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Effects of finger taping on forearm muscle activation in rock climbers

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ABSTRACT

Flexor tendon pulley injury is associated with a change in relative activation of the flexor digitorum superficialis (FDS) and flexor digitorum profundus (FDP) muscles. The purpose of this study was to determine the effect of taping of the fingers on relative muscle activation of the FDS and FDP muscles in uninjured rock climbers. Muscle activation in 10 healthy volunteers were recorded using intramuscular electromyography (EMG) during a static hang with subjects utilizing the crimp grip without tape, with a circumferential tape and with an H-tape in random order. EMG data were normalized to a static hang with a non-crimp grip (RVC). Average EMG activity of the FDS as a percentage of RVC was 102.4 ± 59.1 without tape, 116.9 ± 35.3 with H-tape and 99.3 ± 35.3 with circumferential tape. Average EMG activity of the FDP as a percentage of RVC was 96.6 ± 40.0 without tape, 98.9 ± 30.3 with H-tape and 90.6 ± 28.7 with circumferential tape. Taping did not have a significant effect on average relative muscle activation of the FDS or FDP muscles ($p = 0.069$). This study showed that finger taping may not significantly affect the activity of the FDS and FDP during static holds while rock climbing.

1. Introduction

As the sport of rock climbing has become increasingly popular and safety gear has improved, the difficulty of routes and moves performed has dramatically increased. With the rise in difficulty, increased stress is being put on climbers' bodies. This increase in stress has led to a high rate of overuse injuries, with the most common site of injury being in the hand and wrist (Maitland, 1992). The most common injury to the hand associated with overuse during climbing is damage to the flexor tendon pulleys (Backe et al., 2009; Bollen and Gun, 1990; Schwartz, 2008; Rohrbough et al., 2000; Schöffl et al., 2003).

Surrounding the fingers is a flexor tendon sheath which functions to keep the flexor tendons close to the bones. The pulley portion of the sheath wraps around the tendons of the Flexor Digitorum Superficialis (FDS) and Flexor Digitorum Profundus (FDP) muscles. These pulleys function to withstand the greatest forces during finger flexion, and the A2 pulley receives the most force and is the most common site of flexor tendon pulley injury (Crowley, 2016; Rohrbough et al., 2000).

The crimp position (defined by hyperextension of the distal interphalangeal joint and flexion at the proximal interphalangeal joint (Sheikh and Wong, 2006; Quaine and Vigouroux, 2004) puts extreme forces on the flexor tendon pulleys; it is estimated as high as 380N of force on the A2 pulley in recreational climbers and likely much higher for competitive climbers (Schweizer and Oeschner, 2001). Repetitive loading of the A2 pulley with such high forces can lead to partial or complete rupture of the pulley. Pulley injury is most common in the middle and ring fingers as these fingers can apply higher forces and the pulley forces reached are closer to their rupture thresholds than the other fingers (Vigouroux et al., 2008).

The common way of preventing flexor tendon pulley injury is to apply supportive tape to the finger. However, the effectiveness of preventative taping has not yet been proven successful. Using cadaver hands, Warme and colleague showed no significant difference in load to rupture of the A2 pulley with or without a circular application of tape to the proximal phalanx (Warme and Brooks, 2000). Taping at the proximal edge of the proximal phalanx also has been shown to have minimal effectiveness on decreasing bowstringing of the tendons, which would decrease the force applied to the pulley (Schweizer, 2000). A new taping method introduced by Schöffl et al. (2007) significantly decreased the tendon-bone distance in a previously injured finger, but had no significant effects on uninjured fingers.

The purpose of this study was to investigate the effect of taping on muscle activation in the FDS and FDP muscles. An increase in activation of the FDP has been associated with the crimp grip, which is associated with flexor pulley injury (Vigouroux et al., 2006; Schweizer and Hudek, 2011). If taping could decrease activation of FDP and increase activation of the FDS, it could be used as evidence that taping is effective as a preventative measure against flexor tendon pulley injury. Two taping methods were compared, the circular method as used by Schweizer (2000) and the H-tape method as developed by Schöffl et al. (2007).

