Approach to Quantify Thumb Carpometacarpal Joint Laxity *In Vivo*

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Summary

This work proposes a thumb carpometacarpal (CMC) joint passive laxity assessment system for in vivo testing. The system is designed to measure laxity in the primary movement directions of the thumb CMC joint. The system provides objective data about the thumb CMC mechanical behavior, independent of examiners.

Introduction

Impairment of the thumb results in 40% to 50% of all disability of the upper limb [1], with the CMC joint at the thumb's base being a key contributor to this digit's functionality. Passive (ligamentous) and active (muscular) stabilisers support the CMC joint. These ligaments may loosen or become lax with ageing or osteoarthritis [2]. A recent paper examined the passive properties of the thumb CMC joint of healthy specimens [3]. This work proposes an approach for assessing laxity in vivo, addressing the subjectivity in previous approaches that compromised accuracy, reproducibility, and incomplete laxity data [4-5].

Methods

A custom-designed experimental setup was developed (Figure 1) for use with optical motion capture (Qualisys AB, Sweden) and surface EMG (Delsys Inc, USA) systems.

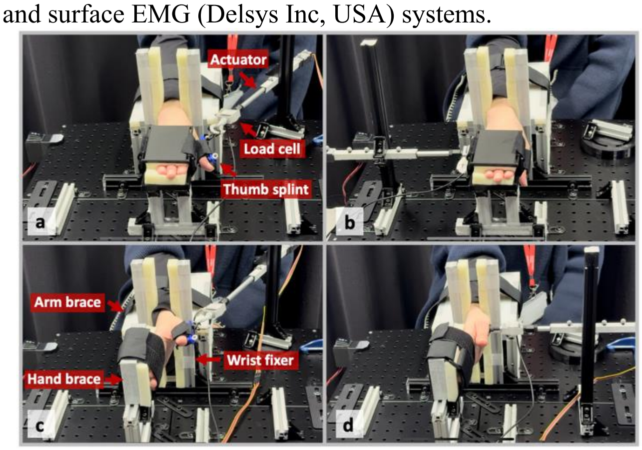

Figure 1: The designed experimental setup for laxity assessment; from (a) dorsal (extension), (b) volar (flexion), (c) radial (abduction), (d) radial (adduction) sides.

The system quantifies first metacarpal kinematics relative to the hand plane while applying force to the metacarpal head and ensuring relaxation of five thumb muscles: extensor pollicis longus, flexor pollicis longus, opponens pollicis, abductor pollicis brevis, flexor pollicis brevis. A pulling or pushing force is applied using an actuator through a custom-designed thumb splint, preventing metacarpophalangeal joint flexion and directing force to the dorsal, volar, and radial sides, respectively. The force is recorded via a load cell. The system is controlled using custom-written code in LabVIEW (National Instruments, USA). The kinematics of the thumb CMC are estimated using the approach outlined in [6]. The kinematics and force data are processed using MATLAB (MathWorks, USA). Results are presented as a torque-rotation curve.

Results and Discussion

Preliminary results show that quantifying thumb CMC laxity in vivo is feasible and can be independent of an examiner's judgment. Non-linear regimes of torque-rotation curves reflect the laxity of the capsule, cartilage, and ligaments of the CMC joint under the applied external force with relaxed muscles (Figure 2). Data collection is underway to assess the effect of age on thumb CMC joint laxity.

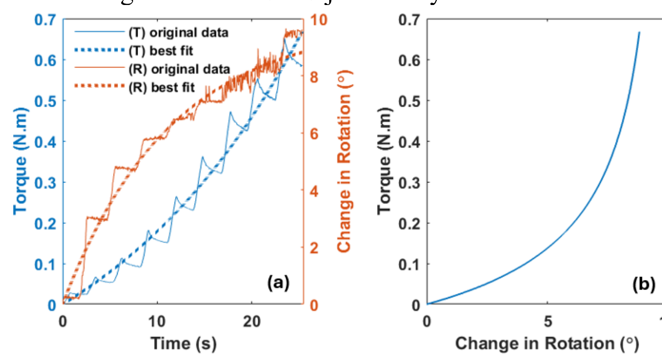

Figure 2: (a) Measured data over time, (b) Torque (T)-rotation (R) curve, for one participant for extension movement.

Conclusions

This proof-of-concept study demonstrates the feasibility of quantifying thumb CMC joint laxity in vivo. This approach contributes to personalised medicine in orthopaedics, where data can be incorporated into computational models. The collected data will support the development of computational models for investigating new hand-surgical intervention techniques. Additionally, this approach can be further refined for clinical use to help clinicians assess soft tissue damage and, therefore, provide an effective treatment plan.

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