Electromyographic Activities during Isometric Contraction of Interphalangeal Joint Extensors of the Finger

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Objective: *To investigate which hand muscles were used for interphalangeal joint (IP) extension when holding the metacarpophalangeal joint (MCP) in 90° flexion, 0°, and full hyperextension.*

Material and Method: *Fifteen volunteers extended IP when MCP was manually maintained in 90° flexion, 0°, and full hyperextension for 5 seconds with and without maximal manual resistance twice each. Maximal resistance was ensured and maintained manually by the actions of both researcher and subject. By using needle electromyography, the root mean square(RMS)* values representing the muscle function of the extensor digitorum communis(EDC), lumbrical, and interosseous muscles of the middle fingers of the dominant hands were recorded and averaged from the two tests conducted on each subject.*

Results: *In 87% of the subjects, EDC had the highest RMS value in 90° MCP flexion without resistance, and in 100% of them, it had the highest value in both 90° MCP flexion and 0° with resistance. There were no clear differences between the three muscles when extended in all other positions. When the same muscles were compared, it was found that EDC had the highest value in 90° MCP flexion, especially without resistance. Its RMS values were significantly increased when the resistance was applied in all positions. It was also found that the lumbrical and interosseous muscles had the highest RMS values in full hyperextension.*

Conclusion: *EDC had the highest muscle activity for IP extension in 90° MCP flexion, especially when the resistance was applied. However, the activities among the three muscles could not be clearly differentiated when extended in other positions.*

Keywords: *EMG activity, Intrinsic hand muscle, Extrinsic hand muscle, Interphalangeal joint, Metacarpophalangeal joint*

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In 1964, Long and Brown[1,2] studied the electromyographic kinesiology of the hand muscles for moving the long finger with regard to the time relationships of muscle contraction. They concluded that the extension of the interphalangeal joint (IP) with self holding the metacarpophalangeal joint (MCP) flexion is primarily produced by the lumbrical and interosseous muscles. The extensor digitorum communis (EDC) and lumbrical act synergistically to maintain MCP extension and to produce IP extension. The lumbrical predominates when MCP is flexing or flexed, and the function of EDC equals that of the lumbrical or predominates when MCP is extending or held extended. The interosseous acts as a reserve extensor of IP in reinforcing the function of the lumbrical. The anatomy and physiology of the finger extensors, as studied by Tubiana and Valentin[3,4], have revealed that the extensor action of the lumbrical on IP is effective when MCP is in flexion or extension. The interosseous is capable of extending IP only when MCP is stabilized in extension. The EDC acts as the extension of IP whenever MCP must be in extension or flexion, but never hyperextension. Srinivasan[5] found that in complete median and ulnar nerve palsied patient, the long extensor produces simultaneous extension at MCP and PIP but

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cannot achieve full PIP extension.

In a complete ulnar nerve palsied patient, the rate and extent of associated MCP extension are diminished and the patient still cannot fully extend PIP(6). In the clinical texbook examination of Aulicino and Thiomine(7,8), it is noted that the interosseous and lumbrical are of fundamental importance in extension of IP and flexion of MCP.

At present, the exact functions of the intrinsic and extrinsic hand muscles for IP extension are still questionable. Almost all of the studies obtained the activities of IP extension during moving MCP, but in clinical practice, the authors usually test the muscle action for IP extension without and with manual resistance while MCP is stabilized in different positions. Thus, the authors need to know which hand muscle is actually used for IP extension while holding MCP in the same positions as we generally apply in physical examination.

Many studies(9-15) have consistently confirmed that the electromyographic signals recorded by root mean square(RMS) value can represent the muscle functions. The root mean square is the square root of the mean square voltage over the period of interest, indicates the effective power that the voltage will deliver to a resistance load. It is often used to regulate muscle force, biofeedback training, muscle fatigue, and muscle action(9). The objective of the present study was to evaluate the activity of the muscles that extend the IP joints of the long finger.

Study subjects

Fifteen healthy volunteers who recruited for the present study consisted of 5 men and 10 women, age 21-43 (31.47) years, and 12 of them were right hand dominants.

The subjects were excluded on those having neurological and musculoskeletal problems of the upper limbs, bleeding disorders, taking antiplatelet and anticoagulant medications, and a history of allergic reaction to anesthetic agents. Each subject had been fully informed about the objective of the experiment. They read and signed an informed consent form approved by the Ethic Committee on Human Experimentation of Faculty of Medicine, Ramathibodi Hospital, Mahidol University.