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Table 1
Subject demographics.

Age (years)	Height (meters)	Mass (kilograms)	Climbing experience (years)	Time spent climbing (hours/week)
21.0 ± 1.7	1.8 ± 0.1	71.0 ± 6.3	2.6 ± 1.9	5.2 ± 3.3

2. Methods

2.1. Subjects

The subjects in this study consisted of 13 males and females between the ages of 18 and 22. Three participants did not finish the study because of a vasovagal syncope response due to insertion of the fine-wire electrodes. The 10 subjects used for analysis were all males. As the mechanism of injury examined in this study most commonly occurs in expert rock climbers, subjects were asked to demonstrate that they can climb at least the V4 level. The "V" scale is a common rating scale used to define the difficulty of climbing routes. Routes given the V4 rating correspond with an 18 by the International Rock Climbing Research Association reporting scale and require extensive skill and strength to be completed. Subjects were also limited to those with at least 6 months of climbing experience, and climb at least two hours a week on a regular basis. According to IRCRA guidelines subjects were also limited to those who describe themselves as primarily boulderers and spend at least 75% of their climbing time indoors. Before data collection, all subjects were asked to read and sign the informed consent. This research study was approved by the Institutional Review Board at Western Washington University. Subject demographics are displayed in Table 1.

2.2. Set up

Data was collected in the biomechanics lab at Western Washington University. Boards were bolted to the wall so that climbing holds could be placed at a distance of 0.91 m apart and 1.22 m above the ground (Fig. 1A). Two sets of climbing holds were used (Fig. 1B). The first set, used for normalization of the electromyography (EMG) data and was referred to as relative voluntary contraction (RVC) trial, were seven centimeters wide and had a two-centimeter lip that protruded 4 cm from the wall. This was large enough that subjects distal and middle phalanges could be in contact with the hold. The second set of holds were five centimeters wide and protruded horizontally two centimeters from the wall. This was small enough that only the subjects' distal phalanx was in contact with the hold, necessitating the crimp grip. Protective mats were placed under the wall in case of falls.

2.3. Procedures

After the informed consent was signed, the subjects were led through a standardized warm up, starting with wrist circles. Subjects

