position the participants' spine was in a neutral position.

On initiation of the test the second table was lowered and the subject was requested to place their arms across their chest and maintain a neutral spinal position. The chronometer was started as soon as arms were positioned across the chest and the participant was maintaining this position without assistance (Fig. 3). The researcher was positioned so that his line of vision was aligned with the axis of the inclinometer needle. In order to ensure the test was a true measure of resistance to fatigue the researcher gave constant verbal motivation to maintain neutral spinal alignment, or "0" on the inclinometer [15,54,65]. However at no point was either the researcher or participant aware of the amount of time that had passed [54], as this has been shown to be a factor directly influencing test results [8,12]. An oscillation of the inclinometer needle of 10° during the test was permitted, between 5° of extension and 5° of flexion [16]. The test ended when any part of the participant's upper limb touched the table or when they were unable to recover the test position even with verbal encouragement [12,16]. At this point the chronometer was stopped and the test finished. To ensure blinding of the researcher after completion each participant went back behind a screen before removing the tape.

2.6. Statistical analysis

All data were entered into SPSS version 18.0 for Windows. The results are shown as mean and standard deviation (M ± SD) with confidence intervals of 95%. Kolmogorov-Smirnov (KS) test was used to check whether parametric tests could be performed. Results between groups were compared by one-way ANOVA. Post-hoc analysis was conducted using the Games-Howell test. A p-value < 0.05 was considered as significant. Effect sizes were calculated using Cohen's d.

3. Results

In total 103 study subjects consented for the trial. Four participants meet at least one of the exclusion criteria and where immediately excluded from the study before randomization. Therefore, 99 subjects were randomly allocated into one of the three treatment arms (Fig. 4). Another 2 participants were excluded after randomization due to inappropriate testing technique. The rest of the sample (41 males and 56 females, 22.4 ± 4.2 years old, weight 67.2 ± 11.5 kg, height 170.3 ± 9.1 cm) completed the test successfully. There were no significant differences between the groups at baseline (Table 1) ($p > 0.05$). The three groups were normally distributed for the variables of age, height, weight and body mass index (BMI) according to the KS test and for the variable sex according to the Chi square test (Table 1). The times obtained in the Biering-Sorensen test in each intervention group were compared using the one-way ANOVA. A significant difference ($p = 0.029$, $F = 3.668$) was detected at intergroup level. In post-hoc analysis significant differences where observed between the times of the KT group versus the control group $p = 0.028$ (Table 2) demonstrating that subjects with correctly applied KT were able to maintain the test position on average 35.5 seconds (effect size 0.65 (95% CI 0.157 to 1.143)) longer than those without tape.

4. Discussion

The results of our study indicate that KT, when correctly applied over the extensor musculature of the trunk, can improve their resistance to fatigue. Those subjects with correctly applied KT over their extensor musculature could maintain the test position for a significantly longer duration than those without any taping. It is therefore plausible to deduce that KT influences some of the mechanisms associated with muscle fatigue and could therefore have a possible role in the management of LBP.

A possible theory to explain our results is that KT may increase blood flow intramuscularly. During the execution of an isometric contraction above 20% of the maximum voluntary contraction, blood flow decreases to 30–40 mm Hg within the intramuscular capillaries [58]. This leads to a decrease in oxygen supply and an accumulation of metabolites such as lactate and algogenic substances e.g. bradykinin [21–24]. During the performance of the Beiring-Sorensen test, an isometric contraction of 45–55% MVC, blood volume within the muscle decreases [54,58]. There is some evidence to suggest that KT can improve peripheral blood circulation. Following application of KT over muscles pectoralis major and gastrocnemius blood flow was improved [47,49]. It is assumed that the application of KT stimulates the autonomic nervous system leading to vasodilation of the blood vessels in the area under the tape thus improving blood circulation. It is interesting that results appear to be larger in those subjects with pathology than healthy subjects [47]. An improved blood, and therefore oxygen supply to the muscle, would improve the muscles resistance to fatigue.

