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Subject-specific thumb muscle activity during functional tasks of daily life

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ABSTRACT

Background: The trapeziometacarpal joint is subjected to high compressive forces during powerful pinch and grasp tasks due to muscle loading. In addition, muscle contraction is important for stability of the joint. The aim of the present study is to explore if different muscle activation patterns can be found between three functional tasks.
Methods: Isometric forces and fine-wire electromyographic (fEMG) activity produced by three intrinsic and four extrinsic thumb muscles were measured in 10 healthy female volunteers. The participants performed isometric contractions in a lateral key pinch, a power grasp and a jar twist task. The tasks were executed with and without EMG recording to verify if electrode placement influenced force production.
Results: A subject-specific muscle recruitment was found which remained largely unchanged across tasks. Extrinsic thumb muscles were significantly more active than intrinsic muscles in all tasks. Insertion of the fEMG electrodes decreased force production significantly in all tasks.
Conclusion: The thumb muscles display a high variability in muscle activity during functional tasks of daily life. The results of this study suggest that to produce a substantial amount of force, a well-integrated, but subject-specific, co-contraction between the intrinsic and extrinsic thumb muscles is necessary.

1. Introduction

The human thumb plays a key role in normal hand function. The trapeziometacarpal (TMC) joint is the osteoarticular basis from which the opposable thumb is able to perform its numerous functions and movements. The specific geometry of this joint allows multiplanar movement (Eaton et al., 2000; Edmunds, 2011). While the TMC joint is loose and unstable during a resting posture, the joint is subjected to high compressive forces during powerful pinch and grasp. Cooney and Chao (1977) estimated joint forces of 88–127 N during lateral key pinch and 834–1608 N during power grasp which, combined with the small articular surface of the TMC joint (ca. 130 mm^2), lead to elevated contact pressures. High mechanical loading at the joint can lead to the development of osteoarthritis (OA). In contrast to weight-bearing joints, such as the knee joint, the mechanical loading of the TMC joint is largely generated by contraction of intrinsic and extrinsic thumb muscles. It is, therefore, of high clinical relevance to investigate thumb muscle activations during functional tasks.

Muscle activity and muscle activation patterns are typically investigated using surface electromyography (sEMG) or fine-wire electromyography (fEMG) (Konrad, 2005; Türker, 1993). Fine-wire EMG seems to be the most appropriate method to document the function of muscle groups which have a deep location and small size, such as the intrinsic thumb muscles (Corneil et al., 2012; Rudroff et al., 2008). In addition, cross-talk is limited as fEMG-electrodes are implanted directly into the muscle, contrary to sEMG where the electrodes are applied to the overlying skin (Solomonow et al., 1994). Even though several studies used fEMG to investigate the muscle activity of the thumb muscles (Burgar et al., 1997; Johanson et al., 2001; Valero-Cuevas et al., 1998), muscle activation patterns for specific functional tasks remains inconclusive.

To get a better insight into the role of the thumb muscles during activities of daily living and their relation with the development of OA at the TMC joint, baseline muscle activation patterns in healthy persons need to be established. The aim of this study is to evaluate if specific muscle activation patterns can be recognized during a lateral key pinch, a power grasp and a jar twist task, by analysing

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the activity of the relevant intrinsic or extrinsic muscles. Based on the muscle function (Cooney et al., 1985; Maier and Hepp-Reymond, 1995), we hypothesize that there will be a task-specific activation of the thenar muscles, with strong activation of the thumb adductors and flexors during lateral key pinch and co-contraction of the pollical adductors and abductors during power grasp and jar twist. Furthermore, we expect to see a higher recruitment of the intrinsic thenar muscles during lateral key pinch and a relatively higher activity of the extrinsic thenar muscles during grip tasks such as power grip and jar twist. Finally, we expect to see co-contraction of the antagonistic muscles during all tasks to stabilize the TMC joint.

2. Materials and methods

2.1. Participants

Eleven healthy young women (mean age: 22.88 years ± SD: 4.75 years) volunteered for this study. Volunteers with musculoskeletal problems in the forearm or hand region, previous trauma or surgery in this area or neurological conditions were excluded from the study. Approval from the medical ethical commission of the University of Leuven was obtained prior to the start of the project (ML9602) and an informed consent was signed by each participant.

2.2. Force data collection

Force data were collected using a custom-made polycarbonate jig (Orthopaedic Bioengineering Laboratories, Brown University/ Rhode Island Hospital, Providence, RI, USA) with an embedded load cell (0–50 lb, Model D, Thrue-Hole, Honeywell International Inc., NJ, USA) (Fig. 1). Using a universal inline amplifier (model UV, Sensotec, Columbus, USA), force data were recorded using custom-written data acquisition software (Labview, Texas Instruments, Austin, USA). This experimental setup and protocol have been used extensively in other studies (Crisco et al., 2015; Halilaj et al., 2014, 2013).