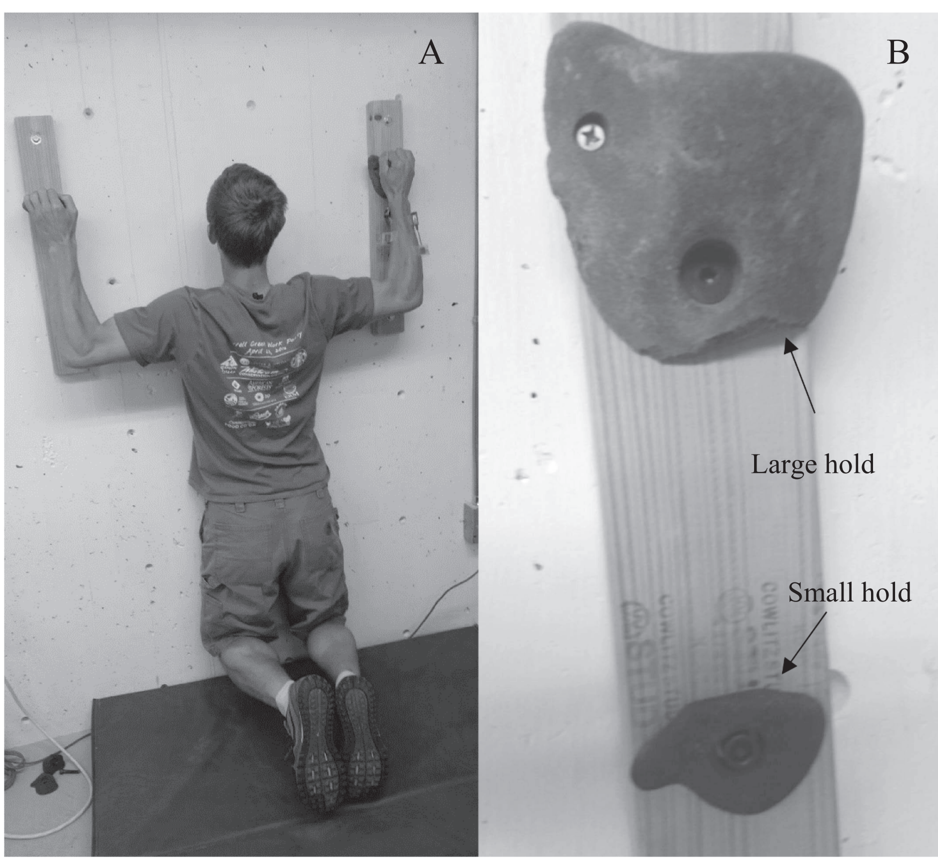

Fig. 1. (A) Subject demonstrating a hang from the holds used for data collection. (B) Large (used for warm-up and RVC trial) and small (used for experimental trials) holds.

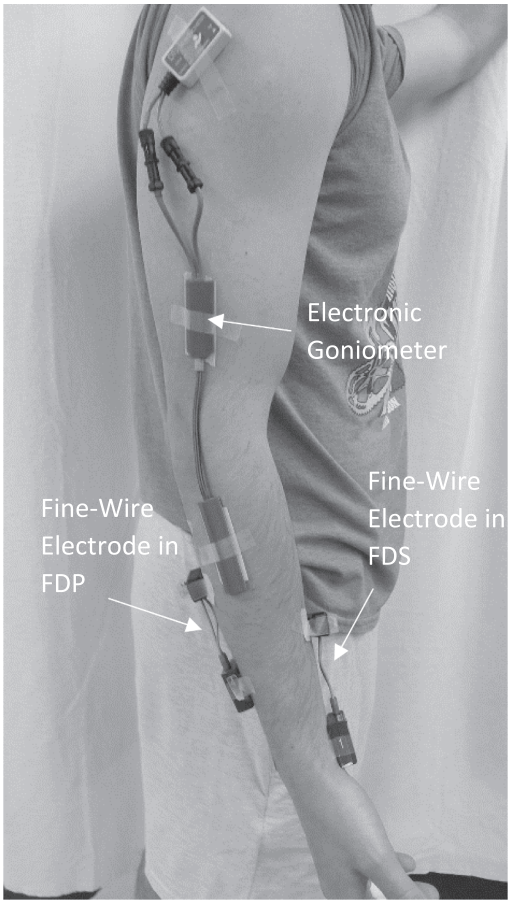

Fig. 2. Subject set-up with both fine-wire EMG electrodes (Flexor Digitorum Profundus and Flexor Digitorum Superficialis) and electrogoniometer.

were instructed to make circles with their wrists ten times clock-wise, followed by ten times counter clock-wise. After doing these three times, they were instructed to stretch their forearms by applying pressure to hyperextend their wrists and hold this position for 15 counts two times. Subject were then allowed to practice a couple of hangs from the large set of holds (Fig. 1B). After the practice trials, the subjects were briefed on the details of the procedure. They were instructed that EMG data would only be taken during static holds, during which they must hang from a crimp grip with elbow angles between 85 and 95 degrees. The difference between an open and closed grip was explained; open grip being with all finger joints flexing and closed grip being defined by hyperextension of the distal interphalangeal joint (Bollen, 1988; Sheikh and Wong, 2006).

