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Original Research

Electromyography-based evaluation of extensor pollicis longus muscle activities in healthy volunteers fitted with a rubber band traction apparatus

Chimi MIYAMOTO, OTR, PhD* — *Department of Occupational Therapy, Faculty of Health Sciences, Aino University, Japan*

Akira MIYAMOTO, RPT, PhD — *Department of Physical Therapy, Faculty of Health Sciences, Kobe International University, Japan*

Kenji KANEKIYO, PhD — *Department of Physical Therapy, Faculty of Rehabilitation, Biwako Professional University of Rehabilitation, Japan*

Norihiko NAKANO, Dr. PhD — *Department of Physical Therapy, Faculty of Rehabilitation, Biwako Professional University of Rehabilitation, Japan*

Chi ZHANG, Dr. PhD — *Rehabilitation Medicine Department, The Affiliated Hospital of Southwest Medical University, Luzhou, Sichuan, People's Republic of China*

Shuhei TAKAHATA, OTR, M. ed — *Department of Occupational Therapy, Faculty of Health Sciences, Aino University, Japan*

Shingo YAMANE, OTR, PhD — *Department of Occupational Therapy, Faculty of Health Sciences, Aino University, Japan*

Hiroshi SAKAI, OTR, PhD — *Department of Occupational Therapy, Faculty of Health Sciences, Aino University, Japan*

Chizuka IDE, Dr. PhD — *Department of Occupational Therapy, Faculty of Rehabilitation, Biwako Professional University of Rehabilitation, Japan*

*Correspondence author : Chimi MIYAMOTO, OTR, PhD E-mail : c-miyamoto@ot-u.aino.ac.jp

Abstract

The author conducted experimental studies of active flexion/passive extension of the IP・MP joints of thumbs fitted with a Dynamic Extension Splint by using and not using rubber band traction apparatus, and evaluated the electromyographical wave pattern and electromyographic muscle activities of the EPL and FPL of eight healthy male adults. Statistically significant differences were not detected between the experimental (passive extension using rubber band traction apparatus) and control (active extension) groups. The authors concluded that there is a limitation of the effectiveness of active flexion/passive extension of the IP・MP thumb joints conducted with a rubber band traction apparatus as a postoperative early motion therapy for EPL tendon rupture.

Key words : Electromyography, Extensor Pollicis Longus (EPL), healthy adults, fine wire electrode

Introduction

Extensor Pollicis Longus (EPL) tendon rupture is one of the most common tendon injuries of the hand. Adhesions formed around the sutured tendon cause decreased gliding distance of the repaired tendon. To prevent adhesion formation, early motion of the thumb is advised in postoperative treatment programs, which is typically designed with active flexion and/or passive extension of the IP and MP joints using a rubber band traction apparatus fitted with a Dynamic Extension Splint. However, evaluations of the efficacy of early motion protocols are so far not fully studied.

Evans and Burkhalter[1] reported that under surgical observation, passive flexion of the IP joint with the wrist in a neutral position mobilized the EPL tendon by 5 mm at the lister's tubercle. Further, they noted that this passive tendon mobilization prevented postoperative adhesions. These data were obtained from fresh cadavers or surgical findings.

In another study, Chen (Miyamoto) et al. also conducted a study to determine the efficacy of early motion in preventing EPL tendon adhesion[2]. In this approach, the gliding distance of the EPL at the dorsal surface of metacarpal bone (zone 4) was measured *in vivo*, while the angle of the carpometacarpal (CM) joint was fixed at a constant angle during passive flexion and extension of the IP/MP. These measurements were conducted in healthy adults. The gliding distance of the EPL was only 2.49±1.02 mm when the wrist was fixed in an extension position of 30°. The efficacy of preventing adhesion with early motion therapy with passive flexion and extension of the IP and MP joints was not supported by these findings because the gliding distance is too small.