Material and Method

Each subject was trained to use the long finger of the dominant hand to extend IP while his/her MCP was manually stabilized in 90° MCP flexion, 0°, and full hyperextension until he/she could correctly follow the procedure. The anesthetic cream (EMLA® 1g: Lidocaine 25 mg, Prilocaine 25 mg) was pasted on the skin at all three positions where the needle electrodes would be inserted and left for half an hour. The subject sat in the chair with the elbow comfortably flexed about 70° on the table. The wrist was stabilized in 0° position with plastic restrained splints. A ground surface electrode was placed over volar surface of the distal forearm(1). A monopolar needle electrode was inserted into EDC at proximal 1/3 of the forearm between ulna and radius(16) and the reference surface electrode was placed 1 cm away from the needle insertion(1) (Fig. 1). The needle was moved until the motor unit action potentials were correctly recorded. Then, he/she actively extended IP of the long finger while MCP was stabilized in 90° MCP flexion by a researcher's hand (Fig. 2) and maintained for 5 seconds. The root mean square (RMS) values were recorded and averaged. The procedure was repeated twice with the maximal resistance toward IP extension from the researcher's other hand (Fig. 3) for 5 seconds and RMS values were recorded. After that, the positions of MCPs were changed to 0° (Fig. 4, 5) and then to full hyperextension (Fig. 6, 7). The RMS values were then again recorded respectively.

Next, the recording needle electrode was moved into 3rd dorsal interosseous muscles at just radial to the 3rd metacarpal bone over the transmetacarpal line at the level of the 1st MCP joint(17) (Fig. 8) and the 2nd lumbrical muscles at just proximal to the 3rd MCP and radial to the long flexor tendon(18) (Fig. 9) respectively. The reference surface electrode was placed at the dorsal surface of the ulnar styloid(1). The RMS values were thereafter recorded in the same sequence as EDC.

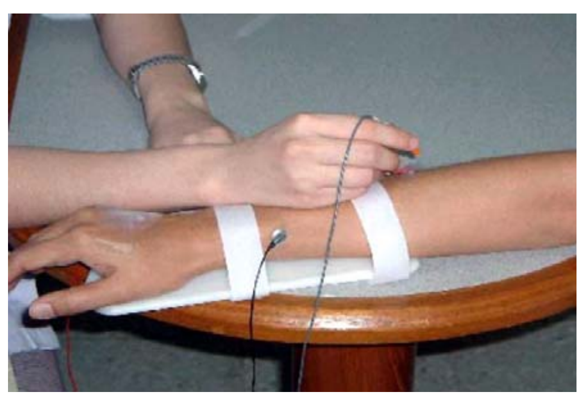

Fig. 1 The position of needle examination of EDC muscle

Fig. 2 The subject extended IP while MCP was hold in 90° flexion by the researcher

Fig. 3 The subject extended IP while the researcher hold MCP in 90° flexion and maximally resisted IP extension

Fig. 4 The subject extended IP while the MCP was hold in 0° by the researcher

Fig. 5 The subject extended IP while the researcher hold MCP in 0° and maximally resisted IP extension

Fig. 6 The subject extended IP while MCP was hold in full hyperextension by the researcher

Fig. 7 The subject extended IP while the researcher hold MCP in full hyperextension and maximally resisted-IP extension

Fig. 8 The position of needle examination of dorsal interosseous muscle

Fig. 9 The position of needle examination of lumbrical muscle

Statistical analysis

The average RMS values of all subjects in each muscle acting in the same positions of MCP were compared by descriptive statistics. Analysis of the data by ANOVA using SPSS version 12.0 was performed to compare the average RMS of each position in the same muscle. When comparing no resistance with having resistance in the same positions of the same muscles, the unpaired t-test was employed. A p-value of less than 0.05 was considered statistically significant.

Results

Regarding the average RMS of all subjects in the same MCP positions (Table 1), it was found that EDC had the highest value while MCP was in 90° flexion, both actively maintained IP extension by the subject and with researcher's resistance, in 87% and 100% of the subjects, respectively. Additionally, in 100% of the subjects it also had the highest RMS value in 0° with resistance. No obvious difference of the average values was found in the other positions. Interestingly, for IP extension when MCP was in 90° flexion, either actively maintained by the subject or with researcher's resistance, nobody gave the highest RMS value in the interosseous muscle.

When compared within, each muscle acted on different MCP positions while IP extension was actively maintained by the subject (Table 2); it was found that the average RMS value of all subjects was highest in EDC when MCP was in 90° flexion. The interosseous and lumbrical had highest RMS values in full hyperextension. They were all significantly different when compared with each position.

