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Immediate effect of forearm Kinesio taping on maximal grip strength and force sense in healthy collegiate athletes

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ABSTRACT

Objectives: To determine the immediate effects of applied forearm Kinesio taping on maximal grip strength and force sense of healthy collegiate athletes.
Design: Single group, repeated measures study.
Setting: Clinical sports medicine laboratory at a university hospital.
Participants: Twenty-one healthy collegiate athletes voluntarily participated in this study. All subjects were male (average height: 181.24 ± 7.60 cm; average body weight: 72.86 ± 7.03 kg; average age: 20.86 ± 2.59 years).
Main Outcome Measures: First, maximal grip strength of the dominant hand was assessed by hand-held dynamometer. Then, 50% of maximal grip strength was established as the reference value of force sense. Absolute and related force sense errors and maximal grip strength were measured under three conditions: (1) without taping; (2) with placebo taping; and (3) with Kinesio taping.
Results: Results revealed no significant differences in maximal grip strength between the three conditions ($p = 0.936$). Both related and absolute force sense errors in grip strength measurements significantly increased the accuracy of the results under the three conditions (related force sense errors: $p < 0.05$; absolute force sense errors: $p < 0.05$).
Conclusion: Forearm Kinesio taping may enhance either related or absolute force sense in healthy collegiate athletes. However, Kinesio taping did not result in changes in maximal grip strength in healthy subjects.

1. Introduction

Grip strength refers to the ability of the fingers and hand to generate muscle power and force. In athletes, grip strength is an important component of participating in many sports, including rock climbing, judo, weight lifting, baseball, martial arts and racquets sports (Mathiowetz, Kashman, Volland, Weber, Dowe, & Rogers, 1985). Grip strength may be enhanced by handling a ball or racket with the hands or grasping exercise equipment, which also helps to develop sports abilities. If the forearm muscles have been overused, the resulting decrease in grip strength or fatigue of the forearm muscles may result in the muscles not being able to maintain force output. This would result in decreasing the overall effectiveness of an athlete's sports ability. Previous studies found that neuromuscular control and accuracy of proprioception was affected following muscle fatigue or decreasing muscle strength (Chang, Chen, Wei, & Huang, 2006; Lattanzio, Petrella, Sproule, & Fowler, 1997). Therefore, as muscle fatigue or muscle force degeneration occurs, it will place the forearm muscle at risk of injury (Michael, Michael, & Michael, 2004).

The term "proprioception" was first proposed by Sherrington in 1907(McCloskey, 1978). Proprioception described mechanoreceptors in the body that provide signal information relative to joint position and movement and also the perceived sensation of these forces by the central nervous system (Grigg, 1994; Jones, 1994; Riemann & Lephart, 2002). Proprioception includes joint position sense, kinesthesia, and force sense (FS) (Grigg, 1994; Jones, 1994; Riemann & Lephart, 2002). The specialized receptors exist in skin,