In the present study, experiments were conducted to study the muscle motion patterns of the EPL during IP/MP joint motions with a universal joint splint. Passive extension of the IP・MP joints of thumbs was achieved by using rubber band traction apparatus. The intensity of EPL muscle activity was compared between active flexion/passive extension motion and active flexion/active extension motion. As a reference for EPL muscle activity, that of the flexor pollicis longus (FPL) was measured.

Materials/Subjects

Enrollment

Eight healthy male volunteers (mean age, 21.75±0.43 years) were enrolled. Body Mass Index (BMI) was recorded using a platform scale, thumb lengths were measured using a caliper, and total active motion of the thumb IP/MP joint was measured using a goniometer. Subsequently, the relationship between EPL muscle force and IEMG of the EPL was analyzed.

All volunteers gave written consent prior to participating this study. This study was approved by the ethical committee of the Sapporo Medical University (Approval No. 20-1-21).

Methods

Electromyogram (EMG)

Fine Wire Electrodes were inserted and left in place during the measurements, during which the subjects remained in a seated position with a telemeter communicator around the waist. The electrode was inserted by an experienced doctor guided by the EMG manual[3]. For the EPL at the maximum pronation of the forearm, the electrode was inserted at the central half of the forearm to the radial border of the ulna through the extensor carpi ulnar. For the FPL at the maximum supination of forearm, the piercing was made at the central half of the forearm to the radial border of the palm side through the flexor carpi radials and the superficial flexor muscle. The electrodes were inserted using ultrasound guidance. After proper skin preparation and isolation of the particular muscle, dual 50 mm insulated wires with 2-3 mm barbed tips were inserted in the EPL and FPL muscles using a 25-gauge hypodermic needle as a cannula. The wires were then attached to leads that were insulated from ground plates and taped to the subject's body. The signals from the leads were transmitted using an AM-FM telemetry system (NIHON KOHDEN) capable of transmitting data from two muscles simultaneously. The EMG information was filtered at a range of 50-500 Hz, and was recorded on a multichannel instrument recorder for later retrieval, as described previously[4]. The EMG data were converted from analog to digital signals at a sampling rate of 1000 Hz, and were quantified by computer integration (KISSEI COMTEC, Inc. TOSHIBA K20 180 E/W) . The cutoff frequencies of the signal filter were set at 50 and 500 Hz in order to obtain the flat portion of the impulse. The sweep Speed was set to 10～50 msec/div. The amplifier sensitivity was set to 50 μV～5 mV/div. The measurement was carried out in a shielded room. Prior to testing, each subject was allowed to warm up until he felt comfortable with the EMG wires. The CH 1 of the EMG was set to detect the EPL muscle activity signal, while the CH 2 was set to detect the FPL muscle activity signal. In order to normalize for movement of the IP joint, CH 3 was set to detect the electric goniometer signal. The motor trajectory of thumb was recorded at three phases: flexion, flexion holding, and extension. Hand fixation was conducted using a universal joint splint. The wrist joint was fixed at a 30° dorsal extension. The CM joint was fixed at a 30° radial abduction and a 30° palmar radial abduction. The IP and MP joints were not fixed.

Passive extension of the thumb

Similar to a common dynamic extension splint, the universal joint splint was equipped with a rubber band traction system. The spring constant of the rubber band was 0.02 N/m. In order to reduce the friction between the rubber and the nylon band, two pulleys were fitted. The rubber band was fixed from a natural state to a 10 mm extension, and motions were started from the IP/MP joint at a 0° extension using a metronome (Figure 1-(a)).