The participants performed isometric contractions for 5 s with their dominant hand during three tasks; a lateral key pinch, a power grasp and a jar twist task. The exact positioning of the hand and thumb in each task is shown in Fig. 1A–C. Each task was executed on two different effort levels using visual feedback: two maximal isometric contractions and one contraction at 80% of maximal force (Submax). The tasks were executed before and after electrode placement to evaluate the influence of electrode insertion on force production.

2.3. EMG data collection

Electromyographic (EMG) data were collected using an 8-channel Trigno wireless system (Delsys, Inc., Boston, USA) equipped with fine-wire electrodes. The raw EMG signal was recorded with an amplifier band pass of 2000 Hz, an A/D conversion sampling rate of 4000 Hz and a gain setting between 1 and 300. The fine-wire electrodes consisted of pairs of disposable, bipolar, sterilized, 50 mm long, hooked wire electrodes with a 25 gauge needle as a cannula (Motion Lab Systems, Inc., LA, USA). The wire were made out of 304 series stainless steel with a green nylon insulation with 5 mm bare-wire terminations.

The skin of the participant's dominant forearm and hand was disinfected before insertion of the electrodes. An ultrasound-guided technique based on the recommendations of Perotto was used to insert the electrodes in each of the eight target muscles (Perotto, 1994). Ultrasound images were obtained with a S8-Sonoscape portable digital color Doppler ultrasound system (Sonoscape, Shenzhen, China) using a linear, L-shaped hockey stick probe (probe 10l2, 6–11 Hz, 19 mm). This procedure was executed by a hand surgeon (PDA). The ends of the fine-wire electrodes were attached to preamplifiers on the forearm and hand (Fig. 2).

In each volunteer and during each task, the activity of eight thumb muscles was recorded simultaneously; four intrinsic thumb muscles: m. opponens pollicis (OP), m. flexor pollicis brevis (FPB), m. abductor pollicis brevis (APB) and the m. adductor pollicis (ADP), and four extrinsic thumb muscles: m. extensor pollicis longus (EPL), m. extensor pollicis brevis (EPB), m. abductor pollicis longus (APL), and m. flexor pollicis longus (FPL). These muscles were selected based on their reported activity during specific thumb movements (Kaufman et al., 1999).

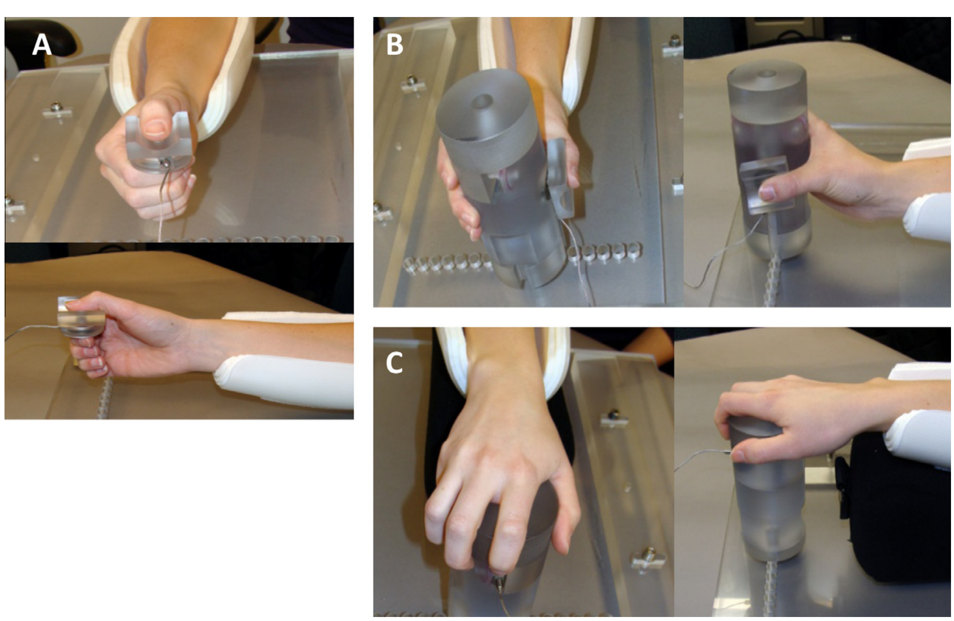

Fig. 1. Hand positioning in the polycarbonate jig during the three functional tasks. A: lateral key pinch, B: power grasp and C: jar twist.