To measure muscle activation, a Noraxon desktop direct transmission system (DTS) EMG system (Noraxon, Scottsdale, AZ, USA) was used to monitor amplitude. Sampling frequency was set to 1500 Hz with a gain of 500 and CMRR > 100 dB. All EMG data were rectified and smoothed using RMS technique. After the warm up and procedural explanation were completed, each subjects' right arm was sterilized with alcohol pads. Sterilized fine-wire electrodes, 27ga. 30 mm – paired wires for the FDS muscle and 25ga 50 mm – paired wires for the FDP muscle (Chalgren Enterprise, Inc, Gilroy, CA) were inserted intramuscularly by the co-principal investigator JSJ. Subjects were all in a supine position laying in treatment table during electrode insertion. To insert the electrode into the FDS muscle, a subject's supinated forearm was grasped by the investigator such that the investigator's index finger was pointing directly at the subject's biceps tendon. The electrode was then inserted just ulnarly to the tip of the investigator's index finger (Perotto et al., 2005). To insert the electrodes into the FDP muscle, subject's arm was placed so that the forearm was fully supinated and the forearm was maximally flexed at the radioulnar joint. The investigator then placed the tip of their little finger on the subjects' olecranon and the rest of their fingers along the shaft of the subject's ulna. Electrodes were then inserted just beyond the tip of the investigator's little finger, just ulnarly to the shaft of the ulna (Perotto et al., 2005). Correct placement of the electrodes was tested for the FDS by asking the subject to flex the proximal interphalangeal (PIP) joint against resistance while maintaining the DIP joint in hyperextension. Correct placement in the FDP was tested for by instructing the subject to flex DIP joint against resistance. Resistance was provided by the investigator's hand. After the electrodes were inserted correctly a Noraxon DTS 2D Electrical Goniometer (Noraxon, Scottsdale, AZ, USA) was used to measure angular displacement about the elbow joint. The proximal part of the electrogoniometer was placed along the lateral mid-line of the humerus, using the acromion for reference. The distal part of the electrogoniometer was placed along the later midline of the radius, using the radial styloid process for reference (Fig. 2). Both the EMG and the joint angles were collected using the MR3.4 (Noraxon, Scottsdale, AZ, USA) software.

Once the electrodes and goniometer were inserted correctly, the RVC was taken. This was recorded for six seconds, starting when the subject had achieved a hanging position with their hands on the larger set of holds and their elbows bent between 85 and 95 degrees of flexion. After the RVC was taken, subjects were given a three-minute rest. A resting trial was then taken to control for extra noise on the EMG. Subjects stood relaxed with their arms at their sides and activation was recorded for six seconds. Subjects were then lead through the three experimental trials, done in random order, with three-minute rest intervals between each trial (Schöffl et al., 2007). Muscle activation was only recorded when subjects were maintaining a hanging position with elbow angles between 85 and 95 degrees on the small set of holds. Activation was recorded for six seconds. For one trial, no tape was applied to the subject. For the other two trials tape was applied by the investigator to the middle and ring fingers of the right hand, as these are the fingers that are most at risk of pulley injury (Vigouroux et al., 2008). Tape was applied once in the circular method, as described in a study done by Schweizer (2000) and once in the H-tape method, as described by Schöffl et al (2007). The principal investigator performed all the taping across all subjects (Fig. 3).

2.4. Data analysis

All EMG data were normalized to the RVC. Average EMG signal during the resting trial was calculated and subtracted from all other trials to correct for residual electrical noise. Data from the middle two seconds of the six second data collection period was utilized. Average EMG during the two second period was calculated, as well as standard deviation and peak value. Two-way repeated measures ANOVA tests were used to determine statistical significance between taping conditions and muscles for both the average and peak activation values. Alpha level was set to 0.05.

3. Results

Fig. 4 is a representative raw EMG data of a subject during the crimp hold with the H-tape condition. Average muscle activations of the FDS and FDP muscles are presented in Fig. 5. A two-way repeated measures ANOVA was conducted that examined the effect of taping (no tape, H-tape, circumferential tape) and muscle (FDS, FDP) on average relative muscle activation. Mauchly's test of sphericity revealed that the