Thumb movement

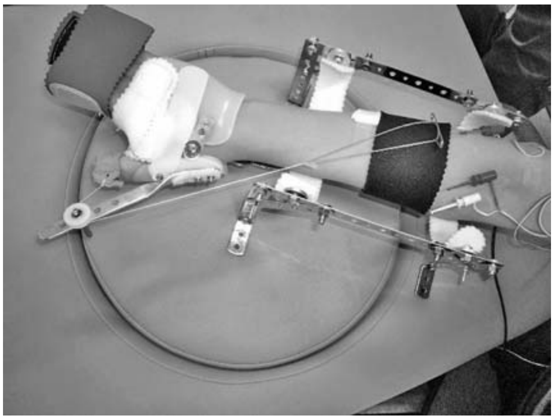
In the flexion phase, the tip of thumb moved from the flexion 0° to the maximum flexion of the IP and MP joints toward the proximal palmar crease in 3 sec. The thumb then held in the maximum flexion position for 3 secs in a flexion holding phase. Finally, the IP and MP joints were moved from the maximum flexion to 0° extension in 3 secs by active flexion/passive extension and active flexion/extension, respectively. This phase was termed the extension phase (Figure 1-(b), (c)).

Data analysis

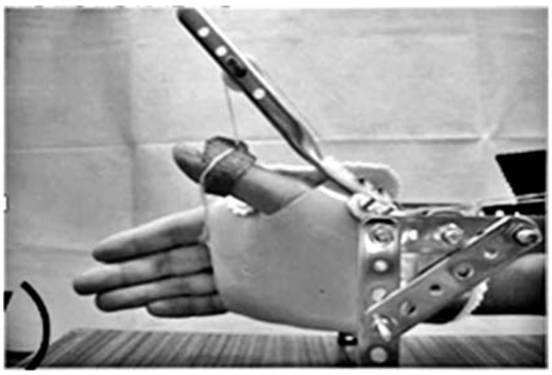
Data were processed and evaluated for normality. All signals were then rectified and smoothed. The first 1 sec and the final 1 sec of the rectified 5-sec EMG data obtained from the EPL and FPL muscles were removed, and the remaining 3 sec data were integrated to obtain the maximal IEMG. The averaged percentages of IEMG and SD were then calculated for muscles in each phase.

Statistical analyses

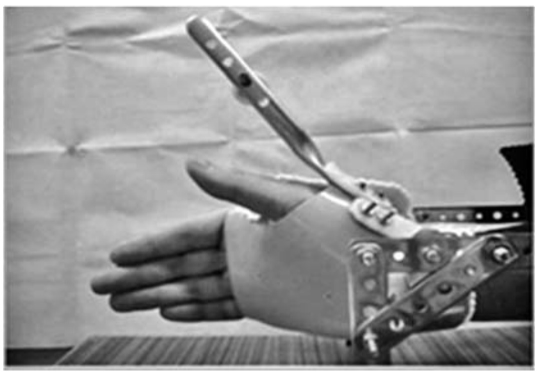
Data for the %IEMG of both muscles in each



(a)



(b)



(c)

Figure 1 (a) hand fixation was done by using a universal joint splint, (b) Active flexion/passive extension, and (c) active flexion/extension phase were analyzed. A Student's t-test was applied to compare the %IEMG of active extension motion to that of passive extension motion. In addition, the Pearson correlation method was used to compare the BMI, thumb length, and thumb ROM values under different muscle activities. $p<0.05$ was considered statistically significant.