Pain during the Biering-Sorensen test has been reported as a factor limiting performance of the test [16, 19,61]. It is excepted that as fatigue develops there is an increase in production of nociceptive pain stimulating algogenic substances such as bradykinin [23, 24]. It has also been hypothesized that Kinesio® Tape improves lymphatic drainage [27,34,35,66] and therefore it facilitates the removal of rising levels of lactate and bradykinin. Paoloni et al. [33] demonstrated that a similar taping technique as the one used in our study can reduce perceived pain (VAS) in patients with chronic low back pain. This effect of KT on pain has also been shown with other pathologies [31,41,52] and myofascial pain [37,43]. Although there are several theories as to the precise mechanisms that propitiate these, the exact pain reduction mechanisms are still unknown [33]. Currently the most accepted theory suggests that keratinocytes, which are found in the skin, may represent the primary transduction of mechanical non-neuronal stimuli. These mechanisms would activate cascade processes such as intracellular Ca^{2+} flows evoking a response from C-fibers or C-polymodal nociceptors [67,68]. Therefore, the stimulation caused by the KT on the skin would interfere with the transmission of mechanical and algogenic stimuli and decrease perception of pain. In addition, KT produces afferent stimuli, which can facilitate pain inhibition mechanisms through the pain-gate control theory [69]. Karatas et al. [50] found that surgeons who experi-

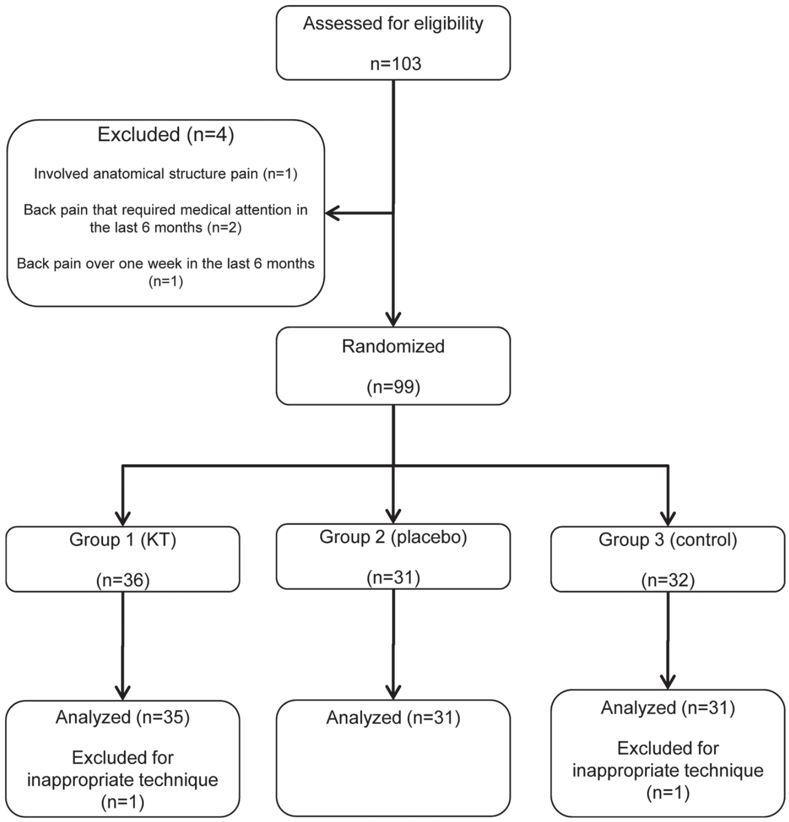

Fig. 4. Flow chart showing participant selection and randomization.

enced low back pain after performing surgery experienced less pain following application of KT to the lumbar spine region. During surgery the static isometric muscle activation, although smaller in size, is likely to experience fatigue similar to that experienced during the Biering-Sorensen test. However, in this clinical trial pain experienced during the test was not assessed, therefore it can only be hypothesized that a reduction the perceived pain could have been responsible for the significant improvement in the test times.

Fatigue can be influenced by proprioceptive stimuli but there remains conflicting information whether KT can act as a stimulus for physical function. There is evidence to suggest KT applied to the knee can improve EMG activation of the vastus medialis oblique muscle with an increased sensation of stability and decreased pain perception [29,32]. Additionally, awareness of ankle joint position was shown to improve with KT in healthy subjects. Subject with KT could actively reposition the joint into previously demonstrated positions more accurately and frequently than those without [70]. However, Halseth et al. [30] found no difference in ankle proprioception of 30 healthy subjects measured with KT, a placebo taping and control (no taping). It is thought that the main proprioceptors for positional awareness are located within the muscles and joints with the skin receptors accommodating quickly to stimuli. Our subjects performed the test immediately after KT application and therefore it is appropriate to assume that it still provided a proprioceptive stimulus in the skin at the level of the lumbar region. This possibly could have helped to improve the final time in the Biering-Sorensen test by giving better awareness to small changes in position and could explain the non-significant difference between the KT and placebo group results.