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muscles, tendons, and joints. Proprioception can change with ageing, disease, injury, exercise training, and the use of external protective equipment or taping methods (Riemann & Lephart, 2002). Recent studies have documented significant effects on proprioception resulting from the application of white athletic tape (Callaghan, Selfe, Bagley, & Oldham, 2002; Callaghan, Selfe, McHenry, & Oldham, 2008; Hughes & Rochester, 2008; Refshauge, Kilbreath, & Raymond, 2000; Refshauge, Raymond, Kilbreath, Pengel, & Heijnen, 2009; Robbins, Waked, & Rappel, 1995; Simoneau, Degner, Kramper, & Kittleson, 1997). Most studies considered that taping over the skin could stimulate cutaneous mechanoreceptors and deliver more signals to the central nervous system for information integration. In recent years, a new form of cotton tape with acrylic adhesive was introduced as Kinesio® Tex Tape (Kinesio Holding Corporation, Albuquerque, NM, USA). This elastic therapeutic tape was invented by Dr. Kenso Kase, Tokyo, Japan, in the 1970s. It features elastic adhesive material that is often used in rehabilitation and sports medicine. Kinesio tape is about the thickness of human skin, and it can be stretched to 20–40% of its original length longitudinally. The acrylic mounting of this new type of Kinesio tape differs from traditional white athletic tape in that it is designed with a wave-like grain. As the specialized grain and elasticity of the tape is applied to the skin, it provides a pulling force to the skin and creates more space by lifting the fascia and soft tissue under the areas where it is applied (Kase, Wallis, & Kase, 2003). Kase et al. proposed several taping mechanisms with various intended results depending on the characteristic of the grain and elastic of the tape as it was applied. Using these mechanisms, different beneficial effects could be achieved, including: (1) to increase proprioception by providing constant cutaneous afferent stimulation through the skin, (2) to realign fascial tissue function by normalizing muscle tension, (3) to create more space for improving circulation of blood and lymph flow by eliminating extra fluid, edema, or bleeding beneath the skin, (4) to correct muscle function by strengthening muscle weakness, (5) decreasing pain through neurological suppression (Kase et al., 2003). Kase et al. suggested that the possible mechanism of Kinesio taping in increasing proprioceptive function was the cutaneous afferent stimulation through the skin (Kase et al., 2003). Skin sensation plays an important role in detecting joint position and movement (Riemann & Lephart, 2002; Simoneau et al., 1997). However, some researchers examined the effects of Kinesio taping on proprioception and concluded that improving proprioceptive abilities are only seen in the midrange of motion where ligament mechanoreceptors are inactive, otherwise no increase in proprioceptive function occurs (Halseth, McChesney, DeBeliso, Vaughn, & Lien, 2004; Murray & Husk, 2001). Muscle receptors involved in proprioception may play a dominant role in the midrange of motion where the ligament mechanoreceptors are inactive (Chang & Wei, 1999; Sterner, Pincivero, & Lephart, 1998). For this reason, we wondered if the possible mechanism to improving proprioceptive function was to increase cutaneous afferent input to detect joint position and movement.

Furthermore, Dr. Kenzo Kase claimed that one of the effects of Kinesio tape is to increase muscle strength (Kase et al., 2003). Słupik et al. determined the effect of Kinesio Taping on bioelectrical activity of vastus medialis muscle. The results revealed an increase in the electromyographic activity of the vastus medialis muscle after 24 h of Kinesio taping, and even maintenance of motor activity after 2 days of Kinesio taping and following removal of the tape (Słupik, Dwornik, Białoszewski, & Zych, 2007). However, Fu et al. examined the effect of Kinesio taping on quadriceps strength of healthy athletes by isokinetic dynamometry. They concluded that no significant difference in muscle strength was found either immediately after tape application or after 12 h of taping (Fu, Wong, Pei, Wu, Chou, & Lin, 2008). There is limited evidence on the effects of Kinesio Taping on muscle strength.

Based on the above studies we have two hypotheses. First, that Kinesio Taping on muscle would increase the muscle strength. Second, we hypothesized that the possible mechanism to improving proprioceptive function was to enhance the force sense activated by the muscle receptors following the applied Kinesio taping. Therefore, the purpose of this study was to determinate the immediate effects on maximal grip strength and force sense in healthy collegiate athletes after the application of forearm Kinesio taping.

2. Materials and methods

2.1. Study design and participants

The present study was conducted as a blind, repeated measures design with a single group. Twenty-one healthy male collegiate athletes voluntarily participated in this study. Subjects were recruited from two universities (Chung Shan Medical University and National Chang hua University of Education). All subjects participated in extra-curricular leisure activities such as jogging, running, soccer, cycling, and swimming, at least 2 times a week. No one had done weight training, especially in the upper extremities, within two weeks of participating in the study. The age range of subjects was between 18 and 24 years (average age: 20.86 ± 2.59 years; average height: 181.24 ± 7.60 cm; average weight: 72.86 ± 7.03 kg). All subjects received screening and interviews by a certified senior physical therapist. Exclusion criteria applied during screening included (1) elbow ligament injury or laxity, elbow or wrist tendon injuries/tendonitis, forearm muscle overuse/strain, forearm fracture, or nerve injuries within the previous 6 months, and (2) a positive resisted wrist extension test. The study protocol was approved by the Institutional Review Board of the National Taiwan Sport University. All subjects understood the details of the study procedure and signed an informed consent prior to participation in the study.