Results

Relationship between EPL Muscle Force and IEMG of EPL

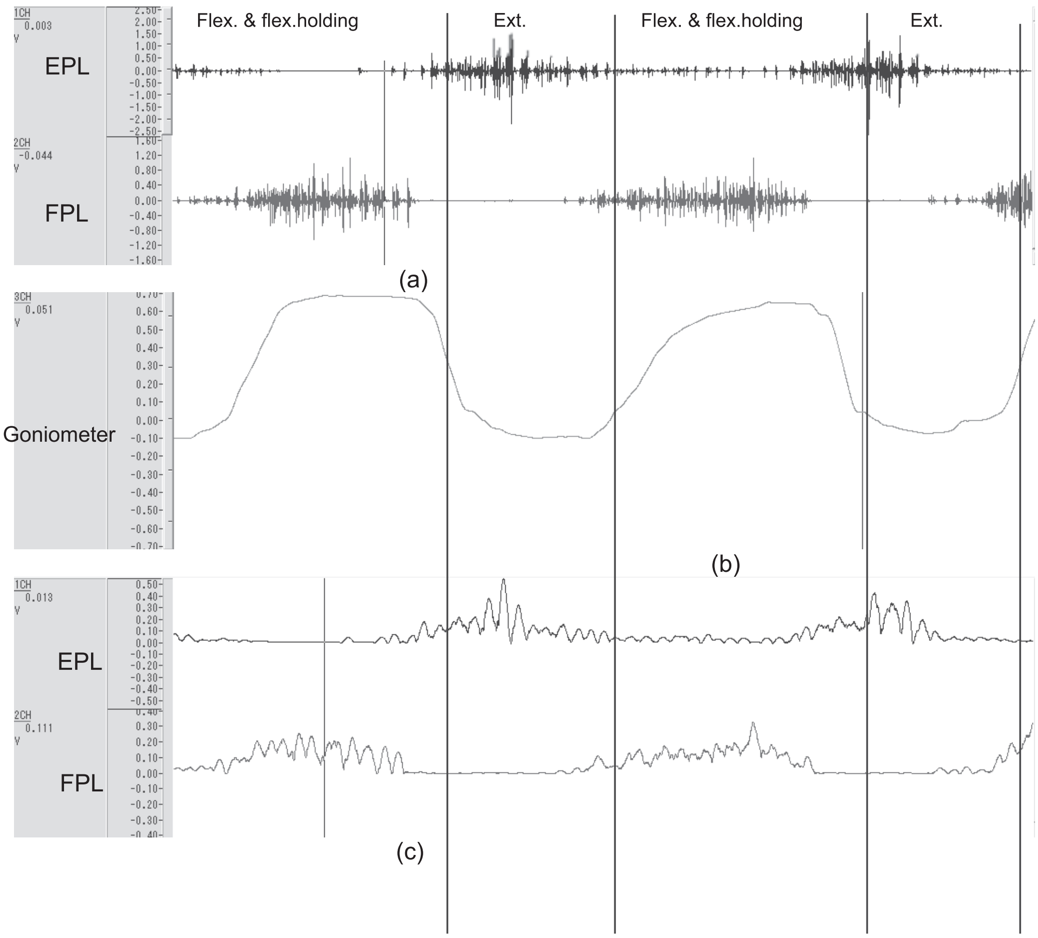
EPL muscle force and IEMG of the EPL were highly correlated, with ($r=0.97$, $p=0.05$).

Raw EMG signals of EPL and FPL muscles

Raw EMG signals collected from EPL and FPL muscles in passive flexion/passive extension motion with rubber band traction are shown in Figure 2. EPL muscle activity in the extension phase and FPL muscle activity in the flexion and flexion holding phases were increased. However, EPL muscle activity was still observed during the flexion and flexion holding phases. Raw EMG signals collected from EPL and FPL muscles in active flexion/active extension motion are shown in Figure 3. Muscle activity patterns measured in this experiment were similar to that of the previous experiment with rubber band traction shown in Figure 1. In conclusion, based on the two experiments, there was no statistically significant difference in EPL muscle activity pattern between passive extension and active extension phases.

