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### Cover Page Footnote

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## A Critical Review of the Abductor Pollicis Longus Electromyographic Activity

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### **Abstract**

*The aim of this study was to review the current evidence of the abductor pollicis longus electromyographic activity during thumb movements. The author performed an electronic thorough search for EMBASE, MEDLINE, CINAHL, and Web of Knowledge articles. Nine pieces in particular were found to explore the electromyographic activity of the abductor pollicis longus during thumb functional and non-functional movements. Consistent results were noticed, all emphasizing the key role of abductor pollicis longus in stabilizing the thumb's carpometacarpal joint. All target studies provided useful information about the abductor pollicis longus electromyographic activity. However, none of them examined the relationship between abductor pollicis longus electrical activity and thumb functional movements during functional hand use. Besides, these studies did not provide a firm conclusion as to the nature of the activity of the abductor pollicis longus during pinch and power grip strength, and the findings were somehow contradictory. Further studies are highly recommended to give an insight into the abductor pollicis longus electromyographic activity during thumb functional use. The gender differences of abductor pollicis longus electromyographic activity associated with kinematic motion analyses would be a core issue in future research.*

**Keywords:** *Thumb, abductor pollicis longus, electromyography.*

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## Introduction

The Abductor Pollicis Longus (APL) has been used frequently in reconstructive surgery of Osteoarthritis (OA) at the base of the thumb (Robinson et al., 1991; Kaarela and Raatikainen, 1999; Sigfusson and Lundborg, 1991; Chang and Chung, 2008; Mathoulin et al., 2008; Saehle et al., 2002; Kochevar et al., 2011; Avisar et al., 2013; Soejima et al., 2006; Sirotakova et al., 2007). Although these surgical studies reported significant improvement of the thumb and hand function, hand function tests were not used. Therefore, it was hard to interpret the effect of APL tendon transfer on thumb function. Furthermore, reported improvements of grip and pinch strength of patients are not valid when compared to a healthy population of the same age and sex. This is because the relevant literature compared grip and pinch strength improvements with strength measurements on the contralateral hand of the same patients without considering the possibility of these patients having a bilateral disease.

Cadaveric studies revealed inconsistent findings regarding the primary function of the APL muscle. For instance, an experimental study (Smutz et al., 1998) of the moment potentials of thumb muscles, using six frozen cadaveric arms, concluded that the APL, the Abductor Pollicis Brevis (APB) and Flexor Pollicis Brevis (FPB) are the main thumb's Carpometacarpal (CMC) joint abductor muscles. However, an experimental study (Li et al., 2008) on 10 cadaveric arms found that APL did not significantly abduct the thumb's CMC joint.

Although anatomical studies have concluded that the APL tendon has multiple slips which can be removed as a deforming force without thumb abduction weakness (El-Beshbishy and Abdel-Hamid, 2013; Dos Remédios et al., 2005), the complex functional role of the APL in thumb mechanics remains unclear. Because of the overlapping kinematic function of the individual muscles, a specific movement could be generated by multiple muscles. For example, extension and supination at the thumb's CMC joint can be achieved by the APL, EPB and EPL (Li et al., 2008). Moreover, the kinematics generated by a muscle is more complex than its anatomically implied function, because a single muscle can generate movements in multiple directions across multiple joints. For instance, the APL, an abductor by name, produces extension and supination at the CMC joint, but little abduction (Li et al., 2008). At the same time, it was found that healthy people select different combinations of thumb muscles to accomplish a functional goal (Gustafsson et al., 2011; Johanson et al., 1996). Therefore, the function of the APL should be explored using an Electromyographic (EMG). The present effort seeks to provide an overview of

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the APL EMG activity during thumb functional and non-functional movements. Literature concerning the EMG analysis of the APL is reviewed in an attempt to make a synthesis of the available information, with implications for researchers and clinicians.

## **Method**

### **Search Strategy**

A comprehensive search of the following electronic databases was performed: EMBASE, MEDLINE, CINAHL, and Web of Knowledge. The key terms were “thumb”, “function”, “abductor pollicis longus”, and “electromyography”. A combination of these keywords was used. The search was done in English and only results in English were considered, and without customizing time. Reference lists of relevant articles were searched to identify any other studies evaluating APL EMG activity.

### **Inclusion/ Exclusion Criteria**

With the aim of reviewing the literature in a systematic way, the articles were selected according to the following criteria:

- a) Articles that used intramuscular or surface EMG procedure to measure the APL muscle activity.
- b) Articles that examined and analyzed the APL EMG activity during the measurement of functional or non-functional grip movement.