2.2. Taping techniques

Subjects randomly received one of the three taping conditions, including without taping applied (WT group), placebo taping applied (PT group), and Kinesio taping applied on forearm (KT group). The three taping conditions were assigned by using a random-number allocation table and an interval of 1 week for each of the conditions. According to Dr. Kase, Kinesio tape can improve strength, circulation, and proprioceptive function. We thought that residual effects of Kinesio taping might remain immediately after taping, so we decided to allow one-week intervals between taping conditions. Guidelines for Kinesio taping of the forearm were consistent with the protocol for medial epicondylitis of the elbow as suggested by Kase et al. (2003). Kinesio tape was applied on the wrist flexor muscle of the dominant hand. Standard 2-in (5 cm) blue Kinesio® Tex Tape (Kinesio Holding Company, Albuquerqe, NM) was used for all applications of tape (PT, KT) among the 3 taping conditions. Before applying the tape, the length of tape was measured from 2 cm inferior to the medial epicondyle of the humerus to the wrist joint line. A roll of tape was cut into a strip and then cut down the middle of the strip to produce 2 tails or a "Y-strip." The Y-strip was applied on the common wrist flexor muscle from its insertion to origin with 15–20% stretch tension. The first tail of the Y strip was applied on the middle of the forearm with the wrist in a hyperextended position and with the elbow in full extension and the forearm in full supination. The second tail of

the Y-strip, also applied from insertion to origin with 15–20% stretch tension, was taped along the medial edge of the forearm to wrap the common wrist flexor muscles (Fig. 1a-b).

The placebo taping also used the same roll of Kinesio tape. The sham taping consisted of one I-strip (10 cm) applied with no tension. The placebo taping was applied on 5 cm inferior to medial epicondyle of the humerus from the middle line to the medial side of the forearm and across the belly of the common wrist flexor muscle fibers with 15–20% stretch tension (Fig. 1c).

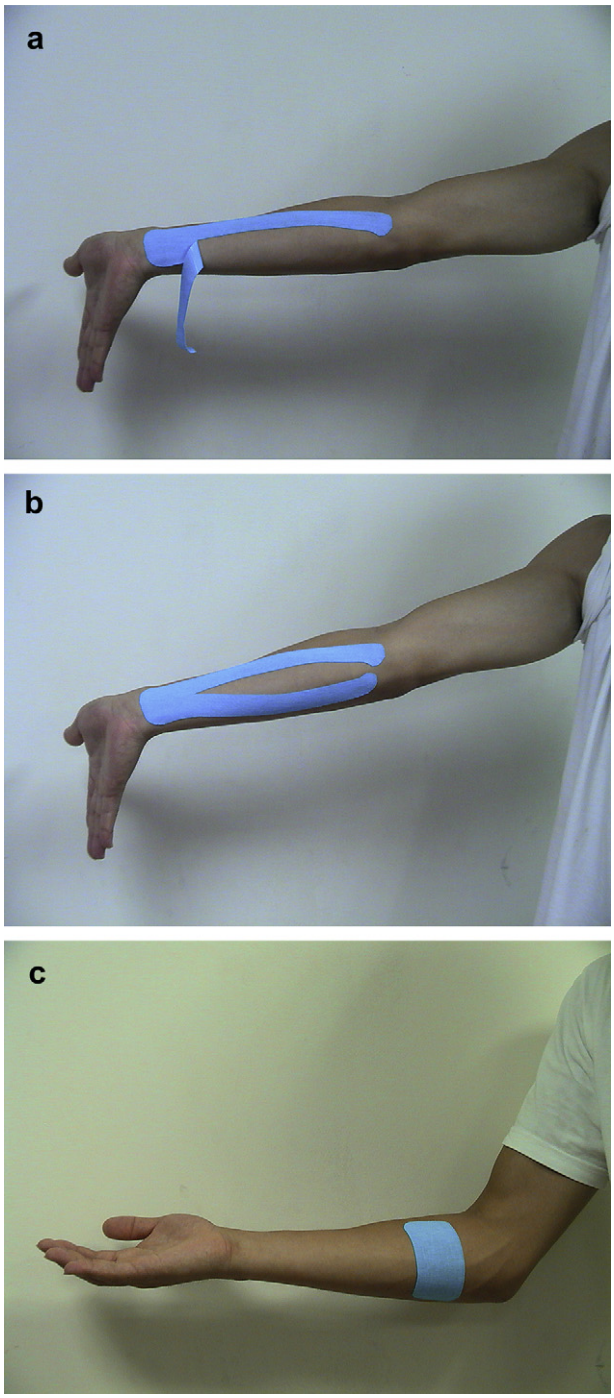

Fig. 1. The application of taping in (a–b) Kinesio taping and (c) sham taping conditions.