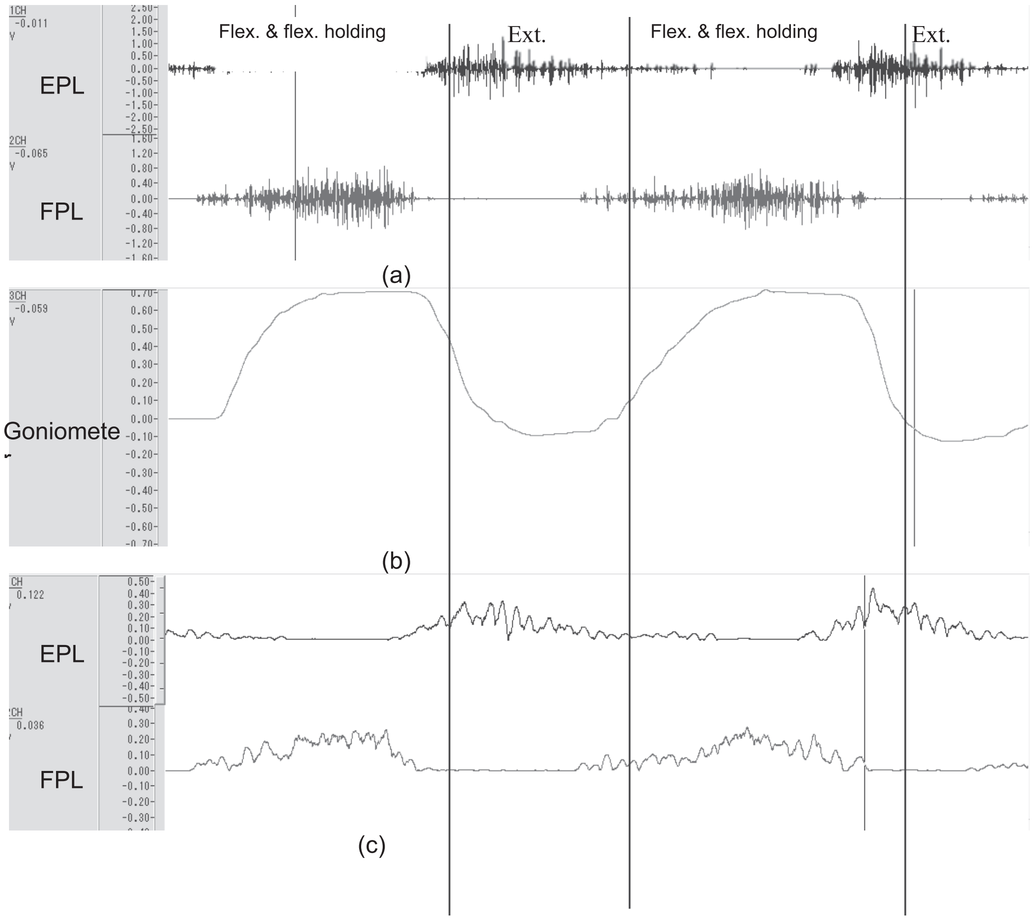
Intensity of muscle activities of the EPL

During the flexion phase, %IEMG of the EPL was 8.53±3.25% in the active flexion/passive extension phase and 7.16±3.46% in the active flexion/extension phase. During the flexion holding phase, %IEMG of the EPL was 4.90±2.12% in the active flexion/passive extension phase and 4.48±1.71% in the active flexion/



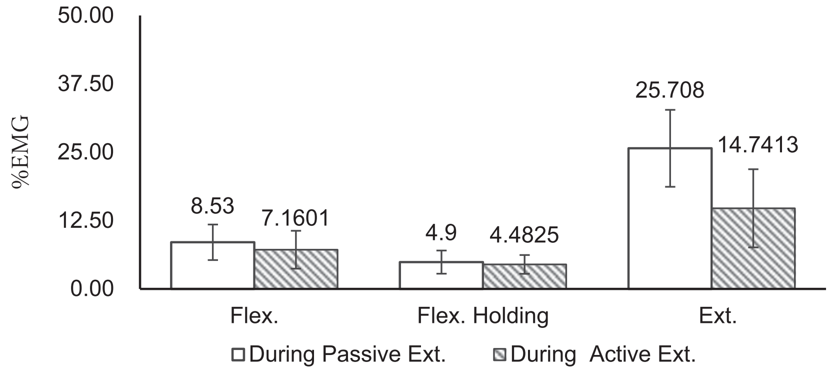
(a) Raw signal of EPL and FPL, (b) goniometer signal, and (c) rectification of the electromyographic signals of the three phases of the EPL and FPL.