### **Data Extraction**

The author screened the titles and abstracts of articles. As it was not always possible from the abstract to ascertain details, the author first identified all papers including EMG of the thumb and hand muscles. The full texts of articles were then inspected to obtain details of the muscles tested and EMG values. Data extraction checklist was used to obtain data on the size of the samples, EMG assessment method, and thumb movements tested.

## **Results**

Nine articles were found to meet the inclusion criteria. Table 1 shows the reviewed articles according to the sample size, EMG recording procedure, thumb movements tested, and results.

## **Discussion**

The reviewed articles in this study were not a hundred percent comparable as they varied greatly in their sample size, EMG assessment method, and thumb movements tested. Alternatively, comparison of similarities between the studies was drawn, and differences were highlighted.

**Table I: Details of the Reviewed Studies**

Author	Sample size	EMG procedure	Thumb movements tested	Results
Cooney et al., 1985	8 ( 4 Males, 4 Females)	Intramuscular electrodes.	Thumb isometric strength in flexion, extension, abduction and adduction during maximum, moderate and mild contraction. In addition, they measured the EMG signals in isometric contraction in lateral pinch, tip pinch pulp-to-pulp strength, and power grasp.	A correlation was found between the APL electrical activity and thumb isometric extension strength. Moreover, strong correlation was found in maximum thumb isometric abduction, where in moderate and mild isometric contraction no correlation was found. In Lateral pinch, the electrical activity was detected for only one participant.
Gibbs et al., 1997	9 Males	Surfaces electrodes	Oppose in turn the thumb to each finger, starting from the index and moving in sequence to the little finger and then back again as fast as the participants can.	A weak correlation ( $r=0.14$ ) was found between finger skill assessment and the thumb abductor muscle electrical activity.
Gustafsson et al., (2011)	60 young adults with and without musculoskeletal symptoms.	Surfaces electrodes	Texting using phone.	Higher muscle activity was registered in the APL muscle in the group who used a one-handed grip compared to those who used two-handed grip. In addition, higher APL EMG activity was recorded for groups who worked with high velocity.
Gustafsson et al., 2010	60 young adults with and without musculoskeletal symptoms.	Surfaces electrodes.	Making a phone call with the standard mobile phone. Composing and entering their 300 character SMS message while sitting and standing.	There were significant gender differences in muscular activity in the abductor pollicis longus, with females having higher muscle activity levels. Lower muscle activity in the APL was reported in the group with musculoskeletal symptoms.
Johanson et al., 2001	7 ( 5 Females, 2 Males)	Intramuscular electrodes.	Maximal thumb-tip force in 2 key postures and 1 opposition posture during stable and unstable pinch.	The APL was active during pinch and opposition. The activity of the APL was the same during all tested movements, where it was mostly active during stable pinch and opposition tests.
Kaufman et al., 1999	5 (3 Males, 2 Females)	Intramuscular electrodes.	Voluntary isometric contraction of the thumb in flexion, extension, abduction, adduction, and a combination of these movements.	The results reported a high electrical activity of the APL during maximal voluntary contraction in abduction, extension, and a combined movement of abduction and extension. The APL was more active during the combined movement of thumb abduction and extension.
Maier and Hepp-Reymond, 1995	6 (3 Males, 3 Females) the APL EMG was recorded for only 4 participants.	Intramuscular electrodes	Isometric tip pinch.	The correlation was calculated between three different isometric contractions and the EMG signals. The correlations between APL electrical activity and the forces produced were statistically significant and moderate ( $0.40 \leq r \leq 0.52$ ). It was concluded that the APL has a stabilizer function in the grip, at least at lower forces.
Oudenaarde et al., 1995	8 (4 Females, 4 Males)	Intramuscular electrode	Isometric and dynamic contractions of the thumb and hand. Thumb movements include abduction, adduction, extension, flexion, and opposition. Hand movements include supination with palmer flexion, pronation with palmer flexion, and mid-position with palmer flexion.	Out of 22 tested movements of the thumb and hand, in four directions significant correlations were found between the two divisions. A correlation was found between hand dynamic movements and APL EMG signals in mid-position of the forearm in palmer flexion, dorsal flexion and pronated palmer flexion. In addition, a correlation was found between the two divisions in dynamic thumb abduction. It was noticed that the activity of the APL during thumb tests was high in extension in both dynamic and isometric contraction and very low in adduction as the muscle is inactive.
Simard and Cerqueira, 1992	13 ( 6 Males, 7 Females)	Intramuscular electrodes	Slow and fast hand writing	The APL was found to be more active during slow handwriting, which indicates the importance of this muscle during slow fine motor activities.