2.3. Outcomes measures

The outcome measures for this study consisted of maximal grip strength and force sense measurements. The maximal grip strength was assessed to determine the strength of hand grip. It was measured by using the JAMAR Hydraulic Hand Dynamometer (Sammons Preston, USA). The maximal muscle strength was measured with subjects standing with the upper arm that received assessment held tightly to the trunk, elbow flexion 90°, and wrist placed in neutral position. Subjects held the hand dynamometer and were asked to grip the handle of the dynamometer as hard as they could for 5 s, and then release the handle. Three trials were conducted for each subject and the mean value of the 3 trials was recorded for analysis. In a previous pilot study, the reliability test for the hand dynamometer indicated an intra-class correlation coefficient of 0.973.

Force sense was also measured by using the same hand dynamometer. After assessment of maximal grip strength, we used the value of maximal grip strength to calculate the target force or reference value for force sense testing. We set 50% of the maximal grip strength as the value of target force. Previous authors have suggested that using 50% of the maximal voluntary isometric contraction for the target force generated less error with force reproduction (Dover & Powers, 2003; Jones & Hunter, 1982). To begin force sense testing, the subject attempted to exert the handle of the hand dynamometer while receiving visual feedback; this was done by putting a mirror behind the subject to allow observation of producing the force value. Once the target force was achieved, the subject was instructed to maintain it for 3 s and to concentrate on how much force value was being exerted. After 3 s, the subject was instructed to relax. We then removed the mirror (visual feedback) and instructed the subject to reproduce the force value. When the subject told us that the target force had been achieved, that force value was recorded. The measurement was repeated 3 times. The error score of each trial was calculated as the absolute and related difference between the target force and the verbally reported force of the subject, indicating absolute force sense errors and related force sense errors. The absolute force sense error represented the absolute difference between the reference and reproduction values, while the related force sense errors represented the difference between the reference and reproduction values. A value was scored as negative when the reproduction value underestimated the referred value, or conversely when the reproduction value overestimated the referred value. Each trial error of measurement was used to calculate the absolute error and related error for each subject. The average of 3 trial errors, either related or absolute error, was used in the statistical analysis and final results. The higher the error scores, the lower the force sense. The test–retest reliability of force sense was established in a previous pilot study and the intra-class correlation coefficient of force sense was 0.704.

2.4. Statistical analysis

The independent variables in this study were the taping conditions (WT, PT, and KT) and dependent variables were the maximal grip strength, absolute force sense errors, and related force sense errors. Data analysis was done using the Statistical Package for the Social Sciences (SPSS, Version 14.0; SPSS Inc, Chicago, IL). The one-way ANOVA and Scheffe post hoc comparison test were used to compare the differences between the three taping conditions. The level of statistical significance was set at $p < 0.05$.

3. Results

No significant differences were found in the maximal grip strength between WT (53.5 ± 7.6 kg), PT (53.6 ± 8.2 kg) and KT