Figure 2 Raw Processed Electromyographic Signal of the EPL&FPL during Passive Ext. Motion



(a) Raw signal of the EPL and FPL, (b) goniometer signal, and (c) rectification of the electromyographic signals of the three phases of the EPL and FPL.

Figure 3 Raw Processed Electromyographic Signal of the EPL and FPL during Active Ext. Motion

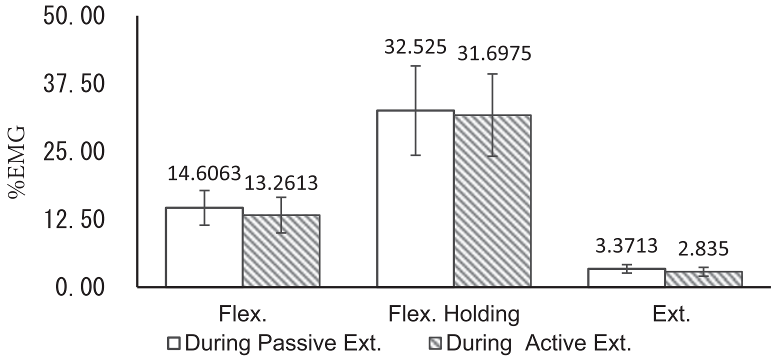


	Flex.	Flex. Holding	Ext.
EPL During Passive Ext.	8.53±3.25%	4.90±2.12%	25.71±7.04%
EPL During Active Ext.	7.16±3.46%	4.48±1.71%	14.74±7.15%

Average±SD (%)

Figure 4 Comparison between %IEMG of the EPL during passive ext. motion and %IEMG of EPL during active ext. motion

extension phase. The muscle activity of the EPL in this phase decreased, but still remained. There was no significant ($p<0.01$) difference between %IEMG in the EPL at the flexion phase and that at the flexion holding phase (Figure 4). The %IEMG of the EPL was 25.71±7.04% during passive extension, and 14.74±7.15% during active extension, which implies that relatively more activity was



	Flex.	Flex. Holding	Ext.
FPL During Passive Ext.	14.61±3.20%	32.53±8.22%	3.37±0.78%
FPL During Active Ext.	13.26±3.28%	31.70±7.58%	2.84±0.81%

Average±SD (%)

Figure 5 Comparison between %IEMG of the FPL during passive ext. motion and %IEMG of the FPL during active ext. motion

detected during passive extension (Figure 4).

Intensity of muscle activities of the FPL

During the flexion phase, %IEMG of the FPL was 14.61±3.20% in the active flexion/passive extension phase, and 13.26±3.28% in the active flexion/extension phase. During the flexion holding phase, %IEMG of the FPL was 32.53±8.22% in the active flexion/passive extension phase and 31.70±7.58% in the active flexion/extension phase. During the flexion holding phase, the muscle activity of the FPL increased more than that of the flexion phase. The %IEMG of the FPL was 3.37±0.78% during passive extension and 2.84±0.81% during active extension, indicating that muscle activity of the FPL remained at a low level in the extension phase (Figure 5).

Discussion

Compared to the flexor muscle tendon, extensor muscle tendon injury in the hand has not been thoroughly studied so far. However, Newport et al[5] demonstrated that flexion disturbance occurs as a result of complex extensor muscle tendon injury. EPL tendon injury is a typical and one of the most common tendon injury to the hand. In the past, a 3–6 week fixation method was a common process suggested by most hand surgeons to help the tendon heal and restore. However, new research revealed that the fixation method frequently promoted adhesion between the EPL and surrounding tissue, resulting in flexion limitations. In the 1990's, early motion therapy was introduced after repair of EPL tendon injury[6–9].