### Activity of the APL During Functional and Non-Functional Movements

The EMG of the APL was explored during simple thumb movements of flexion, extension, abduction and adduction (Cooney et al., 1985; Oudenaarde et al., 1995). However, measuring the activity of the APL during simple thumb movements will not necessarily provide sufficient information about the APL activity, as the thumb makes combined movements during hand functional use. The EMG of the APL was recorded during maximum isometric contraction (Cooney et al., 1985; Oudenaarde et al., 1995), where thumb movements during daily use require both isometric and isotonic muscle contraction. The activity of the APL was measured during maximum voluntary contraction in combined thumb's movements (Kaufman et al., 1999). Nevertheless, the combined thumb movements were achieved depending on visual feedback, which is a limitation, since it is dependent on the researcher's subjective judgment. Additionally, the EMG activity of the APL was recorded during one-dimensional dynamic thumb's movements (Oudenaarde et al., 1995). However, the load was constant during contraction, so the effect on APL activity when the load increased or decreased could not be concluded. Furthermore, the velocity was also constant during dynamic contraction; therefore, the study could not reveal the effect of velocity on APL activity. A recent study (Gustafsson et al., 2010) reported significant gender differences in muscular activity in the APL, with females having higher muscle activity levels (Gustafsson et al., 2010). The results of Gustafsson and co-workers would give a justification of why females are more susceptible to OA at the base of the thumb than males (i.e. females' APL muscle is very weak, with insufficient stability to the thumb's CMC joint, and this subsequently leads to OA at base of the thumb). Additionally, a higher APL EMG activity was recorded for a group of people who use their phone with high velocity, suggesting the key role of the APL in stabilizing the thumb CMC joint (Gustafsson et al., 2011).

Very little attention has been made to explore the activity of the APL during hand prehensile movements. The study of Gibbs and co-workers explored the association between the activities of the thumb abductor muscles (i.e. APL and APB) and finger skill assessments (Gibbs et al., 1997). However, finger skill assessment only measures one aspect of prehensile movement (i.e. tip pinch), while other prehensile movements are not covered by this test. Additionally, the finger skill assessment procedure did not include any object to grasp, thus limiting the ability to explore the activity of the APL during the grasping phase. Another study (Simard and Cerqueira, 1992) explored the activity of the APL during slow and fast writing. However, the correlation between

the time to complete the writing tasks and the activity of the APL was not noticed. Furthermore, the ability to write requires the individual to perform one prehensile movement (i.e. tripod pinch), thus other prehensile patterns are not evaluated. In conclusion, there is a knowledge gap regarding the activity of the APL during prehensile movements.

### **Activity of the APL During Grip and Pinch Strength**

The activity of the APL was explored while measuring lateral pinch and power grip strength (Cooney et al., 1985; Johanson et al., 2001). However, studies provided inconsistent findings of the APL EMG activity during lateral pinch strength. It was reported that during lateral pinch strength, the activity of the APL was detected for only one participant (Cooney et al., 1985). By contrast, the study of Johanson and co-workers found that the APL was active during lateral pinch strength to the maximal level (Johanson et al., 2001). The variation of the studies' results could be due to the differences in testing positions. For instance, lateral pinch strength measured with the forearm is supported in orthoplast splint (Cooney et al., 1985), while the forearm was unsupported in the study of Johanson and co-workers (Johanson et al., 2001). However, a standardized procedure for measuring pinch and grip strength was never used in the previous studies (Cooney et al., 1985; Johanson et al., 2001), and as a result, variation of grip and pinch testing procedure has led to different results. The activity of the APL was explored during tip pinch strength (Cooney et al., 1985; Maier and Hepp-Reymond, 1995), but a standardized procedure was not used.

Most of the studies reviewed did not account for the exact correlation coefficients between the thumb strength in simple or combined movements and the EMG activity of the APL (Cooney et al., 1985; Kaufman et al., 1999; Oudenaarde et al., 1995). Therefore, it is difficult to interpret the strength of the association between thumb strength and the activity of the APL. Likewise, the exact correlation coefficients between pinch and power grip strength were not also mentioned in the reviewed studies (Cooney et al., 1985; Johanson et al., 2001). One study (Maier and Hepp-Reymond, 1995) calculated the correlation coefficients between the APL EMG activity and tip pinch strength. Yet, it did not measure the maximum tip pinch strength, which limited the study ability to view the relation between the APL activity and maximum tip pinch strength.