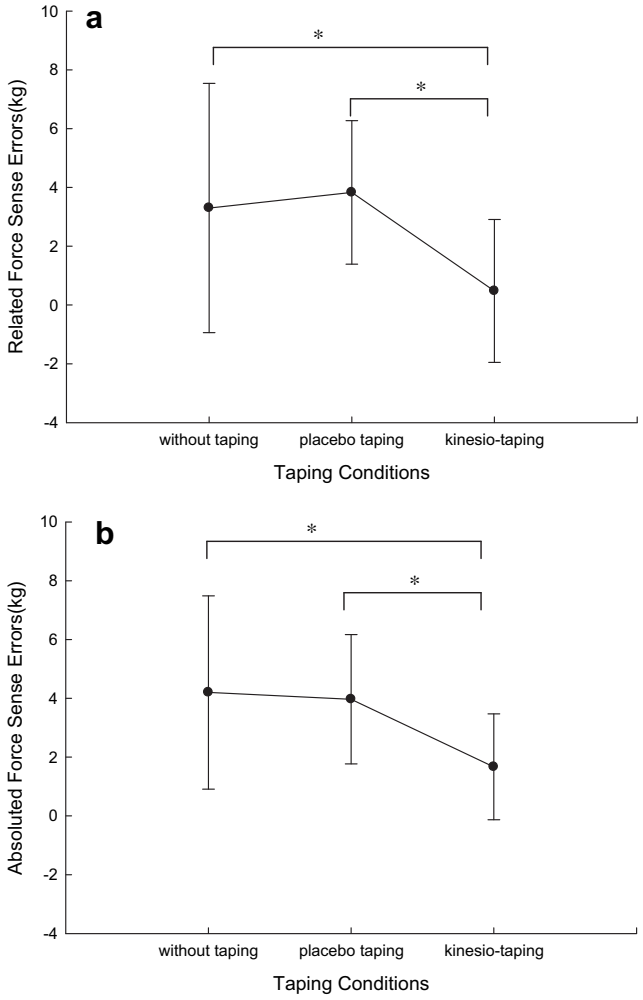

Fig. 2. The difference of result in related force sense errors (a) and absolute force sense errors (b) for three taping methods. *Significant difference between two groups.

(54.3 ± 6.9 kg) ($p = 0.936$). However, statistically significant differences were found in the absolute and related force sense errors between the three taping conditions ($p < 0.05$) (Fig. 2). KT (0.5 ± 2.4 kg) had smaller errors than WT (3.3 ± 4.2 kg) and PT (3.8 ± 2.4 kg) in related force sense errors measurement (Fig. 2). Also, significant differences were seen between the three taping conditions in absolute force sense errors measurement ($p < 0.05$). PT (4.2 ± 3.3 kg) and WT (4.0 ± 2.2 kg) had higher absolute force sense error measurement than KT (1.7 ± 1.8 kg) (Fig. 2).

4. Discussion

The results of the current study demonstrated that subjects who received Kinesio taping (KT group) exhibited statistically significant improvements in force sense errors and no effective change in maximal grip strength immediately following application of Kinesio tape, when compared to groups receiving placebo taping (PT group) and no taping (WT group). Regarding the measurement of maximal grip strength, the results of the present study disagree with previous possible mechanisms of Kinesio taping proposed by Kase et al. and others for strengthening muscle function (Kase et al., 2003; Słupik et al., 2007). Furthermore, neither facilitation nor inhibition effects on grip strength were demonstrated in the current study, similar to the results of a pilot study by Fu et al. (Fu et al., 2008), which investigated the effectiveness of Kinesio taping on muscle strength in athletes. In the study by Fu et al., the Kinesio tape was first applied on the quadriceps and hamstring and again 12 h after taping, but no increases or decreases were seen in muscle strength in healthy, non-injured young athletes (Fu et al., 2008). Another study by Slupik et al. (Słupik et al., 2007), does not support our results. The study by Slupik et al. was conducted to determine the effects of Kinesio taping on changing the transdermal electromyography of the vastus medialis muscles during isometric contractions following 24 h and 72 h of Kinesio tape application, and another 48 h following removal of the tape. Significant increases in the bioelectric activity of the vastus medialis were found after 24 h of Kinesio taping and in maintaining this effect for 2 days following removal of the Kinesio tape (Słupik et al., 2007). But the increase in the bioelectric activity of the muscles may not express in force output to change the muscle strength. Hence, in the current study, the absence of improvements in grip strength indicated that there were no improvements in muscle tension either for the sham Kinesio taping or proper Kinesio taping applied to subjects' forearms. It is possible that the tension applied by the real and proper application might have provided tactile input to the subjects' forearm. However, cutaneous afferent stimulation has been reported to interact with the motor cortex by altering muscle excitability of the central nervous system (Ridding, Brouwer, Miles, Pitcher, & Thompson, 2000; Roll, Kavounoudias, & Roll, 2002; Słupik et al., 2007; Simoneau et al., 1997). A possible explanation for the negative results observed in our current study, is that the magnitude of cutaneous afferent stimulation generated by Kinesio taping may not have been strong enough to modulate the muscle strength of healthy collegiate athletes in a short-term application of Kinesio tape. Nevertheless, we cannot make this inference relative to long-term applications of Kinesio tape. Few studies have been done regarding altering motor response from increases in tactile input to explain a possible mechanism for Kinesio taping. Further study is needed to examine the long-term effects on muscle strength following application of Kinesio taping for extended periods of time.