After the extension tendon was repaired, the clinical effect of active extension motion following the physical therapist's instructions was similar to passive extension motion using rubber band traction[10]. Khandwala et al.[11] reported similar outcomes between patients treated with active flexion/passive extension using a dynamic outrigger splint and patients treated with active flexion/extension using a palmar blocking splint.

In order to clarify the influences of passive extension motion and active extension motion of the IP/MP joint on EPL muscle activity, we measured EPL muscle activity using wire electrode electromyography. Our results demonstrated similar patterns of EPL muscle activity during active flexion/passive extension motion and active flexion/extension motion of the thumb IP/MP joint.

As expected, % IEMGs of the EPL during flexion and flexion holding phases were similar, and there was no significant difference between two phases. We also demonstrated that EPL muscle activity in the flexion holding phase was less than that in the flexion phase, but still remained. In the flexion phase and flexion holding phases, we could palpate the tension of the EPL tendon under the subcutaneous surface of the palmar side of the proximal phalanges when the tip of thumb was directed toward the proximal palmar crease. At the same time, adduction movement was present in the thumb CM joint.

The EPL muscle activity patterns of the extension phase were expected to take different patterns between passive and active motions, as passive extension did not require the power of the EPL, but active extension did require the power of the EPL. However, contrary to our expectation, % IEMG of the EPL in the extension phase exhibited higher muscle activity in passive extension although it is not statistically significant. In the extension phase, when the IP/MP joint was extended, extension was detected in the thumb CM joint by palpation. At that time, increased tension of the EPL tendon was confirmed by lifting the tendon in the dorsal surface of the first metacarpal bone (zone 4). These findings suggested that the CM joint movement was directly related to EPL muscle activity.

In this case, there was no statistically significant difference between active extension and passive extension in % IEMG of the EPL. This suggested that no additional muscle activity increase was required for the EPL during active extension of the IP/MP joint. This result could be partially explained by that extension of the MP joint is also associated with the Extensor Pollicis Brevis (EPB) and extension of the IP joint is also associated with the lateral band.

The most important function of the EPL is to extend the thumb IP/MP joint. In addition, because the EPL tendon passes through the dorsal adduction/abduction axis of the CM joint, the EPL tendon applies adduction force to the thumb. Moreover, the EPL tendon applies extension, lateral rotatory and adduction force to the first metacarpal bone. Therefore, there is a high possibility that EPL muscle activity is related to the CM joint movement.

The results of this study clearly showed that there is a possibility of improvement in the present postoperative early motion therapy after the EPL tendon injury. The new early motion technique and therapy, including early motion of the CM joint for EPL injuries, should be evaluated in future studies, which should also include the evaluation of pathological findings that affects the muscle contraction such as edema and scar formation surrounding the tendon after injury.

This study was done with only eight healthy adult male volunteers. The minor surgical procedure associated with fitting fine wire electrodes inhibited the wider entrance of volunteers. The more extensive studies including female volunteers and patients of EPL injury are needed to determine the best treatment for EPL tendon injuries.

Conclusions

The present study evaluated the suitability of the currently widely used technique of passive extension of the thumb for EPL injury. The amount of EPL muscle activity was revealed by using wire electrode electromyography to measure muscle activity during defined motions of active flexion/passive extension and active flexion/extension in eight healthy male volunteers with rubber band traction apparatus for passive extension. The results did not suggest an obvious difference between %IEMG in the EPL between active extension and passive extension motions. In addition to the main result, it is suggested that the EPL activity is also related to the CM joint movement. In the future, in order to increase the gliding distance of the EPL, it is necessary to study the active flexion/extension motion of the thumb, including that of the CM joint, under physician guidance.

Disclosure of Conflicts of Interest

The authors have no conflicts of interest directly relevant to the content of this article.

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