In case of having resistance for IP extension (Table 3), EDC still had highest value in 90° MCP flexion but was not significantly different from the other positions, whereas the interosseous and lumbrical still had the highest RMS values in the same position as no

Table 1. Number of subjects (%) who had the highest RMS of the muscles acting on IP extension while MCP was maintained in 90° flexion, 0° and full hyperextension

Position of MCP when IP extension	Maximal manual resistance	No. (%) of subjects who had highest RMS in each muscle		
		EDC	Interosseous	Lumbrical
90° Flexion	No	13 (87%)	0 (0%)	2 (13%)
	Yes	15 (100%)	0 (0%)	0 (0%)
0°	No	8 (53.4%)	2 (13.3%)	5 (33.3%)
	Yes	15 (100%)	0 (0%)	0 (0%)
Full hyperextension	No	4 (27%)	6 (40%)	5 (33%)
	Yes	8 (53.4%)	2 (13.3%)	5 (33.3%)

Table 2. The average RMS of all subjects in each muscle acting on different MCP positions without resistance

Muscle	Average RMS of all subjects in each MCP position			p-value
	90° Flexion	0°	Full hyperextension	
EDC	343.17	201.93	232.13	0.011*
Interosseous	128.80	108.47	267.53	0.004*
Lumbrical	134.33	173.43	262.30	0.002*

Table 3. The average RMS of all subjects in each muscle acting on different MCP positions with resistance

Muscle	Average RMS of all subjects acting with resistance in each MCP position			p-value
	90° Flexion	0°	Full hyperextension	
EDC	504.20	480.97	407.00	0.278
Interosseous	177.60	162.17	290.50	0.030*
Lumbrical	168.67	209.30	290.50	0.008*

Table 4. The average RMS of all subjects in each muscle acting on different MCP positions compared no resistance with having resistance

Muscle	Position of MCP when IP extension	Average RMS of all subjects		p-value
		No resistance	With resistance	
EDC	90°Flexion	343.17	504.20	0.007*
	0°	201.93	480.97	<0.001*
	Full hyperextension	232.13	407.00	0.008*
Interosseous	90°Flexion	128.80	177.60	0.321
	0°extension	108.47	162.17	0.153
	Full hyperextension	267.53	290.50	0.708
Lumbrical	90°Flexion	134.33	168.67	0.346
	0°extension	173.43	209.30	0.264
	Full hyperextension	262.30	290.50	0.487

* Statistical significance different

resistance and were significantly different from each position.

When comparing between actively maintained IP extension by the subject and having researcher's resistance (Table 4), the average RMS of EDC was significantly increased, but it did not increase in the other two muscles.

Discussion

Most subjects had the highest RMS of EDC in the action of IP extension when MCP was passively maintained in 90° flexion and all of them had highest EDC activities in 90° MCP flexion and 0° with resistance (Table 1). When compared itself in different positions, both no resistance and having resistance (Table 2, 3), it had the highest RMS in the 90° flexion as well, whereas the interosseous and lumbrical muscles had higher values than EDC in full hyperextension (Table 2). It might be explained by its large size, but in the other positions, especially in full MCP hyperextension, there were the highest RMS values in the other two smaller muscles. Many authors(1-8) have shown that the extension of IP joint while the MCP is in different position uses different muscles. There are many researches(9-15) indicating that RMS value is proportional to the muscle function and force. Thus, it seemed that EDC acted mostly as IP extension while MCP was stabilized in 90° flexion, and with manual resistance, it had significantly more activity. Although the interosseous and lumbrical had a lot of activities in 0° and full hyperextension, the RMS values were not distinctly different from those of the EDC.

This finding was in agreement with that of Tubiana(3,4) but in contrast with the study of Long and Brown(1,2) and Srinivasan(5,6). This might be because their studies obtained the muscle activities during joint movements, which there were changes in length of the muscles. However, the present study recorded the isometric contraction of the muscle with no motion of the MCP. Moreover, almost all of the interosseous and lumbrical muscles had two insertions terminated into the proximal phalanx and extensor.

Apparatus(19,20). When passively flexed the MCP, these muscles were loosened and ineffectively contracted to extend the IP whereas EDC was slightly stretched so it should effectively extend IP. When MCP was in passive full hyperextension, these muscles were slightly stretched and better extended IP.

It was possible that the position for clinical examination tested by IP extension when maintained 90° MCP flexion tends to be the main action of EDC, particularly when added by the manual resistance. Thus, it was not surprising to find that the patients could extend IP whether MCP was held flexed or extended in cases of complete ulnar nerve palsies, whereas in cases of complete radial nerve palsies, the patients could extend IPs when MCPs were stabilized in extension.

A major drawback of the present study was that it was a pilot study using only 15 subjects. The manually holding of the MCP positions and manually resistant IP extension by the researcher could not insure the consistency of the resistance, although this procedure was performed by the same researcher and all subjects had tried their best to maximize the force in each position, so the RMS values might not be exactly correct. However, these positions were the same as those usually used in clinical examination.