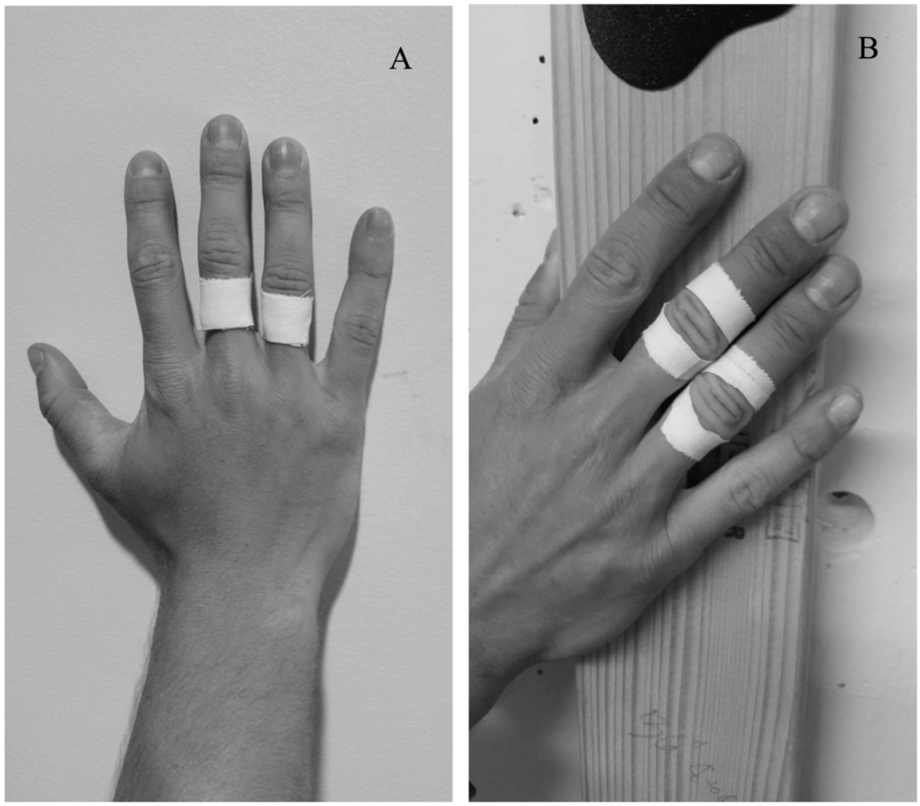

Fig. 3. (A) Circular taping method according to Schweizer and (B) H-tape method according to Schoffl et al.

assumption of sphericity was not violated. No significant interaction effect was found between taping condition and muscle on EMG level (F[2–18] = 0.225, η_p^2 = 0.024, p = 0.801). Taping did not have a significant effect on average relative muscle activation of the FDS or FDP muscles (F[2–18] = 3.122, η_p^2 = 0.257, p = 0.069. There was also no significant difference between the FDS and FDP muscles during the experimental trials (F[1–9] = 0.053, η_p^2 = 0.006, p = 0.822).

Peak muscle activations of the FDS and FDP are displayed in Fig. 6. Mauchly's test of sphericity revealed that the assumption of sphericity was not violated. There was no significant interaction between taping condition and muscle (F[2–18] = 0.376, η_p^2 = 0.017, p = 0.692). Taping did not have a significant effect on peak relative muscle activation of either muscle (F[2–18] = 0.511, η_p^2 = 0.054, p = 0.608). There was also no significant difference between the peak muscle activation of the FDS and FDP muscles (F[1–9] = 0.159, η_p^2 = 0.040, p = 0.699).

4. Discussion

The purpose of this study was to determine the effect of taping on relative muscle activation of the FDS and FDP muscles during a static hang with a crimp grip. Both average and peak activation of each muscle was investigated during a no tape, H-tape, and circumferential tape trial. There was no significant difference in either average or peak muscle activations of either muscle between the no tape and the tape trials.

The relative muscle activation of the FDS and FDP muscles has not been investigated before this study in regard to taping. Vigouroux et al (2006) investigated relative tendon tensions of the FDS and FDP musculotendinous unit during a crimp grip (characterized by hyperextension of DIP joint) and a slope or hanging grip (characterized by flexion at all interphalangeal joints). An increase in relative activation of the FDP and decrease in relative activation of the FDS occurred during the crimp grip due to the changed positioning of the fingers. The tension in the FDP tendon was 60% higher than that of FDS tendon during the crimp grip, but less than 90% of the FDS tendon tension during the slope grip. This means the FDP is the major finger flexor during the crimp grip, which is associated with forces on the A2 pulley as much as 36 times higher than in the slope grip (Vigouroux et al., 2006).