Although no facilitation or inhibition effects were noted for maximal grip strength by using Kinesio taping, we found that the effect of Kinesio taping on forearm force sense had smaller related errors or absolute errors than placebo taping and no taping at all. Previous studies of the effects of Kinesio taping on proprioception used joint position sense as a variable outcome measure. However, the results of those studies did not support the hypothesis that Kinesio taping could improve proprioceptive function (Halseth et al., 2004; Murray & Husk, 2001). Halseth and colleagues examined the effects of Kinesio taping on ankle joint position sense with application of Kinesio tape at the ankle plantar flexion and plantar flexion 20° with inversion. They concluded that the application of Kinesio taping does not appear to enhance ankle joint position sense in healthy individuals at either of the plantar flexion angles. Murray and Husk (2001) also determined the effects of Kinesio taping on ankle joint angle replication for 26 healthy subjects at 26° and 10° of plantar flexion, and 8° of dorsiflexion (Murray & Husk, 2001). They found that Kinesio taping for a lateral ankle sprain only improved proprioceptive abilities in non-weight-bearing positions in the midrange of ankle motion where the ligament mechanoreceptors were inactive and muscle receptors were more active. Hence, we wonder about the possible effect of Kinesio taping for joint position sense. We suggest that the possible effects of Kinesio taping may come from skin and muscle receptors. Our study confirmed that Kinesio taping improved the force sense of the forearm for healthy subjects. We postulated that Kinesio taping always parallels muscle alignment when applied. As Kinesio tape was applied on the skin and stretched, the skin and underlying superficial fascia covering the muscle stimulated the muscle receptors to sense the alteration of

length and tension of muscle fiber, and other mechanoreceptors to pass down the message concerning changes in stretch, load, pressure, and shear force (Myers, 2009; Schleip, 2003). Furthermore, it has been stated by other researchers that skin, fascia, and muscle receptors might play a role in detecting the feedback of force production (De Domenico & McCloskey, 1987; McCloskey, Gandevia, Potter, & Colebatch, 1983; Myers, 2009; Winter, Allen, & Proske, 2005; Schleip, 2003). De Domenico and McCloskey (1987) also mentioned that proportional change in muscle fascicle length is a significant variable for the central nervous system in proprioception and control of voluntary movement. Schleip mentioned the viewpoint from mechanoreceptors to modulation of muscle tone (Schleip, 2003). They suggested that slow pressure stimulation on connective tissue leads to alteration of mechanoreceptor input to the central nervous system, resulting in changed gamma motor neuron firing and regulation of muscle tonus.

The present findings suggest that Kinesio taping may be able to enhance force sense. Force reproduction assessment (force sense errors) is a highly reliable measure of proprioception. At this time, there are no reports of force sense being measured in the forearm. In our prior study, intra-class correlation coefficient of force sense was moderate reliable (ICC = 0.704). Although the ICC of force reproduction in the present study was only 0.704, this value was indicative of moderate reliability (Portney & Watkins, 2000). Benjaminse, Sell, Abt, House, and Lephart (2009) reported that only flexion showed good intersession reliability (ICC = 0.764) of force sense in the hip joint, while other planes did not show good reliability. The reliability of force sense measurement has been found to be highly reliable in shoulder and ankle joints (Docherty & Arnold, 2005; Dover & Powers, 2003), but to our knowledge, no one has reported the reliability of force sense for grip strength. Hence, in the present study, the moderate reliability of the grip force sense was acceptable. The target force setting to be reproduced is often selected from the percentage of maximum voluntary isometric contraction (MVIC) of the measured muscle or muscle groups. Because of a variety of previous studies of target force reproduction (Benjaminse et al., 2009; Dover & Powers, 2003; Jones & Hunter, 1982), our pilot study selected 3 target force values (30%, 50%, and 80% of MVIC) as force sense error assessment to identify the best target force. The results of our pilot study showed smaller errors of force sense with 50% MVIC than other studies of target force values, and were similar to the results of Jones and Hunter (1982), who also suggested that the measurement of target force reproduction was not more than one target value that prevented muscle fatigue and learning effects during the study process (Dover & Powers, 2003; Jones & Hunter, 1982). It is possible that a decrease in error is associated with a target force equivalent to 50% of the MVIC, which may have contributed to our Kinesio taping findings.

