Arthrokinematics of the Thumb CMC Joint During Pinch and Grasp

INTRODUCTION:
The thumb carpometacarpal (CMC) joint is critical to hand function, as nearly all manipulative hand tasks require forceful positioning of the thumb. This joint undergoes compressive forces that are 10 to 15 times higher than the load required to perform a task. Injury or degeneration of the thumb CMC joint may make daily tasks painful and disabling, due to the thumb’s central role in grasp and handling maneuvers. Despite its importance, there is currently no published data on in-vivo CMC joint kinematics. Studying movement in a healthy joint is an initial step to characterizing changes that occur with joint pathology, particularly the common disorder of osteoarthritis. The purpose of this study was to measure arthrokinematics in asymptomatic individuals, during high-demand functional tasks of object grasping and key pinching. We sought to determine the positional changes of the CMC joint during these tasks, as well as the role gender influences CMC kinematics.

METHODS:
After obtaining informed consent, 15 volunteers, 7 males (age 32 ±10) and 8 females (age 42±17) were scanned with their dominant wrist in neutral, key pinching, and jar grasping positions. Two scans were acquired for each functional task; one with the hand relaxed (unloaded), and one with the participants applying 80% of their maximum effort. CT volumes were generated with a 16-slice clinical CT scanner (General Electric, Milwaukee, WI) at tube settings of 80kVp and 80mA, slice thickness of 0.625mm, and in-plane resolution of (~0.3mm)².

The trapezial (TPM) and first metacarpals (MC1) were manually segmented from the neutral-position CT volumes using Mimics software (Materialise, Leuven, Belgium). 3-D bone models were exported as meshed surfaces. Anatomical coordinate systems were calculated for the TPM and MC1 by using principal curvature directions of the saddle shaped articulating surfaces as guiding features. Bone kinematics were calculated by automatically registering the bones with a previously reported markerless bone registration algorithm. Euler angles of the MC1 with respect to the trapezium were calculated for each position. CMC extension/flexion was defined as rotation about the anatomically oriented radial-ulnar axis (X), abduction/adduction was defined as rotation about the dorsal-volar axis (Y), and internal-external rotation was defined as rotation about the long axis of mc1 (Z). Translation of the MC1 on the trapezium was quantified by tracking the origin of the MC1 coordinate system with respect to the mathematically fixed trapezium and was expressed in the trapezial coordinate system.

RESULTS:
Motion of the MC1 from the neutral position to the unloaded key pinching position was not consistent across subjects, as the paired t test showed no statistically significant rotations, in all three directions. Moving from the unloaded to the loaded states the MC1 flexed, abducted, and internally rotated over the trapezium (Table 1, Fig 2.a).

From neutral to unloaded jar grasping, the MC1 flexed (-18.6 ± 12.6, p = 0.0009), abducted (-20.7 ±10.4, p = 0.00009), and internally rotated (-17.0 ± 11.9, p = 0.0011). It only ab ducted, at a statistically significant level, as it moved from the unloaded to the loaded state (Table 1, Fig 2.a).

| Table 1. MC1 Rotations (deg.) and translations (mm) from unloaded to loaded states. |
|---|---|
| Pinch | Grasp |
| X Rotation | Y Rotation |
| Translation | Translation | Translation |
| -12.9 ± 6.6 (p<0.0001) | -7.0 ± 7.4 (p<0.009) | -1.2 ± 6.7 (p<0.0001) |
| 0.6 ± 0.6 (p<0.005) | 1.3 ± 0.9 (p<0.00015) | 0.3 ± 0.7 (p<0.015) |
| 1.5 ± 2.3 (mm) | -3.0 ± 1.7 (p<0.00001) | -0.0 ± 0.3 (mm) |

Figure 1. a) The thumb CMC joint with the TPM and MC1 coordinate systems b) The trapezial coordinate system with directions

Paired t-tests were used to evaluate differences in flexion-extension, abduction/adduction, and internal-external rotation between the unloaded and loaded conditions. Unpaired t-tests were used to compare the kinematics between the male and female subjects.

RESULTS:
The same approach can be readily extended to osteoarthritic populations, in efforts of portraying a kinematic spectrum that spans from normal to severely impaired states.

DISCUSSION:
This study is a first step in establishing thumb CMC in-vivo kinematic patterns that characterize healthy joints. A larger asymptomatic cohort may be needed to reveal differences between male and female kinematics, if any exist. The same approach can be readily extended to osteoarthritic populations, in efforts of portraying a kinematic spectrum that spans from normal to severely impaired states.

REFERENCES:
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