This study investigated the effects of taping on activation of these two muscles during a crimp grip. The slope grip was used as the RVC to normalize the data. A consistent increase in activation of the FDP and decrease in activation of the FDS with the crimp grip, as found in the above-mentioned study, was not found in this study. This could be due to the large variance in EMG values in this study. The large variance was likely due to the relatively small sample size. Only 10 subjects completed the procedure. Post-hoc analysis using the results in the current experimental design revealed that the calculated power was 0.16 which is considered small. This large variance could also be due to the experience and skill level of the subjects. Subjects were recreational climbers who climb on average about five hours per week and have been climbing on average about two and a half years. As the risk of injury increases with increased climbing ability and time spent climbing, different results may be found in professional climbers who climb more often.

Though muscle activation has not been investigated in regard to finger taping, other studies have looked into the effectiveness of taping on other factors that also reduce force on the A2 pulley. Taping has not yet been proven to be effective prophylactically. Taping, either circular or H-tape, does not significantly decrease the tendon to bone distance

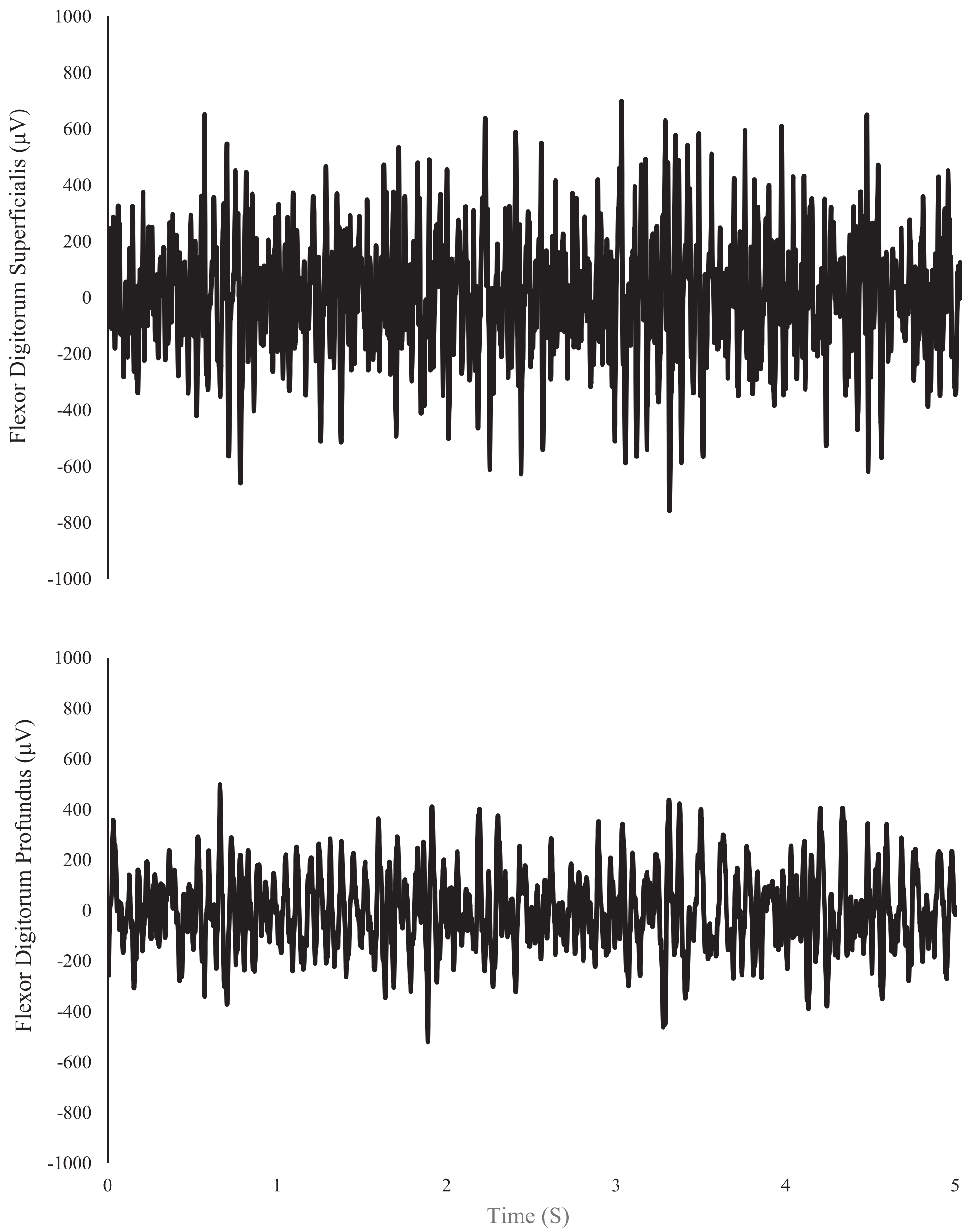

Fig. 4. An example of the raw EMG data of a subject during the isometric crimp hold with the H-tape condition.