In the present study, we considered that applying tape may affect the subjects' psychological condition. Therefore, the utilization of sham taping was intended to help reduce subjects' psychological effects. Also, sham taping was applied mostly on the muscle belly of the common wrist flexor muscles to simulate skin stimulation, as in actual Kinesio taping. Although the sham taping did not look similar to standard Kinesio taping, the subjects had no previous experience with Kinesio taping, so they were unaware of whether the taping methods were correct or not.

4.1. Limitations of our study

The present study has several limitations, which should be mentioned. One of the limitations of this study is the lack of an assessment for joint position sense on the forearm, which may have given us clear findings in comparing the force sense effects following Kinesio tape application. However, some of the common wrist flexor muscles cross over the wrist and elbow joint. It seemed difficult to measure the joint position sense of the wrist joint or elbow joint. In addition, Kinesio Taping applied across the joint would possibly have stimulated the receptors that detected joint position and thus interfered with our results. In order to clearly understand the effects of Kinesio taping on force sense and joint position sense, future study needs to be conducted on tape application on other joints or muscles, not on muscle groups or muscles that cross over 2 joints. Secondly, one of the characteristics of Kinesio tape is that it must be worn longer than traditional white tape, usually 2–3 days (Kase et al., 2003). However, in the current study, we only assessed the short-term effects of Kinesio taping, measured immediately after the tape was applied. Some previous studies investigating shoulder pain, oedema elimination, or electromyography activities of muscle reported long-term effects related to the application of Kinesio tape (Chang, Kao, Ho, Chou, & Wang, 2006; Słupik et al., 2007; Thelen, Dauber, & Stoneman, 2008). Their results also showed significantly improved effectiveness of Kinesio taping when it was applied for as long as 1 or 2 days, even after removing the tape. Therefore, we suggest that future research should not only demonstrate the short-term effects but also examine the long-term results of Kinesio tape application. Finally, when placebo taping condition was applied, the cutaneous afferent stimulus did not provide the same result as the proper Kinesio tape condition on the skin. Future research needs to look for elastic-like taping material and utilize the same taping methods as the control groups, which would be more consistent across the experimental group and control group when the effects of Kinesio taping were determined.

4.2. Clinical application

Based on the results of the current study, force sense was enhanced by Kinesio tape application. This is an issue of importance for competing athletes. In addition, it has been suggested that Kinesio tape application may be used in competitive sports that require more precise hand force control such as pitching or shooting. Finally, force reproduction may be better than joint repositioning as a measured variable of proprioception when Kinesio tape is applied. Future studies of Kinesio taping might involve applying Kinesio tape on injured populations or during rehabilitation to understand possible mechanisms of neuromuscular control.

4.3. Conclusion

The application of Kinesio tape on the forearm appeared to enhance the force sense of forearm muscles immediately after application in healthy subjects. However, no statistically significant improvements in maximal grip strength were exhibited after Kinesio taping. Future studies should investigate the long-term effects of Kinesio taping on force sense.

Ethical approval statement

This study was approved by Human Research Ethics Committee of National Taiwan Sports University.

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Conflict of interest statement

All authors state that they do not keep any commercial, financial or personal relationships which may lead to a conflict of interests

that could inappropriately influence (bias) their work. The research grant sponsors had no involvement in the study design, in the collection, analysis and interpretation of data; in the writing of the manuscript; or in the decision to submit the manuscript for publication.

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