Another limitation in the present study was that RMS values were recorded with needle electrodes to cut off the signal interference. Due to different size and shape of the three muscles and no reference value from prior study, RMS value recorded by needle electrode could not be directly compared between each muscle so the authors had to analyze by descriptive statistics. The authors were also aware of pain from the needle electrodes during muscle contractions, so the local anesthetic agent (EMLA®) was applied before needle insertion and the subject had enough time to rest during each action. The problems of the needles moving away from the recording area, due to the rather small size of the intrinsic hand muscles, were prevented by finding out and recording only the motor unit action potentials with rise time less than 500 microseconds and precise sound.

In conclusion, the isometric extension of IP, when MCP was held in 90° flexion, was found to be the main action of EDC. Moreover, when the manual resistance was applied, EDC was significantly increased in its activity. The dorsal interosseous and lumbrical muscles were likely to act on isometric IP extension when MCP was maintained in full hyperextension. This was contrary to previous knowledge.

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การศึกษาการทำงานของกล้ามเนื้อที่ใช้ในการเหยียดข้อนิ้วมือด้วยเครื่องตรวจไฟฟ้ากล้ามเนื้อ

วรรณภา เลิศประภามงคล, รัชวรรณ สุขเสถียร

วัตถุประสงค์: *ศึกษาการทำงานของกล้ามเนื้อภายในมือกับกล้ามเนื้อภายนอกมือในการเหยียดข้อนิ้วมือเมื่อข้อโคนนิ้วมืออยู่ใน 3 ท่า คือ งอ 90 องศา เหยียดตรง และเหยียดสุด ทั้งขณะที่ไม่มีและมีแรงต้าน*

รูปแบบการวิจัย: *การวิจัยเชิงพรรณนา*

กลุ่มที่ถูกทำการวิจัย: *อาสาสมัครจำนวน 15 ราย*

วัสดุและวิธีการ: *วัดการทำงานของกล้ามเนื้อ extensor digitorum communis (EDC), lumbrical และ interosseous ของนิ้วกลางของมือข้างที่ถนัด ขณะผู้รายงานยึดข้อโคนนิ้วมือให้อยู่ในท่างอ 90 องศา เหยียดตรงและเหยียดสุด และอาสาสมัครเกร็งเหยียดข้อนิ้วมือ 5 วินาที โดยไม่มี และมีแรงต้านเต็มที่จากผู้รายงาน บันทึกค่า RMS ด้วยเครื่องตรวจไฟฟ้ากล้ามเนื้อ*

ผลการศึกษา: *ในการเหยียดข้อนิ้วมือขณะที่ข้อโคนนิ้วมืองอ 90 องศาและไม่มีแรงต้าน 87% ของอาสาสมัคร มีค่า RMS สูงสุดอยู่ที่กล้ามเนื้อ EDC และ อาสาสมัครทุกรายมีค่า RMS สูงสุดที่กล้ามเนื้อ EDC ในการเหยียดข้อนิ้วมือในท่าที่ข้อโคนนิ้วมืออยู่ในท่างอ 90 องศาและเหยียดตรงโดยมีแรงต้าน ส่วนในท่าเหยียดตรงไม่มีแรงต้าน และท่าเหยียดสุดทั้งมีและไม่มีแรงต้าน ค่า RMS สูงสุดกระจายไปในกล้ามเนื้อทั้ง 3 มัด เมื่อเปรียบเทียบภายในกล้ามเนื้อมัดเดียวกัน พบว่า กล้ามเนื้อ EDC มีค่า RMS สูงสุดเมื่อข้อโคนนิ้วมืองอ 90 องศา การเพิ่มแรงต้านทำให้ค่า RMS ของกล้ามเนื้อ EDC สูงขึ้นในทุก ๆ ท่าอย่างมีนัยสำคัญทางสถิติ สำหรับกล้ามเนื้อ lumbrical และ interosseous มีค่า RMS สูงสุดในท่าที่ข้อโคนนิ้วเหยียดสุด และการเพิ่มแรงต้านทำให้ค่า RMS เพิ่มขึ้นแต่ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ*

สรุป: *การเหยียดข้อนิ้วมือเมื่อข้อโคนนิ้วอยู่ในท่างอ 90 องศา ทั้งไม่มีและมีแรงต้าน ใช้กล้ามเนื้อ EDC มากที่สุด ส่วนในกรณีที่ท่าข้อโคนนิ้วเหยียดตรงและเหยียดสุด ไม่สามารถระบุการทำงานของกล้ามเนื้อทั้ง 3 มัดได้ชัดเจน*