or increase strength in an uninjured finger (Schöffl et al., 2007). Circumferential taping has not proven to significantly increase load to A2 pulley failure in cadaver hands, though the H-tape method has not been tested (Warme and Brooks, 2000). These results are in accordance with the current study. Neither the circumferential nor H-tape caused a significant change in relative muscle activation of the FDS or FDP muscles, which effects force put on the A2 pulley.

This study was not without limitations. Muscle activation was only recorded during a static hang with elbows in 90 degrees of flexion. While this joint position was chosen to maximize torque on the interphalangeal joints, it might have limited application to rock climbing. Rock climbing involves dynamic movement of the elbow joint through the full range of motion. Future studies should investigate muscle activation during a dynamic movement through a larger range of motion. Secondly, it was not tested if subject's pulleys were intact prior to the study. Subjects presented with no knowledge of previous injury or complaints of pain that fits the symptoms of a tendon pulley injury, but we did not confirm this using any imaging. This should be addressed in the future. Future studies should also investigate relative muscle activation in professional climbers who climb more than subjects in this study, since the likelihood of this injury increases with time spent climbing.

Results of this study suggest that taping the fingers may not affect relative muscle activation of the FDS and FDP muscles in uninjured climbers completing a static hold. Effectiveness of taping as a preventative measure for flexor tendon pulley injury is therefore not supported by the results of this study, but this study is limited to its testing procedure and subject demographics. Future studies investigating the effects of taping on muscle activation are necessary.