It is well excepted that abnormal lumbar muscle activity is related to pain in people with chronic low back pain [33,71]. It has been shown that KT can normalize muscle tone [33], cause an increase in strength of concentric muscle [36] and isometric contraction [37]. The increase in isometric force could be responsible

Table 1
Descriptive statistics by groups

	N	KT group 35	Placebo group 31	Control group 31
Sex	Male/female	12/23	11/20	19/12
	p-value	0,09	0,09	0,09
Age (years)	M ± SD	22,31 ± 4,83	22,58 ± 3,62	22,19 ± 4,87
	p-value	0,08	0,13	0,20
Height (cm)	M ± SD	169,87 ± 9,26	169,48 ± 9,61	171,83 ± 8,68
	p-value	0,93	0,33	0,58
Mass (kg)	M ± SD	64,83 ± 10,14	66,91 ± 10,43	70,45 ± 13,51
	p-value	0,69	0,78	0,62
BMI	M ± SD	22,44 ± 2,90	23,21 ± 2,38	23,74 ± 3,51
	p-value	0,48	0,68	0,32

M ± SD: mean ± standard deviation; BMI: body mass index.

Table 2
Results of the comparison between groups for time (seconds) variable in Biering-Sorensen Test. Effect sizes calculated by Cohen's d

Group	KT	Placebo	KT	Control	Placebo	Control
Mean time ± SD	203,15 ± 68,93	188,94 ± 46,67	203,15 ± 68,93	167,68 ± 36,38	188,94 ± 46,67	167,68 ± 36,38
Between-groups mean difference (95% CI)	14,21 (−20,28 to 48,70)		35,46 (3,25 to 67,68)		21,26 (−4,32 to 46,48)	
Between-groups effect sizes (95% CI)	0,247 (−0,235 to 0,729)		0,650 (0,157 to 1,143)		0,251 (0,002 to 1,018)	
p-value	0,59		0,03*		0,12	

$^*p < 0.05$.

for the results of this study, since during the execution of the test, the lumbar muscles work at an intensity of about 50% and the increase in force would facilitate the task. On the contrary, the results obtained by Fu et al. [28] found no significant differences in the facilitation nor in the inhibition of quadriceps and hamstrings muscle strength in healthy athletes. Fu et al. [28] concluded that, the mechanical stimulation on the skin is possibly not powerful enough to generate differences in the muscles of athletes without pathology. The lack of pathology was again presumed the reason for lack of effect from KT on the reflex response of the muscles biceps femoris [44] and gastrocnemius [46]. However, the tests used to measure the effect of the KT in these studies was difference from our study because we used an isometric contraction sustained until failure therefore possibly supporting more the hypothesis of the effect of tape on blood supply than muscle force directly.

The results of our study also indicate that correct application of KT is more beneficial than non-specific application (placebo) and non-specific application has more benefit than no application. Although neither were statistically significant they are in line with similar finding from previous research [36,51–53] supporting the accuracy of the findings from this study. Although this study had significantly more subjects than in previous studies it was calculated that a population size of $n = 253$ would have been needed to confirm a significant difference between correct and non-specific application and non-specific and no taping. Therefore further studies with a larger population sizes are needed to confirm the results.

Specificity of the Biering-Sorensen test is one limitation to this study. There is evidence to suggest that the test also causes other muscle to fatigue in addition to the lumbar paravertebral muscles. These include other the multifidus [16] and the hip extensor muscles, particularly the gluteus maximus, and biceps femoris [8,15,17]. Therefore, further research is needed to discover the effects of KT application on these muscles during the Biering-Sorensen test. Additionally the use of a single variable during the performance of the test, time, is not the only possible measure to provide information about the actual nature of the fatigue inside muscle and how the KT affect its. Therefore, the use of EMG or blood lactate concentration might have provided more information on the actual affected mechanisms. Further, measuring pain experienced during the test would have provided information on whether pain significantly affected the results of the test. We also only measured the effect of KT directly after application, so we cannot make any conclusions about the medium or longer term effects of KT and rule out the possible short term stimulus effect from the skin proprioception. We are therefore only able to speculate on the mechanisms that could have influenced the results of this study. Further we used healthy subjects and direct application of our results to a population with LBP is not appropriate. Reproducing this study on subjects with LBP is required to confirm the role of KT in the management of LBP and our results support this.

5. Conclusion

The Kinesio® Tape applied on the lower back significantly delays the onset of paravertebral muscle fatigue in healthy young subjects compared to no tape and produces better effects, although not significant, than placebo application. The results of this study may support the use of correctly applied Kinesio® Tape when there is a need to prevent lumbar paravertebral muscle fatigue. More research is needed to confirm the mechanisms of the effect of KT.

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