### **EMG Recording Procedures**

A vital issue, which should be considered in the relevant literature, is the EMG recording procedure. All studies, except for those of Gibbs and co-authors and Gustafsson and co-authors (Gibbs et al., 1997; Gustafsson et al., 2011; Gustafsson et al., 2010) have used an intramuscular

EMG procedure. Recording the EMG with intramuscular electrodes is likely to produce errors that are caused by location of needle tip, local hematoma formation, interference from connective tissue and pain that can inhibit muscle contraction (Cooney et al., 1985). The correct location of the electrodes was confirmed by electrical stimulation of the APL muscle (Cooney et al., 1985), playing piano movements of the fingers (Oudenaarde et al., 1995), palpation (Johanson et al., 2001), and muscle function testing (Kaufman et al., 1999). However, the EMG recording procedures used were not standardized; thus the validity and reliability of the EMG were limited. Overall, it was difficult to find a standardized EMG procedure to record the activity of the APL, which necessitates a search for a reliable procedure for measuring the APL EMG activity during functional thumb tasks.

### **Conclusions and Recommendations**

To the knowledge of the author, this is the first critical review which compressively assays the APL EMG activity in a systemic manner. This review suggests a knowledge gap related to the APL EMG activity during thumb functional use. To bridge the gap, future research needs to consider exploring the activity of the APL while performing daily life tasks. All articles reviewed in this study highlighted the APL role in stabilizing the thumb's CMC joint. While females are more susceptible to OA at the base of the thumb, the APL in females might be a weak muscle, with insufficient stability to the thumb's CMC joint during thumb functional movements. This, in turn, leads to OA at the base of the thumb. It would be of interest to do a research as to whether strengthening the APL might be an appropriate conservative treatment method to manage the symptoms of OA at the base of the thumb. Only one study (Gustafsson et al., 2010) was found to explore the difference in the APL EMG activity between males and females during thumb non-prehensile movements. Thus, further research might be conducted to explore the APL EMG activity in healthy participants and different age groups, with a special focus on gender differences. It would be helpful for any further studies to record the kinematic motion of the wrist and thumb while exploring the APL activity during daily life activities. For any future research, exploring the reliability of the EMG procedure is highly recommended.

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## مراجعته نقديه للنشاط الكهربائي للعضلة الطويلة المبعده لإبهام اليد

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### ملخص

الهدف: تهدف هذه الدراسة إلى مراجعة الأبحاث العلمية التي قامت بقياس النشاط الكهربائي للعضلة الطويلة المبعده لإبهام اليد خلال الحركات المختلفة لإبهام اليد.

المصدر: تم البحث في كل من قواعد البيانات التالية: Web of Knowledge, CINAHL, MEDLINE, EMBASE.

النتائج الأساسية: تم العثور على تسعة أبحاث استكشفت النشاط الكهربائي للعضلة الطويلة المبعده للإبهام خلال استخدام إبهام اليد في النشاطات اليومية المختلفة. الأبحاث التي تم مراجعتها في هذه الدراسة أكدت على دور العضلة الطويلة المبعده لإبهام اليد في تثبيت المفصل القاعدي للإبهام. بالرغم من أن الدراسات التي تم مراجعتها قدمت معلومات قيمة عن النشاط الكهربائي للعضلة الطويلة المبعده لإبهام اليد إلى أنه لا يوجد دراسة بحد ذاتها قد تطرقت إلى بحث العلاقة ما بين النشاط الكهربائي لهذه العضلة والنشاط الوظيفي لإبهام اليد. بالإضافة إلى ذلك كان هناك نتائج متناقضة فيما يخص النشاط الكهربائي للعضلة الطويلة المبعده لإبهام اليد خلال قياس قوة قبضة اليد وقوة القبضة الجانبية لليد.

الخلاصة: هناك حاجة ماسة إلى دراسات مستقبلية للتعرف على دور العضلة الطويلة المبعده لإبهام اليد أثناء الاستخدام الوظيفي للإبهام مع الأخذ بالحسبان دراسة الفروق ما بين الذكور والإناث بحيث يكون ذلك متزامنا مع التحليل الحركي لليد والإبهام.

الكلمات الدالة: الإبهام، العضلة الطويلة المبعده للإبهام، النشاط الكهربائي للعضلة.