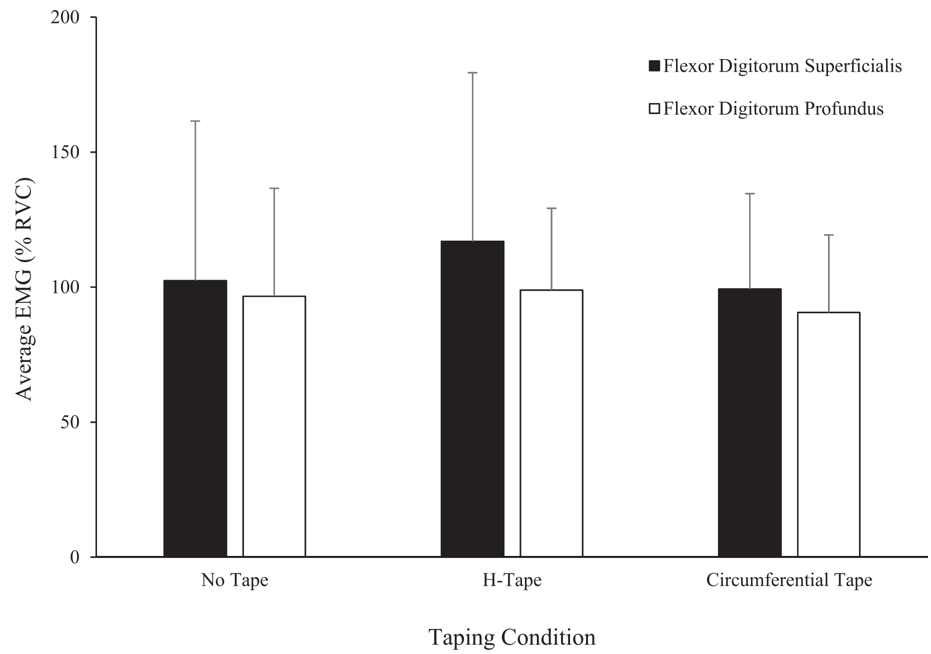

Fig. 5. Average muscle activation of the Flexor Digitorum Superficialis and Profundus during different taping condition compared to no finger tape.

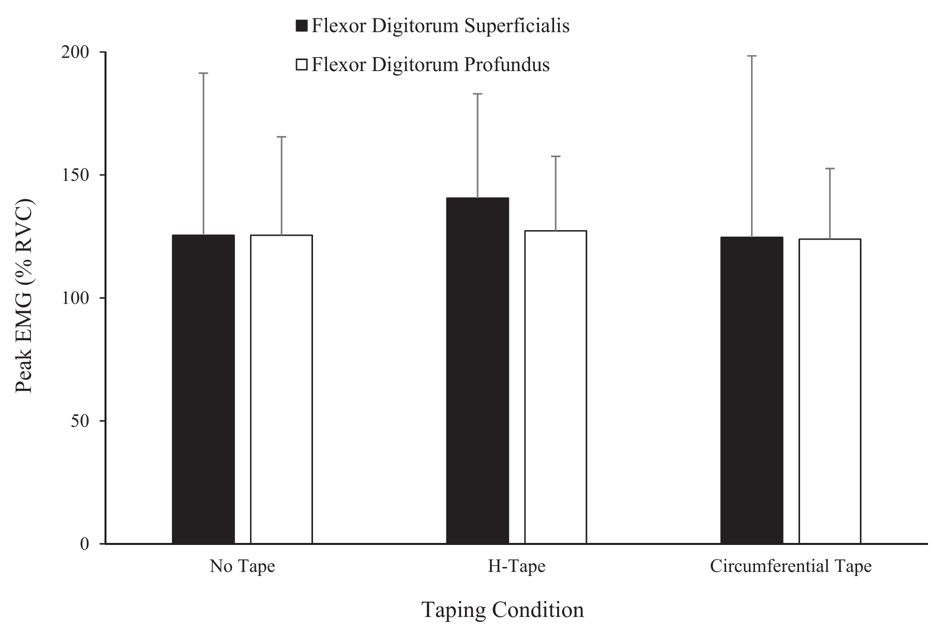

Fig. 6. Peak muscle activation of the Flexor Digitorum Superficialis and Profundus during different taping condition compared to no finger tape.

Conflict of interest

There are no conflict of interest or financial disclosure.

Acknowledgement

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jelekin.2019.01.004.

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Julianna Johnson obtained her Bachelor's degree in Exercise Science at Eastern Washington University in Cheney, WA (2016) as a direct transfer of her Associate's degree in General Science from Centralia College (2014). She is currently earning her M.S. degree in Kinesiology at Western Washington University with her thesis emphasizing on proprioception and joint position sense. Julianna is a certified coach for United States Soccer Federation (USSF) with a level E license and plans on continuing her education in her pursuit for her National Strength and Conditioning Association certifications (NSCA).

Jun G. San Juan received his Bachelor's degree in Sport Science at the University of the Philippines in Diliman, Quezon City (2000). Dr. San Juan earned his M.A. degree in Physical Education with a major in Biomechanics and Athletic Training at San Diego State University (2003). He then continued graduate school at the University of Oregon and finished his PhD in Human Physiology specializing in Biomechanics (2009). Dr. San Juan is a certified Athletic Trainer and is currently an Associate Professor of Kinesiology at Western Washington University. His research interests includes assessment of the biomechanics of shoulder and running related injuries.